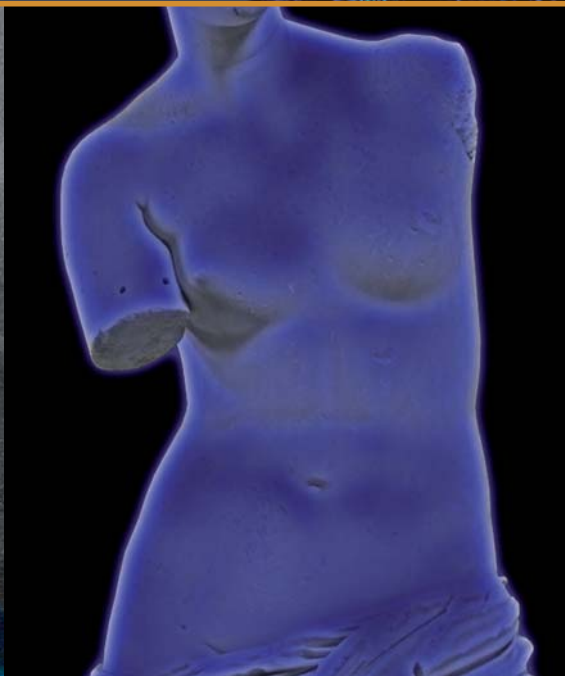
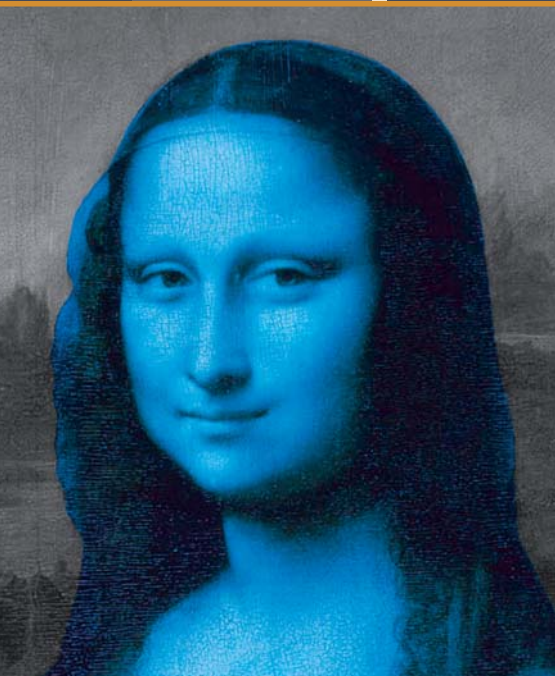




2011
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**10TH INTERNATIONAL STEREOTACTIC
RADIOSURGERY SOCIETY CONGRESS**

Brain & Body Radiosurgery

ABSTRACTS BOOK

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PLENARY SESSION 1

WELCOME, LECTURES & ORAL PRESENTATIONS

PS-1-1 NOVALIS RADIOSURGERY FOR ARTERIOVENOUS MALFORMATIONS: CONSEQUENCES OF A DOSIMETRIC ACCIDENT ABOUT 22 PATIENTS

Monday 9 May 2011, 08:45 - 10:00

Pierre-Yves Boriux¹ Igor Latorzeff² Anne-Christine Januel³ Pierre Duthil² Jean-Yves Plas² Jean-Albert Lotterrie² Emanuelle Cassol² Alain Redon² Philippe Bousquet² Bertrand Debono² Christophe Cognard³ Isabelle Berry² Yves Lazorthes¹ Jean Sabatier¹

(1) Neurosurgery Department, Toulouse University Hospital, Toulouse, France (2) Centre Régional de Radiochirurgie Stéréotaxique, Toulouse University Hospital, Toulouse, France (3) Service de Neuroradiologie, Toulouse University Hospital, Toulouse, France (4) Groupe ONCORAD Garonne, Clinique Pasteur, Toulouse, France (5) Service de Neurochirurgie, Clinique des Cèdres, Toulouse, France (6) Unité de Radiophysique et Radioprotection, Toulouse, France

We study outcomes and complications in patients who harbored AVMs and underwent stereotactic radiosurgery in our department.

Between May 2006 and March 2007, 22 patients were treated by radiosurgery. The mean patient age was 43.5 years [11.8-78]. The discovered mode was bleeding in 13 cases (59.1%), epilepsy in 4 cases (18.2%), headache in 3 cases (13.6%), fortuitous in 2 cases (9.1%). Nine patients had a history of embolization, one patient had a LINAC radiosurgery eight years before, and one a partial surgery resection. The average volume was 2.1 cm³ [0.2-6.4]. The mean prescribed isocenter dose was 20.7Gy [18-22.5] with a median of 21Gy. An initial error in the estimation of scatter factors led to an overexposure to radiation. Due to this accident, the mean delivered dose was 32Gy [25.4-45.1] at the isocenter. The mean minimum dose was 25.4Gy [12.1-38.4] with median dose of 25Gy. Ninety-five percent of AVM volume received at least 28.6Gy [23.3-40.6]. The mean volume of healthy parenchyma, receiving more than 12Gy (V12Gy), was 8.1cm³ [2.7-17] and 7 patients had a V12Gy more than 10 cm³.

One patient (4.5%) with a right parieto-rolandic AVM presented a new neurological deficit 12 months after treatment (left spastic hemiparesis, facial hypoesthesia) due to edema and radionecrosis. The volume was 2.9cm³ with a minimum dose of 25.3Gy. The V12Gy was 12.8 cm³. One patient developed post-radiosurgery asymptomatic cyst gradually increasing volume requiring surgery 12 months after radiosurgery. No patient had bleeding during follow-up. Three patients (13.6%) refusing arteriography and then were considered lost for follow-up. On average control angiography was performed 37.3 months after treatment [36.3-40.1] and showed a complete obliteration in 19 patients (68.2%), disappearance of the nidus with persistent micro shunt in 2 patients (9%), a very significant reduction of the nidus volume in 2 patients (9%).

We do not observe a difference between morbidity and effectiveness of population-irradiated and the main series in the literature.

PS-1-2 REVIEW OF ACCIDENTS IN RADIOSURGERY: LESSONS FROM THE LAST 20 YEARS

Monday 9 May 2011, 08:45 - 10:00

German Rey¹

(1) Ruber Internacional, Madrid, Spain

Invited Lecture

PS-1-3 TUMOR CONTROL AND TOXICITY OF OUTPATIENT SINGLE FRACTION RADIOSURGERY IN SPORADIC VESTIBULAR SCHWANNOMA

Monday 9 May 2011, 08:45 - 10:00

Berndt Wowra¹ Christoph Fürweger¹ Christian Drexler¹ Alexander Muacevic¹

(1) European CyberKnife Center, Munich, Germany

Objective: To assess tumor control and toxicity of single fraction radiosurgery (RS) in sporadic vestibular schwannoma (VS) with Gamma Knife (GK) or Cyberknife (CK)

Method: A prospective cohort study of sporadic VS treated either with the GK or the CK. Patients with neurofibromatosis type 2 and residual or recurrent VS after surgery were excluded. Follow up with MRI and clinical examination was mandatory and performed at regular intervals. Minimum follow up was 3 years. A minimum tumor dose of 12 - 13 Gy was given. Tumor control was defined as absence of further tumor growth after RS (stable or smaller VS size). FN function was scored according to House and Brackman (Otolaryngol Head Neck Surg 1985;93). Hearing level was assessed by the Hannover classification (Samii and Matthies, Neurosurgery 1997;40) and, quantitatively by pure tone audiometry (PTA). In PTA the frequency band between 0.5 and 8 kHz was recorded. The effective hearing loss after RS was determined by 2 equations: 1) the difference in the hearing level of both ears was calculated; 2) the additional hearing loss of this difference during follow up was calculated. For data analysis the STATA 10.1 software was used.

Results: A total of 293 (GK 192; CK 101) patients met the inclusion criteria (representing 35 % of all VS treated radiosurgically by us). Mean (\pm SD) follow up after RS was 68,3 \pm 30,2 months (GK 74,0 \pm 30,8; CK 44,5 \pm 5,5; $p < 0.0001$). 12 (4 %) treatment failure were observed (GK 8; CK 4; n.s.). Actuarial tumor control after 5 years was 93 % (CI 88 - 96). Trigeminal dysfunction was not observed. There was no permanent FN toxicity. In 3 (1 %) patients FN function was reduced by 1 class, transiently. The rate of preserving a class 1 or 2 hearing level was 77%. At an average the hearing level assessed by the Hannover classification sagged by 1 class ($p < 0.001$). After a median follow up of 5 years (min 3; max 13,9) effective median hearing loss in PTA was - 20 dB (minimum +10; maximum -80); no difference in ototoxicity was observed for GK and CK.

Conclusion: Outpatient single fraction radiosurgery in sporadic vestibular schwannoma shows a high efficacy and a very low facial and a low cochlear nerve toxicity. The results are independent of the treatment technology and compare favorably to other treatment methods.

PS-1-4 A ROLE OF RADIOSURGERY FOR FUNCTIONAL PRESERVATION: FROM PERSONAL EXPERIENCES OF 4500 PATIENTS TREATED WITH MICROSURGERY, GAMMA KNIFE AND CYBERKNIFE RADIOSURGERY

Monday 9 May 2011, 08:45 - 10:00

Hiroshi Inoue¹ Yoshiyuki Suzuki² Takeo Takahashi² Hideyuki Sakurai³

(1) Institute of Neural Organization, Fujioka, Japan (2) Gunma University Graduate School of Medicine, Maebashi, Japan (3) University of Tsukuba, Proton Medical Research Center, Tsukuba, Japan

Objective: Therapeutic policy and indication of neurosurgery have changed after development of radiosurgery. Patients treated in the era of radiosurgery were evaluated from consecutive series of a neurosurgeon.

Methods: Since 1991, 1080 patients were treated with microsurgery and 3420 patients with radiosurgery (Gamma Knife and CyberKnife). Radiosurgery was generally used for patients with surgical risks or recurrent or residual lesions. Patients with acute symptoms or pathologies not indicated for radiosurgery were operated on. Combination treatment was intended for large lesions in eloquent areas. Indication and functional outcome were analyzed from the 4500 patients.

Results: In microsurgery, tumors occupied in 32.2% of patients, spinal 30.4, vascular 23.1, pediatric 8.1, functional 2.1, and others 4.0. Central skull base surgery was most frequent in tumors because of acute symptoms of optic pathways and endocrinopathy. Functional restoration was obtained immediately after surgery. However, surgical complications such as hemorrhage, infection, CSF leakage, and functional deterioration due to dissections of critical tissues were found. In radiosurgery, tumors indicated in 72.5%, vascular 12.1, pediatric 3.4, Head and Neck (HN) 7.4, functional 2.4, and spinal 2.2. Most frequent indication was metastatic tumors. After introduction of CyberKnife (CK), HN, spinal, invasive lesions such as glioblastomas, and large metastases were increased for indications. Functional preservation was obtained in most patients. No severe complications were found, though microsurgery was required in patients with edema, tumor expansion or regrowth. Intended combination treatment was more effective for functional restoration in patients with large lesions or lesions around the optic pathway.

Conclusions: Development of radiosurgery increased therapeutic indications and improved functional outcomes in neurosurgery. Intended combination treatment brought functional restoration in patients with large lesions or lesions in and around functional areas.

PLENARY SESSION 2 ORAL PRESENTATIONS & INVITED CONFERENCE

PS-2-1 QUALITY ASSURANCE OF CT FOR GAMMA KNIFE RADIOSURGERY AN INTERNATIONAL AUDIT

Monday 9 May 2011, 11:30 - 12:30

Ian Paddick¹

(1) Medical Physics Limited, London, UK

Objective: CT is widely considered to be the 'gold standard' with respect to geometrical fidelity for SRS treatment planning. This has meant that in many cases the accuracy of CT is not measured, but assumed. However, a blind belief in the accuracy of any imaging modality is not appropriate when sub-millimetric targeting is essential for safe treatment delivery. A worldwide audit has been performed to examine the accuracy of this imaging modality and to investigate if scanning accuracy is dependent on the equipment or protocol used. Parameters such as the effect of helical versus axial acquisition and single slice versus multi-slice acquisition were investigated.

Methods: Using a Scheib Known Target Phantom (PTGR, Germany) the accuracy of stereotactic localisation using the Leksell stereotactic system was investigated, by measuring the positions of 21 points at known Leksell coordinates, using CT scans only. A total of 24 CT scanners used for radiosurgery planning were tested using this method.

Results: The overall mean and the overall maximum errors for scanners in the audit was 0.53mm and 0.98mm respectively. However, in one case, individual mean and maximum errors were as high as 1.59mm and 3.97mm.

For a series of five scanners, helically acquired scans generally gave lower errors than those produced axially by serial movements of the couch (a mean of 0.40mm versus 0.55mm). Errors were greatest in the Z direction.

Equipment age also appeared to affect accuracy with errors being significantly lower for newer scanners.

Conclusion: Errors from using CT for localisation can be as much as 4mm. This is not widely appreciated within the radiosurgical community. Errors varied from scanner to scanner as well as between imaging protocols. Errors tend to be greatest in the z direction, suggesting that table movement during acquisition is the weakest link in the generation of accurate scans. Distortion levels can generally be reduced by using helical acquisition.

PS-2-1bis QUALITY ASSURANCE OF MRI FOR GAMMA KNIFE RADIOSURGERY AN INTERNATIONAL AUDIT

Monday 9 May 2011, 11:30 - 12:30

Ian Paddick¹

(1) Medical Physics Limited, London, UK

Objective: MRI is the primary imaging modality used for Gamma Knife radiosurgery and is used in a majority of all intracranial SRS procedures. Many Gamma Knife planners use the errors calculated during the definition of fiducial markers by Leksell GammaPlan (LGP) to give an indication of distortion levels present in the images. However, these figures only refer to the fidelity of the fiducials in the periphery of the image and not in the area of the target. Furthermore, the method of scaling and defining images changed with the advent of LGP version 7 and up. Pixel dimensions listed in the DICOM image header are now used to scale the images instead of the fiducial dimensions and this results in different errors produced for the same set of images. Geometrical distortions inherent in the imaging process are well known and documented, though there are no published results from a range of MRI scanners tested by a reproducible and uniform method.

Methods: Using a Scheib Known Target Phantom (PTGR, Germany) actual/phantom distortion at 21 points was measured for multiple protocols on 54 scanners at 38 Gamma Knife sites. The distortion levels in the clinical target area were compared with the fiducial errors of each scan and the overall accuracy of the MRI scans were investigated.

Results: The average mean and the average maximum errors for all scanners in the audit was 0.84mm and 1.42mm respectively. The largest mean error for an individual protocol/scanner was 1.58mm. The ratio between fiducial and actual error differed depending on the planning system used to define the stereotactic images:

Mean errors were on average 2.4 times larger than fiducial errors quoted by LGP version 5, but only 1.42 times larger for LGP version 7 and up.

Maximum errors were a mean of 1.4 times larger than fiducial errors quoted by LGP version 5, but 0.99 times the error for LGP version 7 and up.

Conclusion: Mean and maximum errors varied as much from site to site as they did with the MR protocol used, suggesting that the MR sequence is as important as the type of scanner used. Fiducial errors alone cannot be used to estimate the accuracy of the MR sequence. Furthermore, a scan with lower fiducial errors can, in some cases, have a higher level of distortion in the treatment area.

PS-2-2 FUNCTIONAL NEUROSURGERY WITH THE GAMMA KNIFE: 17 YEARS EXPERIENCE.

Monday 9 May 2011, 11:30 - 12:30

Ronald Young¹ Francisco Li¹ Sandra Vermeulen¹

(1) Northwest Hospital Gamma Knife Center, Seattle, Wa, United States

Approach: We describe our experience over 17 years in using the Leksell Gamma Knife (LGK) for treatment of functional diseases of the nervous system.

Innovation: Between 1993 and 2010 we performed 1187 procedures with the LGK for treatment

of: Trigeminal Neuralgia (TN) 702, Thalamotomy for tremor 364, Thalamotomy for pain 68, Pallidotomy 49 and miscellaneous 4.

Results: For TN median follow up is 8.25 years and we achieved total pain relief in 61.5%, partial relief in 29.1% and failure in 9.4%. 5.6% of patients experienced varying degrees of loss of orofacial sensation but in only 1.1% was the loss permanent or significant. Statistically significant reductions in tremor scores for writing and drawing ($p < 0.0001$) were achieved following Ventral Intermediate Nucleus Thalamotomy. Temporary complications were seen in 8.1% of patients but only 4.1% suffered permanent complications. Medial thalamotomy performed for the treatment of chronic pain achieved $>50\%$ reduction in VAS pain scores in 60.1% of patients with a complication rate identical to that seen with VIM Thalamotomy for treatment of tremor. Pallidotomy achieved statistically significant reductions in Unified Parkinson's Disease Ratings Scale scores for dyskinesias, tremor, rigidity and bradykinesia. Two patient (4%) sustained contralateral homonymous hemianopsias following the procedures. Four other procedures, 2 cingulotomies and 2 hypophysectomies resulted in significant reductions in chronic pain due to metastatic cancer.

Conclusions: Certain functional diseases of the nervous system can be treated effectively with LKG radiosurgery. Success rates are virtually identical to those achieved with open ablative neurosurgical procedures or with deep brain stimulation. Complication rates for radiosurgery to treat functional disorders are similar to or in some cases significantly lower than, those found after open neurosurgical procedures. LGK radiosurgery is a valuable weapon in the armamentarium of neurosurgeons who treat functional disorders of the nervous system.

PLENARY SESSION 3

DATA BLITZ, LECTURE & ORAL PRESENTATIONS

PS-3-3 CLINICAL EXPERIENCE ON THE TREATMENT OF LUNG AND LIVER LESIONS WITH STEREOTACTIC BODY RADIOTHERAPY (SBRT) USING A NOVALIS EXACTRAC ADAPTIVE GATING TECHNIQUE.

Tuesday 10 May 2011, 08:45 - 10:00

Ovidio Hernando Requejo¹ Carmen Rubio Rodriguez¹ Emilio Sánchez Saugar¹ Mariola García-aranda Pez¹ Jeannette Valero Albarran¹ Mercedes López Gonzalez¹ Daniel Zucca Aparicio¹ Juan María Pérez Moreno¹ Pedro Fernández Letón¹

(1) University Hospital Madrid Sanchinarro, Madrid, Spain

Introduction: Gating techniques can improve the accuracy of the treatment of lung and liver lesions with SBRT, by monitoring organ tumor motion and irradiating within a selected area of the respiratory cycle.

Methods: Since April 2008 to October 2010 we have treated 90 patients (43 lung and 47 liver) with a Novalis LINAC SBRT Adaptive Gating Technique. A total of 148 lesions, 61 lung lesions (16 primary NSCLC and 45 metastases) and 87 liver lesions (13 primary and 74 metastases).

Prior to treatment, a fiducial marker is implanted and CT simulation is performed in breathholding

with infrared external skin markers. Based on these external markers, internal tumor motion is correlated with the external respiratory signal. This omits the requirement for 4D-CT imaging. The outlined PTV includes CTV=GTV + 5 mm margin. As the tumor is strictly irradiated in a selected respiration window, no ITV is necessary. PET-CT is used to define the GTV in the case of liver metastases. The following doses are prescribed: liver (5Gy x 10 or 12-20Gy x 3), peripheral lung lesions (12-20 Gy x 3), and central lung lesions (5Gy x 10 or 10Gy x5). The dose was delivered with multiple coplanar static beams. During patient setup, infrared markers track the respiratory cycle. Exactrac X-Rays localize the internal marker, quantify the tumor movement, and define the «beam on area» by correlating the external marker motion to the internal marker position. Intrafraction verification of the validity of this model is performed in real time by Exactrac X-Rays.

Results: At follow-up (mean 10,6 months [1-28]), 133 lesions were evaluated with 91,1% local control at two years [97.6% in lung and 87,3% in liver lesions]. Due to the implantation of internal markers, pneumothorax was observed in 26% of all lung patients. Clinical tolerance was excellent and no lung or liver toxicity grade 3 was observed.

Conclusion: Our clinical experience with Novalis SBRT Adaptive Gating shows that this technique is safe and efficient for the treatment of lung and liver lesions, while reducing the volume of irradiated healthy tissue. Intrafraction verification improves the treatment accuracy by a real time verification of tumor position.

PS-3-4 STEREOTACTIC RADIOSURGERY OF THE POST-OPERATIVE RESECTION CAVITY OF BRAIN METASTASES: TARGET MARGIN AND TUMOR CONTROL

Tuesday 10 May 2011, 08:45 - 10:00

Scott Soltys¹ Iris Gibbs¹ Steven Chang¹ John Adler¹ Griffith Harsh¹ Robert Lieberman¹ Clara Choi¹

(1) Stanford University Medical Center, Stanford, United States

Objective: Our initial report on stereotactic radiosurgery (SRS) of the postoperative resection cavity of brain metastases suggested improvement in local control (LC) with the addition of a 2 mm margin. The purpose of this study was to evaluate the effects of such margin on LC and toxicity. Factors associated with distant brain failure and overall survival were identified.

Methods: We retrospectively reviewed 120 cavities in 112 patients. SRS was delivered to a median marginal dose of 20 Gy (range, 12-30 Gy), targeting a median target volume of 8.7 cm³ (range, 0.1-66.8 cm³). SRS was delivered in 1-5 fractions, with 48% and 43% of the lesions treated in one- and three-sessions, respectively. The median single-session equivalent dose calculated using the linear quadratic model was 16 Gy₁₀ (range, 12-24 Gy₁₀).

Results: Local failure was observed in 13 of 120 cavities. With a median follow-up of 11 months (range, 1-87 months), Kaplan-Meier LC rates at 6- and 12-months were 93% and 86%, respectively. On univariate analysis, expansion of the cavity gross tumor volume (GTV) with a 2 mm margin was a significant predictor of improved LC. The 6- and 12-month LC rates with and without the 2 mm margin were 100% and 94% compared to 87% and 78%, respectively (p=0.045). There were 8 patients with edema requiring intervention; the 12-month toxicity rates were 3% and 8% with and without a 2 mm margin, respectively (p=0.31). On multivariate analysis, melanoma histology (p=0.02) and >2 brain metastases (p=0.02) were significant predictors of distant brain failure.

The median overall survival time was 17 months (range, 2-114 months), with 6- and 12-month overall survival rates of 86% and 62%, respectively. KPS ($p=0.0009$), presence of extracranial metastases ($p=0.02$), and graded prognostic assessment (GPA) score ($p=0.019$) were significant predictors of overall survival. WBI was avoided in 72% of the patients.

Conclusions: The LC rate of adjuvant SRS targeting the resection cavity of brain metastases compares favorably with historic results of post-operative WBI and allows WBI to be avoided in a majority of patients. This technique represents an alternative treatment option for those wishing to minimize the risk of toxicity associated with WBI. The addition of a 2 mm margin on the GTV improved LC without increasing toxicity.

PLENARY SESSION 4 DATA BLITZ & ORAL PRESENTATIONS

PS-4-3 SALVAGE THERAPY OF RECURRENT MALIGNANT GLIOMAS WITH RADIOSURGERY AND BEVAZICUMAB

Wednesday 11 May 2011, 08:45 - 10:00

Kyle Cuneo¹ James Vredenburgh² John Sampson^{1, 2} David Reardon² Annick Desjardins² Katherine Peters² Henry Friedman² Karen Allen¹ Zheng Chang¹ John Kirkpatrick^{1, 2}

(1) Department of Radiation Oncology, Duke University, Durham, Nc, USA (2) Preston Robert Tisch Brain Tumor Center, Duke University, Durham, Nc, USA

Background: Most patients with high-grade gliomas (HGG) recur after surgery and chemoradiation, with a median time to progression of less than one year. Conventional salvage therapies offer modest and limited benefit. We hypothesized that administration of stereotactic radiosurgery (SRS) and an anti-angiogenic agent might provide durable benefit with minimal toxicity.

Methodology: A retrospective analysis was performed on patients with recurrent malignant glioma treated with salvage SRS at our institution. All patients had progressed following primary treatment with temozolomide and radiotherapy - SRS was typically administered only after patients had failed multiple post-chemoradiation systemic regimens, many involving bevacizumab alone or in combination with other agents. SRS was administered as a single 15-24Gy fraction per RTOG guidelines or, for lesions >4cm diameter, as five 5Gy fractions to the contrast-enhancing T1-weighted MRI and/or FDG-avid PET target.

Results: From September 2002 to March 2010 63 patients were treated with SRS for recurrent HGG; 14 and 49 with WHO grade III and IV disease, respectively. Median follow-up was 31 months from primary diagnosis and 7 months from SRS. Median overall survival from primary diagnosis was 41 months for all patients. Median progression-free (PFS) and overall survival from SRS (OS-SRS) were 6 and 10 months for all patients, respectively. One-year OS-SRS for patients with grade IV disease who received adjuvant (concurrent or following SRS) bevacizumab was 50% versus 22% for patients not receiving adjuvant bevacizumab ($p=0.005$). Median PFS for patients

who received adjuvant bevacizumab was 5.2 versus 2.1 months for patients who did not receive adjuvant bevacizumab ($p=0.014$). KPS and age were not significantly different between these groups. Treatment-related grade 3-4 toxicity was 10% versus 14% for patients receiving versus not receiving adjuvant bevacizumab ($p=0.58$). On multivariate analysis, the relative risk of death and progression with adjuvant bevacizumab were 0.37 (CI 0.17-0.82) and 0.45 (CI 0.21-0.97), respectively. KPS >70 and age <50 years were significantly associated with improved survival.

Conclusions: The combination of radiosurgery and bevacizumab for recurrent malignant glioma was well-tolerated and appeared associated with improved outcomes in this heavily pre-treated population. A prospective trial of concurrent SRS and bevacizumab is underway at our institution and a multi-institutional study will be required to determine efficacy and long-term toxicity of this approach.

PS-4-4 EXPANSION OF GLIOMA STEM-LIKE CELLS IN DE NOVO GLIOBLASTOMAS AFTER GAMMA KNIFE SURGERY PLUS EXTERNAL BEAM RADIATION

Wednesday 11 May 2011, 08:45 - 10:00

Kaoru Tamura¹ Masaru Aoyagi¹ Takahiro Ogishima¹ Hiroaki Wakimoto¹ Masaaki Yamamoto² Kikuo Ohno¹

(1) Department of Neurosurgery, Tokyo Medical and Dental University, Tokyo, Japan

(2) Department of Neurosurgery, Katsuta Hospital Mito GammaHouse, Ibaraki, Japan

Objectives: Recent evidence suggests that a glioma stem-cell subpopulation contributes to radioresistance in malignant gliomas. We examined malignant gliomas for the expression of stem-cell markers in histological sections of primary and recurrent tumors after high-dose irradiation with Gamma Knife surgery (GKS) and external beam radiation therapy (EBRT).

Methods: Tumor samples were collected during surgery from 63 patients with different grades of gliomas prior to any adjuvant treatment. The samples were subjected to CD133 immunohistochemistry on paraffin-embedded sections with a catalyzed signal amplification method. The frequency of CD133 expression on glioma cells was compared between primary and recurrent tumors in 24 patients after irradiation.

Results: CD133 expression on glioma cells was mostly confined to de novo glioblastomas but was rarely observed in lower grade gliomas. The frequency of CD133-positive glioma cells was very low in primary sections, but markedly increased in sections from recurrent tumors after GKS plus EBRT in de novo glioblastomas. The frequency of CD133-positive glioma cells was apparently higher in sections after high-dose radiation than after EBRT alone. Two autopsy cases of de novo glioblastomas showed extensive distribution of CD133-positive glioma cells in remote sites of recurrence. In contrast, secondary glioblastomas rarely expressed CD133 antigen after malignant progression following radiation. CD133 and Ki-67 dual-positive cells were significantly increased in CD133-positive glioma cell clusters in recurrent glioblastomas after radiation therapy.

Conclusion: Our results indicate that CD133-positive glioma stem-like cells could survive, change to a proliferative cancer stem cell phenotype, and cause recurrence after high-dose irradiation with GKS plus EBRT in de novo glioblastomas.

PS-4-5 RISK OF MALIGNANCY AFTER GAMMA KNIFE RADIOSURGERY: AN UPDATE 1985-2009

Wednesday 11 May 2011, 08:45 - 10:00

Jeremy Rowe¹ John Yianni¹ Alison Grainger¹ Lee Walton¹ Alan Waterworth¹ Matthias Radatz¹ Andras Kemeny¹

(1) National Centre for Stereotactic Radiosurgery, Sheffield, UK

Summary: We previously published a retrospective cohort study showing no increased risk of malignancy in UK patients treated with radiosurgery upto the end of 2004.[1] Because of the long duration after cranial irradiation before neoplastic changes may become evident, it was proposed to run this as an ongoing flagging study. To address this, we have re-analyzed the data with an additional five years of follow-up.

Objective: To assess the risk of radiosurgery in causing malignant transformation in benign tumours, or in inducing new malignancies.

Methods: A retrospective cohort study comparing the Sheffield England radiosurgery patient database with national mortality and cancer registries. This was previously reported with data from 1985-2004, and here is updated to the end of 2009. This now totals 7998 patients, excluding 183 patients with abnormal tumour suppressor genes, this constitutes 56,788 patient-years of follow-up data.

Results: In this material, and including our previously reported case, we have identified four new tumours, principally astrocytomas/gliomas, developing after radiosurgery. On an age, sex and year matched basis, we would have predicted that there would have been a background rate of 5.1 cases. Additionally no further cases of malignancy were identified in the patients with abnormal tumour suppressor genes to those published previously.[2]

Conclusion: These data further support the long-term safety of stereotactic radiosurgery, and suggest that the risk of a malignant transformation or a new malignancy developing is so low as not to be a factor in clinical decision making.

Rowe J, Grainger A, Walton L, Silcocks P, Radatz M, Kemeny A. (2007) The Risk of Malignancy after Gamma Knife Stereotactic Radiosurgery *Neurosurgery* 60:60-66.

Rowe J, Grainger A, Walton L, Radatz M, Kemeny A. (2007) The safety of radiosurgery applied to conditions with abnormal tumour suppressor genes. *Neurosurgery* 60:860-4

PLENARY SESSION 5

LECTURE, ORAL PRESENTATIONS & INVITED CONFERENCE

PS-5-1 STEREOTACTIC HIGH INTENSITY FOCUSED ULTRASOUND: A NOVEL NON INVASIVE MODALITY FOR BRAIN TREATMENTS

Wednesday 11 May 2011, 11:30 - 12:30

Jean-François Aubry¹, L. Marsac^{1,2}, M. Pernot¹, D. Chauvet³, A.-L. Boch³, S. Lehericy⁴, C. Cohen-Bacrie², J. Souquet², M. Fink M¹, M. Tanter¹

(1) Institut Langevin, CNRS UMR 7587, INSERM U979, ESPCI ParisTech, Paris, France
(2) SuperSonic Imagine, Aix en Provence, France, (3) Neurosurgery Department, Groupe Hospitalier Pitié-Salpêtrière, Paris, France (4) Centre de Neurolmagerie de Recherche - CENIR, Centre de Recherche de l'Institut du Cerveau et de la Moelle epiniere, Université Pierre et Marie Curie-Paris 6 UMR-S975, Inserm U975, CNRS UMR 7225, Groupe Hospitalier Pitié-Salpêtrière, Paris, France

In the 50's, Leksell pioneered in experimenting the possibility to treat brain tumors with ultrasound. He performed first trials with partial craniectomy but due to the strong defocusing effect of the brain, he switched to ionizing radiations with success and paved the way to stereotactic radiotherapy. In the same time Frank and William Fry developed in the USA the first prototype able to perform ultrasonic transcranial brain hyperthermia by using a set of confocal transducers. But due to the limited ultrasound power and number of transducers that could be operated in that time, a craniectomy could not be avoided.

Thanks to the development of multi-element phased array transducers and the improvement of the capabilities of the electronics, new devices have been developed in the last decade in order to non invasively target the brain with ultrasound. The three available devices at this time will be presented in this talk, working respectively at 0.22 MHz, 0.6 MHz and 1 MHz. A novel prototype jointly developed by the Institut Langevin and SuperSonic Imagine is presented with more details. It is working at the highest frequency envisioned for transcranial brain treatment (1 MHz) in order to obtain sharp focusing. In order to overcome the defocusing effect of the skull, a time reversal mirror has been implemented. Temperature elevation monitoring has been achieved in both a 1.5 T Achieva Philips scanner and a 3 T Verio Siemens. The millimetric precision obtained in 15 cadavers heads will be presented.

Clinicians now have the choice between different systems, efficacy and safety of these "ultrasonic scalpels" will have to be carefully studied in the near future.

This should open the way to a variety of innovative non ionizing brain treatments including neurostimulation, ultrasonic drug delivery, tumor ablation, treatment of neurological disorders and strokes.

PS-5-2 AN OVERVIEW OF CLINICAL EXPERIENCE WITH THE EXABLATE® IMAGE GUIDED ACOUSTIC SURGERY SYSTEM USING MR GUIDED FOCUSED ULTRASOUND TECHNOLOGY - REPORT OF CURRENT APPLICATIONS AND FUTURE DEVELOPMENTS

Wednesday 11 May 2011, 11:30 - 12:30

Andreas Melzer¹

(1) Institute for Medical Science and Technology, Dundee, UK

Purpose: This paper reports the current technical, clinical and regulatory status of the ExAblate® Image Guided Acoustic Surgery system which employs Magnetic Resonance Imaging guided Focused Ultrasound (MRgFUS) Technology. The paper includes review of current treatment applications and future developments. ExAblate® is developed and manufactured by InSightec Ltd. (Tirat Carmel, Israel)

Techniques and application: Image guided acoustic surgery using MR guided focused ultrasound technology combines high intensity focused ultrasound that heats and destroys targeted tissue, non-invasively, and Magnetic Resonance Imaging to identify and target tumors providing temperature monitoring of the treated tissue in real time. The advantages of MR guidance is tumor visualization, beam path shaping and MR thermometry together providing a closed loop procedure for optimal treatment outcome.

The ExAblate system can house multiple indications utilizing a single table with applications specific cradles that are interfaced with the standard table. The system offers both commercially approved and research treatment options for a multitude of clinical indications.

- The most frequent use of MR guided Focused Ultrasound Technology is for ablation of uterine fibroids, a commercially approved application. During the past eight years more than 6000 patients have been treated in over 80 sites with sustained symptom relief. In addition, the system is CE approved for treating adenomyosis.

- MRgFUS for pain management includes treating pain palliation of bone metastasis with over 220 patients treated in over 25 sites worldwide. An ongoing phase III clinical study for FDA approval is currently being conducted. This indication received CE mark in 2007.

More than 15 patients have been treated in Europe with MRgFUS for facet joint pain with promising initial results.

- More than 200 patients were treated with MRgFUS for breast cancer (T1, N0, Mo), with 100 of them as part of an excision-less protocol and an international FDA clinical trial is currently set up. An ongoing clinical trial is underway in Europe for treating pre-surgery patients.

- More than 20 patients received treatment of functional brain disorders and pain at University Children's Hospital in Zurich and initial experience in brain tumor ablation at BWH, Boston.

- A feasibility trial is currently being conducted for low risk prostate cancer. More than 7 patients have received successful transrectal prostate ablation in St Petersburg and Singapore without major complication.

Future developments encompass sonication of brain hemorrhages, thrombosis sonication of moving organs, and MRgFUS mediated targeted drug delivery for chemotherapy in cancer

Conclusion: The results generated clearly show the potential of MRgFUS for non-invasive ablation of benign tumors. Increasing evidence show its potential in the treatment of various oncology indications and in pain management. Randomized prospective trials are required to further prove the initial positive results.

PLENARY SESSION 6

DATA BLITZ, LECTURE & ORAL PRESENTATIONS

PS-6-3 BEVACUZIMAB AS A THERAPY FOR RADIATION NECROSIS IN PATIENTS WITH BRAIN TUMORS

Thursday 12 May 2011, 08:45 - 10:00

Olivier Chinot¹

(1) Hôpital de la Timone, Marseille, France

Invited Lecture

PS-6-4 PROGNOSTIC FACTORS FOR THE LOCAL CONTROL OF SPINAL METASTASES TREATED WITH HIGH DOSE STEREOTACTIC RADIOSURGERY.

Thursday 12 May 2011, 08:45 - 10:00

Yoshiya Yamada¹ Zhiqiang Zhang¹ Michael Lovelock¹ Kelvin Chan¹ Floria Chi¹ Joan Zatzky¹ Mark Bilsky¹ Mark Bilsky¹

(1) Memorial Sloan Kettering Cancer Center, New York, USA

Background: A number of fractionation schedules have shown overall equivalence for palliative radiotherapy of solid tumor spine metastases. However, tumor phenotypical features such as histology and size impact upon the probability of palliation and tumor control. Stereotactic radiosurgery has been shown to provide very effective palliation of spinal metastasis with minimal morbidity. Prognostic factors for local control were examined in a prospective database to determine clinically relevant factors to guide the management of these patients.

Methods and Materials: Two hundred and forty six consecutive lesions in 229 patients underwent stereotactic radiosurgery between 2003-2009 with a single fraction (1800-2400cGy). Maximum spinal cord was 1400cGy. Each patient was followed every 3-4 months, and included MRI or CT imaging of the treated site. Statistical analysis was performed with progression-free time defined from the time of radiosurgery to local failure, which was defined as radiographic evidence of tumor enlargement, or pathologic progression (either biopsy or surgical). Death without progression was treated as a competing risk, and patients who were alive without local progression were censored. A Cox-type competing risks model was used for obtaining p-values. The event-free time was defined from treatment to local progression or death, whichever came first; while patients still alive without local progression were treated as censored.

Results: With a median follow up of 17 months (2-64 months) 12 patients have experience local failure. The actuarial local control rate is 90% for the entire cohort. One hundred and thirty two patients had died without progression, and 102 patients were alive without local progression. Thus in terms of events (either local failure or death), 144 patients had an event, while 102 patients had no events. Using death as a competing variable, progression free survival analysis found the dose of radiation (24 Gy vs. < 24 Gy) as the only significant variable for local control (HR 0.241,

$p = 0.013$), while tumor histology and gross tumor volume were not significantly associated with local control. The cumulative actuarial incidence of local failure in the 2400cGy cohort was 4%, compared to 14% for the 1800-2200cGy cohort ($p=0.013$).

Conclusion: The dose of radiation used for radiosurgery was the only factor predictive of local control. Traditional predictors of outcome for conventionally fractionated palliative radiotherapy was not found to be predictive. This is likely a function of the high doses or radiation employed for radiosurgery. The current analysis suggests that dose escalation to 2400cGy provides superior tumor control compared to lower doses.

PS-6-5 STEREOTACTIC RADIATION TOXICITY TO THE SPINAL CORD. A DOSE VOLUME HISTOGRAM ANALYSIS

Thursday 12 May 2011, 08:45 - 10:00

Antonio De Salles¹ Alessandra Gorgulho¹ Nzhde Agazaryan¹ Steve Tenn¹ Philip Chu¹ Chul Lee¹ Michael Selch¹

(1) University of California Los Angeles, Los Angeles, USA

Objective: Review the incidence of radiation induced symptomatic toxicity in patients undergoing radiosurgery of spinal cord related tumors.

Material and Methods: One hundred and twenty three consecutive patients with 185 lesions undergoing spinal radiosurgery at UCLA from May 2002 to June 2009 were analyzed to detect spinal cord radiation induced toxicity. Age ranged from 16 to 96 years old. There were 71 women and 52 men. Histology, tumor relationship with the spinal cord, symptoms and presence of myelitis as detected by MRI scan T2 changes and T1 post-gadolinium injection enhancement were analyzed. Patients were treated to avoid maximum point dose to the surface of the spinal cord of more than 12Gy. Discrete intra-spinal cord tumors and arteriovenous malformations were treated to a maximal dose to the periphery of the lesions of 12Gy. Patients with diffuse tumors were not treated with single dose and were excluded from this analysis.

Results: The incidence of radiation induced toxicity was 0.08% per patient and 0.006% per lesion. One patient with a sarcoma metastasis to the C4 vertebrae involving the body and the right pedicle, also encompassing the vertebral artery and approaching the epidural space was treated with 14Gy delivery to the 95% isodose line, the GTV was 10.11 cc. The conformality index was 0.98. Sixteen month after the treatment, the patient presented decreased strength in the right arm and leg. The patient had full motor strength in his left arm and left leg. Sensation to light touch was intact. Review of the radiosurgery plan dose volume histogram showed that the volume of the spinal cord at the C4 level receiving 12Gy was 13.33 % of the total cord volume (= 0.26 cc). And this was above our rule of 12Gy as the maximal dose to the dose point.

Conclusion: Although the dose constrain limit of 12Gy to the surface of the cord cannot always be achieved for patients with tumor touching the cord, one should strive to develop stereotactic radiosurgery plans for spinal cord related tumors to keep the 12Gy dose away from the spinal cord. When it is not possible, resorting to hypofractions or full fractionated schemes may be the chosen stereotactic radiation approach.

PLENARY CLOSING SESSION

PS-7-1 THE FUTURE OF EXTRACRANIAL RADIOSURGERY

Thursday 12 May 2011, 11:30 - 13:00

John Adler¹

(1) Stanford University Medical Center, Stanford, USA

Invited Lecture

PS-7-2 CITATION MEASURES IN STEREOTACTIC RADIOSURGERY: PUBLICATION ACROSS A DISCIPLINE

Thursday 12 May 2011, 11:30 - 13:00

Douglas Kondziolka¹

(1) Department of Neurological Surgery, Pittsburgh, United States

Objective: It is possible to judge the impact of scientific research by the number of citations a publication has received. We identified the most cited works in the field of stereotactic radiosurgery to study the evolution of this field from the perspective of publication.

Methods: A web of science search was performed for articles that included the word -æradiosurgery- in the title. We studied those reports with more than 100 citations.

Results: 5,532 published works were available for study between 1951 and 2010. Eighty-five (85) articles had >100 citations, and these were published in 19 separate journals. The majority were published in the International Journal of Radiation Oncology, Biology and Physics, the Journal of Neurosurgery, and Neurosurgery, but 16 other journals contained highly cited reports. The most common topics included brain metastasis management (n=20), arteriovenous malformations (n=17), vestibular schwannomas (n=9), technologies (n=9), meningiomas (n=8), and dose response/radiobiology (n=6). Fifty-seven percent of the articles were published in the last 10 years. The mean number of articles per year in the 1980s was 9.6, in the 1990s it was 178 and during the 2000s it was 313. Factors affecting the importance of specific topic reports will be discussed.

Conclusions: The first radiosurgery report by Leksell (1951) initiated the field. The 1980s were a period of new technology development followed in the 1990s by introductory articles on specific indications that consisted mainly of retrospective case series. More sophisticated higher level evidence reports were published in the last decade. The most significant works in radiosurgery include initial technology descriptions, multicenter studies with large numbers of patients, randomized clinical trials, and reports that provide dose prescription guidelines.

FABRIKANT AWARD AND LECTURE: WHEN SERENDIPITY MEETS CREATIVITY

Thursday 12 May 2011, 11:30 - 13:00

MASAAKI YAMAMOTO, M.D., Ph.D.

Katsuta Hospital Mito GammaHouse, Hitachi-naka, Japan

I believe it to be absolutely true that established evidence does not endure forever, often becoming out-dated soon after publication. Even the results of meticulously conducted randomized controlled trials are eventually challenged. Breaking free of an established paradigm requires a creative mind and, sometimes, serendipity as well. Herein, reviewing my over two decade career in gamma knife radiosurgery (GKRS), I describe key cases which prompted me to launch four new trials.

GKRS for multiple brain metastases (METs)

Although widespread computed tomography (CT) use in the 1970's simplified diagnosing multiple METs, most such patients, over the next two decades, died due to brain tumor progression. In 1975, the first picture appearing on the small cathode ray tube display of a CT (EMI) scanner caught us all by surprise. This patient was the first in Japan to receive a CT. The apparent diagnosis was multiple brain METs. This patient died 10 days later and underwent postmortem examination. Again, we were very surprised by the brain slice. CT and autopsy findings coincided exactly and both images remained strongly imprinted in my brain. In 1995, I treated a young man with miliary brain lesions from a primary malignant germ cell tumor using a GK. Before GKRS, death had been imminent due to lack of an established treatment. However, post-GKRS, he returned to essentially full activity within a week and remained in excellent condition for 3.5 months, though his condition eventually deteriorated again and he died. Postmortem study revealed tumor cell loss and fibrosis within treated areas, though there was diffuse tumor cell infiltration in the subarachnoid space. I was struck by the possibility of treating multiple METs with the GK.

Two-stage GKRS for relatively large arteriovenous malformations (AVMs)

In 1990, I examined an autopsy case who had undergone GKRS for an AVM and died due to pulmonary artery embolism the day after angiography performed 26 months later. The angiogram had demonstrated complete nidus obliteration. While inspecting the autopsy specimen with a microscope, a continuous-gradation pattern of pathological changes in the choroid plexus, according to irradiation doses from lower to higher, caught my eye. I realized that even a low, i.e. sub-optimal, irradiation dose to an AVM might trigger certain changes proceeding for three or more years. This experience prompted me to treat a patient with a relatively large AVM by two-stage GKRS with an interval of three years.

GKRS for meningiomas using a modified dose-planning technique

In 1997, I studied a cerebello-pontine angle meningioma case. The postmortem examination was performed 42 months after GKRS. Microscopic examination of an autopsy specimen revealed vessel wall thickening and stenosis of dural and pial arteries surrounding the tumor. This post-GKRS stenosis of tumor feeding arteries prompted me to consider applying GKRS to patients with skull base meningiomas as a preoperative procedure, instead of the established endovascular embolization technique. I dubbed this strategy "radiosurgical thrombolization." However, the result was quite different from what I had expected. There was a marked decrease in tumor enhancement as well as subsequent tumor shrinkage. The referring neurosurgeon no longer saw a need to resect the tumor and followed this patient without surgical intervention. This experience prompted me to treat falx or falco-tentorial meningiomas using a modified dose planning technique, basically

involving irradiation of the dural attachment of the tumor, in hopes of decreasing the blood supply to this part of the tumor enough to control growth or even produce tumor shrinkage.

Pre-operative GKRS for relatively large brain METs

Surgical removal plus subsequent whole brain radiotherapy (WBRT) has long been the gold standard for treating a single, relatively large MET. However, several recent retrospective studies advocate focal radiation techniques, i.e., stereotactic radiosurgery (SRS), as an alternative to WBRT for postoperative irradiation. I started employing this treatment strategy in the late 1990s. Based on awareness of a relatively high incidence of subsequent meningeal dissemination, particularly subdural seeding, I considered “reversing the order” of preoperative GKRS. I hypothesized that once preoperative radiation is performed, even if cell clusters spread and settle within the brain, already-irradiated tumor cells have less capacity to proliferate.

A New Scientific Method

I would like to leave you with a message and this is addressed particularly to my young colleagues, worldwide. The message is this: Even the most widely published and well-established evidence can ultimately be invalidated. Even labor-intensive randomized controlled trials may eventually be seen as flawed. SRS use is spreading rapidly, with technologies and clinical applications still advancing. The recent developments in body SRS are particularly surprising. There is no question that technological advances are absolutely crucial. However, it is even more important for us to continuously maintain open, creative minds. Serendipity is a necessary complement to creativity. Furthermore, to create something new, we must have the courage to challenge and overcome the established paradigm. If everyone participating in this congress strives to think independently, beyond the established viewpoints, radiosurgery will have a very bright future.

MONDAY, 9 MAY 2011

10:30 - 11:30 ORAL SESSION

OS1 BRAIN METASTASES 1

Room: La seine

OS1-1 COMBINED WHOLE BRAIN RADIOTHERAPY AND SIMULTANEOUS INTEGRATED BOOST (WBRT+SIB) FOR BRAIN METASTASES

Ben Slotman¹ Wietse Eppinga¹ Patricia De Haan¹ Niels Haasbeek¹ Frank Lagerwaard¹

(1) VU University medical center, Amsterdam, The Netherlands

Introduction: Several publications have addressed stereotactic planning by volumetric modulated arc therapy (VMAT) or tomotherapy for multiple brain metastases (BM) using integrated WBRT+SIB. However, clinical outcome data of this have been limited. Since June 2008, RapidArc VMAT (Varian medical systems) has been performed at our center for patients with 2-6 BM and patients receiving postoperative WBRT with SIB to residual BM. We report on the clinical outcomes in a cohort of patients treated in this manner.

Methods: WBRT+SIB was delivered to 62 consecutive patients with RapidArc VMAT on the Novalis TX, using the BrainLab frameless masksystem, ExacTrac and 6D-Robotics couch. WBRT was delivered in 20Gy/5fx and SIB to the BM was also 20Gy/5fx (total 40 Gy/5fx). The median age of 37 males and 25 females included was 61 years. Primary tumors were lung cancer (71%), breast cancer (11%), melanoma (10%), and others (8%). The median number of BM-™s receiving a SIB was 3 (range 1-6). The median cumulative volume of the treated BM was 6.1 cm3 (range 0.2-»29.7 cm3). Patients were followed-up with 3-monthly MRI scans, and where necessary, GP-™s were contacted to ensure complete follow-up data.

Results: All patients completed WBRT+SIB, delivered with two arcs within 3 minutes beam-on time. Median overall survival (OS) was 6.2 months, and OS rate at 1 year was 28.5%. OS correlated with RTOG RPA class, with grouped patients in RPA I (n=4) and RPA II (n=42) having a median OS of 9.0 months versus 2.2 months in 16 RPA III patients (p<.001). Neither the number of BM boosted (≤ 3 BM vs. > 3 BM; p=.66), nor the cumulative volume of the BM (≤ 10 cm3 vs. > 10 cm3; p=.87) correlated with OS. Intracranial progression, defined as radiological and/or clinical progression was seen in 22 patients. Actuarial intracranial progression rates were 28.1% and 43.6% at 6 and 12 months. Toxicity was mild with fatigue (28%), headache (16%) and nausea (8%) being most frequently reported; 44% of patients reported no side effects. In 3 patients (6%), follow-up MRI scans showed a volume increase of a treated BM in combination with hypoperfusion, consistent with tumor necrosis.

Conclusions: WBRT+SIB using volumetric arc therapy is a patient friendly and effective option for radiosurgery of favorable patients with multiple BM. Patients with multiple BM in RPA Class III do not benefit from it. A randomized multicenter trial to evaluate the precise role of this new approach is being prepared.

10:30 - 11:30 ORAL SESSION

OS1 BRAIN METASTASES 1

Room: *La seine*

OS1-2 GAMMA KNIFE RADIOSURGERY FOR MULTIPLE BRAIN METASTASES: WHAT IS A SAFE INTEGRAL DOSE FOR THE WHOLE SKULL?

Takuya Kawabe^{1, 2} Masaaki Yamamoto^{1, 3} Bierta E. Barfod¹ Yoichi Urakawa¹

(1) Katsuta Hospital Mito GammaHouse, Hitachi-naka, Japan (2) Kyoto Prefectural University of medicine, Kyoto, Japan (3) Tokyo Women's Medical University Medical Center East, Tokyo, Japan

Purpose: Gamma knife radiosurgery (GKRS) has recently been employed in patients with multiple brain metastases (METs), even those with five or more lesions. However, very little information is available on threshold doses to the whole brain, which may have adverse effects on the brain. We attempted to determine the safest integral dose for the whole skull.

Methods and Materials: We analyzed the treatment protocols of 1246 GKRS procedures performed for 900 patients (40.3% of cohort) with five or more brain METs (maximum, 89) during the period between January 1999 and December 2009. The median lesion number was 10 (range: 5-89) and the median cumulative volume of all tumors was 7.3 (range: 0.1-115.3) cc. The median selected dose at the lesion periphery was 20 (range: 10-27) Gy.

Results: Integral skull doses were computed using the Leksell Gamma Plan (Elekta AB, Stockholm). The median integral skull dose was 8.5 (0.2-28.7) Joules. The median brain volumes receiving >5 Gy and >12 Gy were 327 (range 5-1942) cc and 50 (range 0-313) cc. Among five patients who received over 20 Joules, one (20%) experienced acute brain swelling 2 days after GKRS. Among 58 patients receiving doses between 15 and 20 Joules, one (1.7%) experienced gradual brain swelling due to necrotic change 4 months after GKRS.

Conclusions: We conclude that integral skull doses of 15 Joules or less are clearly safe, while those of more than 20 Joules carry a relatively high risk of radiation-induced brain injury. The zone between lower and higher risk thus appears to be somewhere between 15 and 20 Joules.

10:30 - 11:30 ORAL SESSION

OS1 BRAIN METASTASES 1

Room: *La seine*

OS1-3 STATISTICAL ANALYSIS OF TRENDS IN THE RESULTS OF GAMMA KNIFE SURGERY FOR LARGER NUMBERS OF METASTASES

Michael Torrens¹ Panos Nomikos¹ Katerina Kafkoulas¹ Christos Stergiou¹ Vasilis Vasdekis²

(1) Hygeia Hospital, Athens, Greece (2) University of Economics and Business, Athens, Greece

Aim: This study was designed to compare the **Results:** of treatment by radiosurgery in cases of cerebral metastasis according to the number of metastases. The aim was to define whether multiplicity alone represents a contraindication to radiosurgery as is often proposed.

Material And Methods: A total of 227 patients were available from whom data had been collected

prospectively and potential follow up existed for at least 2 years. The patients were divided into 3 groups, single metastases, 2-9 metastases and >9 metastases. Matching was assessed for age, sex, diagnosis, size, Karnowsky performance score (KPS) and BSBN prognostic index using Kruskal Wallis or Cross-tabs tests. Some patients were randomly selected until the groups were adequately matched for analysis. The Kaplan-Meier method with log rank tests (Bonferroni correction) was used to evaluate outcome. Outcome was defined as survival in months from date of treatment.

Results: Within the groups the numbers analyzed were single metastases (n=24), 2-9 metastases (n=30) and >9 metastases (n=16). In the latter group there were a total of 294 treatment targets (average = 19.6 per case). The groups were matched for age (p=0.150), sex (p=0.087), KPS (p=0.079) and diagnosis (p=0.095). Groups were not matched for size (p=0.004) and BSBM (p=0.016). The Kaplan Meier method revealed no statistically significant difference in outcome of single vs. 2-9 (p=0.236), 2-9 vs. >9 (p=0.516) and single vs. >9 (p=0.064). The latter value approaches significance and so a further analysis (Cox regression) was made to take into account the effect of size and BSBM in this subgroup. This then revealed a less obvious difference (p=0.220). Visual appraisal of the Kaplan-Meier curves however does suggest a slightly worse trend in the group of >9 metastases. There were also more frequent retreatments in the group of >9 metastases.

Conclusion: There is no significant difference in outcome dependent on number of metastases that represents a relative contraindication to Gamma Knife radiosurgery in patients with multiple metastases. The decision to treat should be based on the various prognostic indexes and not on the multiplicity of lesions.

10:30 - 11:30 ORAL SESSION

OS1 BRAIN METASTASES 1

Room: La seine

OS1-4 A PROSPECTIVE PHASE II CLINICAL TRIAL. STEREOTACTIC RADIOSURGERY (SRS) OF THE RESECTION CAVITY FOLLOWING SURGICAL REMOVAL OF BRAIN METASTASIS (BM): PRELIMINARY REPORT

Andrew A. Kanner^{1, 2}, Diana Majetvsky^{1, 2, 3}, Dan Schifter^{1, 2, 3}, Natan Shtraus^{1, 2, 2}, Shlomi Alani^{1, 2, 3}, Benjamin W. Corn^{1, 2, 3}

(1) Tel Aviv Sourasky Medical Center, Tel Aviv, Israel (2) Stereotactic Radiosurgery Unit, Tel Aviv, Israel (3) Institute of Radiotherapy, Tel Aviv, Israel

Background: Local control of BM is increased by whole-brain irradiation (WBI) with or without resection. However, patients who have new or recurrent BM after WBI and undergo resection are left without adjuvant therapy options. Patients who do want to defer WBRT as an upfront therapy after resection of BM are also left without reasonable adjuvant treatment.

Methods: We performed a retrospective analysis evaluating the addition of a SRS boost to the resection cavity both as an adjuvant and salvage procedure (Kanner et al. Radiosurgery 2010). As a second step we initiated a prospective Phase II clinical evaluation of patients who underwent resection of BM and were subsequently treated with a SRS to the resection cavity and WBRT was

postponed.

Results: In our prospective study we enrolled 31 patients between 01-2009 and 10-2010. Twelve patients were female and the median age for the group was 62.2 years (range 37.5-84.5) and median KPS 90 (50-100) at the time of SRS. Median time to SRS after surgical removal was median 1.1 months (0.7-3.3) and the overall median follow-up was 6.5 months (3.0-26.2, mean 8.9), including 7 patients followed for more than 1 year. Six patients had a second lesion treated simultaneously. During the follow up 5 (16.1%) patients received WBI as salvage procedure. In 2 (6.5%) patients partial external radiotherapy was added. And 24 patients (77.4%) did not receive additional WBI. At last evaluation six patients had died 12.7 to 3.5 months (median 5.8) after treatment.

Conclusion: This represents the first prospective study investigating the impact of post resection SRS in patients with metastatic disease deferring WBI. These preliminary **Results:** demonstrate feasibility of post-resection SRS in selected patients with outstanding local tumor control and might justify to postpone WBI on selected patients. Larger multicenter prospective studies and longer follow-up are needed to determine the role of post-resection SRS as upfront therapy.

10:30 - 11:30 ORAL SESSION

OS1 BRAIN METASTASES 1

Room: La seine

OS1-5 *ROLE OF LINEAR ACCELERATOR BASED STEREOTACTIC RADIOSURGERY IN CONTROL OF BRAIN METASTASES IN THE ELOQUENT BRAIN*

Surbhi Jain¹

(1) H. Lee Moffitt Cancer Center, Tampa, United States

Introduction: The authors evaluated the efficacy of linear accelerator based single fraction Stereotactic Radiosurgery (SRS) in patients with brain metastases located in the eloquent brain.

Materials/Methods: Between Jan 2008 and Aug 2010, 242 patients (124 men and 118 women) with 692 brain metastases were treated with stereotactic radiosurgery (SRS) at Moffitt Cancer Center, Florida, USA. Of 692 tumors, 141 (20%) tumors were located in the eloquent brain. Melanoma was the most common primary malignancy, followed by lung cancer, breast cancer and renal cell carcinoma. The metastatic tumors were located in the primary somatosensory cortex in 61 patients, the brain stem in 35, speech in 15, basal ganglionic-capusloinsular area in 7, thalamo-ventricular in 12, and the visual pathways in 11. The radiation dose was based on tumor volume, location in the eloquent brain, and a predicted dose-response relationship of brain tissue necrosis. The median tumor volume at the time of the treatment was 0.721 cm3 (range 0.012-16.42 cm3). The median prescribed radiation dose was 21 Gy to the 80% isodose line (range 14-25 Gy). The end point of the study was local tumor control based on radiological response of serial follow-up imaging.

Results: Metastatic tumors were followed with post-radiosurgery MR imaging every 2-3 months following treatment. Imaging follow-up studies were not completed in 33 patients, because of the short term survival and patients being lost to follow-up. Of the remaining 108 evaluable tumors,

with an imaging follow-up evaluation at a median of 24 weeks (range 5-116 weeks), the tumors disappeared in 36, shrank in 36, unchanged in 31, and grew in 5. Lesions that were unchanged, disappeared or reduced in size were considered to be under control. Overall local tumor control rate was 95%. Adverse neuro-imaging changes leading to worsening of neurological functions occurred in 12 (11%) metastatic tumors. Of which, intra-tumoral hemorrhage occurred in 7 (6%) and radiation induced changes in 5 (5%) of the evaluable treated tumors.

Conclusion: Linear accelerator based stereotactic radiosurgery appears to be a promising therapeutic option in patients presenting with metastatic tumors in the critical eloquent parts of the brain. It offers optimal local tumor control. The risks associated with such a treatment in an eloquent location are low.

10:30 - 11:30 ORAL SESSION

OS2 VASCULAR 1 – ARTERIOVENOUS MALFORMATIONS – GENERAL

Room: Miles Davis

OS2-1 DOES THE ANGIOARCHITECTURE DETERMINE OCCLUSION RATES FOLLOWING GAMMA KNIFE (GK) RADIOSURGERY FOR BRAIN ARTERIOVENOUS MALFORMATIONS (BAVMS)?

Patamintita Taeshineetanakul¹ Krings Timo¹ Ravi Menezes³ Michael L. Schwartz²

(1) Division of Neuroradiology, Toronto, Canada (2) Division of Neurosurgery, Toronto, Canada (3) Joint Department of Medical Imaging, Toronto, Canada

Objective: To test whether the angioarchitecture of brain arteriovenous malformations determines the obliteration rate following gamma knife radiosurgery.

Methods: Retrospective analysis of 117 consecutive patients (m/f= 61/56, age: 6-47, mean 36) with BAVMs who underwent radiosurgery between September 2005 and December 2009 at a single institution. The following angioarchitectural characteristics were reviewed by two experienced neuroradiologists in consensus by evaluating the digital subtraction angiogram (DSA) on the day of SRS: Enlargement of feeding arteries, flow related aneurysms, shift of the arterial watershed, perinidal neoangiogenesis and intranidal aneurysms. The arterio-venous transit-time was estimated by counting the number of DSA frames between first depiction of the nidus and first visualization of a vein. Concerning the venous analysis: Venous ectasias, circumscribed venous pouches, venous rerouting and the presence of a pseudophlebotic pattern (corkscrew-like dilated veins draining normal brain parenchyma in the late venous phase) were evaluated in patients who did NOT present with venous stenoses. The radiation plan was reviewed for nidus volume and eloquence of AVM location. A chart review was performed to determine clinical presentation and previous endovascular treatment. Outcome was dichotomized into complete vs. incomplete obliteration and chi-square tests were performed, examining whether outcome status was associated with the described factors.

Results: The presenting symptoms were hemorrhage in 72 patients, headaches in 15, seizures in 10, incidental in 5 and other in 15. The mean nidus volume was 3.74 cm³ (range 0.08-14.58 cm³). Embolization prior to SRS had been performed in 23 patients.

The follow-up duration ranged from 6-48 months (mean 24 months). In the subsequent analysis, patients with a minimum follow-up of 36 months (n=39) and patients with confirmed complete obliteration prior to 36 months (n=21) were included to avoid biasing our data with incomplete obliteration due to insufficient follow-up. In this group of 60 patients 39 complete occlusions and 21 incomplete occlusions were present.

There was no significant association between incomplete obliteration and flow-related or intranidal aneurysms, shift of the arterial watershed, angiogenesis, venous ectasias, eloquence of location, age, previous hemorrhage or embolization. Incomplete obliteration was associated with arterial enlargement (p=0.023), high flow (0-1 frame between depiction of nidus and depiction the vein) (p=0.001), venous pouches (p<0.001), venous rerouting (p=0.002), pseudophlebetic pattern (0.054) and AVM size (p=0.033).

Conclusions: In addition to larger AVM size, some angioarchitectonic factors that indicate high flow are associated with lower rate of AVM obliteration following SRS.

10:30 - 11:30 ORAL SESSION

OS2 VASCULAR 1 – ARTERIOVENOUS MALFORMATIONS – GENERAL

Room: Miles Davis

OS2-2 GAMMA-KNIFE RADIOSURGERY FOR ARTERIOVENOUS MALFORMATIONS. PATIENTS WITH A 15 YEAR FOLLOW-UP.

Laura Paul¹ Roberto Martinez¹ Elena Kusak¹ Nuria Martínez¹ Jorge Gutiérrez¹ Germán Rey¹

(1) Unidad gamma. hospital ruber internacional, Madrid, Spain

OBJECT: To evaluate the long term effectiveness and clinical **Results:** of Gamma-Knife treatment for arteriovenous malformations (AVMs) in a series of the first 111 patient treated at a single institution.

METHOD: Between august 1993 and October 1995, 111 patients with intracranial AVMs were treated with Gamma Knife radiosurgery. There were 53 females and 58 males, with a mean age of 34 years. The treated nidus volume ranged between 0.6 and 19 cc, with a mean volume of 3.4 cc. Eighty-five percent of the AVMs had a volume of less than 5 cc. The administered marginal dose varied between 12 and 30 Gy (mean 20.74 Gy) to an isodose line of 50 to 60%. The number of isocenters ranged between 1 and 8, with a mean of 3. Forty-three percent of AVMs had been previously embolized. In 2009, with a minimum post-radiosurgery follow-up of 15 years, this consecutive series of patients was retrospectively reviewed. The angiographic or MRI obliteration of the AVMs, the patient's clinical evolution and any further treatment were evaluated.

Results: Imaging follow-up was obtained for 100 of the 111 patients. The global obliteration rate was 65% (67% for AVMs smaller than 5 cc, 45% for AVMs between 5 and 10 cc, and 40% for those larger than 10cc). Clinical follow-up was completed on 101 patients. In 90% the clinical evolution was favourable, while in 6% the previous symptoms were aggravated or new symptoms appeared. During these 15 years 5 cases of hemorrhage have been recorded (annual bleed rate of 0.33%). Twenty percent of patients (22 out of the 111) had repeat radiosurgery to the same or different treated areas. The global obliteration rate after retreatment was 77%.

CONCLUSION: Long term follow-up is essential in the evaluation of the actual **Results:** of any treatment. Our experience with this group of patients provided **Results:** similar to those of other series with shorter follow-up times. Due to its high effectiveness, low morbidity and reproducibility, radiosurgery has become the first management option for AVMs smaller than 5 cc that have not bled. As the experience increases, adequate endovascular treatments are provided and the analysis of other variables is accomplished, the effectiveness in larger volume AVMs will increase.

10:30 - 11:30 ORAL SESSION

OS2 VASCULAR 1 – ARTERIOVENOUS MALFORMATIONS – GENERAL

Room: Miles Davis

OS2-3 STEREOTACTIC RADIOSURGERY FOR ARTERIOVENOUS MALFORMATIONS OF THE BASAL GANGLIA AND THALAMUS

Hideyuki Kano¹ Douglas Kondziolka^{1, 2} Huai-che Yang¹ Thomas Flannery¹ Nasir Awan¹ Ajay Niranjani¹ Josef Novotny Jr² John Flickinger^{1, 2} L. Dade Lunsford^{1, 2}

(1) Department of Neurological Surgery, University of Pittsburgh, Pittsburgh, United States (2) Department of Radiation Oncology, University of Pittsburgh, Pittsburgh, United States

INTRODUCTION: To define the long-term outcomes and risks of stereotactic radiosurgery (SRS) for arteriovenous malformations (AVMs) of the basal ganglia and thalamus.

METHODS: Between 1987 and 2006, we performed Gamma knife® SRS on 996 patients with brain AVMs; 56 patients had AVMs of the basal ganglia and 77 had AVMs of the thalamus. In this series, 113 patients (85%) had prior hemorrhage. The median target volumes were 2.7 cc (range, 0.1-20.7 cc). The median margin dose was 20 Gy (range, 15-25 Gy).

Results: The actuarial rates of total obliteration documented by angiography or MR were 57%, 70%, 72%, and 72% at 3, 4, 5, and 10 years, respectively. The median time to complete MR obliteration was 31 months. The actuarial rates of total obliteration documented by angiography were 47%, 60%, 63%, and 63% at 3, 4, 5, and 10 years, respectively. The median time to complete angiographic obliteration was 37 months. Factors associated with a higher rate of AVM obliteration were AVM in the basal ganglia, smaller target volume, smaller maximum diameter, and higher margin dose. Fourteen patients (11%) had a hemorrhage during the latency interval and five patients died due to hemorrhage. The rate of AVM hemorrhage after SRS was 4.5%, 6.2%, 9.0%, 11.2%, and 13.8% at 1, 2, 3, 5, and 10 years, respectively. The overall annual hemorrhage rate was 3.8%. A larger nidus volume was associated with an increased risk of hemorrhage after SRS. Permanent neurological deficits due to adverse radiation effects (AREs) developed in six patients (4.5%) after SRS and one patient developed delayed cyst formation 56 months after SRS. No patient died due to AREs. Factors associated with higher risk of symptomatic AREs were larger target volume, larger maximum diameter, lower margin dose, and higher Pollock-Flickinger score.

CONCLUSIONS: SRS is a gradually effective and relatively safe management option for AVMs of the basal ganglia and thalamus. Although hemorrhage after obliteration did not occur in this series, patients remain at risk during the latency interval until obliteration occurs. The best candidates for SRS are patients with a smaller volume AVMs located in basal ganglia.

10:30 - 11:30 ORAL SESSION

OS2 VASCULAR 1 – ARTERIOVENOUS MALFORMATIONS – GENERAL

Room: Miles Davis

OS2-4 STEREOTACTIC RADIOSURGERY FOR BRAINSTEM ARTERIOVENOUS MALFORMATIONS

Hideyuki Kano¹ Douglas Kondziolka^{1, 2} Huai-che Yang¹ Thomas Flannery¹ Nasir Awan¹ Ajay Niranjan¹ John Flickinger^{1, 2} L. Dade Lunsford^{1, 2} L. Dade Lunsford^{1, 2}

(1) Department of Neurological Surgery, University of Pittsburgh, Pittsburgh, United States (2) Department of Radiation Oncology, Pittsburgh, United States

INTRODUCTION: To define the long-term outcomes and risks of stereotactic radiosurgery (SRS) for brainstem arteriovenous malformations (AVMs).

METHODS: Between 1987 and 2006, we performed Gamma knife® SRS on 996 patients with brain AVMs; 67 patients had brainstem AVM. Fifty-one patients had prior hemorrhage. The median target volumes were 1.4 cc (range, 0.1-13.4 cc). The median margin dose was 20 Gy (range, 14-25.6 Gy).

Results: The actuarial rates of total obliteration documented by angiography or MR were 41%, 50%, 50%, and 76% at 3, 4, 5, and 10 years, respectively. The median time to complete MR obliteration was 40 months. The median time to complete angiographic obliteration was 41 months. Only higher margin dose was associated with a higher rate of AVM obliteration. Three patients (4%) had a hemorrhage during the latency interval and no patient died from a hemorrhage. Two patients had a hemorrhage 6 months after SRS (3.3 and 3.5 months) and one had a hemorrhage 12 years after SRS. The overall annual hemorrhage rate was 1.4%. Permanent neurological deficits due to adverse radiation effects (AREs) developed in seven patients (10%) after SRS and two patients (3%) developed delayed cyst formation. One patient died secondary to unrecognized hydrocephalus and ARE 35 months after SRS. Higher Spetzler-Martin grade was associated with higher risk of symptomatic AREs. Ten of 22 patients who had ocular dysfunction before SRS had improvement, nine were unchanged, and three had deterioration due to AREs. Eight of 14 patients who had hemiparesis before SRS improved, five were unchanged, and one had deterioration.

CONCLUSIONS: Although hemorrhage after obliteration did not occur in this series, patients remain at risk during the latency interval until obliteration occurs. Approximately half of the patients who had neurological deficits due to prior hemorrhage improved. Higher dose, conformal and highly selective SRS is needed for safe and effective treatment.

10:30 - 11:30 ORAL SESSION

OS2 VASCULAR 1 – ARTERIOVENOUS MALFORMATIONS – GENERAL

Room: Miles Davis

OS2-5 LINAC RADIOSURGERY FOR CEREBRAL ARTERIOVENOUS MALFORMATIONS. OBLITERATION, REBLEED AND COMPLICATION RATES, IN A SERIES OF 117 CONSECUTIVE CASES

Cesare Giorgi¹ Michelina Casale¹ Marco Italiani¹ Ernesto Maranzano¹ Nevia Caputo¹

(1) S.Maria Hospital, Terni, Italy

Summary: This study reports on 69/117 patients treated at our Institution 11/ 2001 - 11/ 2010, with a minimum observation span of two years. Patient selection was performed in a multidisciplinary setting, according to guidelines indicated by Spetzler Martin and RSG scales and outcome predictors. Pretreatment evaluation of angioarchitecture and flow were performed in order to prescribe embolization (EE) before radiosurgery (SRS).

Method: 69 patients with a follow-up equal or longer than two years, were considered. 44 males, 25 females. 37 were previously treated with EE, 10 were previously operated. Mean age: 38 yrs (8-78), median volume: 5,42 cc (0,1-61,5cc), mean dose: 19 Gy (11,5-24 Gy). SM grade I= 21; II=19; IIIA+B= 29. 4 were lost at follow up; 2 died for unrelated reasons. All patients underwent complete angiographic workout to rule out nidus volume and configuration , flow, number and location of feeders and draining veins. EE was always performed, when feasible, to reduce nidus volume, avoiding its fragmentation, to reduce flow and to eliminate angioarchitectural risk factors (flow related aneurisms, and intranidal pseudo-aneurisms). After 4 to 8 wk, SRS was performed. Target and dose plan were designed importing stereotactically acquired angiography in the frame of reference of MR images. Elekta dynamic micro-multileaf collimator, mounted on a 6MeV Linac and Ergo++ treatment plan were used for high conformal and homogenous delivery of the dose.

Results: Angiographic obliteration of the nidus resulted in 42%, and MR nidus volume reduction > 50%, in the entire group. Patient followed for a period of 4 years or longer had the obliteration of the nidus in 71,4% of the cases, and major MR volume reduction in 21% .Three cases rebled, 6m, 8m, and 1 yr following SRS (3,17%). All were SM grade III B. One pt died, two, with a Rankin scale of 2 and 4, remained stable. Three cases of MR signal abnormalities: two cases of radionecrosis, 8-15 month following treatment, with moderate morbidity, reversed in 3-6 mo. One asymptomatic parenchymal cyst, one yr after treatment. Three cases with new seizures, controlled with therapy.

Conclusions: Low complication rate and satisfactory obliteration/reduction of the nidus was obtained Obliteration rate or time to obliteration were not statistically different in patients treated with SRS alone or following EE .

10:30 - 11:30 ORAL SESSION

OS3 FUNCTIONAL DISORDERS 1 - TRIGEMINAL NEURALGIA

Room: Auditorium

OS3-1 *RESULTS OF RESCUE MICROVASCULAR DECOMPRESSION AFTER UNSUCCESSFUL GAMMA KNIFE SURGERY FOR MEDICALLY INTRACTABLE TRIGEMINAL NEURALGIA: IN COMPARISON WITH THOSE OF SECOND GAMMA KNIFE SURGERY*

Shinji Matsuda¹ Toru Serizawa² Osamu Nagano¹ Yoshinori Higuchi³ Junichi Ono¹

(1) Chiba Cardiovascular Center, Ichihara, Japan (2) Tokyo Gamma Unit Center, Tokyo, Japan (3) Chiba University, Chiba, Japan

Long-term **Results:** of rescue microvascular decompression (MVD) after unsuccessful GKS have not been well evaluated. The authors report long-term **Results:** of rescue MVD compared with second-GKS. **Materials/Methods:** One hundred-five patients of essential TN were treated with GKS. In 20 patients, first GKS was judged as unsuccessful (Barrow Neurological Institute pain score (BNI-P) IV (inadequate pain improvement) or V (severe pain)). No improvement was achieved in 2 patients, and facial pain recurred in 18. Ten patients were treated with second-GKS, 8 were treated with MVD (one lost in this study). Finally, 10 second-GKS patients and 7 rescue MVD patients were included. Median age at first GKS was 68 years old (range: 46-90). Four patients had history of MVD before first GKS. Median interval from first GKS to second procedure was 16 months (range: 6-106). Pain control status, medication and trigeminal dysfunction were recorded at each clinic visit. **Results:** Median total follow-up duration was 58 months (range: 20-121). All 4 patients who had history of MVD were treated with second-GKS. Rescue MVD group had shorter history of TN and tendency of younger age than second-GKS group. Another surgical treatment was needed in 2 of rescue MVD group (peripheral nerve block and second-GKS) and in 2 of second-GKS group (MVD and third-GKS). Pain control was judged as followed. In rescue MVD group, BNI-P I (pain-free without medication) was in 2 cases, BNI-P IIIa (pain-free with medication) in 2, BNI-P IIIb (adequate pain improvement) in 1, BNI-P IV or V in 2. In second-GKS group, BNI-P I was in 4 cases, BNI-P IIIa in 3, BNI-P IIIb in 1, BNI-P IV-V in 2. Status of trigeminal dysfunction at the final visit was followed. In rescue MVD group, BNI facial numbness score (BNI-N) I (no trigeminal dysfunction) was in 0 case, BNI-N II (mild, not bothersome) in 5, BNI-N III (moderate, somewhat bothersome) in 1, BNI-N IV (severe, very bothersome) in 1. Second-GKS group: BNI-N I; 3, BNI-N II: 5, BNI-N III; 2, BNI-N IV; 0. **Conclusions:** In this series, the **Results:** of rescue MVD after unsuccessful GKS were not superior to second-GKS. Further evaluation is necessary to confirm the **Results:** of this study.

10:30 - 11:30 ORAL SESSION

OS3 FUNCTIONAL DISORDERS 1 - TRIGEMINAL NEURALGIA

Room: Auditorium

OS3-2 LEKSELL GAMMAKNIFE RADIOSURGERY FOR IDIOPATHIC TRIGEMINAL NEURALGIA: A NEUROVASCULAR ANATOMICAL STUDY.

Emile Simon^{1, 5, 6} Nicolas Reyns¹ Gustavo Touzet¹ François Dubois⁴ Marcos Dellaretti^{1, 7} Thierry Sarrazin^{2, 3} Eric Lartigau³ Serge Blond^{1, 4}

(1) Gammaknife Center, Department of Stereotaxy and Functional Neurosurgery, Hospital Roger SALENGRO, Centre Hospitalier Régional Universitaire de Lille, Lille, France (2) Department of Medical Physics, Centre Oscar LAMBRET, Lille, France (3) Gammaknife Center of Lille, Department of Radiotherapy, Centre Oscar LAMBRET, Lille, France (4) Center of Evaluation and Treatment of Pain, Hospital Roger SALENGRO, Centre Hospitalier Régional Universitaire de Lille, Lille, France (5) Department of Functional Neurosurgery, Hospital Pierre WERTHEIMER, Hospices Civils de Lyon, Lyon, France (6) Department of Anatomy, Faculté de Médecine Lyon-Est, Claude Bernard University Lyon 1, Lyon, France (7) Department of Neurosurgery, Santa Casa Hospital, Belo Horizonte, Brazil

Purpose: To study the anatomy of neurovascular compression, and pain outcome in patients with idiopathic trigeminal neuralgia treated with Leksell gammaknife radiosurgery.

Material & methods: 155 consecutive patients (79 men and 76 women) with proven medically refractory idiopathic typical trigeminal neuralgia, treated with Leksell 4C gammaknife radiosurgery (Elekta Instruments, Stockholm, Sweden) in our institution between January 2004 and December 2008 were included. 52 patients (33,5%) had a history of previous surgery for trigeminal neuralgia. Images acquisition was done with 1 mm thick CT-scan and 1 mm thick MRI, in both axial T1-weighted enhanced and axial T2-weighted with Balanced Fast-Field Echo (Achieva, Philips Medical Systems, Best, The Netherlands), with coronal and sagittal reconstructions.

Patients were treated using a single 4 mm shot to the retrogasserian cisternal portion of the trigeminal nerve, with a mean maximal GKS dose of 85 Gy (65-90 Gy).

Follow-up data were obtained by face-to-face interviews, using the Barrow Neurological Institute Pain Intensity Scale. The follow-up period ranged between 2 and 75 months (median 24 months).

The anatomical analysis of the images was performed with the Gammaplan software (Elekta Instruments, Stockholm, Sweden). Neurovascular compression and morphometric data were recorded retrospectively by an independent observer, blind of the treated side, and the territory of neuralgia. Neurovascular compression was quantified using a 3 grades score (grade I : simple contact, grade II : indentation of the vessel on the nerve, grade III : distortion of the nerve by the vessel).

Results: In 85,2% of the patients a neurovascular compression was observed on the side of the neuralgia. Preoperative pain was more severe if the compression was near the trigeminal root entry zone ($p=0,007$). A last follow-up, complete pain relief (BNI I to IIIa) was achieved in 56,1% of the patient. Pain recurrence (requiring additional surgery) occurred in 33,5% of the patient. Neither previous treatment, grade III neurovascular compression, the type of vessel responsible of compression nor the position of the compression were associated with a different outcome.

A new trigeminal dysfunction (paresthesia or facial numbness) was found in 37,4% of the patients, bothersome or severe in 19,8%. No neuropathic pain, trigeminal anesthesia nor anesthesia dolorosa was found. A favorable outcome (BNI I-IIIa) was associated with the presence of a trigeminal dysfunction ($p=0,001$).

Conclusion: The visualization of a neurovascular compression was not associated with pain outcome. In our study, patients with a trigeminal dysfunction had a better outcome.

10:30 - 11:30 ORAL SESSION

OS3 FUNCTIONAL DISORDERS 1 - TRIGEMINAL NEURALGIA

Room: Auditorium

OS3-3 *GAMMA KNIFE SURGERY FOR ESSENTIAL TRIGEMINAL NEURALGIA USING
MODEL C-APS: EVALUATION OF OUTCOME IN 130 PATIENTS WITH AT LEAST 3
YEARS FOLLOW UP*

Motohiro Hayashi¹ Noriko Tamura¹ Masahiro Izawa¹ Yoshikazu Okada¹ Yoshikazu Okada¹
(1) Tokyo Women's Medical University, Tokyo, Japan

The objective of the present study was evaluation of outcome in 130 patients with essential trigeminal neuralgia, who were treated using Leksell Gamma Knife model C with automatic positioning system and followed at least 36 months thereafter. Radiosurgery was guided by thin sliced CT and MR images. Retrogasserian part of the trigeminal nerve at the level of the trigeminal incisura was selected as a target. In all cases one 4 mm collimator was used for delivery of maximum irradiation dose of 90 Gy. The coordinates of the isocenter were adjusted for positioning of the nerve into the center of 80% isodose area, and were corrected in each individual case with regard to presence of distortion artifacts on MRI evaluated three-dimensionally by their fusion with bone window CT images. Relief of the typical paroxysmal facial pain was marked in 127 patients (98%) within a median interval of 3 weeks after treatment. However in 23 of these patients the pain re-appeared later on. In overall, at the time of the last follow-up 112 patients (86%) were pain-free, and 86 of them were both pain- and medication-free after initial radiosurgery. In 31 patients (24%) the treatment was complicated by facial hypesthesia and/or paresthesia. In **Conclusion**, radiosurgical management of essential trigeminal neuralgia **Results:** in high rate of initial pain relief, but pain recurrences and associated complications are not uncommon. The outcome may be influenced by various technical nuances therefore it should be preferably done in specialized centers with sufficient expertise in the treatment of this disorder.

10:30 - 11:30 ORAL SESSION

OS3 FUNCTIONAL DISORDERS 1 - TRIGEMINAL NEURALGIA

Room: Auditorium

OS3-4 *RETROGASSERIAN GAMMA KNIFE RADIOSURGERY FOR IDIOPATIC TRIGEMINAL
NEURALGIA*

Constantin Tuleaşcă¹ Noriko Murata² Anne Donnet³ Jean Regis¹
(1) Timone Hospital, Department of Stereotactic and Functional Neurosurgery, Marseille, France (2) Department of Neurosurgery, Tokyo Women's Medical University, Tokyo, Japan (3) Timone Hospital, Department of Neurology, Marseille, France

Object: Intractable trigeminal neuralgia (ITN) pain is a clinical condition causing severe disability. This study analyses the role of Gamma Knife surgery (GKS) for patients presenting with trigeminal neuralgia and long- term outcomes.

Methods: Between December 1992 and November 2010, 737 patients presenting with ITN were operated by GKS and followed prospectively. The range of patient's age was between 29 and 96 years. The GKS typically was performed using MR and CT imaging guidance, a single 4- mm isocenter and a maximum dose of 90 Gy. The target was placed on the cisternal portion of the V-th nerve at a mean distance from the brainstem emergence of 7.5 mm. Prior surgery was performed in 216 patients (48%).

Results: 451 patients were evaluated for more than one year and up to 17 years after GKS. 400 (89%) patients were pain free in a range between a few hours and 300 days. 101 patients (25.25%) of 400 patients who achieved initial pain relief reported some recurrent pain after initial relief requiring a new surgery in 26 cases (5.7%). A facial numbness is reported in 71 patients (15.7%) which was discrete in 46 cases (10.19%), severe in 24 patients (5.32%) and we also report one case of anesthesia (0.22%). The follow- up was longer than 12; 24; 48; 60; 72; 84; 96; 108 and 120 months for 451 (100%); 360 (79.8%); 197 (43.68%); 151 (33.48%); 115 (25.49%); 89 (19.73%); 61 (13.52%); 45 (9.97%) and 38 patients (8.42%). Long term pain free rate at last follow- up was 66.3%.

Conclusion: Retrogasserian high dose GKS turned out to be very safe with only 15% hypoesthesia, which was rarely disabling (<1%) while achieving high quality pain control.

10:30 - 11:30 ORAL SESSION

OS3 FUNCTIONAL DISORDERS 1 - TRIGEMINAL NEURALGIA

Room: Auditorium

OS3-5 RESULTS OF THE GAMMA KNIFE RADIOSURGERY TREATMENT OF PATIENTS WITH TYPICAL TRIGEMINA NEURALGIA (TTN) AFTER AT LEAST TWO YEARS OF FOLLOW-UP

Nuria Martinez¹ Elena Kusak¹ Jorge Gutierrez¹ German Rey¹ Roberto Martinez¹

(1) gamma knife unit. hospital ruber internacional, Madrid, Spain

Introduction: Typical trigeminal neuralgia is a disease of controversial etiology. Most of the patients suffer the idiopathic form. Patients with Atypical Facial Pain are not included in the profile of TTN. Medical treatments reduce or control pain in 75% of patients with TTN approximately, being considered the first therapeutic election. After pharmacological management, different surgical techniques are offered. If both procedures fail, Gamma Knife Radiosurgery (GKRS) provides as good **Results:** with low toxicity, limited to alterations in facial sensation, becoming a first choice treatment. We analyze our **Results:** of GKRS in TTN patients with a follow-up of at least two years. **Methods:** We have treated and followed 117 patients with TTN between 1996 and 2008. The mean age is 64 years. Patients had facial pain for a mean of 10 years and 72% presented good initial response to oral medication. Thirty two had been previously operated on (mean 2 surgeries/patient). We found previous alterations of facial sensation in 32% patients. Fourteen of these 117 cases were second GKRS treatments. Treatment was delivered by one isocenter with the 4 mm

collimator located in the third of the nerve proximal to the brainstem, applying a mean maximum dose of 86 Gy. The brainstem of 83% of patients received more than 10 Gy at a mean volume of 0.15 cc. Mean follow-up has been 68 months: 5.5 years (range: 2-14 years).

Results: Pain relief was achieved in 81.5 % of patients, 3.3 months after GKRS. Sensation toxicity appeared in 32 % after a mean of 14 months from treatment. The percentage of pain control is lower in subgroups «without initial response to drugs» and «previous surgery», but it is similar in subgroups with «TTN longer than 5 years», «previous GKRS» or «vessel contact with nerve on MRI». Time necessary to pain relief and toxicity are higher in repeat GKRS. Only 16 % of patients with previous surgery had additional toxicity because in this group a altered facial sensation was present before GKRS.

Conclusions: GKRS is a simple technique that achieves good **Results:** with low and tolerable morbidity. The presence of a certain degree of sensation toxicity after the procedure is associated to a better pain relief prognosis. Its use should be considered after a failed first GKRS in select patients. Further follow-up in this group is necessary.

14:00 - 15:00 ORAL SESSION

OS4 BODY 1 (LUNG)

Room: La seine

OS4-1 CLINICAL OUTCOME OF STEREOTACTIC RADIOTHERAPY FOR STAGE I NSCLC

Frank Lagerwaard¹ Cornelis Haasbeek¹ Ben Slotman¹ Naomi Verstegen¹ Suresh Senan¹

(1) VU University medical center, Amsterdam, The Netherlands

Introduction: In many countries, stereotactic radiotherapy (SRT) has replaced conventionally fractionated radiotherapy as standard treatment for Stage I non-small cell lung cancer (NSCLC) patients, who are at too high risk for surgery or refuse such treatment. We report on the clinical outcomes in a cohort of 651 patients treated with SRT at the VU University medical center Amsterdam between 2003 and 2010.

Methods: This analysis pertains to 651 Stage I NSCLC patients, referred from 70 Dutch hospitals. Patients treated for double tumors or recurrent tumors were excluded from this analysis. Included were 405 T1N0 (62%) and 246 T2N0 (38%) tumors. Mean age was 72 years. All but 4 patients underwent pre-treatment 18FDG-PET staging; 81% of patients were medically inoperable and 19% refused surgery. The following risk-adapted SRT schemes were used: 3x20 Gy (n=236;36%) for T1 tumors, 5x12 Gy (n=283;44%) for T1 tumors adjacent to the thoracic wall/mediastinum or T2 tumors, and 8x7.5 Gy (n=132;20%) for lesions adjacent to the pericardium or hilus. Evaluations after SRT included serial CT-scans, and FDG-PET scans were obtained on clinical indication. Median follow-up duration of this patient cohort was 29.2 months.

Results: Median survival was 37.9 months (95% CI 31.8-43.0) and 3-year survival was 41.6%. Local failure was seen in 23 pts (3.5%), resulting in an actuarial local control rate of 92.9% at 3 years. Corresponding regional and distant control rates at 3 year were 89.0% and 79.6%. On multivariate analysis, overall survival was significantly better for operable patients (p<0.001), younger patients (p=0.004), those with Stage IA (p=0.017) and with a lower Charlson co-morbidity score

($p=0.022$). Disease-free survival was significantly better for older patients ($p=0.037$) and Stage IA ($p=0.047$). Pathological confirmation of malignancy was obtained prior to SRT in only 36% of patients, however, overall survival ($p=0.62$), local control ($P=0.20$) and disease-free survival rates ($P=0.96$) were not different between patients with or without pathology. Treatment was well tolerated, with fatigue (27%) being the most frequent early side effect, followed by dyspnea, cough, nausea and chest wall pain (each 5%). Late toxicity included chronic chest wall pain in 18 pts (3%), G3 radiation pneumonitis in 13 pts (2%), and rib fractures in 6 pts (1%).

Conclusions: SRT **Results:** in high control rates with acceptable toxicity, and should be considered the new standard for care for inoperable Stage I NSCLC pts. The outcome suggests that SRT may compete with surgery to become the new standard for (elderly) operable pts.

14:00 - 15:00 ORAL SESSION

OS4 BODY 1 (LUNG)

Room: La seine

OS4-2 CANCELLED

14:00 - 15:00 ORAL SESSION

OS4 BODY 1 (LUNG)

Room: La seine

OS4-3 *NOVALIS STEREOTACTIC RADIOTHERAPY FOR EARLY-STAGE LUNG CANCERS AND SMALL LUNG METASTASES*

Chisa Hashizume¹ Yoshimasa Mori¹ Takahiko Tsugawa¹ Tatsuya Kobayashi¹ Yuta Shibamoto² Takeshi Yanagi² Shinya Otsuka²

(1) Nagoya Radiosurgery Center, Nagoya Kyoritsu Hospital, Nagoya, Japan (2) Department of Radiology and Radiation Oncology, Nagoya City University Graduate School of Medicine, Nagoya, Japan

Purpose: Stereotactic Body Radiation Therapy (SBRT) is highly expected to be a standard treatment for patients with primary or metastatic lung cancers who are inoperable or refuse surgery. We started SBRT using a stereotactic linear accelerator 'Novalis' equipped with micro-multi-leaf collimator and accurate patient setup system (ExacTrac) in July 2006.

Materials: We treated 103 patients (77 men and 26 women) with a median age of 76 years (range: 37- 92) with lung cancers (76) or lung metastases (27) by SBRT using 'Novalis'. Thirty-seven patients had Stage IA (T1N0M0) lung cancer and 39 had Stage IB (T2N0M0). Twenty-seven patients had lung metastasis, including 6 from epipharyngeal cancer, 5 from rectal cancer, 5 from lung cancer, 4 from renal cancer and 7 from several other cancers.

Method: We delineated CTV using CT taken at 3 phases (expiratory, inspiratory and spontaneous breathing) and PTV with a margin of 5-7mm. We planned 3-D non-coplanar 7-beam irradiation. The lesions were covered at a 95% or higher isodose level. We delivered 48 Gy in 4 fractions over

2 weeks for tumors up to 3 cm in diameter and 52 Gy in 4 fractions in 2 weeks for large ones over 3 cm. The other patients were treated with 48-56Gy in 8 fractions because of large size (over 5cm in diameter) or central location.

Results: The treatment Results were evaluated with a median follow-up period of 22 months (range, 4 to 33 months) in all patients. Local control (CR+PR+SD) rate at two years was 94% in Stage 1A and 88% in stage IB <5cm. Cause-specific survival rate at 2 years was 84% in Stage 1A and 88% in stage IB <5cm . Rate of distant metastasis development was 22 % in 1A, and 29 % in a subgroup of IB with smaller tumor, less than 5 cm in max diameter. Local control rate at 2 years was 84% in metastatic lung tumor. Grade 2 radiation pneumonitis developed in 15 (15%) patients and Grade 1 developed in 56 of 103 (54%) patients.

Conclusions: SBRT was a generally safe and effective treatment. Long-term follow-up data are awaited to determine late complications and tumor control rate.

14:00 - 15:00 ORAL SESSION

OS4 BODY 1 (LUNG)

Room: *La seine*

OS4-4 *EARLY EFFICACY AND TOXICITY EVALUATION OF CYBERKNIFE XSIGHT LUNG TREATMENT*

Jean-emmanuel Bibault¹ Bernard Prevost¹ Eric Dansin² Xavier Mirabel¹ Thomas Lacornerie¹ François Dubus¹ Eric Lartigau¹

(1) Academic Radiation Therapy Department - Centre Oscar Lambret, Lille, France (2) General Oncology Department - Centre Oscar Lambret, Lille, France

Purpose: Several methods are currently available for stereotactic lung cancer treatment with the CyberKnife : one of them requires the use of fiducials (Synchrony®) while the other is completely fiducial-free (Xsight Lung Tracking System®). We will report our initial experience with 22 treated patients.

Materials: Eligibility - Selection criteria were as follow : inoperable patients with single pulmonary tumor, T1 or T2 stage, tumor size between 15 mm and 60 mm, N0, M0. Initial staging included CT-Scan with contrast agent and FDG-PET. If an anatomopathological proof could not be obtained, treatment was proposed for evolutive lesions : increase in size on two consecutive CT-Scans and single FDG uptake of the tumor on PET.

Results: Patients characteristics - The Xsight Lung Tracking System was used for 22 patients treated for primary lung cancer. Median age was 70 years old (52-85 y.o.). Median Charlson score was 3 (3-7). Twenty one patients (95%) were smokers. Median tumor size was 24 mm (15-60mm). Histology was known for 6 patients (27%) : 5 squamous cell carcinomas (23%), 1 adenocarcinoma (4%). Median tumor size was 24 mm (15-60mm). Seven patients (31%) were treated for a relapse after prior surgery or radiation therapy.

Treatments characteristics - Median delivered dose was 60 Gy (45-60 Gy) in 3 fractions. When the tumor was located near a vascular structure, treatment was delivered with 5 fractions of 12 Gy (60 Gy total dose). Prescription isodose was 84%. Median margin used for treatment was 3 mm

(1,5-5 mm). Median Growth Tumor Volume (GTV) was 11 cm³ (2-115 cm³). Median Clinical Tumor Volume was 24 cm³ (4-142 cm³). Median number of beams used was 46 (24-118 beams). Median treatment duration was 64 min for each fraction (37-112 min).

Treatment response - Median follow-up period was 6 months (3-16). Local control rate was 100%. 11 complete responses (50%), 5 partial responses (23%) and 6 stabilities (27%) were observed. Disease-specific survival rate was 100% at 6 months.

Toxicity - Seven grade 1 and one grade 2 radiation pneumonitis were found on CT-Scan.

Conclusion: Local control rate was similar to what is reported in other studies using fiducials for tumor tracking. Toxicity was lower since we didn't need to use fiducials. This method could represent a completely non-invasive curative treatment for inoperable patients with T1 or T2 N0M0 lung cancer.

14:00 - 15:00 ORAL SESSION

OS4 BODY 1 (LUNG)

Room: La seine

OS4-5 *WITHHOLDING STEREOTACTIC RADIOTHERAPY IN ELDERLY PATIENTS WITH STAGE I NON-SMALL CELL LUNG CANCER AND CO-EXISTING COPD IS NOT JUSTIFIED: OUTCOMES OF A MARKOV MODEL ANALYSIS*

Alexander Louie¹ George Rodrigues^{1, 2} Malek Hannouf² Frank Lagerwaard³ David Palma¹ Gregory Zaric^{2, 4} Cornelis Haasbeek³ Suresh Senan³

(1) Department of Radiation Oncology, London Regional Cancer Program, London, Canada (2) Department of Epidemiology and Biostatistics, University of Western Ontario, London, Canada (3) Department of Radiation Oncology, VU University Medical Center, Amsterdam, The Netherlands (4) Richard Ivey School of Business, London, Canada

Approach: To compare outcomes in elderly COPD patients with stage I non-small cell lung cancer (NSCLC) treated with either stereotactic body radiation therapy (SBRT) or best supportive care (BSC).

Innovation: A growing body of evidence suggests that SBRT is the standard of care for medically inoperable stage I NSCLC patients.

Relevance: Up to 30% of patients aged >75 years with stage I NSCLC are left untreated. High cure rates with low toxicity have been reported after SBRT in elderly patients. Severe COPD is often cited as a reason for withholding SBRT from these patients.

Materials and Methods: A Markov model was constructed to simulate the quality adjusted life expectancy (QALE) and overall survival in patients >75 years undergoing either SBRT or BSC for a 5-year timeframe. For SBRT, the rates of local, regional and distant recurrences were obtained from 247 patients entered into a prospective cohort at the VUMC, Amsterdam. Recurrences were converted into monthly transition probabilities and stratified into 4 groups according to T stage and COPD GOLD score. The 4 patient groups were: I (T1, GOLD I-II), II (T2, GOLD I-II), III (T1, GOLD III-IV), and IV (T2 GOLD III-IV). For untreated patients, overall survival by T stage was modeled according to 1,432 untreated patients from the California Cancer Registry. Markov state utilities consistent with the four stages of the AJCC staging system and COPD status based on GOLD score,

were extracted and adapted from the literature.

Results: Our Markov model showed a close correlation with overall survival data for all 4 groups treated with SBRT, with differences at 5 years ranging from 0.1% to 1.5%. For untreated patients, the differences were 0.1% for T1 patients and 2.2% for T2 patients at 5 years. After SBRT, 5-year overall survival ranged from 6.8% to 47.2% and QALE ranging from 14.9 to 27.4 quality adjusted life months (QALMs). 5-year overall survival for untreated T1 and T2 patients was 9.0% and 2.8%, and 10.1 and 6.1 QALMs, respectively. Outcomes were not sensitive to the quality of life post-SBRT or the disutility of disease progression in untreated patients. The relative benefit of SBRT over BSC appears to be least for group IV patients.

Conclusion: In elderly patients with COPD, our Markov model predicts superior overall and QALE at 5 years after SBRT when compared to no treatment. Advanced age, COPD, and tumor size should not preclude such patients from curative SBRT.

14:00 - 15:00 ORAL SESSION

OS5 IMAGING 1

Room: *Miles Davis*

OS5-1 *QUALITY ASSURANCE OF 3T MRI FOR GAMMA KNIFE RADIOSURGERY*

Ian Paddick¹

(1) Medical Physics Limited, London, UK

Objective: MRI is the primary imaging modality used for Gamma Knife radiosurgery, and is used in a majority of all intracranial SRS procedures. The recent use of 3 Tesla scanners for radiosurgery treatment planning has raised concerns over the use of distorted images in radiosurgery, as magnetic field inhomogeneity is technically more difficult to attain for higher field strengths. Geometrical distortions inherent in the imaging process are well known and documented, but so far there are no published **Results:** from a range of 3T MRI scanners, tested by a reproducible and uniform method.

Methods: Using a Scheib Known Target Phantom (PTGR, Germany) actual/phantom distortion at 21 points was measured for five different 3T scanners. MR scans of the phantom were imported into Leksell GammaPlan and defined in stereotactic space. The apparent position of each target was noted and compared with its known coordinates. Comparisons were made between modern 3T scanners and their 1.5T counterparts.

Results: The best **Results:** obtained for each 3T scanner are summarised in the table below.

Site Scanner/Protocol Mean Error (mm) Max Error (mm)

1 GE Signa 3.0T (FSPGR) 1.24 2.07

2 Siemens Trio 3.0T (MPRage) 1.03 1.88

3 Siemens Trio 3.0T (MPRage) 1.38 2.38

4 Siemens Verio 3.0T (MPRage) 0.57 0.88

5 Philips Achieva 3.0T (FFE) 0.92 1.40

Mean Errors 1.03 1.72

The average mean and the average maximum errors for all scanners in the audit was 1.03mm and

1.72mm respectively. These values are approximately 30% higher than those for equivalent 1.5T scanners. Distortion levels from two of the above scanners changed dramatically following shimming of the magnet by an engineer, suggesting that reproducibility of accuracy may be an issue and more intensive QA might be necessary than for a 1.5T scanner. **Conclusion:** Distortion levels in 3T scanners are larger than those produced by equivalent 1.5T scanners. Technical maintenance of these scanners is essential to maintain acceptable magnetic field homogeneity, which can have serious consequences with respect to image distortion.

14:00 - 15:00 ORAL SESSION

OS5 IMAGING 1

Room: Miles Davis

OS5-2 3D-ASSESSMENT OF MRI GEOMETRIC DISTORTION AND MR-IMAGING QUALITY CONTROL FOR GAMMA KNIFE SRS

Andrei Z. Damyanovich¹ Marcus Rieker³ Beibei Zhang¹ Jean-pierre Bissonnette¹ Cynthia Menard² David Jaffray¹

(1) Department of Radiation Physics, Princess Margaret Hospital, Toronto, Canada (2) Department of Radiation Oncology, Princess Margaret Hospital, Toronto, Canada (3) Department of Information Analysis/Image Processing, University of Applied Science, Dresden, Germany

Introduction: Magnetic Resonance Imaging (MRI) plays a central role in Gamma Knife (GK) stereotactic radiosurgery (SRS) treatment planning. Key imaging parameters must be optimized and subsequently checked at regular intervals to ensure the best target/normal tissue contrast, while maintaining a viable signal-to-noise/imaging-time ratio. Crucially, since GK radiosurgery requires sub-millimetre accuracy, confidence in the spatial/geometric accuracy of MR images is critical to the treatment planning process. In this work we present a comprehensive MR imaging quality control protocol for GK SRS, incorporating a method to assess MRI-geometric distortion in all three orthogonal imaging planes simultaneously; **Results:** acquired on both 1.5- and 3-Tesla clinical MRI scanners over a two-year period are also presented. **Methods:** The MR imaging quality control protocol makes use of the GRID3D system, consisting of a dual MRI/CT 3D-geometric distortion phantom/analysis software package, to assess geometrical accuracy; a multi-purpose MR-imaging phantom; and a MR-Spectroscopy (MRS) phantom to evaluate magnetic field homogeneity. The GRID3D phantom design comprises a three-dimensional Cartesian grid, incorporating control points spaced at 10 mm intervals in all three planes, thereby allowing assessment of geometrical image distortion in all three orthogonal imaging-planes simultaneously. The novel design of this phantom produces positive-signal-MR/negative-signal-CT images, enabling both MRI and CT-visualization of 3D-vertices/control points, separated by intervening planar grids, all in a 3D-(10 mm)³ Cartesian lattice. Images were acquired monthly over a two-year period, on both 1.5T and 3T scanners at the University Health Network, using 3D T1-Fast Spoiled Gradient Recalled Echo (FSPGR) and 3D-T2-

Fast Recovery Fast Spin Echo (FRFSE) sequences (22 cm FOV). Spatial resolution, image uniformity, SNR and other key imaging parameters were subsequently tested and magnetic field homogeneity assessed using a MRS-PRESS sequence prescribed over (50 mm)³ and (80 mm)³ ROIs.

Results: The complete protocol required ~1.5 hrs to complete, including imaging and analysis. Geometric distortion was found to vary between 0.4 to ~1.5 mm at 1.5T and 0.5 to > 3 mm at 3T; magnetic field homogeneity remained consistently at 2 to 4 Hz at 1.5T and 3 to 6 Hz at 3T indicating excellent uniformity across the volume of interest.

Conclusions: An MR imaging quality assurance program has been implemented for use with clinical MRI scanners used for GK-SRS. The methodology provides a quantitative assessment of both the 3D-spatial/geometric accuracy of the MR images used for GK treatment planning, as well as the quality and consistency of key MR-imaging parameters.

14:00 - 15:00 ORAL SESSION

OS5 IMAGING 1

Room: Miles Davis

OS5-3 3D ULTRASOUND TUMOR SEGMENTATION AND FUSION WITH CT FOR STEREOTACTIC RADIATION THERAPY PLANNING OF RETINOBLASTOMA

Alessia Pica¹, ² A Ciurte³ Fi Karahanoglu³ S Gorthi³ A Balmer⁴ FI Munier⁴ Jp Thiran³ M Bach-cuadra³

(1) Radiation Oncology, University Hospital CHUV, Lausanne, Switzerland (2) Radiation Oncology, University Hospital Inselspital, Bern, Switzerland (3) Signal Processing Laboratory (LTS5), Ecole Polytechnique Fédérale (EPFL), Lausanne, Switzerland (4) Ophthalmic Hospital Jules Gonin, Lausanne, Switzerland

Purpose: CT scan is very useful in providing information on physical density for dose calculation and morphological volumetric information in the radiotherapy treatment planning of retinoblastoma but presents a low sensitivity in assessing the tumor viability. On the other hand, 3D ultrasound (US) allows a highly accurate definition of the tumor location and volume thanks to its high spatial resolution but its current use in the planning is for diagnosis and follow-up only. Here, we present a case study of the computer aided fusion of the 3D US and the CT images for stereotactic planning of non-calcified retinoblastoma.

Material and methods: One patient of 4.5 years old presenting a peripapillary and perimacular unilateral retinoblastoma of the right eye was treated with LINAC-based stereotactic fractionated radiotherapy with a micromultileaf collimator. We delivered 50.4 Gy, 1.8 Gy/ fraction with one isocenter and four static conformal shaped beams. The plan was made on Branscan 5.31 (BrainLAB). The patient had a recurrent tumor after treatment. In this paper we recalculate a posteriori, as a proof of concept, the planning including in the CT planning the tumor delineation from the 3D US. To this end the steps are: first, the automated segmentation of the organs at risk (OARs) in the CT, second, the landmark-based fusion of both image modalities and third, the automated segmentation in the Active Contour framework of gross tumor volume (GTV) in the 3D US.

Results: Results of the computer aided segmentation and fusion of 3D US and CT were validated by expert radiation oncologist and ophthalmologist. When we integrated the new planning target volume (nPTV) generate from the fusion of CT and US, we found an under dosage (D98%PTVCT

94% dose vs D98% nPTV 76% dose; D95% PTVCT 97% dose vs D95% nPTV 89% dose) in the cumulative dose-volume histograms, showing a geographical missing in the target.

Conclusions: We present a multimodal imaging framework for the OARs and GTV delineation in children with retinoblastoma. Such framework represents the standardization of a procedure for including 3D US imaging in the stereotactic radiotherapy planning. This allows a more precise target definition in the CT thanks to the high resolution of US imaging.

14:00 - 15:00 ORAL SESSION

OS5 IMAGING 1

Room: Miles Davis

OS5-4 COMPARISON OF IMAGE-GUIDANCE MODALITIES FOR STEREOTACTIC RADIOSURGERY (SRS): A SINGLE INSTITUTION EXPERIENCE.

Casey Kernan² Lu Meng¹, ² Carol Marquez¹ James Tanyi¹, ² Martin Fuss¹

(1) Oregon Health and Science University, Portland, USA (2) Oregon State University, Corvallis, USA
Purpose: To compare image-guidance shifts derived from a six-degree-of-freedom (6DOF) stereoscopic x-ray imaging system (ExacTrac, BrainLAB) to shifts derived from 4DOF volumetric cone-beam computed tomography (CBCT) imaging (OBI, Novalis TX, Varian/BrainLAB) for frameless intracranial stereotactic radiosurgery (SRS).

Methods: One hundred and eighty-five paired clinical ExacTrac/CBCT data sets formed the basis of this study. Pre-positioning alignment was based on automatic detection of infrared marker configuration on each patient's thermoplastic mask (Orfit Industries) using the ExacTrac system. Frameless image-guided repositioning for brain SRS was based on stereoscopic x-ray imaging followed by CBCT (for residual error assessment) and subsequently stereoscopic x-ray imaging (for intra-treatment motion evaluation). Isocenter localization accuracy of stereoscopic x-ray imaging relative to CBCT imaging was quantified by anthropomorphic phantom measurements. For the purpose of this data analysis, CBCT was defined as the gold-standard for data comparison.

Results: Standardized phantom measurements showed a relative system agreement between ExacTrac x-ray imaging and CBCT of 0.08 ± 0.18 mm (lateral), 0.13 ± 0.31 mm (longitudinal), and -0.16 ± 0.32 mm (vertical). Pre-positioning alignment errors were -0.04 ± 4.43 mm (lateral), -0.65 ± 2.99 mm (longitudinal), and -0.98 ± 4.30 mm (vertical). Residual errors were 0.80 ± 0.80 mm (lateral), 0.60 ± 0.80 mm (longitudinal), and -0.10 ± 0.90 mm (vertical). ExacTrac monitored intra-treatment patient-motion based errors were 0.08 ± 0.56 mm (lateral), 0.18 ± 0.61 mm (longitudinal), and -0.08 ± 0.59 mm (vertical).

Conclusions: Bony anatomy-based target positioning for image-guided frameless SRS resulted in accuracy comparable to frame-based alignment. ExacTrac and CBCT image-guidance resulted in comparable shifts. Thus, ExacTrac as the modality requiring less time to assess patient setup can be considered superior in clinical use. Intra-treatment positioning monitoring significantly contributes to the precision of frameless intracranial SRS.

14:00 - 15:00 ORAL SESSION

OS5 IMAGING 1

Room: *Miles Davis*

OS5-5 *MINIMALLY INVASIVE FRAMELESS CRANIAL RADIOSURGERY: A FEASIBILITY STUDY USING A 3D SURFACE IMAGING SYSTEM*

Lu Meng^{1, 2} James Tanyi¹, ¹ Martin Fuss¹

(1) Oregon Health and Science University, Portland, USA (2) Oregon State University, Corvallis, USA

Purpose: To assess the overall geometric positioning accuracy of a surface imaging system (Vision RT, London, UK) in patient setup for frameless stereotactic radiosurgery.

Materials and methods: An anthropomorphic head phantom combined with a novel design of a minimally invasive thermoplastic mask immobilization system was used to assess the positioning accuracy of the Vision RT 3D surface imaging system. The following three metrics were analyzed. (1) Surface mapping reproducibility. (2) End-to-end test absolute correction accuracy of the surface imaging system. (3) The relative correction accuracy of the surface imaging systems compared with that of both a 6-degree of freedom stereoscopic x-ray imaging (ExacTrac, BrainLAB) and 4-degree of freedom volumetric imaging systems (OBI, Varian/BrainLAB).

Results: Phantom-based surface mapping reproducibility was within 0.18 mm in the translational direction and 0.45 degrees in the rotational direction. The absolute positional accuracy with the surface imaging system was 0.3 ± 0.28 mm. The maximum positional difference between the surface imaging system and the stereoscopic x-ray system was 0.3 mm in the translational direction and 0.13 degrees in the rotational direction. Comparable Results were observed with volumetric imaging.

Conclusion: Positional accuracy of the surface imaging system combined with the minimally-invasive thermoplastic mask was seen to be within the tolerance given in the American Association of Physicists in Medicine report no. 54.

14:00 - 15:00 ORAL SESSION

OS6 SCHWANNOMAS 1

Room: *Auditorium*

OS6-1 *GAMMA-KNIFE RADIOSURGERY FOR UNILATERAL VESTIBULAR SCHWANNOMA: FOLLOW-UP OF 292 PATIENTS UNIFORMLY TREATED WITH A MARGINAL DOSE OF 11 GRAY*

S Klijn¹ HB Verheul¹ GN Beute¹ ST Lie¹ JJ Overbeeke¹ PEJ Hanssens¹

(1) Gamma Knife Center, Tilburg, The Netherlands

Objective: To present follow-up data of patients primarily treated with Gamma Knife radiosurgery (GKRS) for vestibular schwannoma. We aimed to assess (1) clinical and volumetric control and complication rates and (2) patterns in volumetric changes after GKRS.

Methods: We studied 292 consecutive patients with a follow-up of at least 2 years. A dose of 12,5

to 13 Gy was prescribed to the isodose covering 90% of the tumor volume, resulting in a marginal tumor dose of 11 Gy \pm 0,45. We retrospectively assessed complication rates by means of patient chart review and telephonic interview. Tumor volumes were evaluated on treatment and follow-up images using Gamma Plan software.

Results: Mean pre-treatment tumor volume was 2,7 cm³ (range 0,01 - 17,7). After a median follow-up of 3,1 years, twenty-seven patients (9,2%) needed additional treatment. Risk for requiring additional treatment increased with larger tumor volumes. In retrospect, these clinical failures did not necessarily coincide with failures based on volumetric findings. Thirteen patients (4,5%) developed de novo or worsening of pre-existing trigeminal nerve symptoms, most of which were transient. Two patients (0,7%) developed transient facial paralysis, which recovered completely without specific treatment. Eight patients (2,7%) reported transient facial spasms. Decrease, stability and increase of pre-existing tinnitus was noted in 30%, 61% and 9%, respectively. For vertigo these numbers were 42%, 41% and 17% respectively. De novo complaints of tinnitus or vertigo appeared in 25% and 17% of patients, respectively. Preservation of serviceable hearing was shown to be 41% in a subgroup analysis that was published earlier [1].

Conclusions: Our tumor control rate of 90,8% is lower compared to other large studies, which report 10-year control rates of 97-98% with a 12-13 Gy marginal dose [2-4]. Complication rates were comparable to other studies. We suggest three possible explanations. (1) a marginal dose of 11 Gy may be too low to achieve an optimal trade off between tumor control and complication rate. (2) Our definition of treatment failure, in particular whether or not a certain volumetric change should be regarded as such, may be different. Better understanding of volume dynamics and establishment of accurate failure criteria may allow reliable treatment decisions to be made on the basis of volumetric assessments. (3) The majority of patients had documented pre-treatment progression. Tumors without a growth tendency were not included in this study, which may hamper direct comparison with other reports.

14:00 - 15:00 ORAL SESSION

OS6 SCHWANNOMAS 1

Room: Auditorium

OS6-2 GAMMA KNIFE AND LINAC RADIOSURGERY FOR THE TREATMENT OF VESTIBULAR SCHWANNOMAS: COMPARATIVE OBSERVATIONS OF 204 PATIENTS TREATED AT ONE INSTITUTION

Svetlana Zolotova¹ Sergey Ilyalov¹ Igor Pronin¹ Nataliya Nikonova¹ Valeriy Kostuchenko¹ Marina Zotova¹ Andrey Golanov¹

(1) Burdenko Neurosurgery Institute , Moscow, Russian Federation

Object. We review our experience of vestibular schwannoma (VS) treatments at one institution using a Gamma knife (GKS) and LINAC stereotactic radiosurgery (SRS) with respect to treatment-related toxicity and local control. **Methods.** All 204 consecutive patients (58 men and 146 women) treated between April 2005 and December 2008 at our Institute were evaluated by means of serial imaging studies, clinical examinations, and questionnaires. One hundred sixty five patients

were treated on the Gamma knife, and 39 patients (40 tumors) were treated on the LINAC. Forty eight patients had undergone resection of their VS. Facial nerve function was normal in 164 patients (80%) before radiosurgery, and 11% of them had useful hearing Class I. The mean prescription peripheral dose was 12.6 ± 1.14 Gy (Gamma Knife) and 12.2 ± 0.74 Gy (LINAC); the corresponding central dose was 16 to 28 Gy (mean 22 ± 2.9 Gy) and 13.5 to 20.4 Gy (mean 15 ± 1.4 Gy), respectively. The mean volume of the tumor was higher at 5 ± 3.2 ml (range 0.1-»13.8 ml) in GKS group versus 3.7 ± 2.68 ml (range 0.5-»11 ml) in LINAC SRS group. At a median follow-up period of 36 months (range 16-»61 months), tumor shrinkage was observed in 68% of patients, and the tumor size was stable in 24%. Of patients with a follow-up of ≤ 24 months, we noted tumor control rates of 98%: one patient underwent repeated GKS after an interval of 26 months and four continues to be observed. Twelve patients experienced trigeminal dysfunction: in four the dysfunction was transient and in the other eight the dysfunction persists (4%). Nine patients suffered facial palsy (4.4%). Useful hearing was preserved in 75% of patients. No differences in outcome after GKS and LINAC SRS has been received, except that the risk of trigeminal neuropathy was higher in the treatment of the linear accelerator ($r = 0.6$; $p < 0.005$).

Conclusions. Gamma knife and LINAC stereotactic radiosurgery provides a low risk, minimally invasive treatment option for patients with newly diagnosed or residual vestibular schwannomas.

14:00 - 15:00 ORAL SESSION

OS6 SCHWANNOMAS 1

Room: Auditorium

OS6-3 ANALYSIS OF DISTRIBUTION OF RADIATION DOSE IN GAMMA KNIFE TREATMENT OF VESTIBULAR SCHWANNOMA AND RELATION WITH OUTCOME.

Nicolas Massager¹ Sarah Lonneville¹ Carine Delbrouck¹ Françoise De Smedt¹ Philippe David¹ Daniel Devriendt¹

(1) Gamma Knife Center, Brussels, Belgium

Purpose: We investigated variations in the distribution of radiation dose inside (dose inhomogeneity) and outside (dose fall-off) the target volume during Gamma Knife (GK) irradiation of vestibular schwannoma (VS). We analyzed the relationship between some parameters of dose distribution and the clinical and radiological outcome of patients.

Methods and Materials: Data from dose plans of 402 patients treated for a vestibular schwannoma by GK C using same prescription dose (12-Gy at the 50%-isodose) were collected. Four different dosimetric indexes were defined and calculated retrospectively in all plannings on the basis of dose-volume histograms: Paddick conformity Index (PI), Gradient Index (GI), Homogeneity Index (HI), and Unit Isocenter (UI). The different measures related to distribution of the radiation dose were compared with hearing and tumor outcome of 203 patients with clinical and radiological follow-up of minimum 2 years.

Results: Mean, median, SD and ranges of the 4 indexes of dose distribution analyzed were calculated; large variations were found between dose plans. We found a high correlation between the target volume and PI, GI and UI. No significant association was found between the 4 indexes

of dose distribution calculated in this study and tumor control, tumor volume shrinkage, hearing worsening, loss of functional hearing or complete hearing loss at last follow-up.

Conclusions: Parameters of distribution of the radiation dose during GK radiosurgery for VS can be highly variable between dose plans. The tumor and hearing outcome of patients treated is not significantly related to these global indexes of dose distribution inside and around target volume. in GK radiosurgery for VS, the outcome seems more to be influenced by local radiation dose delivered to specific structures or volumes than by global dose gradients.

14:00 - 15:00 ORAL SESSION

OS6 SCHWANNOMAS 1

Room: Auditorium

OS6-4 HYDROCEPHALUS OR CSF MALABSORPTION AFTER GAMMA KNIFE
RADIOSURGERY FOR VESTIBULAR SCHWANNOMA

Seung Hoon Lee¹ Doo Sik Kong¹ Ho Jun Seol¹ Do-hyun Nam¹ Kwan Park¹ Jong Hyun Kim¹
Jung-il Lee¹

(1) SAMSUNG MEDICAL CENTER, Seoul, Korea, Republic of

Objective: We performed retrospective analysis of 222 patients with vestibular schwannomas treated primarily by gamma knife radiosurgery. Investigation was focused on hydrocephalus developing after radiosurgery.

Methods: We retrospectively reviewed 222 patients (mean age 54.1 ; 77 male and 145 female) who underwent gamma knife radiosurgery for newly diagnosed vestibular schwannoma between January 2002 and August 2010.

Results: Mean follow up period was 33 months (1-103). Surgical intervention for CSF diversion was necessary in 10 (4.5%) (VP shunt 9 and third ventriculostomy 1) among 222 patients. Interval between radiosurgery and surgical intervention ranged from 2 to 38 months. Nine among them presented with symptom and sign of increased ICP and one patient presented with NPH. In these patients, there was female dominance (10 female and no male) and tumor volume was significantly larger than the others without hydrocephalus (6.7 cc vs. 3.0 cc; $P < 0.05$). There was no significant difference in age, marginal dose and tumor control rate. Loss of enhancement and swelling of tumor were observed in all patients and CSF protein was elevated in 3 among 4 patients with available data. All patients improved after VP shunt or third ventriculostomy and finally tumor size decreased too.

Conclusion : Hydrocephalus or CSF malabsorption after radiosurgery for vestibular schwannoma is more likely to develop in the patients with large volume of tumor. It does not mean failure of tumor control. Even though symptom and sign of increased ICP may be accompanied with tumor swelling, CSF diversion procedure should be considered prior to microsurgery of tumor.

14:00 - 15:00 ORAL SESSION

OS6 SCHWANNOMAS 1

Room: Auditorium

OS6-5 CANCELLED

15:00 - 16:00 ORAL SESSION

OS7 BODY 2 (LIVER)

Room: La Seine

OS7-1 *IMAGE-GUIDANCE BY INTRAHEPATIC FIDUCIAL MARKERS AND DOSE ESCALATION IN STEREOTACTIC RADIOTHERAPY FOR LIVER METASTASES: INFLUENCE ON LOCAL CONTROL*

Franco Casamassima¹ Stefano Masciullo¹ Claudia Menichelli¹ Laura Masi¹ Ivano Bonucci¹ Rafaela Doro¹

(1) U.O. Radiobiologia Clinica - University of Florence - Casa di Cura S. Chiara, Florence, Italy

Purpose: To evaluate the influence on local control of implanted gold fiducial markers used as target surrogate for stereotactic IGRT, in comparison to diaphragm contour alignment.

Materials and methods: 92 patients (43 f, 49 m), median age 65 years (37-85) were treated in our Institution by SBRT for liver metastases (n=150). Primary tumor was colorectal in 50 Pts, breast in 15, pancreas in 7, other in 20. Ten patients underwent other SBRT-courses for new lesions. The median number of hepatic metastases at the time of first SBRT course was 2 (1-6). In 50% of cases there were extrahepatic metastases. Sixty-one patients received prior or following chemotherapy within six months of radiotherapy. GTV was delineated on two CT scans acquired in expiration and inspiration, in order to obtain an ITV. For 70 Pts a spirometer (Elekta ABC) was used for respiratory motion monitoring during image acquisition and treatment. For 58 Pts 2-4 fiducial markers were implanted by CT-guidance in the proximity of lesion. Median PTV was 35.2 cc (4-632). Median prescription dose was 36 Gy in three fractions (9-12.5 Gy) at isodose line ranging from 67% to 100%. Maximum dose at isocenter ranged from 30 to 66 Gy in three fractions (median 39). A Cone-Beam CT was acquired before the treatment for setup corrections and target localization, using diaphragm contour (34 Pts) or implanted fiducials (58 Pts). A 6 MV Elekta Synergy equipped with dynamic mMLC was employed. CTCAE v.4 and modified RECIST criteria was used for toxicity and response evaluation.

Results: With median follow-up of 13 months (2-43), the 1- and 2-years actuarial local control was 86% and 72%. There were 24 local failure in 18 Pts. Median in field time-to-progression was 12 months. Comparing LC of lesions treated by fiducial-alignment with diaphragm-alignment there was a significant difference (1-year LC 90% vs 64%, p=0.009). However, in the fiducials group higher doses were given by virtue of a more precise set-up (maximum dose median 57 Gy vs. 36 Gy). Kaplan Meier OS at 1- 2- and 3-years was 65%, 32% and 20%. Acute toxicity was GI of grade <=2 in 9 Pts, late toxicity was observed in 3 Pts as gastrointestinal ulceration medically recovered.

Conclusions: In our experience stereotactic IGRT for liver metastases appears effective and with

mild and acceptable acute/late toxicity. Local control is clearly influenced by use of fiducial markers as target surrogate and dose escalation, but it is difficult in this series to establish the relative weight of these two factors.

15:00 - 16:00 ORAL SESSION

OS7 BODY 2 (LIVER)

Room: La Seine

OS7-2 LIVER METASTASES (LM) FROM COLORECTAL CANCER (CRC): ENCOURAGING RESULTS OF STEREOTACTIC RADIOTHERAPY (SRT)

Xavier Mirabel¹ Sylvain Dewas¹ Claire Vautravers-dewas¹ Ingrid Fumagalli¹ Jacques Fourquet¹
Hajer Jarraya¹ Thomas Lacornerie¹ Eric Lartigau¹
(1) Centre Oscar Lambret, Lille, France

Purpose: The liver is the most frequent site of metastatic spread from colorectal cancer, 25% of colorectal cancer patients will have liver metastases at the time of initial colorectal resection and more than 50% of colorectal cancer patients will develop liver metastases during the course of the disease. The current standard of care for LM is chemotherapy and, whenever possible, liver resection which provides long term survival. For unresectable CRC LM, local ablative therapies are widely applied : radiofrequency ablation or, more recently, conformal or stereotactic radiotherapy.

Material and Methods: From June 2007 to April 2010, we have treated 51 patients with LM from CRC by RTS with CyberKnife. The majority of the patients (94%) have been previously treated for metastatic disease, including 21 (41%) surgery and 39 (76.5%) chemotherapy. The median diameter of the LM was 34 mm. Two dose levels were used: 40 Gy in 4 fractions then 45 Gy in 3 fractions.

Results: Local control is 69.6 % at 1 year. Liver disease free survival is 59.9 % at 1 year, 42.8 % at 2 years. In univariate analysis, local control is correlated with the dose ($p < 0.05$). In patients who received 45 Gy, local control was 90% at 1 year, 67.5% at 2 years. Overall survival at 1 year appears to be higher when the lesions are treated < 4 cm: 94.1% vs. 84.5%.

Discussion: In this retrospective monocentric experience, SRT has been proposed as a rescue treatment. In this population, presumably with a poor prognosis, local control Results appear excellent for patients receiving 45 Gy in 3 fractions. A Phase II RTS CyberKnife study, with strict inclusion criteria, homogenous dose and prospective evaluation seems essential to strengthen the role and the positioning stereotactic radiotherapy in the treatment of liver metastases from CRC.

Conclusion: RTS is a simple, outpatient, routine treatment which allows local control of liver metastasis from CRC at the expense of low toxicity. We just started a phase II international trial.

15:00 - 16:00 ORAL SESSION

OS7 BODY 2 (LIVER)

Room: La Seine

OS7-3 PHASE I-II STUDY FOR LIVER METASTASES USING VOLUMETRIC MODULATED ARC THERAPY (VMAT).

Simona Castiglioni¹ Angelo Tozzi¹ Piera Navarria¹ Giacomo Reggiori¹ Francesca Lobefalo¹ Antonio Modugno¹ Sara Pentimalli¹ Filippo Alongi¹ Elena Clerici¹ Pietro Mancosu¹ Marta Scorsetti¹

(1) Istituto Clinico Humanitas , Milano (rozzano), Jamaica

Aim: To report the feasibility and early clinical **Results:** of a phase I study of stereotactic body radiotherapy (SBRT) delivered with modulated volumetric arc therapy (VMAT) for the treatment of patients with liver metastases.

Materials&Methods: Patients with one to three hepatic lesions and maximum individual tumour diameters less than 6cm, that were inoperable or medically unsuitable for resection were recruited to this research ethics board approved trial. Patients were required to have total bilirubin less than 3 mg/dL, albumin greater than 2.5 g/dL, and normal prothrombin/partial thromboplastin times unless on anticoagulants. Patients with ascites were excluded. Chemotherapy was not given from 2 weeks before to 4 weeks after SBRT. Between March -th09 and May -th10, twenty-five consecutive patients were enrolled in this trial. Patients were immobilized during multi-phases CT simulation with vacuum pillow and personalized body mask using abdominal compression. Daily cone beam CT was performed before each fraction to minimize the set-up uncertainties. The first 12 patients received a total dose to the isocenter of 50Gy/3fractions (group A), while the following 13 patients received 75Gy/3fractions (group B) by RapidArc technique. The organs at risk (OAR) considered were: healthy liver (Dose at 700cm³<15Gy), spinal cord (Maximum dose -> DMax<18Gy), kidneys (volume receiving 15Gy - V15<35%), Stomach and duodenum (DMax<21Gy); heart: mean dose <30Gy.

Results: Overall treatment was well tolerated with no radiation induced liver disease, serious liver toxicity, or other dose limiting toxicity for both groups A and B. In the group A, after RT, all the hematologic values were normal; while for the group B, 4 patients increased the gamma GT. Local response was defined using modified RECIST (Response Evaluation Criteria in Solid Tumor) to describe the change in the irradiated metastases. At median follow up of 6 months 8 patients had partial remission, 3 stable disease and 1 local progression in the group A; 12 patients had partial remission and 1 stable disease in the group B.

Conclusions: SBRT using VMAT is feasible for patients with liver metastases, with minimum toxicities and good local control; however deeper investigation is required to evaluate the global life expectancy.

15:00 - 16:00 ORAL SESSION

OS7 BODY 2 (LIVER)

Room: La Seine

OS7-4 *DAILY PERCUTANEOUS HYDRODISSECTION IN HEPATIC STEREOTACTIC BODY RADIOTHERAPY.*

David Roberge¹ Tatiana Cabrera¹

(1) McGill University Health Centre, Montreal, Canada

Background

Stereotactic body radiotherapy (SBRT) is an emerging treatment modality in the management of primary and oligometastatic liver tumors. Although generally well tolerated, toxicities of SBRT occur because of inactivation of liver parenchyma or irradiation of adjacent organs.

Methods: An 81 year old patient was referred to radiation oncology for treatment of a small hepatitis-related hepatocellular carcinoma of segment 3 of his liver. On planning imaging, the lesion was approximated to the medial aspect of the stomach. Once a 5mm PTV margin was added, there was only 2-3mm between the target and the stomach. A 7 field plan was devised to deliver a marginal dose of 37.5Gy to the PTV in three 12.5Gy fractions using adaptive gating on the Novalis Tx linear accelerator (Brainlab, Heimstetten, Germany). Although the plan was felt to be acceptable, a point in the outer gastric wall was predicted to receive 31.3Gy.

With the patient in treatment position, at the linear accelerator, ultrasound-guidance was used to access the space between the liver and stomach with an 21 gauge needle. Approximately 300 cc of water was injected and 120cc of air. Treatment proceeded based on fiducials previously implanted in the liver parenchyma.

Results: On ultrasound, approximately 20mm buffer space was created by the percutaneous injection. It is estimated, based on the patient dosimetry, that this may have reduced the point dose to the gastric wall by as much as 60%. The injections and radiation treatments were acutely well tolerated with no Grade ≥ 1 toxicity.

Conclusions: Daily percutaneous injection of water / air is feasible and may contribute to reducing SBRT bowel toxicity attributable to high doses to small volumes in areas of steep dose gradient.

15:00 - 16:00 ORAL SESSION

OS7 BODY 2 (LIVER)

Room: La Seine

OS7-5 *UNRESECTABLE INTRA-ABDOMINAL MALIGNANCIES: DOSE AND TOXICITY EVALUATION IN 241 PATIENTS TREATED WITH STEREOTACTIC BODY RADIATION THERAPY*

John O'connor¹ Robert Goldstein¹

(1) Baylor University Medical Center, Dallas, USA (2) Baylor Regional Transplant Institute, Dallas, USA

Approach/Relevance: Stereotactic body radiation therapy is an emerging modality in the treatment of unresectable intra-abdominal malignancies. We evaluate the toxicity of SBRT in a large cohort of patients with intra-abdominal tumors.

Innovation: From January 2005 until July 2010, 241 patients received SBRT for unresectable intra-abdominal tumors. Patients were treated at Baylor University Medical Center. All patients were evaluated by a surgeon prior to SBRT. Most patients 85% (205/241) were treated to the liver. Of these 20% (41/205) where hepatocellular cancer or intrahepatic cholangiocarcinoma. The remaining liver cases were metastasis.

Other cases were pancreas 12%, adrenal 2%, and spleen 1%. Fiducials were implanted for tumors and treatment with respiratory tracking was delivered using the CyberKnife radiosurgery system. Most patients 207 of 241(86%) received SBRT in three daily fractions to a median dose of 42 Gy. Twenty three patients (10%) received SBRT in a single fraction to a median dose of 18 Gy and eleven (4%) in five fractions to a median dose of 30 Gy. Toxicity was assessed using CTC guidelines v3.0.

Results: Over time, the prescribed SBRT dose has increased from a median of 30 Gy in 2005, 45 Gy in 2007, and 51 Gy in 2010. Only 4 (1.6%) patients developed Grade 3 toxicity. These were: gastric ulcer, hepatoduodenal fistula, duodenal ulcer, and gastroparesis. All grade 3 toxicities were in the first year of the centers operation and in these cases the bowel received BED of 60 Gy (early). Since this experience we have limited the maximum bowel dose to 24 Gy in three fractions (early BED = 43.2 Gy). Since then, we have had no episodes of Grade 3 bowel toxicity despite increasing our prescription dose over time.

We have seen no cases of radiation induced liver disease in 205 cases. Liver constraints in three fractions are: <35% of liver gets >15 Gy and >700cc of normal liver gets <15 Gy.

There were no grade 4 or 5 toxicities. Acute toxicities were well tolerated and included Grade 1 and 2 nausea/vomiting, fatigue, and abdominal pain occur in about 1/3 of patients.

Conclusions: Overall, SBRT for unresectable intra-abdominal malignancies is well tolerated. In this large series, exposure of bowel to SBRT doses with BED 60 Gy early resulted in several grade 3 complications. Limiting bowel to 24 Gy max dose in three fractions is safe and feasible while still escalating dose to tumor. Limiting the liver to <35% receiving >15 Gy and >700cc receiving <15 Gy is safe. As our experience has grown, we have escalated our dose while decreasing complications.

15:00 - 16:00 ORAL SESSION

OS8 PHYSICS 1 (MICROBEAMS)

Room: Miles Davis

OS8-1 *CURRENT WORLDWIDE PRACTICE IN CALIBRATION OF SMALL RADIOSURGERY FIELDS - RESULTS FROM THE LEKSELL GAMMA KNIFE INTERNATIONAL CALIBRATION SURVEY*

Josef Novotny Jr.¹ Marc F Desrosiers² Jagdish P Bhatnagar¹ Josef Novotny³ Masaaki Yamamoto⁴ Saiful M Huq¹ James P Puhl² Dade L Lunsford⁵

(1) Department of Radiation Oncology, University of Pittsburgh Cancer Institute, Pittsburgh, United States (2) National Institute of Standards and Technology, US Department of Commerce, Gaithersburg, United States (3) Department of Medical Physics, Na Homolce Hospital, Prague, Czech Republic (4) Katsuta Hospital Mito Gamma House, Hitachinaka, Japan (5) Department of Neurological Surgery, University of Pittsburgh Medical Center, Pittsburgh, United States

Purpose: Survey approximately 100 Leksell Gamma Knife (LGK) units worldwide to 1) gather detailed information about calibration procedures and to 2) measure output of the surveyed LGK units.

Methods and Materials: Each participant of the project received a LGK calibration questionnaire seeking the following information: LGK model, calibration protocol, phantom, and ion chamber used for calibration, LGK calibration personnel, whether independent verification of calibration was performed, and relative collimator output factors used. Alanine dosimeters were used to measure the dose rate of each surveyed LGK unit and these **Results:** compared with calibration data.

Results: To date, 45 LGK units from 43 different centers spanning 12 different countries have participated in this study (23 from North America, 11 from Europe and 11 from Asia). The calibration protocols used are: AAPM TG21 (19 units), AAPM TG51 (4 units), IAEA TRS277 (1 unit), IAEA TRS398 (16 units) and NPL Code of Practice (5 units). ELEKTA ABS phantom was used in 42 (93%) and ELEKTA solid water phantom in 3 (7%) units. Ion chambers most frequently used for the calibration are: PTW 31010 (0.125 cm³) 16 times (36%), Capintec PR-05P (0.070 cm³) 8 times (18%) and Exradin A16 (0.007 cm³) 7 times (16%). Calibration of the LGK unit was performed by an on-site physicist in 36 (80%) cases, by ELEKTA physicist in 8 (18%) cases and in 1 (2%) case calibration was done by a consulting physicist. Independent verification was done only in 23 (51%) cases; RPC, IAEA or similar audit was done only in 12 (27%) cases. All LGK units surveyed are currently using the default values for collimator relative output factors. Observed deviations between LGK users reported calibration and alanine dosimetry measurements were of small magnitude with mean value of 1.4%. In total 43 (96%) LGK units were within 3% deviation. None of measured units exceeded 4% deviation in calibration.

Conclusions: Different calibration procedures, especially calibration protocols are used worldwide (North America mostly AAPM TG21, Europe and Asia mostly IAEA TRS398). Small (1.4%) but systematic deviation between LGK users reported calibration and alanine dosimetry measurements are observed for LGK centers in Europe and Asia where IAEA TRS398 protocol is used. This can be explained by the fact that the ABS plastic phantom is considered to be water equivalent. Overall, very good agreement between reported calibration and alanine dosimetry measurements are observed in this study so far.

15:00 - 16:00 ORAL SESSION

OS8 PHYSICS 1 (MICROBEAMS)

Room: *Miles Davis*

OS8-2 EVALUATION OF 4.0 MM CONICAL COLLIMATOR OUTPUT FACTOR FOR STEREOTACTIC RADIOSURGERY BEAMS

Juan García Ruiz-zorrilla¹ Daniel Zucca Aparicio¹ Pedro Fernández Letón¹ Juan María Pérez Moreno¹ Ángel Miñambres Moro¹

(1) Hospital Universitario Madrid Sanchinarro / Grupo Hospital de Madrid, Madrid, Spain

Objectives: Dose Characterization for narrow beams is complicated due to the finite size of the radiation detector, loss of lateral electronic equilibrium and the setup of the radiation measuring equipment.

Methods: A scanning beam/scanning chamber method has been used to overcome the limitation/difficulty of using a relatively large detector in narrow beam output factor measurement following method described in the literature by J. Fan et al (Med Phys, Nov 2009).

For the scanning chamber method, multiple narrow beams are used for the dose measurement using a finite size chamber. These multiple scanning beams form an equivalent large uniform field which provides lateral electron equilibrium condition.

After the measurement, the contributions from neighbouring beams are deconvolved and the value is used for output factor determinations.

The output factors determined in such a method has been obtained with pin-point PTW 31014 and semiflex PTW 31010 ion chambers and compared to direct measurement by diode and radiochromic film as described in BrainLAB Physics Reference Guide and with direct measurement from pin-point PTW 31014 and plane-parallel PTW 34001 convolving by the detector size.

The contribution factor of each single beam is derived from the beam profile and the off-axis distance accurately measured by diode PTW 60012 and PTW MP3 water tank with a scan resolution of 0.1 mm (SSD 98.5 cm and depth of 1.5 cm) and for the scanning chamber method with a scan resolution of 2.5 mm for point to point measurements.

Radiochromic film dosimetry was else performed to obtain the contribution factors as for diode detector having a good agreement for both dose profiles except for outer zone because of the lower dose inaccuracy values from the dose calibration curve for Gafchromic EBT2

ROI analysis was performed by defining a 2 px, 5 px and 10 px ROI diameter for the center region of each film (100 dpi scan resolution) and getting as the proper value the 5 px ROI because of uncertainties about center placing for each ROI

Results: The following table summarizes the **Results:** obtained for the different methods explained for the 4.0 mm conical collimator output factor and the relative deviations respect diode.

detector size convolution

OF(PTW 31014) 0.600 (-7.1%)

OF(PTW 34001) 0.508 (-21.4%)

scanning chamber method

OF(PTW 31014) 0.699 (9.0%)

OF(PTW 31010) 0.704 (8.2%)

direct measurement
OF(PTW 60012) 0.646 (-----)
OF(Gafchromic EBT2) 0.562 (-13.0%)

Conclusions: Large discrepancies are observed between methods performed. Due to high resolution properties for diode detector and lower dependence on processing analysis as for radiochromic film Output Factor from diode has been accepted for dosimetric issues.

15:00 - 16:00 ORAL SESSION

OS8 PHYSICS 1 (MICROBEAMS)

Room: Miles Davis

OS8-3 *A DUAL DETECTOR METHOD FOR DETERMINING CYBERKNIFE TOTAL SCATTER FACTORS (TSF)*

Janos Szanto^{1, 2} Elizabeth Henderson^{1, 2}

(1) The Ottawa Hospital Cancer Center, Ottawa, Canada (2) University of Ottawa, Ottawa, Canada

Introduction: Making total scatter factor measurements in small fields is known to be challenging: While diode detectors tend to over-respond, even the smallest ion chambers tend to under-respond in very small fields. We propose a method for making TSF measurements for CyberKnife using two classes of detectors: a small volume ion chamber for fields greater than 10mm, and a diode detector for fields 10mm and smaller.

Methods: TSF was measured as a function of collimator size (5-60mm) for three ion chambers (A16, Pinpoint, CC01) and the EDGE detector on a CyberKnife G4. In addition, a comparison was made with the Accuray average data (collected mostly using the PTW 60008 diode detector) (3). TSF for field sizes 10mm and smaller were corrected for detector effects using the Monte Carlo derived correction factors (1,2).

Results: All corrected TSF measurements agree within 5.2% regardless of detector used for all collimators. For field sizes measuring 12.5mm diameter and larger, the ion chamber measurements all agree within 0.5%. The stereotactic EDGE detector agrees with the Accuray average data (3) within 1%, however the stereotactic EDGE detector data is systematically higher than the averaged small volume ion chamber data by as much as 3% in this range. Therefore, if stereotactic EDGE TSF data is used for planning, a systematic dose error of up to 3% compared to A16 (correction factor 1.01 (1) for 10mm collimator) is introduced.

Conclusion: For CyberKnife collimator sizes of 12.5mm and greater, dosimetric error in the measurement of TSF is minimized if a small volume ion chamber is used compared to a diode such as the stereotactic EDGE detector or PTW 60008 diode. Since for a 5mm collimator, published correction factors that eliminate detector effects are 0.95 and 1.096 for the EDGE and A16 detectors respectively, the magnitude of correction, if any is used, is minimized by using the stereotactic EDGE detector for TSF measurements for collimators 10mm and smaller. We recommend that a small volume ion chamber is used for TSF measurements for collimator sizes greater than 10mm and that a diode detector used for collimator sizes 10mm and smaller.

References:

1. Francescon, P, et al. Medical Physics 35(2), p. 504-513 (2008).
2. Francescon, P, et al. JACMP 10(1), p. 147-152 (2009).
3. Sharma, S., et al. JACMP 8(3), p. 119-125 (2007).

15:00 - 16:00 ORAL SESSION

OS8 PHYSICS 1 (MICROBEAMS)

Room: Miles Davis

OS8-4 *DETERMINATION OF DOSE AT THE PENUMBRA REGIONS AND OUTPUT FACTORS FOR SMALL STEREOTACTIC CONES BY MONTE CARLO SIMULATION AND GAFCHROMIC EBT FILM*

Kin Wa Chan¹ Soo Min Heng¹ Robert Smee¹

(1) Prince of Wales Hospital, Randwick, Austria

Accurate dose measurement at the penumbra region is difficult due to the rapid change of the dose and energy spectrum in this area. Ion chambers are used extensively in dose measurement and are reasonably energy independent. However, due to the large sensitive volume, ion chambers fail to provide good spatial resolution at the penumbra region especially in the case of small stereotactic cones. Diode detectors have small sensitive volume but suffer from energy dependence; which makes them not suitable for measuring dose in the penumbra region. Gafchromic EBT films provide high resolution and are almost energy independent [ref 1]. However, the measured dose is affected by environmental factors such as the film scanner quality. This gives rise to about $\pm 3\%$ uncertainty in the data. As a result, Monte Carlo Simulation (MCS) has been chosen to calculate the penumbra region and output factors for small stereotactic cones in our department.

Method: The profiles measured using (i) an ion chamber (Scanditronix CC01) in a water tank, (ii) EBT film in solid water and (iii) MCS were compared. For the output factors, comparison were done for measurement performed with (i) a diode detector in water, (ii) EBT film in solid water and (iii) MCS.

Result: At the penumbra region, the Results of MCS agreed with that of the EBT film to within 1mm at all level while the chamber measurement differed by 1mm at the 80% dose region and 1.5mm at the 20% region compared to the EBT film. The output factors from MCS matched to within $\pm 3\%$ compared to Results from EBT film.

References: 1. J. G. H. Sutherland and D.W.O. Rogers, Monte Carlo calculated absorbed-dose energy dependence of EBT and EBT2 film. Vol 37 p.1110-1116.

15:00 - 16:00 ORAL SESSION

OS8 PHYSICS 1 (MICROBEAMS)

Room: Miles Davis

OS8-5 CHALLENGING SMALL FIELDS DOSIMETRY WITH THE USE OF MOSFET AS IN VIVO DOSIMETER IN RADIOSURGERY

Aurélié Sors^{1, 3}, Emmanuelle Cassol^{2, 3}, Abdelbasset Hallil⁴, Igor Latorzeff⁵, Pierre Duthil², Jean Albert Lotterie³, Alain Redon⁵, Isabelle Berry³, Xavier Franceries^{3, 7, 8}, Xavier Franceries³

(1) Laboratoire d'Etude et de Recherche en Imagerie Spatiale et Médicale, Toulouse, France (2) Unité de Radiophysique et de Radioprotection, CHU, Toulouse, France (3) Inserm Imagerie cérébrale et handicaps neurologiques, UMR 825, F-31059, Toulouse, France (4) Best Medical Canada, Ottawa, France (5) Centre de Radiochirurgie Stéréotaxique, CHU Rangueil, Toulouse, France (6) Groupe Oncorad, Garonne, France (7) Université de Toulouse; UPS, INPT; LAPLACE (Laboratoire Plasma et Conversion d'Energie), Toulouse, France (8) Université de Toulouse, UPS, Imagerie cérébrale et handicaps neurologiques, UMR 825, Toulouse, France

Purpose: As intra-cranial stereotactic radiosurgery treatments required small fields, in vivo dosimetry could be considered as technically non applicable, even in shaped beam. Recent developments in MOSFETs technology (Metal Oxid Semiconductor Field Effect Transistor), with very small sensitive area, could make these sensors suitable for microbeams. Our aim is to evaluate and to optimize calibration method from 98x98 to 6x6mm² field size both with MOSFETs and microMOSFETs.

Materials-Methods: This study was performed on a Novalis with a micro-MLC m3 (BrainLab), delivering a 6MV photons beam. MOSFETs (TN-502RD, Best® Medical Canada) were calibrated at the depth of maximum dose, centered on the beam axis at the surface of an acrylic phantom for square field size of 98x98, 60x60, 42x42, 30x30, 24x24 and 18x18mm². MicroMOSFETs (TN-502RDM) were calibrated under identical conditions for same square field sizes and 12x12 and 6x6mm². Calibration Factors Matrices (CFM) were obtained for each SSD-field size combination from TPS computations (Brainscan 5.3.1, BrainLab) and corrected by the inverse-square law to obtain calculated CFM (CFMcal) using a 2D interpolation method (Matlab) between SSD and field size for each calibration mode. Pre-clinical validation measurements were performed on a head phantom of plastic water with bone and vascular inserts. The phantom positioning was verified using the ExacTrac system (BrainLab). The effect of parameters such as gantry angulations, SSD, size and geometry fields was first studied for 4 regular (3 square, 1 asymmetric) and irregular beams defined with m3. The deviation between the measured and prescribed dose related to the geometry was studied by applying CFM and CFMcal to measurements. Secondly 6 irregular fields were studied with microMOSFETs ranging from 33.5x33.5 to 8.9x8.9mm² equivalent square field size.

Results: MOSFET calibration measurements follow the inverse square law with a good correlation ($r^2=0.975$). Using MOSFETs: better **Results:** were obtained with CFMcal since reduced deviation between prescribed and measured dose was observed: mean deviation was 1.78% from -1.80% to +6.01% for regular fields and 2.27% from -6.90% to +1.90% for irregular fields. Using microMOSFETs: mean deviation was 2.66% from -7.09% to +4.38% considering all irregular fields size tested.

Conclusions: A calibration method for MOSFET and microMOSFET was implemented and

evaluated. By using inverse square law, it is possible to reduce number of measurements to be performed. For typical irregular fields encountered in radiosurgery the study on a realistic head phantom showed that MOSFETs and microMOSFETs could be suitable as in vivo dosimeters in shape beam radiosurgery ranging respectively from 18x18 to 98x98mm² and 6x6 to 98x98mm².

15:00 - 16:00 ORAL SESSION

OS9 SCHWANNOMAS 2

Room: auditorium

OS9-1 *MULTI-SESSION RADIOSURGERY FOR VESTIBULAR SCHWANNOMAS. LOCAL CONTROL AND HEARING PRESERVATION.*

Marcello Marchetti¹ Ida Milanese¹ Livia C. Bianchi² Achille Bergantin² Giovanni Broggi¹ Carlo L. Solero¹ Laura Fariselli^{1, 2}

(1) Dept of Neurosurgery, Fondazione IRCCS Istituto Neurologico C Besta, Milano, Italy (2) Centro Diagnostico Italiano (CDI), Milano, Italy

Objective. Aim of the present study is to evaluate the possible advantage of multisession radiosurgery both in terms of effectiveness and safety.

Patients and Methods: All the 61 patients included in present study underwent a multisession radiosurgery treatment with a prescription dose of 18 Gy, in 3 fractions

All patients are classified according to the American Academy of Otorinolaryngology-Head and Neck Surgery classification.

In order to improve the target definition and to obtain more anatomic details about the critical structures the CT images were always fused with MRI.

Cranial nerve function, audiograms, and magnetic resonance images (MRI) were monitored 2 months after treatment and every 6 months thereafter.

The PTV was defined as the tumour volume without margin. The mean tumour volume was 4,5 cc (range 0,05-13,2cc; median 3,6cc). The mean dose to the cochlea was 16,3Gy to the 50% of the volume.

Results: the mean follow-up period was 35 months (range 23-60 months). Four patients died during the follow-up. One patient had a cerebral stroke and other three patients died due to unrelated causes.

The tumour growth control was achieved in 95% of the series. Eighteen percent had a partial response (shrinkage > 25%). Only the 5% of the patients showed a progression disease.

The 75 % of the patients maintained a serviceable hearing function.

Conclusions. Although the short follow-up period, the preliminary Results from this experience suggests that multisession radiosurgery by CyberKnife would be safe and effective. The tumour growth control was optimal and the hearing function preservation rate was promising.

15:00 - 16:00 ORAL SESSION

OS9 SCHWANNOMAS 2

Room: auditorium

OS9-2 MULTI-SESSION STEREOTACTIC RADIOSURGERY FOR VESTIBULAR
SCHWANNOMAS: IS THERE AN ADVANTAGE TO FRACTIONATION?

Clara Choi¹ Ake Hansasuta² Iris Gibbs¹ Scott Soltys¹ Victor Tse³ Gordon Sakamoto¹ Melanie Hayden¹ Robert Lieberman¹ Griffith Harsh¹ John Adler¹ Steven Chang¹

(1) Stanford University Medical Center, Stanford, USA (2) Ramathibodi Hospital, Mahidol University, Bangkok, Thailand (3) Kaiser Permanente Medical Group, Redwood City, USA

Objective: To evaluate tumor control and complication rates following multi-session stereotactic radiosurgery (SRS) treatment of vestibular schwannomas (VSs) (acoustic neuroma).

Methods: We retrospectively reviewed outcomes of 474 patients with VSs treated with SRS at Stanford University Medical Center from 1999 to 2007. Greater than 1 year follow-up information was available for 383 patients; 370 patients were treated with multi-session SRS, including 346 who were treated with 18 Gy in 3 sessions. SRS was delivered to a median 80% isodose line (range, 65-95%), targeting a median tumor volume of 1.1 cm³ (range, 0.02-19.8 cm³). The tumor control rate, defined as the absence of the need for additional surgical or radiosurgical intervention, was calculated using the Kaplan-Meier (KM) product-limit method. Preservation of serviceable hearing was defined as maintenance of Gardner-Robertson Grade 1-2 hearing following SRS. Log-rank test and univariate Cox proportional hazard regression were used to assess categorical and continuous variables, respectively; univariate tests were not adjusted for multiple comparisons. Differences between the groups were assessed using Fisher's Exact Test and 2-Tailed t Test for categorical and continuous datasets, respectively.

Results: With a median follow-up of 3.6 years (range, 1-10 years), 10 tumors required additional treatment, resulting in overall-crude and 3- and 5-year KM tumor control rates of 97%, 99%, and 96%, respectively. The 5-year KM tumor control rate was 98% for tumors less than 3.4 cm³. NF2-associated tumors were associated with worse tumor control ($p=0.018$). Of the 200 evaluable patients with pre-SRS serviceable hearing (Gardner-Robertson Grade 1 and 2), the crude rate of serviceable hearing preservation was 75.5% (median follow-up period of 3.0 years; range, 1.0-8.9 years). Smaller tumor volume was associated with better hearing preservation ($p=0.001$). Patients with tumors smaller than 3 cm³ had a serviceable hearing preservation rate of 80% compared to 59% for > 3 cm³ tumors ($p=0.009$). There was no case of post-SRS facial weakness. Eight patients (2%) developed trigeminal dysfunction, half of which was transient.

Conclusion: Multi-session SRS treatment of VSs Results in excellent rate of tumor control. Hearing, trigeminal nerve, and facial nerve function preservation rates reported herein are promising and compare favorably to published single session SRS experiences. Multi-institutional, prospective studies are needed to properly compare functional outcomes between single- and multi-session SRS.

15:00 - 16:00 ORAL SESSION

OS9 SCHWANNOMAS 2

Room: auditorium

OS9-3 *MANAGEMENT OF LARGE VESTIBULAR SCHWANNOMAS: PLANNED SUBTOTAL RESECTION FOLLOWED BY GAMMAKNIFE RADIOSURGERY.*

Rick Van De Langenberg¹ Patrick Hanssens² Koo Van Overbeeke^{1, 2} Jeroen Verheul² Patty Nelemans¹ Bert-jan De Bondt³ Robert Stokroos¹

(1) Maastricht University Medical Center, Maastricht, The Netherlands (2) St. Elisabeth Hospital, Tilburg, The Netherlands (3) Isala Klinieken, Zwolle, The Netherlands

Approach: Review of patients with a large vestibular schwannoma, treated with a planned strategy of subtotal resection followed by Gammaknife Radiosurgery. Clinical and radiological aspects were evaluated.

Relevance: When dealing with large vestibular schwannomas, intervention is necessary. Microsurgery is the mainstay in treating these benign tumors, and a complete resection is considered as the primary goal. Previous studies performing a complete resection show suboptimal outcome in facial nerve function and hearing preservation. In addition, tumor recurrence may occur up to 11% of the cases (1).

Innovation: Patients were treated with planned subtotal resection followed by Gammaknife Radiosurgery in order to minimize both the risk of facial nerve dysfunction and tumor regrowth. In addition volume measurements were used to analyse changes in vestibular schwannoma size, which are more reliable compared to the clinically used two-dimensional measurements to evaluate tumor control (2).

Results: 50 patients with a large vestibular schwannoma of mean tumor volume of 15cm³ were evaluated. Surgery was performed through a translabyrinthine (25) or retrosigmoid (25) approach. Median follow up was 33,8 months. One major complication occurred in a patient who developed a hemiparesis postsurgically. Radiological tumor control was achieved in 90%. Outcome of facial nerve function was good or excellent (House Brackmann I or II) in 94% of the patients. One of the two patients receiving hearing preserving surgery maintained serviceable hearing after resection followed by Gammaknife Radiosurgery. Four patients underwent a second intervention due to VS growth, consisting of second Gammaknife Radiosurgery (3) and microsurgery (1), resulting in tumor control.

Conclusion: The combination of subtotal resection followed by gammaknife radiosurgery lead to an adequate tumor control and high rate of preservation of facial nerve function. Therefore, this strategy is a valid treatment option of large vestibular schwannomas.

1. Pollock BE, Lunsford LD, Flickinger JC, Clyde BL, Kondziolka D. Vestibular schwannoma management. Part I. Failed microsurgery and the role of delayed stereotactic radiosurgery. *J Neurosurg.* 1998 Dec;89(6):944-8.

2. van de Langenberg R, de Bondt BJ, Nelemans PJ, Baumert BG, Stokroos RJ. Follow-up assessment of vestibular schwannomas: volume quantification versus two-dimensional measurements. *Neuroradiology.* 2009 Aug;51(8):517-24.

15:00 - 16:00 ORAL SESSION

OS9 SCHWANNOMAS 2

Room: auditorium

OS9-4 COMBINED APPROACH IN KOOS IV VESTIBULAR SCHWANNOMAS

Samir Moucharrarfie Naime¹ Pierre- Hugues Roche¹ Vincent Lubrano¹ Jean Marc Thomassin¹ Jean Regis¹

(1) Hôpital de la Timone, Marseille, France

Large size vestibular schwannomas (VS), Koos stage IV, are classically in first intention treated by a radical surgical removal which involves a high risk of facial paralysis and hearing loss. Since 2003 a subtotal surgical removal, followed by a Gamma Knife radiosurgery (GKS) have been systematically proposed and prospectively evaluated.

Patients & methods: The auto come of 51 patients aged from 30 to 78 years treated between 2003 and 2007 following this protocol are compared to a cohort of the last 100 pts operated by radical removal

In the considered approach population the medial extrameatal tumour diameter was 30 mm.

The surgical removal using a retrosigmoid approach (13 cases) or a translabyrinth approach (38 cases) was stopped when the surgery was giving a risk of lesion on the facial nerve in agreement with monitoring data.

GKS was performed between the 6th and 18th postoperative months, depending of the remnants volume and the facial nerves functional condition.

Results: Resection has been total in 9 cases, almost total (microfragment) in 7 cases and subtotal in 35 cases. In this last group, GKS has been performed for 27 patients. The medalled follow-up after surgery was 34 months and 28 months after GKRS. At the last control, facial motor function was satisfactory in 82 % of the cases (House-Brackmann grade I or II) instead of 55% in the control group Intermediary nerve function, evaluated in 39 cases, was normal in 20 cases, partially affected in 13 cases and absent in 6 cases.

Conclusions: In our experience, a deliberately subtotal resection followed by GKS, gives better functional Results on the facial and intermediary nerves in comparison with systematic radical surgical removal of stage IV vestibular schwannomas. Performance of GKS directly on the postoperative remnant keeps discussed and justifies to be compared with simple follow-up.

Upfront GKS on small postoperative remnant versus wait & see remains a matter of controversy.

15:00 - 16:00 ORAL SESSION

OS9 SCHWANNOMAS 2

Room: auditorium

OS9-5 USE OF PET-METHIONINE TO ASSESS FAILED TUMOR CONTROL AFTER RADIOSURGERY FOR VESTIBULAR SCHWANNOMA AND GUIDE RE-IRRADIATION.

Nicolas Massager¹ Françoise De Smedt¹ Daniel Devriendt¹

(1) Gamma Knife Center, Brussels, Belgium

Introduction: The Gamma Knife (GK) radiosurgical treatment of vestibular schwannomas (VS) is associated with a high rate of tumor control. However, the assessment of tumor response to the irradiation can be difficult in the first years after treatment since tumor growth can be related to tumor progression or to a temporary necrotic postradic reaction. This study investigates the role of PET-scan with methionine to help us in differentiation between these two situations and guide us in optimal targeting of a second irradiation in case of tumor progression.

Materials & Methods: Some patients with significant tumor growth following GK treatment for VS have been investigated by PET-scan with methionine. Images of PET-scan were co-registered with the MRI of the follow-up as well as the MRI of the dose planning of GK treatment. An analysis of the metabolic activity of the tumor volume has been achieved. In theory, three different situations could occur: total hypometabolism of the tumor on PETscan in case of success of treatment, metabolic hyperactivity of the whole tumor volume if the entire tumor tissue has not been controlled by radiosurgery, or partial metabolic response with growing areas of the tumor providing hypermetabolic activity and other regions showing hypometabolism.

Results: Patients showed various methionine intensity uptake on PET-scan. In the majority of cases, an heterogeneous metabolism of the tumor was found. For some patients the hypermetabolic area correlated well with the part of the tumor that was growing on MRI. The PET-scan has helped us to decide the best therapeutic option between continuation of the wait-and-scan approach, microsurgical removal or new radiosurgical procedure. When a new GK treatment has been performed, PET-methionine was used to optimize the target of irradiation.

Conclusions: the PET-scan with methionine is a useful examination for patients with significant tumor growth in the follow-up after GK therapy for VS. PET-methionine may help in the differentiation between tumor growth or tumor necrosis after GK, and in the targeting of a second GK procedure in case of incomplete tumor control.

16:30 - 18:00 ORAL SESSION

OS10 BRAIN METASTASES 2

Room: La Seine

OS10-1 A RANDOMIZED STUDY TO DETERMINE THE OPTIMAL PTV FOR RADIOSURGERY OF BRAIN METASTASES: PRELIMINARY RESULTS

John Kirkpatrick^{1, 2} Karen Allen¹ Zhiheng Wang¹ Fang-fang Yin¹ Scott Green¹ Manisha Palta¹ John Sampson^{1, 2} John Sampson¹

(1) Duke University, Durham, USA (2) Preston Robert Tisch Brain Tumor Center, Durham, USA

Background: In treating brain metastases with stereotactic radiosurgery, the goal is tumor control without damaging normal brain. Some advocate treating the GTV expanded by several mm (e.g., PTV=GTV+2mm) to maximize control. Others treat the GTV alone (PTV=GTV), to minimize neurotoxicity. This trial seeks to identify a GTV expansion that yields optimal tumor control and morbidity.

Methods: Adult patients with 1-3 newly diagnosed brain metastases, up to 3.8cm maximum dimension, no previous brain irradiation, and KPS>70 were potentially eligible for this IRB-approved trial. Lesions are randomized to a uniform GTV expansion of 1 versus 3mm, where the GTV is defined on a fine-cut, contrast-enhanced T1-weighted MRI. All lesions are contoured by one physician in iPlan (BrainLAB) and treated in single-fraction SRS on a Novalis Tx (Varian, BrainLAB.) Dose was prescribed to the absolute isodose line encompassing the PTV per RTOG 9508 guidelines based on the PTV (not the lesion.) Patients undergo quality-of-life (FACT-Br) and neurocognitive (MMSE, Trailmaking A&B) evaluation immediately prior to SRS and 1 and 3months post-treatment. MRI and neurologic exam are performed at 3month intervals. Primary endpoint is local control; secondary endpoints included the rate of distant brain metastases, rate of salvage therapy, rate of radionecrosis, quality of life, neurocognitive function, death from neurological causes and overall survival. Enrollment of 40 patients (~80 lesions) is targeted.

Results: From March-October 2010, 17 patients, ages 36-82 years (Median 61) and median KPS=90, with 26 lesions have been enrolled. PTV ranged from 4-36mm (median 15mm) with prescribed doses ranging from 15-24Gy (median 24Gy.) Fourteen lesions were expanded 1mm, twelve 3mm. At median follow-up of 4months post-SRS, two patients died of extracranial disease (one in each arm), one with a melanotic lesion expanded 3mm bled at the SRS site, and three have recurred at a distant site in the brain (all with a single initial lesion expanded 3mm.) At baseline, median MMSE and Trailmaking A&B were 29 (range 27-30), 40sec (range 22-92sec) and 92sec (44-390sec), respectively. No significant change was observed in MMSE (median 29), Trailmaking A (41sec) and B (70sec) in the 20 patients evaluable 1-month post-SRS. No acute adverse neurologic effects were observed

Discussion: As this very early time, radiosurgery appears well-tolerated in this cohort of newly diagnosed patients.

16:30 - 18:00 ORAL SESSION

OS10 BRAIN METASTASES 2

Room: La Seine

OS10-2 *RESPONSE OF LUNG LESIONS AND DPF SURVIVAL AFTER RADIOSURGERY IN PATIENTS WITH BRAIN METASTASES*

Jung Ho Han¹ Dong Gyu Kim² Chang Wan Oh¹ Chae-yong Kim¹ Jeong Hoon Park¹ Eun Kyung Kim¹ Hee-won Jung¹

(1) Department of Neurosurgery, Seoul National University Bundang Hospital, Gyeonggi-do, Korea, Republic of

(2) Department of Neurosurgery, Seoul National University Hospital, Seoul, Korea, Republic of

Background: We retrospectively evaluated the relationship between the response of lung lesions and distant progression-free survival (DPFS) after radiosurgery in patients with brain metastases.

METHODS: A total of 47 consecutive patients were treated with radiosurgery for brain metastases. Distant progression was defined as a new enhancing intracranial tumor or leptomeningeal enhancement noted on follow-up magnetic resonance imaging. Progression of lung lesions was defined as follows: 1) a 20% increase in the summed diameter of the target lesions; 2) an absolute increase of 5 mm when the summed diameter was very small; or 3) detection of new lesions in the lung.

Results: Twenty-one (44.7%) patients displayed distant progression after radiosurgery; we observed development of new distant metastases in nine patients, development of leptomeningeal seeding in eight patients and combined failure of distant progression and local control failure in four patients. Forty-two (89.4%) patients had lung lesions at the time of radiosurgery, and 18 (38.3%) of them showed progression of their lung lesions during the post-radiosurgery follow-up period. The median DPFS was 7.00 months (95% CI, 6.153-7.847). The actuarial DPFS rates were 81.5%, 61.3%, and 36.7% at three, six and twelve months after radiosurgery, respectively. In the multivariate analysis, only the criterion for progression of lung lesions reached statistical and independent significance ($p=0.021$, $OR=3.372$, 95% CI, 1.200-9.480).

Conclusion: The response of lung lesions after radiosurgery is likely to be a good predictor of DPFS after radiosurgery in patients with brain metastases.

16:30 - 18:00 ORAL SESSION

OS10 BRAIN METASTASES 2

Room: La Seine

OS10-3 *BRAIN METASTASES FROM BREAST CANCER TREATED WITH LINAC-RADIOSURGERY: PREDICTING FACTORS FOR NEUROLOGICAL CONTROL AND SURVIVAL*

Charles A Valery¹ Moomina Lekehal¹ Christos Boskos^{1, 3} Michel Duyme⁴ Gilbert Boisserie² Jean-Jacques Mazon² Philippe Cornu¹

(1) Neurosurgery department, Hôpital de la Salpêtrière, APHP, Paris, France (2) Radiotherapy department, Hôpital de la Salpêtrière, APHP, Paris, France (3) Radiotherapy department, Iatriko medical center, Athens, Greece (4) Biostatistics, epidemiology and clinical research, EA 2415, Montpellier, France

Introduction It has been established that radiosurgery can be proposed as a first treatment or as a salvage alternative to control brain metastases. Usually, neurological control does not significantly influence overall survival of these patients. However, some authors have recently shown that this relationship could vary according to the site of the primary cancer. In this study we analyzed, in a homogenous population of patients presenting brain metastases from breast cancer, factors involved in neurological control and survival and try to propose a prognostic index adapted to brain metastases from breast cancer.

Material and methods Hundred and twelve patients were treated on average 3.5 years after the primary was discovered. Mean age was 54 yo (26-82). Mean Karnofsky index was 90. Primary was controlled in 87.5% of the cases. There were extra-CNS lesions in 78% of the cases. Patients were 14% RPA group I, 84% RPA group II and 2% group III. Patients were SIR 8-10 in 35% and SIR 4-7 in 65% of the cases. They had previous surgery in 12% of the cases, WBRT in 50% of the cases. Mean number of metastases was 189, median lesion volume was 1.5 cc (0.008-44). Irradiation was performed with a 6 MV Varian Clinac 2100 C and a BrainLAB® M3 micromultileaf collimator. Delivered doses were 16 Gy at the reference isodose (6.6-17) and 20 Gy at the isocenter (18-24).

Results: Median time before neurological relapse was 379 days. In a multivariate analysis, age, KI and number of metastases, delay between primary and cerebral metastases and RPA were included in a Cox model (χ^2 : 24.7; $p=0.0004$). Age ($p=0.005$), KI ($p=0.05$) and number of metastases ($p=0.0009$) were significant. Median survival was 536 days. Survival rates at 3, 6 and 12 months were 99%, 86%, and 64% respectively. Using a Cox model in a step forward analysis, we found the following parameters to be predictive of survival (χ^2 : 30.6; $p=0.00003$): age, SIR, previous surgery, delay between primary and BM, total volume and number of lesions. Age ($p=0.000005$), SIR ($p=0.000007$) and number of metastases ($p=0.0093$) were significant.

Conclusion Involvement of the number of metastases on survival suggests the influence of neurological control on survival. Other possible explanations will be discussed.

16:30 - 18:00 ORAL SESSION

OS10 BRAIN METASTASES 2

ROOM: LA SEINE

OS10-4 A POOLED ANALYSIS OF ARC-BASED IMAGE-GUIDED SIMULTANEOUS IN-FIELD BOOST RADIATION THERAPY FOR OLIGOMETASTATIC BRAIN METASTASES

George Rodrigues¹ Wietse Eppinga² Frank Lagerwaard² Patricia De Haan² Cornelis Haasbeek² Francisco Perera¹ Ben Slotman² Brian Yaremko¹ Slav Yartsev¹ Glenn Bauman¹

(1) Lawson Health Research Institute, London, Canada (2) VU University Medical Centre, Amsterdam, The Netherlands

Approach: To report pooled overall survival and time to radiological intracranial progression

Results: related to arc-based image-guided radiotherapy for dose-escalation of oligometastatic disease of the brain. The identification of prognostic factors is also an objective of this study in order to better inform clinical decision-making and clinical trial stratification design.

Relevance: Radiosurgery has been the most common technique used to dose escalate individual

lesions following whole brain radiotherapy, however, a variety of alternative radiotherapeutic approaches including image-guided radiotherapy procedures are now available.

Innovation: The combination of highly conformal delivery and image-guidance procedures/technology provides a potential alternative platform to conventional stereotactic frame systems for precision radiotherapy. Arc-based conformal treatment delivery (like other forms of intensity modulated radiotherapy) lends itself to synchronous boost strategies as multiple targets can be easily treated to different dose (and dose per fraction) levels in the course of the treatment. Arc-based radiation therapy may therefore be an efficient approach to deliver radiosurgery-type boost treatments concurrent with whole brain radiotherapy without the need for separate potentially invasive stereotactic procedures.

Methods and Materials: Anonymized patient, tumor, and treatment data were pooled from the VU University medical center and the London Regional Cancer Program for patients treated with whole brain radiotherapy (20Gy/5 VU, 30Gy/10 LRCP) with simultaneous infield boost to individual intracranial lesions (40Gy/5 VU, 35-60Gy/10 LRCP) to perform survival and intracranial control outcome analyses.

Results: A total of 120 patients were treated by both the LRCP (n=70) and VUmc (n=50) between 2005-2010. Median lesional dose BED3/10 for the entire cohort of patients was 147 Gy and 72 Gy, respectively. Median follow-up for the entire cohort of patients was 4.7 months with median follow-up of 5.2 months for living patients. On multivariable analysis, primary lung cancer (HR 2.044), presence of systemic metastatic disease (HR 1.937), and lower baseline WHO performance status (HR 1.742) were significant ($p < 0.05$) predictors of shorter overall survival from treatment. Cumulative volume (HR 1.014, $p = 0.06$) was of borderline significance on multivariable analysis of intracranial control.

Conclusions: This analysis of the largest known database of arc-based radiotherapy with simultaneous infield boost for oligometastatic brain metastatic disease has informed the clinical trial design and stratification of newly activated and planned phase II and III prospective clinical trials.

16:30 - 18:00 ORAL SESSION

OS10 BRAIN METASTASES 2

Room: La Seine

OS10-5 CAN PRE-OPERATIVE GKRS PREVENT MENINGEAL DISSEMINATION IN BRAIN MET PATIENTS? A CASE-MATCHED STUDY

Masaaki Yamamoto¹ Takuya Kawabe¹ Bierta E Barfod¹ Yasunori Sato² Yoichi Urakawa¹

(1) Katsuta Hospital Mito GammaHouse, Hitachi-naka, Japan (2) Clinical Research Center, Chiba University Graduate School of Medicine, Chiba, Japan

Background: Recently, as an alternative to whole brain radiotherapy, stereotactic radiosurgery (SRS) have been applied as postoperative radiotherapy in patients with brain METs. We conducted a case-matched study to test the hypothesis that preoperative irradiation using SRS reduces the incidence of meningeal dissemination.

Methods: This retrospective study employed databases including 155 consecutive MET patients

undergoing GKRS as adjuvant radiotherapy for surgical resection at our facility during the ten-year period from July 1998 to June 2008. All 155 patients were divided into two groups, 139 who underwent surgical tumor removal followed by GKRS (post-op group) and 16 prior to (pre-op group) GKRS. Because there was a major difference in patient numbers possibly producing considerable bias between the two groups, a case-matched study was conducted. Using a propensity matching method, ultimately, 16 patients were selected for each group. The groups were well matched with regard to demographic characteristics.

Results: The median survival times (MSTs) after treatment were 8.9 (95% confidence interval [CI]; 3.1-18.3) months in the post-op group and 10.5 (95% CI; 4.9-13.5) months in the pre-op group (hazard ratio [HR] vs. the post-op group; 1.066, 95% CI: 0.508 -2.252, logrank $p=.8638$). Post-treatment magnetic resonance (MR) images demonstrated tumor recurrence in surgically and radiosurgically treated areas in one (6.2%) of the post-op group and four (25.0) of the pre-op group patients (Fischer exact test $p=.3326$, HR vs. the pre-op group; .294, 95% CI; .033-2.638, logrank test $p=.2742$). Post-treatment MR images demonstrated tumor recurrence in non-treated areas in seven (43.7%) of the post-op group and five (31.2%) of the pre-op group (Fischer exact test $p=.7160$). Among those with remote recurrence, new lesions were located within the brain parenchyma in four (25.0%) in each group (Fischer exact test $p>.9999$). On the other hand, subdural dissemination occurred in seven (43.8%) of the post-op and one (6.2%) of the pre-op group patients (Fischer exact test $p=.0373$, HR vs. the post-op group; .110, 95% CI; .013-.903, logrank test $p=.0339$).

Conclusions: Our preliminary Results showed that GKRS as preoperative radiotherapy may have a certain benefit, i.e., possible prevention of meningeal dissemination, for managing selected patients with relatively large METs.

16:30 - 18:00 ORAL SESSION

OS10 BRAIN METASTASES 2

Room: La Seine

OS10-6 STEREOTACTIC RADIOSURGERY ALONE FOR PATIENTS WITH MULTIPLE BRAIN METASTASES: RETROSPECTIVE REVIEW IN TWO GAMMA KNIFE CENTERS OF 1508 ELIGIBLE CASES MEETING THE MULTI-INSTITUTIONAL PROSPECTIVE STUDY (JLGK0901) INCLUSION CRITERIA

Toru Serizawa^{1, 2, 3} Masaaki Yamamoto² Yasunori Sato³ Yoshinori Higuchi⁵ Takuya Kawabe² Osamu Nagano⁴ Tastuo Hirai¹ Junichi Ono⁴ Naokatsu Saeki⁵

(1) Tokyo Gamma Unit Center, Tsukiji Neurological Clinic, Tokyo, Japan (2) Mito GammaHouse, Katsuta Hospital, Hitachinaka, Japan (3) Clinical Research Center, Chiba University Hospital, Chiba, Japan (4) Gamma Knife House, Chiba Cardiovascular Center, Ichihara, Japan (5) Department of Neurological Surgery, Chiba University, Chiba, Japan

Purposes: A prospective multi-institute study (Japan Leksell Gamma Knife, JLGK0901) of gamma knife surgery (GKS) for multiple brain metastases without whole brain radiation therapy (WBRT) has been conducted by the JLGK society. We retrospectively reviewed the Results of GKS alone meeting the JLGK0901 inclusion criteria in patients treated at two centers according to the same protocol.

Materials and methods: Among 3716 cases with brain metastases treated with GKS in Chiba and Mito between 1988 and 2007, 1508 consecutive patients who satisfied the following 5 major JLGK0901 inclusion criteria, were analyzed: 1) tumor less than 10cc in volume, 2) a maximum of 10 brain metastases; 3) no more than 15 cc total tumor volume; 4) no MR findings of CSF dissemination, 5) KPS score <70 due to any systemic cause. All lesions were treated with GKS in a single session without upfront WBRT. New distant lesions, detected with follow-up MRI at least every three months, were appropriately re-treated with GKS and WBRT. The hazard risks of covariates for overall survival (OS) curves were calculated using the Cox proportional hazard model, in 1200 cases extracted randomly from among the 1508 cases.

Results: There were 963 men and 545 women. The primary organs were the lung in 1114 patients, gastro-intestinal tract in 157, breast in 105, uro-genital in 62 and others in 70. We divided patients, according to tumor number, into groups A (single, n=565), B (2-4, n=577) and C (5-10, n=366). Mean survival time (MST) was 0.98, 0.68 and 0.61 years in groups A, B, and C, respectively (p<0.0001; AB, p=0.036; BC). In multivariate analysis, significant poor prognostic factors for OS were low RPA class (class 1-2, class 2-3, both p<0.0001), male gender (p<0.0001) tumor number (group A vs group B, p<0.0001) and primary site (lung vs breast, p=0.0047, lung vs others, p=0.0160). However, there was no significant difference between groups B and C (p=0.1027, HR: 1.12, CI 0.999-1.265) in the final model.

Conclusion: From the Results of our retrospective study, we can reasonably anticipate that the JLGK0901 study will prove the non-inferiority of SRS alone Results for 5-10 brain metastases, as compared with those for 2-4 lesions.

16:30 - 18:00 ORAL SESSION

OS10 BRAIN METASTASES 2

Room: La Seine

OS10-7 *STEREOTACTIC RADIOSURGERY FOR SINGLE BRAIN METASTASES: INFLUENCE OF SURGERY AND WHOLE BRAIN IRRADIATION*

Dennis Shrieve¹ Annabelle Shrieve¹ Randy Jensen¹

(1) University of Utah, Salt Lake City, USA

Ninety-four patients with single brain metastases received SRS between October 1999 and December 2009. Histologies were Breast (9), Lung (24), Renal cell Carcinoma (RRC) (19) and melanoma (42). Twenty-one patients were treated following surgery. Fifteen received whole brain radiotherapy (WBRT) in addition to SRS at the time of initial therapy. Patients were followed until death with serial MRI scans.

Median survival time (MST) was 10.33 months for all patients. Neither the addition of surgery nor WBRT influenced overall survival. Patients with breast metastases survived longer than other histologies with MSTs of 24.6 mo and 9.9 mo, respectively. Local Control (LC) was evaluable in 81 patients who had post-SRS imaging. LC was maintained at last follow-up imaging in 69.1% of patients; 1 and 2 year actuarial rates of LC were 69.8% and 49.9%, respectively. There was a trend towards a higher local failure rate for melanoma versus non-melanoma metastases: 1- and

2-year failure rates were 45.6% and 70% versus 18% and 35%, respectively. Only 1 of 10 evaluable patients who received upfront WBRT in addition to SRS had a local failure compared to 24 of 71 (34%) patients treated with SRS alone. Surgery conferred no local control benefit compared to SRS alone.

For single brain metastases SRS alone resulted in similar local control and overall survival as surgery followed by SRS. WBRT reduced the risk of local failure but did not result in improved survival in this group of patients. Only 25.1% of patients initially managed without WBRT ever received WBRT. Management of single brain metastases with SRS alone resulted in survival similar to those published after surgery and WBRT. It appears that surgery may be reserved for patients in whom either histologic confirmation of metastasis or decompression of mass effect is required.

16:30 - 18:00 ORAL SESSION

OS11 IMAGING 2

Room: *Miles Davis*

OS11-1 POST THERAPEUTIC FEATURES OF HEPATIC METASTASIS TREATED BY CYBERKNIFE

Hajer Jarraya¹ Sylvain Dewas¹ Xavier Mirabel¹ Thomas Lacornerie¹ Luc Ceugnart¹ Eric Lartigau¹

(1) Oscar Lambret Center, Lille, France

Purpose: To focus on post therapeutic features of focal hepatic lesions of patients treated for hepatic metastasis with stereotactic body radiotherapy

Method and materials: We retrospectively analyzed 17 lesions in 15 patients with 2 years of follow-up, those patients underwent multi slice CT exams before and after treatment (initial phase: 1 to 3 months, intermediate phase: 4 to 12 months and tardive phase: 12 to 24 months)

Results: Complete response (n=2), partial response (n=3), stable lesion (n=3) and progression (n=9)

At initial phase, all lesions become hypodense surrounded by peripheral rim enhancement in a focal hypodense area. Analysis at intermediate and tardive phase is difficult because of heterogeneity of post therapeutic features.

We will describe the signs that specify local recurrence checked on at 2 years.

Conclusion: Post therapeutic features of hepatic metastasis treated by cyberknife are difficult to analyse.

We propose simple criteria for analyzing the response after treatment.

16:30 - 18:00 ORAL SESSION

OS11 IMAGING 2

Room: Miles Davis

OS11-2 CT PERFUSION IN THE DIFFERENTIAL DIAGNOSIS OF RELAPSE VS RADIONECROSIS IN PATIENTS TREATED WITH STEREOTACTIC RADIOTHERAPY

Antonello Vidiri¹ Valentina Pinzi² Antonio Guerrisi⁷ Alessandra Fabi⁶ Andrea Pace⁵ Carmine Maria Carapella⁴ Simona Marzi³ Simona Marzi³

(1) Dept Radiology, Cancer Institute Regina Elena, Rome, Italy (2) Dept Radiotherapy, Cancer Institute Regina Elena, Rome, Italy (3) Dept Physics, Cancer Institute Regina Elena, Rome, Italy (4) Dept Neurosurgery, Cancer Institute Regina Elena, Rome, Italy (5) Dept. Neurology, Cancer Institute Regina Elena, Rome, Italy (6) Dept. Oncology, Cancer Institute Regina Elena, Rome, Italy (7) Dept. Radiology, , Rome, Italy

Purpose: The aim of the present study was to establish a cut-off value for cerebral blood volume (CBV) and cerebral blood flow (CBF) in the differential diagnosis between relapse and radionecrosis, in patients affected by brain metastases who underwent stereotactic radiotherapy (SRT).

Materials and methods: Perfusion CT scans were performed on twenty patients with previously treated brain metastases, who showed recurrent or progressive enhancing lesions on follow-up magnetic resonance imaging (MRI). SRT was delivered using IMRT (Intensity Modulated Radiation Therapy) or dynamic arch technique, in single fraction or multifraction.

Perfusion examinations were carried out by using a 4-slice or a 128-slice CT scanner. A preliminary un-enhanced CT scan was obtained to localize the lesion, then a dynamic scan was performed after the injection of 50 ml of non-ionic contrast agent, at an injection rate of 8 ml/s. Five seconds after the injection began, a 40 s cine scan with 1 s interval was acquired at the chosen slices location. The acquired images were sent to a commercially available workstation, to generate CBV and CBF maps. For each patients, an expert radiologist identified the Region of Interest (ROI) on the unenhanced CT scan, according to morphological MRI. The contralateral ROI was automatically identified, to generate the side-to-side ratios of CBV and CBF, i.e. nCBV and nCBF. Receiver operating characteristic (ROC) curves were calculated to assess the diagnostic accuracy of nCBV and nCBF. The gold standard was the histology, the follow-up of over six months and the (11) C-methionine Positron Emission Tomography.

Results: The mean nCBV value was 0.9 ± 0.3 and 3.5 ± 3.1 for patients affected by radionecrosis and relapse, respectively ($p = 0.01$ Mann-Whitney test). Analogously, a mean nCBF of 0.80 ± 0.2 and 2.1 ± 1.3 resulted for the radionecrosis and relapse group ($p = 0.04$ con Mann-Whitney test). For nCBV, the optimal value was 1.44, with a Sensibility and Specificity of 71.4% and 100.0% respectively, and an accuracy of 91%. Analogously, an optimal value of 0.87 resulted for nCBF, with a Sensibility and Specificity of 85.7% and 71.4% respectively, and an accuracy of 82%. The difference between nCBV and nCBF ROC curves was not statistically significant ($p = 0.30$).

Conclusions: Relapsed tumors showed higher nCBV and nCBF value compared with radionecrosis, with a diagnostic accuracy of 91% and 82%, respectively. The nCBV map appeared more reliable then the nCBF, with a cut-off value of 1.44.

16:30 - 18:00 ORAL SESSION

OS11 IMAGING 2

Room: Miles Davis

OS11-3 *EVALUATING RADIATION-INDUCED WHITE MATTER CHANGES BY STEREOTACTIC RADIOSURGERY USING DIFFUSION TENSOR IMAGING*

Zheng Chang¹ John P. Kirkpatrick¹ Zhiheng Wang¹ Jing Cai¹ Fang-fang Yin¹

(1) Duke University, Durham, United States

Objectives: Stereotactic radiosurgery (SRS) has been an effective treatment for brain tumors; however, few data are available regarding radiation-induced white matter (WM) damage by SRS. WM in the brain is generally vulnerable to radiation, which may compromise sensory and neurocognitive functions. In this work, diffusion tensor imaging (DTI) was used to investigate WM changes following SRS.

Methods: Patients: In this study, 7 patients with recurrent, unifocal malignant gliomas up to 5-cm in maximum dimension were enrolled. The prescription dose received by the patients range from 16Gy to 26Gy. Patients were scanned with MRI 1-4 days before and 7-day and two-month following the final SRS treatment.

MRI studies: All MRI scans including DTI were acquired on a 1.5T clinical scanner (GE Healthcare, Milwaukee, WI). The DTI scans were acquired axially using a spin-echo echo-planar imaging sequence (TR = 9,100 ms, TE = 98 ms, field-of-view = 30x30cm², matrix size = 128x128, slice thickness = 5-mm, b = 1,000s/mm²).

DTI Image registration and processing

Diffusion tensors were calculated and fiber tracking was performed. The course of a fiber is defined by following the direction of the maximum diffusion. Before tracking is initiated, the FA threshold and the minimum fiber length can be adjusted. In this study, the default FA threshold is 0.30, and the minimum fiber length is 80 mm. Tract seeding is performed within a defined volume of interest (VOI). In the study, the volumes of WM receiving dose > 5Gy were contoured as the VOIs.

Statistical analysis

Diffusion coefficient, fractional anisotropy (FA), number of fibers (NF) were statistically calculated. The Wilcoxon signed-rank test was used to assess the differences, with statistical significance considered at $p < 0.05$.

Results: After 7 days of SRS, increased slightly by about 1% ($p = 0.60$), and FA decreased by 3.4% ($p = 0.18$) with 18% decline of NF ($p = 0.46$). After two months of SRS, increased by 3.9% ($p = 0.61$), and FA decreased significantly by 7.8% ($p = 0.02$) with nearly 40% decline of NF ($p = 0.11$).

Conclusions: DTI data indicated compromise of white matter fiber integrity after SRS, which shall not be ignored. These preliminary Results suggest that dose sparing to white matter should be considered in SRS, particularly when the target is close to white matter fiber bundles such as genu and splenium.

16:30 - 18:00 ORAL SESSION

OS11 IMAGING 2

Room: Miles Davis

OS11-4 *INTEGRATION OF DIFFUSION TENSOR TRACTOGRAPHY INTO RADIOSURGERY - SYSTEMATIC REVIEW OF OUR EXPERIENCE*

Keisuke Maryama¹ Tomoyuki Koga² Masahiro Shin² Kyousuke Kamada³ Yoshiaki Shiokawa¹

(1) Kyorin University, Tokyo, Japan (2) Univ of Tokyo, Tokyo, Japan (3) Asahikawa Medical Univ, Asahikawa, Japan

Objects: The authors have integrated diffusion-tensor tractography into treatment planning of Gamma Knife radiosurgery since 2003.

Methods: Our experiences to date were widely and systematically reviewed.

Results: At the beginning, we started integrating the pyramidal tract. We clarified that the tolerable dose of the pyramidal tract was calculated to be around 20Gy, and also found that the internal capsule was more sensitive to radiation injury probably because of its dense concentration of motor fibres. Next, the integration of the optic radiation was started, and the tolerable dose was calculated to be 8Gy. Visual symptoms were related to the proximity of the lesion to the optic radiation. Arcuate fasciculus, which is a language fiber, was analyzed next, and we found that the threshold of the input and output fibers was different, and administration of a 10Gy radiation dose was tolerated in the output fibers but not the input fibers of the arcuate fasciculus. After obtaining these findings, treatment planning in 100 patients with cerebral arteriovenous malformations was made by setting the dose to the input fibers less than 8Gy and output fibers less than 20Gy. As a result, no permanent deficits were observed in these patients. Thus, major neurological deficits could be completely prevented by integrating major three fibers described above out of a complexity of white matter fiber tracts inside the brain.

Conclusions: This novel technique is extremely useful and provide great advantage to patients undergoing radiosurgery especially in critical areas inside the brain. We hope this technique will be widely applied worldwide in the future.

16:30 - 18:00 ORAL SESSION

OS11 IMAGING 2

Room: Miles Davis

OS11-5 *DIFFUSION TENSOR IMAGING-BASED WHITE MATTER TRACTOGRAPHY DEPICTS ACCURATE TUMOR/NERVE RELATIONSHIPS IN PATIENTS WITH SECONDARY TRIGEMINAL NEURALGIA*

Danielle D Desouza^{2, 3} David Q Chen¹ Karen Davis^{1, 2, 3} Mojgan Hodaie^{1, 2}

(1) Division of Neurosurgery, Toronto, Canada (2) Institute of Medical Science, Toronto, Canada (3) Toronto Western Research Institute, Toronto, Canada

Two dimensional MR imaging has limited value in delineating the exact course of the trigeminal

nerve in patients with secondary trigeminal neuralgia. Pre-treatment knowledge of the detailed location of the trigeminal fibers and three dimensional cranial nerve/tumor relationships can be highly informative, and may facilitate planning as well as dose calculations to the trigeminal nerve. Hodaie et al. (2010) recently showed the feasibility of diffusion-tensor imaging (DTI) in performing tractography of cranial nerve fibers. The objectives of the current study was to determine 1) if DTI tractography of the trigeminal nerves is feasible in patients with TN secondary to tumor growth, and 2) if tractography can provide relevant anatomical information about the tumor-nerve relationship. We acquired T1-weighted anatomic and DTI scans on a 3T MRI in patients with secondary trigeminal neuralgia related to cerebellopontine angle tumors, or more distal, cavernous sinus tumors. Axial fast spoiled gradient-recalled acquisition in steady state (FIESTA), diffusion tensor images (slice thickness=3mm; 55 slices; 180) and T1 anatomical images, slice thickness=1mm were acquired for all cases. Tumors were manually segmented (T1 scans) and deterministic tractography of the trigeminal nerved performed (DTI scans: seed spacing=0.5; linear measure start threshold=0.2; stopping volume=0.2; stopping track curvature=0.8). This method allowed us to reconstruct the tumor as a 3D volume, and co-represent tumor and surrounding cranial nerves on anatomical images. Both volumetric analysis and tractography were performed using 3D Slicer version 3.4. Tractography successfully delineated the trigeminal nerve, including the Gasserian ganglion and the fibers of the distal branches. The anatomy of the trigeminal nerve, ganglion and postganglionic branches could be accurately visualized in 3D tracts. Despite the marked thinning and compression of the distal trigeminal fibers by the tumor, DTI-tractography could clearly differentiate tumor compression of the trigeminal nerve from tumor encasement of the nerve. This additional information can allow more precise radiosurgical pretreatment planning and dose calculation This study provides evidence that DTI-tractography of the trigeminal nerve is feasible in patients with TN secondary to tumor growth. Visualization of tumor-nerve relationships may improve pre-treatment planning and help reduce adverse cranial nerve side-effects after radiosurgery.

Reference: Hodaie, M., Quan, J. & Chen, D.Q. (2010). In Vivo Visualization of Cranial Nerve Pathways in Humans Using Diffusion-Based Tractography. *Neurosurgery*, 66:788-796.

16:30 - 18:00 ORAL SESSION

OS11 IMAGING 2

Room: Miles Davis

OS11-6 *USE OF GKRS FOR LOCAL CONTROL OF MALIGNANT GLIOMA DETECTED WITH METHIONINE PET*

Tadashi Nariai¹ Masaaki Yamamoto² Takuya Kawabe² Kaoru Tamura¹ Masaru Aoyagi¹ Toshiya Momose¹ Yoji Tanaka¹ Yasunori Sato³ Kiichi Ishiwata⁴ Kikuo Ohno¹

(1) Department of Neurosurgery, Tokyo Medical and Dental University, Tokyo, Japan (2) Katsuta Hospital Mito Gamma House, Hitachi-naka, Japan (3) Clinical Research Center, Chiba University Graduate School of Medicine, Chiba, Japan (4) Positron Medical Center, Tokyo Metropolitan Institute of Gerontology, Tokyo, Japan

Introduction: 11C Methionine PET (M-PET) has recently been demonstrated to be effective for

the diagnosis of various malignant gliomas. However, there is little information as to whether application of M-PET contributes to better treatment Results for GK-SRS for patients with malignant glioma.

Methods: Two types analysis were performed. One was done for primary glioblastoma (GBM) patients treated at Department of Neurosurgery, Tokyo Medical and Dental University. 59 patients were divided into three groups. 29 patients did not receive GK-SRS. 21 received GK-SRS based on visual inspection of M-PET images. 10 patients received GK-SRS based on fusion image using MRI and M-PET. In the third group, temozolomide (TMZ) treatment was also applied. Mean survival time (MST) among groups was analyzed. Another analysis was done on the patients groups in a GK center, Katsuta Hospital Mito Gamma House. 76 patients who underwent GK-SRS for recurrent malignant gliomas; grade III in 35 and grade IV in 41. M-PET was used in 23 (30.3%) of 76 patients.

Result: 1) In the analysis of primary GBM patients, use of GK-SRS lead to significant but only slight prolongation of MST ($p < 0.04$), 67 weeks in GK-SRS (+) group, 60 weeks in GK-SRS (-) group. 2) In a patients group treated with GK-SRS based on MRI and M-PET fusion image, marked prolongation of MST was obtained (160 weeks). However, as TMZ treatment was also applied in this group, contribution of PET-MRI fusion image based GK-SRS was not clear. 3) In GK center based analysis, there was a significant post-GKRS MST difference between the two diagnostic procedure groups, 14.3 months in patients who underwent both M-PET and MRI and 8.2 in those receiving MRI only ($p = .0186$). 4) Because there might be considerable bias between the two diagnosis groups, a case-matched study was conducted. Patient selection by means of a propensity matching for clinical data, i.e., sex, age, grades, tumor volumes and locations, by one (YS) of the authors who did not participate in other aspects of this study and was blinded to final outcomes. Ultimately, 19 patients were selected for the two groups. There was still a significant post-GKRS MST difference between the two diagnostic procedure groups, 14.3 months in the M-PET [+] group and 8.2 in the M-PET [-] group ($p = .0467$).

Conclusion: Although further accumulation of experience is required, M-PET may be a key examination in selecting the most appropriate malignant glioma candidates for GK-SRS.

16:30 - 18:00 ORAL SESSION

OS11 IMAGING 2

Room: Miles Davis

OS11-7 PET-GUIDED RADIOSURGERY TARGETING OF BRAIN TUMORS PREVIOUSLY IRRADIATED BY GAMMA KNIFE

Nicolas Massager¹ Sophie Schuind¹ Françoise De Smedt¹ Serge Goldman¹ Philippe David¹ Daniel Devriendt¹

(1) Gamma Knife Center, Brussels, Belgium

Introduction: Gamma Knife (GK) radiosurgery creates MR images of scar tissue and postradical edema that is often to differentiate with active tumoral tissue that is growing. We investigate the use of PET-scan with methionine to optimize the targeting of a second radiosurgical procedure.

Materials & Methods: A series of more than 50 patients was analyzed. All the patients included

in this study have undergone 2 GK procedures, and a PET-scan examination using methionine as radiotracer was used during the second radiosurgical treatment to improve delineation of the area to be irradiated. Various malignant or benign histologies have been included in the study. The role and contribution of PET imaging to the dose plan has been investigated.

Results: The patients will be classified in different categories following the contribution of PET-scan during the GK procedure. Correlation between these categories and different dosimetric, demographic and histologic parameters will be performed.

Conclusions: The PET-scan using methionine as radiotracer can have relevance in the targeting of tumors previously treated by radiosurgery. A second radiosurgical procedure is often associated with an increased risk of complications; the use of PET-scan can help reducing the complication rate of a second radiosurgical irradiation in selected cases.

16:30 - 18:00 ORAL SESSION

OS12 PITUITARY TUMORS & CRANIOPHARYNGIOMAS

Room: Auditorium

OS12-1 LONG-TERM OUTCOMES FOLLOWING GAMMA KNIFE RADIOSURGERY IN THE TREATMENT OF NONSECRETORY PITUITARY ADENOMAS

Jason Sheehan¹ Rupa Gopalan¹ Edward Laws^{1, 2} Mary Lee Vance¹

(1) University of Virginia, Charlottesville, USA (2) Harvard University, Boston, USA

Object: Gamma Knife radiosurgery (GKRS) is being used increasingly to treat recurrent pituitary adenomas. This study evaluates the long term rates of tumor control and delayed hypopituitarism in patients with nonsecretory pituitary adenomas.

Methods: Forty-eight patients with nonsecretory pituitary adenoma treated between 1991 and 2004 at the Lars Leskell Center for Gamma Surgery, University of Virginia Health System (Charlottesville, VA) were studied. All patients had greater than 4 years of clinical and radiographic follow-up. The mean number of prior surgical resections was 1.6. Three patients underwent fractionated radiotherapy prior to GKRS. Mean dose to the adenoma margin was 18.4 Gy (range 8 to 25 Gy). Thirty-seven patients had evidence of one or more hormone deficits prior to radiosurgery.

Results: All patients underwent follow-up imaging and endocrine evaluations with duration ranging from 49 to 201 months (mean 90.8 months) and 57 to 201 (mean 102.4 months), respectively. New hormone deficits following GKRS were seen in 19 of 48 patients (39%). These endocrinopathies were experienced in 6% of patients as cortisol deficiency, 18.7% thyroid hormone, 8.3% gonadotropin, 18.7% IGF1, and 5.2% diabetes insipidus, with multiple patients experiencing more than one deficiency. One patient developed panhypopituitarism.

Overall, adenoma volume control was 85.5%. Tumor volume decreased in 37 patients (77%), increased in seven patients (14.5 %) and was unchanged in four patients (8%). Margin doses under 12 Gy were significantly ($p < 0.05$) associated with a lower adenoma control rate (33%) compared to doses equal to or greater than 12Gy (83%).

Conclusions: Gamma knife radiosurgery resulted in a high and durable rate of tumor control in patients who were treated following primary microsurgery. A margin dose greater than 12 Gy was

found to be most efficacious. Although likely underreported in series with shorter follow-up, our higher incidence of long-term hypopituitarism following radiosurgery underscores the need for careful endocrine follow-up and appropriate hormone replacement.

16:30 - 18:00 ORAL SESSION

OS12 PITUITARY TUMORS & CRANIOPHARYNGIOMAS

Room: Auditorium

OS12-2 LONG-TERM OUTCOMES AFTER GAMMA KNIFE STEREOTACTIC RADIOSURGERY FOR NON-FUNCTIONAL PITUITARY ADENOMAS

Kyung-jae Park¹ Hideyuki Kano¹ Phillip V. Parry¹ Ajay Niranjana¹ John C. Flickinger¹ L. Dade Lunsford¹ Douglas Kondziolka¹

(1) University Of Pittsburgh Medical Center, Pittsburgh, USA

Object: The purpose of this study was to evaluate clinical and imaging outcomes of radiosurgery in patients with non-functional pituitary adenomas.

Method: Over an interval of 22 years, the authors evaluated the management outcomes in 125 patients who underwent Gamma Knife stereotactic radiosurgery (SRS) for non-functional pituitary adenomas. The median patient age was 54 years (range, 16-88 years). One hundred and ten patients (88%) had residual or recurrent tumors after one or more surgical procedures, and 17 (14%) had undergone prior fractionated radiation therapy. The median target volume was 3.5 cm³ (range, 0.4 - 28.1 cm³), and the median tumor margin dose was 13.0 Gy (range, 10 - 25 Gy). The median imaging and endocrinological follow-up periods after radiosurgery were 62 and 64 months, respectively.

Results: The tumor volume decreased in 66 patients (53%), remained stable in 46 (37%), and increased in 13 (10%). The actuarial tumor control rates at 1, 5 and 10 years were 99, 94 and 75%, respectively. Factors associated with short progression-free survival included larger tumor volume (>4.5cm³) and 2 or more prior recurrences. Of 88 patients with pituitary function remaining prior to SRS, 19 (24%) suffered new hormonal deficits at a median of 24 months (range 3-114 months). Prior radiation therapy increased the risk of developing new pituitary hormonal deficits. One patient (0.8%) had a decline in visual function and two (1.6%) developed new cranial neuropathies without tumor progression.

Conclusions: At ten years we found that SRS provided long term tumor control in up to 76% of patients with newly diagnosed, residual, or recurrent non-secreting pituitary tumors. Most patients retained existing endocrinological function. Less satisfactory outcomes were noted in patients with larger tumors, those with 2 or more prior recurrences, and those who had failed fractionated radiation therapy. New neurological deficits were noted in less than 3 % of patients.

16:30 - 18:00 ORAL SESSION

OS12 PITUITARY TUMORS & CRANIOPHARYNGIOMAS

Room: Auditorium

OS12-3 GAMMA KNIFE RADIOSURGERY FOR TREATMENT OF RESIDUAL NON-FUNCTIONING PITUITARY ADENOMA IN A LARGE SINGLE INSTITUTE SERIES

Piero Picozzi¹ Micol Angela Valle¹ Marco Losa¹ Alberto Franzin¹ Antonella Del Vecchio² Camillo Ferrari Da Passano¹ Angelo Bolognesi³ Pietro Mortini¹

(1) Gamma Knife Unit, Department of Neurosurgery, IRCCS San Raffaele, Milano, Italy (2) Department of Medical Physics, IRCCS San Raffaele, Milano, Italy (3) Department of Radiation Oncology, IRCCS San Raffaele, Milano, Italy

Introduction: The aim of this study is to evaluate efficacy and safety of Gamma Knife radiosurgery (GKRS) for treatment of incompletely removed non-functioning pituitary adenoma (NFPA).

Methods: Between 1994 and 2008, 166 patients (82 men and 84 women) with a diagnosis of NFPA who had previously undergone surgical treatment at our center underwent GKRS for residual pituitary tumor. 108 patients had undergone surgery once; 49 patients twice and the remaining 9 patients, three times. No patient had previously received external fractionated radiotherapy. Medial marginal dose was 15 Gy with isodose at 50%; median dose to optic chiasm was 7.4 Gy (IQR 5.1-9.5 Gy). GKRS was performed in 111 cases (67.7 %) to prevent regrowth of residual tumor, while 53 cases (32.3 %) underwent GKRS after the regrowth of residual NFPA. Baselines and follow-up studies included MRI, hormone evaluation and neuroophthalmologic examination 6 and 12 months after GKRS and then at yearly intervals.

Results: The mean follow-up after GKRS was 43.6 ± 2.9 months. 153 patients have had at least 6 months of follow-up after radiosurgery and are included in the following analyses. Volume of treated residual tumor was 2.2 ± 0.2 cm³ (IQR 0.2 - 17.7 cm³). Three patients had severe headache for two months after GKRS. Visual function did not deteriorate in any patients. New cases of hypogonadism, hypothyroidism and hypoadrenalism occurred in 11.4 %, 6.1 % and 3.6 % of patients at risk. There were 7 recurrences (4.6%). The 3 years recurrence-free survival was 97.9% (95% CI, 95.1-100) and 5 year recurrence free survival was 94.8% (95% CI, 89.8-99.9).

Conclusion: GKRS was effective in controlling the growth of residual or recurring NFPA after previous maximal surgical debulking carrying a low risk of side effects and hypopituitarism.

16:30 - 18:00 ORAL SESSION

OS12 PITUITARY TUMORS & CRANIOPHARYNGIOMAS

Room: Auditorium

OS12-4 DOSE-VOLUME CORRELATION FOR PITUITARY FUNCTION AFTER GAMMA KNIFE OF PITUITARY ADENOMAS

Antonella Del Vecchio¹ Piero Picozzi² Gianluca Sicignano¹ Giovanni Mauro Cattaneo¹ Marco Losa² Micaela Motta³ Pietro Mortini² Riccardo Calandrino¹

(1) San Raffaele Scientific Institute - Medical Physics Dept., Milan, Italy (2) San Raffaele Scientific Institute - Neurosurgery Dept., Milan, Italy (3) San Raffaele Scientific Institute - Radiotherapy Dept., Milan, Italy

Purpose: The aim is to define clinical and healthy-tissue dosimetric factors predicting the development of hypopituitarism in order to optimize the radiation treatment procedure. The authors undertook a retrospective analysis of the incidence and time course of pituitary insufficiency following GK.

Methods and Materials: Between 2001 and 2008, 367 patients with a diagnosis of pituitary adenoma were treated. In this study we considered only 130 patients who had a follow up of at least 6 months. Diagnosis was of non functioning pituitary adenoma (NFPA) in 68 patients and secreting pituitary adenoma (SPA) in 62.

Patients had an endocrinological follow-up range of 6-103 months after GK radiosurgery. Hypopituitarism was defined as a new pituitary deficit in (at least) one of the three hormonal axes (hypogonadism, hypothyroidism and hypoadrenalism). Before GK radiosurgery, 62 patients had no prior pituitary deficit for all hormonal axes and 94 patients had no prior pituitary deficit for hypothyroidism and hypoadrenalism axes.

Median marginal dose was 15 Gy (range 15-25 Gy) for NFPA and 25 Gy (range 12-25 Gy) for SPA at 50% reference isodose.

For all patients tumor, pituitary stalk and pituitary gland were outlined. The goal of dose planning was to provide complete tumour coverage while minimizing the radiation dose to the normal pituitary gland and optical pathways; many dose-volume data were used during statistical analysis. The predictive value of the considered variables was tested by univariate and multivariate logistic analyses.

Results: After GK radiosurgery, eight patients (12.9%) showed a new pituitary deficit at least one of three hormonal axes at a median of 51 months (range 13-96 months) and six patients (6.3%) developed a new pituitary deficit at least in one of two hormonal axes with a median of 46 months (range 11-48 months).

The Results of the univariate analyses showed that a few clinical and many dosimetric parameters (mainly for hypothyroidism and hypoadrenalism axes) were associated with a higher rate of new pituitary deficits

Preliminary Results of multivariate analysis confirmed the significant correlation between the mean dose to the stalk and to the (healthy) pituitary and the rate of new pituitary toxicities.

Conclusion: The analysis showed a dose-dependence incidence of new hormonal deficits after pituitary adenoma GK. During planning definition, the risk of hypopituitarism could be reduced using the outlined dose-volume predictors. The next step will focus on radiobiological models comparing conventional fractionated radiotherapy and radiosurgery clinical Results.

16:30 - 18:00 ORAL SESSION

OS12 PITUITARY TUMORS & CRANIOPHARYNGIOMAS

Room: Auditorium

OS12-5 FRACTIONATED STEREOTACTIC RADIOTHERAPY FOR PATIENTS WITH PITUITARY FUNCTIONAL AND NON FUNCTIONAL MACROADENOMA

Alessia Pica¹ François Pralong² Jean Guy Villemure³ Jocelyne Bloch⁴ Olivier Pisaturo⁵ Shahan Momjian⁶ Patrick Meyer⁷ Damien C Weber⁸

(1) Department of Radiation Oncology, Centre Hospitalier Universitaire Vaudois, CHUV, Lausanne, Switzerland (2) Department of Endocrinology, CHUV, Lausanne, Switzerland (3) Department of Neurosurgery McGill University, Montreal Qc, Canada (4) Department of Neurosurgery, CHUV, Lausanne, Switzerland (5) University Institute for Radiation Physics, Lausanne, Switzerland (6) Department of Neurosurgery, Geneva University Hospital HUG, Geneva, Switzerland (7) Department of Endocrinology, HUG, Geneva, Switzerland (8) Department of Radiation Oncology, HUG and University of Geneva, Geneva, Switzerland

Purpose: To evaluate the efficacy and toxicity of stereotactic fractionated radiotherapy (SFRT) for patients with pituitary macroadenoma (PMA).

Methods and Materials: Between March 2000 and March 2009, 27 patients (male to female ratio, 1.25) with PMA underwent SFRT (median dose, 50.4 Gy) using a linear accelerator and a micromultileaf collimator. Mean age of the patients was 56.5 years (range, 20.3 -77.4). In all but one patient, SFRT was administered for salvage treatment after surgical resection (transphenoidal resection in 23, transphenoidal resection followed by craniotomy in 2 and multiple transphenoidal resections in another patient). In 11 (41%) patients, the PMAs were functional (3 ACTH-secreting, 3 prolactinomas, 2 growth hormone-secreting and 3 multiple hormone-secretion). Three (11.1%) and 9 (33.3%) patients had PMA abutting and compressing the optic chiasm, respectively. Median tumor volume was 6.7 cm³ (range, 1.0-32.8). Eighteen (66.7%) patients had hypopituitarism prior to SFRT. The median follow-up period after SFRT was 56.8 months (range, 13.8 -125.0).

Results: Tumor size decreased for 6 (22.2%) patients and remained unchanged for 20 (74.1%) other patients. One (3.7%) patient had tumor growth inside the prescribed treatment volume. Another patient, locally controlled, presented with recurrent Cushing's disease and was treated by transphenoidal hypophysectomy. Tumor growth control was 95.2% at 3 and 5 years after SFRT. The risk of developing new anterior pituitary deficits at 3 and 5 years was 4.8%. Six (22.2%) patient had improved visual function and 1 (3.7%) patient had a decline in visual function.

Conclusions: SFRT is a safe and effective treatment for patients with PMA, although longer follow-up is needed to evaluate long-term outcomes. In this study, approximately 1 patient out of five had an improved visual function and the mid-term rate of radiation-induced pituitary dysfunction was low.

16:30 - 18:00 ORAL SESSION

OS12 PITUITARY TUMORS & CRANIOPHARYNGIOMAS

Room: Auditorium

OS12-6 GAMMA KNIFE SURGERY FOR CRANIOPHARYNGIOMAS-8 YEARS EXPERIENCE

Shoji Yomo^{1, 2}, Noriko Tamura², Motohiro Hayashi^{1, 2}, Motohiro Hayashi^{1, 2}

(1) Saitama Gamma Knife Center, Saitama, Japan (2) Tokyo Women's Medical University, Tokyo, Japan

Objective: Although Craniopharyngiomas are histologically benign, the resulting clinical sequelae can be severe because of their proximity to the critical surrounding structures. Recent technical innovation of Gamma Knife surgery (GKS) and refinement of imaging modalities realized more accurate treatment than ever. Retrospective analysis was conducted as to evaluate the current role of GKS in the armamentarium for craniopharyngioma.

Methods: A total of 38 patients with residual or recurrent craniopharyngiomas underwent 39 radiosurgical interventions consistently using Gamma Knife Model C-APS since 2002. The median tumor volume was 1.0 cm³ (range, 0.1-13.9). The median prescription dose delivered to the tumor margin was 12 Gy (range, 10-18). The median maximal dose was 24 Gy (range, 20-36). Median maximal dose to the anterior visual pathways was 9.55 Gy. The median follow-up time was 42 months (range, 1-89).

Results: The overall survival rate after GKS was 91% at 5 years. 3 patients died of unrelated cause. The 3- and 5-year local tumor control rates were 87% and 65%, respectively. The remote recurrence occurred in 2 patients at 10 and 44 months after GKS. 10 patients needed subsequent interventions. Of those, 3 patients underwent repeat GKS for one local- and two remote-recurrence. One patient with anterior hypopituitarism at the time of intervention developed diabetes insipidus after GKS. Four patients aggravated visual functions owing to tumor progression after GKS, which improved after surgical resection. Among the possible factors examined, solid tumors, older age and shorter clinical interval from the first intervention to GKS were significant favorable prognostic factors.

Conclusion: These Results suggest that GKS may provide a favorable benefit-to-risk profile for many patients with residual or recurrent craniopharyngiomas. However longer-term follow-up with a larger group of patients is required to fully evaluate the safety and effectiveness of this treatment modality.

16:30 - 18:00 ORAL SESSION

OS12 PITUITARY TUMORS & CRANIOPHARYNGIOMAS

Room: Auditorium

OS12-7 GAMMA-KNIFE RADIOSURGERY IN CRANIOPHARYNGIOMA MANAGEMENT

Jordi Pérez Bovet² Nuria Martínez Moreno¹ María Elena Kusak¹ Roberto Martínez Álvarez¹

(1) Gamma Unit, Hospital Ruber International, Madrid, Spain (2) Neurosurgery Department, Hospital Universitari Dr. Josep Trueta, Girona, Spain

Objective: Craniopharyngioma is a sellar region neoplasm that although histologically benign represents a clinical challenge due to its recurrence rate, its tendency to develop cysts and the visual and endocrinological alterations it may cause. Treatment is not standardized, options being open or transsphenoidal surgery, cyst drainage, chemotherapy, external or intralesional radiation therapy and radiosurgery. To achieve better tumor control and reduce iatrogenesis (panhypopituitarism, optic pathway lesion, hypothalamic lesion), there is a tendency towards management with surgery followed by irradiation of the remaining tumor, treatment that is superior to surgery alone. We present our experience with Gamma-Knife radiosurgery as the radiation treatment of choice.

Methods and patient profile: A retrospective review of the forty nine cases of craniopharyngioma treated at the Hospital Ruber Internacional between 1993 and 2010 has been performed. Thirty-three patients were adults, and 16 were children (age under 15 years), 21 were men and 28 women, with ages between 3 and 69 years, median 32. Forty-six had visual symptoms and 26 had hormonal alterations. Forty four had undergone one or various previous surgeries, 6 had received previous radiation therapy and 1 had received chemotherapy. In 8 patients a stereotactic drainage of cysts was performed in concomitance with radiosurgery.

Results: After an average follow-up of 45 months, 97 % of the patients showed clinical improvement or stabilization. In 17% cyst drainage was necessary to improve delayed worsening of visual impairment. Only 9 % of the patients needed further treatment (surgery or chemotherapy) and only 2 % experienced tumor progression in the long term. Visual impairments tend to improve, whether immediately or subsequently, while hormonal alterations usually persist.

Conclusion: In the context of a multi-disciplinary approach to craniopharyngioma, Gamma-Knife radiosurgery offers excellent long-term tumor control, without the significant side-effects of other treatments and without interference with other procedures that may be necessary during the course of the disease. The Results we present are comparable and add further experience to other published series. Gamma-Knife radiosurgery is a simple and well tolerated technique with Results that can be reproduced worldwide.

TUESDAY, 10 MAY 2011

11:30 - 12:30 ORAL SESSION

OS13 BODY 3 (OTHER)

Room: La Seine

OS13-1 *PRIMARY SBRT IS MORE EFFECTIVE THAN SALVAGE SBRT AFTER CONVENTIONAL EBRT*

Pretesh Patel¹ John Kirkpatrick¹ Karen Allen¹ John Nelson² Robert Clough¹ Fang-fang Yin¹ Zhiheng Wang¹ Zheng Chang¹ Christopher Kelsey¹ A. Paiman Ghafoori¹

(1) Duke University, Durham, United States (2) Naval Medical Center, Portsmouth, United States

Purpose: Stereotactic body radiotherapy (SBRT) is increasingly used for the definitive treatment of primary malignancies or for palliation of metastases. We hypothesized that primary SBRT is more effective than salvage SBRT that is delivered after failure following external beam radiation therapy (EBRT).

Methods: Records were reviewed for all patients receiving SBRT at Duke University Medical Center between 2006 and 2010 in this IRB-approved retrospective analysis. 139 lesions were treated with SBRT (53 spine, 56 lung, 9 liver, 21 other). 97 metastatic lesions were treated palliatively, while 42 primary and recurrent lesions were treated with curative intent. The number of fractions ranged from 1 to 5 and dose per fraction ranged from 4.5 to 20 Gy. Overall survival (OS) and local control (LC) were estimated using the Kaplan-Meier method. Univariate regression analysis was used to evaluate the effect of patient- and treatment-related factors. Toxicity was assessed by CTCAE v4.0.

Results: Median patient age was 65 years (range 33-90). Median follow-up time was 9.6 months, and was 9.3 months for patients with a radiological study to assess the treated lesion. Nine patients reported a grade 1 acute treatment-related toxicity. Assessment of late treatment-related toxicities was limited by low survival rates. 88% of patients treated for a symptomatic lesion had improvement of their symptoms after SBRT. Actuarial rates of LC and OS at one year were 71 and 59%, respectively. The actuarial one-year radiologic local control was 68%. On univariate analysis, the likelihood of local control at 1 year for all lesions treated with EBRT followed by salvage SBRT was 47 versus 78% when SBRT was the primary therapy ($P=0.005$, 139 lesions), and 44 versus 75% for metastatic lesions ($P=0.01$, 97 lesions). Patients who had undergone prior EBRT were more likely to have SBRT with a lower total dose (median dose 40 vs. 21 Gy, $P<0.0001$). Primary cancer histology (adenocarcinoma vs. other), site treated (lung, spine, other) and goal of therapy (definitive vs. palliative) did not have a significant impact on local control rates.

Conclusion: These hypothesis-generating data suggest that upfront, full-dose SBRT appears associated with improved local control compared to upfront EBRT followed by salvage SBRT. Use of primary SBRT may lead to improved palliation of metastases and control of oligometastatic disease, and it should be tested prospectively in multi-institutional trials.

11:30 - 12:30 ORAL SESSION

OS13 BODY 3 (OTHER)

Room: La Seine

OS13-2 *COMPARISON OF TWO DOSE REGIMENS USING SBRT FOR ORGAN CONFINED PROSTATE CANCER*

Alan Katz¹ Michael Santoro¹

(1) Flushing Radiation Oncology, Flushing Ny, USA

Objective: The purpose of this study is to compare the efficacy and toxicity of 35Gy in five daily fractions versus 36.25 Gy in five daily fractions

Methods: 41 patients with early prostate cancer were treated with 35 GY in five consecutive days were matched with 41 patients who were treated with 36.25 GY in five consecutive days using Cyberknife SBRT. Each group had 37 low risk, 4 intermediate risk patients. Median PSAs were 5.46 and 5.52 respectively. Median ages were 70.2 and 69.8 respectively. No patients received ADT. All patients received intrarectal Amifostine(1500mg in saline) prior to each fraction. Four fiducials were tracked continuously. Both groups were planned similarly, using homogeneous planning with 5mm margins. Failure was defined by Phoenix criteria and toxicity was tracked with the RTOG toxicity scale and QoL was assessed with EPIC scores.

Results: All patients had a followup of 40-55 months. The median fu was 49 months for the 35 GY group and 43 months for the 36.25 GY group. One patient had biochemical failure in each group yielding a 97.5% freedom from biochemical failure for each group. Median PSA was 0.2 for each group at 36 months and 0.11 for the 35GY group and 0.10 for the 36.25 GY group at 42 months followup. Late rectal toxicity was similar with each group having 2/41 or 5% develop grade 2 toxicity. Late grade 2 urinary toxicity occurred in 2/41 or 5% of the 35 GY group and in 4/41 or 10% of the 36.25 GY group. Mean EPIC scores for bowel and bladder function returned to baseline at 36 months for all patients.

Conclusions: From the standpoint of PSA control or nadir, the two treatment regimens have excellent equivalent Results An alpha-beta ratio of 1.5 would explain this lack of difference, as it yields a BED of 91 vs 96 GY at 1.8 Gy per fraction for the two groups, which is on the flat part of the dose response curve. The higher dose was associated with more late GU toxicity but no increase in the rate of late rectal toxicity. The difference may be explained by the use of radioprotection in the rectum, but not the urethra. Our Results show that 35Gy may be the optimal dose for low and intermediate risk patients.

11:30 - 12:30 ORAL SESSION

OS13 BODY 3 (OTHER)

Room: La Seine

OS13-3 CYBERKNIFE STEREOTACTIC HYPOFRACTIONATED BODY RADIOTHERAPY FOR PROSTATE CANCER

**Giancarlo Beltramo¹ Achille Bergantin¹ Federica Locatelli¹ Anna Martinotti¹ Paolo Bonfanti¹,
² Livia Bianchi¹**

(1) Centro Diagnostico Italiano, Milan, Italy (2) Specialization school in Medical Physics, Milan, Italy

Purpose: The low alpha/beta ratio for prostate cancer, suggests a good response to Hypofractionation such as experimental data, high-dose rate (HDR) brachytherapy, and some experiences of hypofractionated EBRT, have already shown yielding high tumour control rates while maintaining an equivalent dose to normal tissues for late effects and reducing acute effects. Cyberknife is currently being used as a monotherapy treatment for early-stage prostate cancer, and because of similar conformality and dose fractionation to HDR brachytherapy, local control and toxicity rates are expected to be similar. We tested this hypothesis in men with clinically localized prostate cancer.

Methods and Materials: Between July 2007 to July 2010, 71 patients with a median age of 74 years (range 60-86), with clinically localized prostate cancer were treated with Cyberknife stereotactic radiosurgery as primary therapy. The treatment regimen consists of a total dose of 38 Gy delivered at 9.5 Gy/fraction, with >95% of the PTV encompassed within the prescription isodose volume.

Three gold fiducial markers were placed in prostate gland using transrectal ultrasound guidance, prostate planning study was performed one week after fiducial implantation. Axial CT images and MRI T1-T2 sequences were acquired and fused to differentiate the prostate and the organ at risk. The PTV included the GTV expanded by 3 mm posteriorly and 5mm in all other directions. Patients were seen in follow up 10 days post-treatment, 1 month later and every 3 months for 2 years with PSA levels assessed at each follow up. Self administered questionnaire, such as the International prostatic Symptom Score and the International Index of Erectile Function, was used to better define urinary function and sexual activities. Toxicity analyses was performed using the RTOG/EORT acute and late radiation morbidity scoring system.

Results: All patients were placed on A-blockade medication at the beginning of Cyberknife treatment. IPSS scores increased over the first month of treatment but return to baseline by four months. Acute side effects were generally mild and resolved shortly after treatment. Long term sequelae as rectal bleeding was observed in 2 patients, hematuria in four. Three patients, one with prior Turp, experienced incontinence. One patient experienced rectal incontinence 12 months after the treatment. The patterns of Psa response, show a gradual decline with a psa nadir below 1.0 ng/ml after 12 months. To date all patients are alive, Two high risk group patients failed biochemically. One developed bone metastases, in one we observed pelvic lymph node involvement

Conclusions: Cyberknife robotic radiosurgery is a feasible and an emerging non invasive treatment approach to deliver Hypofractionated radiotherapy for localized prostate cancer. Additional follow up is required to better evaluated potential late toxicity and long-term psa outcomes.

11:30 - 12:30 ORAL SESSION

OS13 BODY 3 (OTHER)

Room: La Seine

OS13-4 *RESULTS OF FIVE FIRST LEVELS OF DOSE FOR CYBERKNIFE® CONCOMITANT WITH NEO-ADJUVANT CHEMOTHERAPY AND FOR BREAST TUMORS (PHASE I STUDY).*

Pierre-yves Bondiau¹ Philippe Bahadoran¹ Emmanuel Chamorey¹ Adel Courdi¹

(1) Centre antoine lacassagne, Nice, France

Objective: Robotic stereotactic radioablation (RSR) by CyberKnife® allows stereotactic irradiation of thoracic tumors; however, it has never been used for breast tumors and may have a real potential. As a first step toward establishing the feasibility of such an approach, we conducted a Phase I study, including neoadjuvant chemotherapy, with a 5-level dose-escalation study (19.5 Gy, 22.5 Gy, 25.5 Gy, 28.5 Gy, 31.5 Gy in 3 fractions) using RSR, and breast-conserving surgery followed by conventional radiotherapy. Neoadjuvant chemotherapy consist of anthracyclines + taxanes sequential (NACT). We propose this protocol if tumor/breast ratio does not allow a conservative treatment.

The major objective was to define the Limiting Toxicity defines the Maximal Tolerated Dose to find recommended dose. Minor objectives were the evaluation Results of RT-CT on the number of sterilized histological exams, the evaluation of the quality of surgical resection and the evaluation of quality of life

Patient and method: For each patient, we performed 4 clinical dermatologic examinations by two independent observers; before the neoadjuvant chemotherapy treatment onset, after RSR irradiation, after 3 cures of neoadjuvant chemotherapy, and prior to surgery. Surgery was performed 4 to 8 weeks after the last chemotherapy session, the evaluation of surgery quality is made by 3 different surgeons. A pathologic examination was also performed. Complication are noticed. Quality of live is made with QLQ C30 B33

Results: 19 patients have been included in this study. We noticed two grade II axillary toxicity at level I and II (19.5 and 22.5 Gy in 3 fractions) and one grade III skin toxicity at level IV (28.5 Gy in 3 fractions) for a large tumor (123 cc), four more patient were included at this level of dose with no toxicity. The conservative surgery rate is 95%, the clinical complete response rate is 78% and the complete histological response rate is 36%. Maximum tolerable dose was not reached. All patients tolerated RSR with no fatigue, 2 patients presented with mild pain after the third fraction of the treatment, which did not require intervention. Post-operative irradiation (50 Gy) has been delivered without toxicity.

Conclusion: The study showed the feasibility of irradiation with RSR combined with chemotherapy and surgery for breast tumors. We noticed one grade III skin toxicity at a dose of 28.5 Gy delivered in 3 fractions combined with chemotherapy.

11:30 - 12:30 ORAL SESSION

OS13 BODY 3 (OTHER)

Room: La Seine

OS13-5 *HYPOFRACTIONATED STEREOTACTIC BODY RADIOTHERAPY FOR ADRENAL GLAND METASTASES: A MONOINSTITUTIONAL EXPERIENCE OF 34 PATIENTS.*

Filippo Alongi¹ Simona Castiglioni¹ Angelo Tozzi¹ Paola Lattuada¹ Piera Navarria¹ Francesca Lobefalo¹ Sara Pentimalli¹ Elena Clerici¹ Giacomo Reggiori¹ Pietro Mancosu¹ Marta Scorsetti¹
(1) Istituto Clinico Humanitas, Milano (rozzano), Italy

Aims and background: To report the impact of Stereotactic body radiation therapy (SBRT), in terms of tolerability and clinical outcomes, in the treatment of adrenal metastases in 34 consecutive cancer patients.

Materials and methods: Between March 2004 and February 2010, a total of 36 adrenal metastatic lesions, in consecutive 34 patients, were submitted to SBRT. Of these patients, 25 had metastases from primary lung cancer. Nine patients have metastases from other sites. Of the 36 lesions, 19 were in the right and 17 in the left adrenal gland. The clinical target volume ranged from 8,1cc to 579,41cc (median volume: 44.04 cc). The median time from primary diagnosis to adrenal metastasis was 12,5 months(range:0-95 months). The metastases in other sites were previously controlled in each patient using surgery, chemotherapy or radiotherapy. None was concomitantly submitted to chemotherapy during the period of radiotherapy. All 34 patients were evaluated after completion of SBRT with a median follow-up of 12 months (range:3-39). The total administered doses ranged from 20 Gy in 4 fraction to 45 Gy in 18 fractions (median dose:32 Gy; median number of fraction: 4).

Results: No patient developed Grade \leq 3 gastrointestinal, hepatic, renal, or dermatologic toxicity. Only grade 2 nausea was recorded in 2 patients. Of the 34 patients, 27 were evaluable for late toxicity, but it was not seen in any patient. Twenty-seven out of 34 were evaluable for clinical

Results: At the time of definitive analysis, 22 out of 34 were alive. Clinical response was evaluated on CT or PET total body scan. At first clinical evaluation(after 3 months), 1/36 lesions showed complete response, 14/36 lesions showed a partial response, 9/36 had a stable disease, 3/36 had progression in treated area. At third evaluation (9 months after treatment), other two out of 34 patients achieved stable disease. Of 34 patients, 18 showed systemic progression with a median time to systemic progression of 3 months (0-24). During follow-up 8 patients of the 25 local responders or stable patients, showed a local progression. Median time to local progression was 6 months (0-25).

Conclusion: SBRT in adrenal gland metastasis patients is feasible without significant acute and late side toxicities. Clinical control was achieved in more than an half of treated lesions(29/36). New fractionation schemes of SBRT and the possibility to combine radiation with new systemic approaches will require further studies to optimize the duration of local control and minimize the development of systemic progression.

11:30 - 12:30 ORAL SESSION

OS14 BRAIN METASTASES 3

Room: Miles Davis

OS14-1 A NEW INDEX FOR RPA CLASS II PATIENTS WITH BRAIN METASTASES: PART 1, METHODS, RESULTS AND PROPOSAL

Masaaki Yamamoto¹ Yasunori Sato¹ Takuya Kawabe¹ Bierta E Barfod¹ Yoichi Urakawa¹

(1) Katsuta Hospital Mito GammaHouse, Hitachi-naka, Japan (2) Clinical Research Center, Chiba University Graduate School of Medicine, Chiba, Japan

Background: In recent years, although the Recursive Partitioning Analysis (RPA) class is generally used for predicting survival periods of patients with brain metastases (METs), the majority of such patients are class II and clinical factors vary quite widely within this category. This prompted us to develop a new grading system for RPA class II patients, based on division into three sub-classes.

Methods: Our database including 2000 gamma knife radiosurgery (GKRS)-treated patients (787 females, 1213 males, mean age; 65 [range; 19-96] years) with brain METs during the 1998-2008 period was used. The most common primary cancer was lung (1283; 64.2%), followed by alimentary tract (241; 12.1%), breast (216; 10.8%), uro-genital (153; 7.7%) and others (107; 5.2%). RPA class I, II and III patient numbers were 169 (8.5%), 1709 (85.3%) and 125 (6.3%), respectively.

Results: Four factors were identified as strongly impacting longer survival by means of multivariate analysis using the Cox proportional hazard model with a step-wise selection procedure; i.e., KPS; 70-80% vs. 90-100%, tumor numbers; solitary vs. multiple, controlled primary tumor; no vs. yes and non-brain METs; yes vs. no. The new index is the sum of scores (0 and 1) for these four factors and RPA class II-a; score 0 or 1, RPA class II-b; score 2 and RPA class II-c; score 3 or 4. Among 1706 class II patients, the patient numbers were 317, 598 and 788 in the classes II-a, II-b and II-c, respectively. Median survival times were 20.4 months in class I (95% confidence interval [CI]; 16.6-25.4), 15.4 in class II-a (95% CI; 13.5-16.8, $p = .0022$ vs. class I), 8.4 in class II-b (95% CI; 7.6-9.3, $p < .0001$ vs. class II-a), 4.7 in class II-c (95% CI; 4.3-5.1, $p < .0001$ vs. class II-b) and 2.2 in class III (95% CI; 1.7-2.5, $p < .0001$ vs. class II-c). This new system showed highly statistically significant differences among sub-classes ($p < .01$ for all sub-classes). Although 95% CIs overlapped slightly between classes I and II-a, there were no other overlaps.

Conclusions: Our new grading system should be considered when designing future clinical trials involving brain MET patients.

11:30 - 12:30 ORAL SESSION

OS14 BRAIN METASTASES 3

Room: Miles Davis

OS14-1BIS A NEW INDEX FOR RPA CLASS II PATIENTS WITH BRAIN METASTASES: PART 2, VALIDITY TEST

Masaaki Yamamoto¹ Toru Serizawa² Yasunori Sato³ Takuya Kawabe¹ Yoshinori Higuchi⁴ Osamu Nagano⁵ Junichi Ono⁵

(1) Katsuta Hospital Mito GammaHouse, Hitachi-naka, Japan (2) Tokyo Gamma Unit Center, Tsukiji Neurologic Clinic, Tokyo, Japan (3) Clinical Research Center, Chiba University Graduate School of Medicine, Chiba, Japan (4) Department Neurosurgery, Chiba University Graduate School of Medicine, Chiba, Japan (5) Gamma Knife House, Chiba Cardiovascular Center, Ichihara, Japan

Background: Our novel index for Recursive Partitioning Analysis (RPA) class II patients with brain metastases (METs) was applied to our patient series to test whether this system is valid for different patient groups.

Methods: Our Gamma Knife House, Chiba Cardiovascular Center database, including 1753 patients (Chiba-series, 673 females, 1080 males, mean age; 65 [range; 7-94] years) with brain METs treated by gamma knife radiosurgery (GKRS) during the 1998-2008 period was used. Mean and median lesion numbers were 6 and 3, respectively, range one to 50. The most common primary cancer was lung (1183; 67.5%), followed by alimentary tract (200; 11.4%), breast (153; 8.7%), uro-genital (98; 6.8%) and others (119; 6.8%). RPA class I, II and III patient numbers were 103 (5.9%), 1414 (80.7%) and 236 (13.5%), respectively.

Results: For the 1414 in class II, patient numbers were 223, 507 and 684 in sub-classes II-a, II-b and II-c, respectively. Median survival times were 26.0 months in class I (95% confidence interval [CI]; 22.6-33.3), 18.8 in class II-a (95% CI;14.8-21.6, $p=.0016$ vs. class I), 10.8 in class II-b (95% CI;10.0-12.2, $p<.0001$ vs. class II-a), 4.7 in class II-c (95% CI;4.4-5.1, $p<.0001$ vs. class II-b) and 3.8 in class III (95% CI;3.0-4.5, $p=.0068$ vs. class II-c). This new system showed highly statistically significant differences among sub-classes ($p<.01$ for all sub-classes). Although 95% CIs overlapped slightly between classes II-c and III, there were no other overlaps.

Also, based on total patients in our combined Chiba-series and Mito-series (2000 GKRS-treated patients, 787 females, 1213 males, mean age; 65 [range; 19-96] years), this new index was confirmed to be applicable to class II patients of the four original tumor categories, i.e., lung (2118 patients), breast (282), alimentary tract (353) and uro-genital organ (197) cancers. This new system showed highly statistically significant differences among sub-classes ($p<.01$ for all sub-classes).

Conclusions: This new grading system is applicable to different patient groups and should be considered when designing future clinical trials involving brain MET patients.

11:30 - 12:30 ORAL SESSION

OS14 BRAIN METASTASES 3

Room: Miles Davis

OS14-2 HISTOLOGICAL DIFFERENCES IN OUTCOMES OF RADIOSURGICAL TREATMENT OF BRAIN METASTASIS: A CLASSIFICATION AND TREE ANALYSIS

Sachin Batra¹ Aizik Wolf² Pietro Borteletto² Chetan Bettgowda¹ Beatriz Amendola² Laurie Blach² Sammie Ross Coy² Lawrence Kleinberg¹ Daniele Rigamonti¹

(1) Johns Hopkins School of Medicine, Baltimore, Md, United States (2) Miami Neuroscience Center, Miami, FL, United States

Relevance and Innovation: Histology is an important determinant of outcomes of brain metastasis in patients treated with radiosurgery. We describe an algorithm predicting outcomes of patients with brain metastasis in different histological groups.

Methods: 1318 patients were treated at Johns Hopkins Hospital (238 patients: between 2004-2007) and at Miami neuroscience center (1080 patients: between 1990 and 2009). Kaplan Meier survival analysis was applied to determine overall median survival since radiosurgery. Cox proportional hazard was used to determine independent predictors of mortality. Significant variables were treated with classification and regression tree (CART) analysis to develop a decision tree using Stata 9. Minimum node size was set to be 200 patients. Mortality rates, hazard ratios (HR) and median survival (MS) were determined for each branch of the split.

Results: The patient population consisted of metastasis from Non small cell lung cancer(NSCLC) in 480 (36.45%) patients with MS of 7.14mths, breast cancer in 301(22.85%) patients with MS of 9.08mths, Melanoma in 163(12.38%) patients with MS of 5.03mths, colorectal cancer in 69(5.24%) patients with MS of 4.05mths, renal cell cancer in 71(5.39%) patients with MS of 8.26mths, small cell cancer in 64(4.86%) patients with MS of 4.57mths and miscellaneous in 169(12.83%) patients with MS of 7.14mths. Overall median survival was 6.78 months. Overall Cox proportional hazard model revealed KPS (HR 1.03), age (HR 1.01), number of lesions (HR 1.03) and male gender (HR 1.3) to be independent predictors of mortality even when used as continuous variables. Based on CART analysis we classified our data into stage 1A1 (KPS>70, lesions<3, age<65: mortality: 72%, HR 0.65, survival:10.82 mths, stage 1A2 (KPS>70, lesions<3, age>65: mortality: 62%, HR 0.97, survival 8.26 mths), stage1B(KPS>70, lesions>3, mortality:89%, HR 1.2, survival 6.41 mths), Stage2 (KPS<70: mortality: 93%, HR 1.78, survival 3.42mths)(p<0.001). Also, survival significantly correlated with decreasing class, p<0.001. Stratified Cox regression revealed that this model was more applicable to Breast, NSCLC, and miscellaneous group. In patients with melanoma survival was independent of age but adversely effected with >3 lesions and KPS<70. Whereas in Renal, colorectal and small cell lung cancer KPS>70 was the only predictor of survival.

Conclusions: Prognostic markers for brain metastasis treated by radiosurgery differed by histology and thus the model is more predictive of outcomes in NSCLC and Breast Cancer. Our Results contradict the common practice of using single prognostic classification like RPA regardless of histological subclass.

11:30 - 12:30 ORAL SESSION

OS14 BRAIN METASTASES 3

Room: Miles Davis

OS14-3 THE GRADED PROGNOSTIC ASSESSMENT (GPA) FOR PATIENTS WITH BREAST CANCER AND BRAIN METASTASES: MINNESOTA EXPERIENCE

William Sperduto² Ryan Shanley³ Xianghua Luo^{3, 4} Yoichi Watanabe^{1, 5} Charles Watts^{1, 6} Jonathan P.S. Knisely⁷ Paul Sperduto^{1, 2}

(1) University of Minnesota, Gamma Knife Center, Minneapolis, USA (2) Minneapolis Radiation Oncology, Minneapolis, USA (3) University of Minnesota, Masonic Cancer Center, Minneapolis, USA (4) University of Minnesota, School of Public Health, Division of Biostatistics, Minneapolis, USA (5) University of Minnesota, Department of Radiation Oncology, Minneapolis, USA (6) University of Minnesota, Department of Neurosurgery, Minneapolis, USA (7) Yale University School of Medicine and Yale Cancer Center, Department of Radiation Oncology, New Haven, USA

Purpose: To determine the prognosis of patients with breast cancer and brain metastases using the Breast-GPA index.

Methods: The Breast-GPA is a prognostic index based on four factors found to be statistically significant by two methods (multivariate Cox regression, MCR, and recursive partitioning analysis, RPA) in which a GPA score of 4.0 correlates with the best prognosis and 0.0, the worst. The factors include age, Karnofsky Performance Status (KPS), Human Epidermal Growth Factor Receptor (HER2), estrogen and progesterone receptor (ER/PR) status. The genetic subtypes are: Basal (triple negative, HER2/ER/PR-negative; Luminal A (HER2-negative, ER/PR-positive); Luminal B (triple positive, HER2/ER/PR-positive), and; HER2 (HER2-positive, ER/PR-negative). The factors were weighted relative to the magnitude of their regression coefficients to define the Breast-GPA index. The total GPA is the sum of the scores for each of the three factors (KPS, genetic subtype and age), each given a score of 0, 0.5, 1.0, 1.5 or 2.0, as follows: 0.0 (KPS < 60, Basal, age > 60), 0.5 (KPS 60, age < 60), 1.0 (KPS 70-80, Luminal A), 1.5 (KPS 90-100, HER2), 2.0 (Luminal B). A retrospective database of 36 patients with breast cancer and brain metastases who were treated at the University of Minnesota Gamma Knife Center was created. The GPA score was calculated for each and correlated with survival.

Results: The median survival times associated with Breast-GPA scores of 0.5-1.0, 1.5-2.0, 2.5-3.0 and 3.5-4.0 in the original publication were 3.4, 7.7, 15.1 and 25.3 months versus 3.2, 11.0, 16.2, and 20.0 months for the UM data, respectively. The p-value for the log-rank test of overall separation among the four groups is <0.0001.

Conclusions: The University of Minnesota Breast-GPA Results show wide variation in prognosis and clear separation between subgroups of patients with breast cancer and brain metastases. This index will aid clinical decision-making and stratification for future prospective clinical trials. These data also confirm the effect of genetic subtype on survival.

References:

1. Sperduto PW, Chao ST, Sneed PK et al. Diagnosis-specific prognostic factors, indexes, and treatment outcomes for patients with newly diagnosed brain metastases: a multi-institutional analysis of 4,259 patients. *Int J Radiat Oncol Biol Phys* 2010;77:655-661.
2. Sperduto PW, Kased N, Roberge D et al. The Effect of Genetic Subtype on Survival and the

Graded Prognostic Assessment (GPA) for Patients with Breast Cancer and Newly Diagnosed Brain Metastases. Submitted for publication.

11:30 - 12:30 ORAL SESSION

OS14 BRAIN METASTASES 3

Room: *Miles Davis*

OS14-4 *DETERMINATION OF QUALITY CARE AND HEALTH-RELATED QUALITY OF LIFE DURING BRAIN METASTASIS RADIOSURGERY*

Douglas Kondziolka¹ Oren Berkowitz¹ Kristen Jones¹ L. Dade Lunsford¹

(1) Department of Neurological Surgery, University of Pittsburgh, Pittsburgh, USA

Introduction: The definition and determination of quality health care remains unclear. We hypothesized that a quality operation is one that safely and effectively meets the jointly defined goals of the patient and their doctor. We worked to define quality outcomes by documenting that the patient's condition and goals were properly understood by both the patient and the surgeon before surgery, that intra-procedure error was measured, and that goals were met using immediate and later outcomes measures. The purpose of this study was to develop a longitudinal method to define quality by measuring both expectations and Results from both the physician and the patient's point of view.

Methods: Our population consisted of cancer patients with newly diagnosed metastatic brain disease. These patients were recruited before undergoing stereotactic radiosurgery. Our focus was on peri-surgical outcomes, not longer term outcomes. Surgeons recorded objective information peri-operatively related to the pre-operative goals, clinical findings, surgical performance/error, and whether goals were met. They completed a pre-op and post-op questionnaire (Rand SF-36 item Health Survey 1.0). This survey monitors 8 aspects of physical and emotional functioning and well-being. Longitudinal data was analyzed according to the Rand scoring criteria. The minimal clinically significant difference in health survey scores was set at a 5 point difference.

Results: 52 patients enrolled in the study. 13 patients were censored before follow up (9 deceased outside of the neurosurgery service, 4 unable to contact for follow up). 38 were included in the longitudinal analysis. Mean age was 60 and median follow up time was 2 months. Our procedural goals were met in all patients who completed radiosurgery without error or complication and had same day discharge. Our clinically pre-determined goal of tumor palliation was met in all but one patient (who had an increase in tumor followed by resection) at follow up. Paired t-tests were used to compare SF-36 domains. Physical functioning, role limitations (physical or emotional), energy/fatigue, social functioning and pain were unchanged after radiosurgery. Scores for the general health domain were lower ($p=.006$).

Conclusions: Brain metastases carry a guarded prognosis and patient goals for palliation or improvement without functional deterioration are crucial. These goals can be defined and objectively measured. Bringing together the goals and expectations of both the treating clinician and the patient through this approach will help to better determine the advancement of future treatments and protocols. We think that quality care can be defined as a process that achieves

pre-defined goals without significant error, and that maintains or improves health. This process can be quantified.

11:30 - 12:30 ORAL SESSION

OS14 BRAIN METASTASES 3

Room: Miles Davis

OS14-5 ALGORITHM TO AVOID ADVERSE EFFECTS AFTER GAMMA KNIFE RADIOSURGERY OF BRAIN METASTASES

Bodo Lippitz^{1, 2}

(1) Gamma Knife Centre, Bupa Cromwell Hospital, London, UK (2) Karolinska Gamma Knife Center, Stockholm, Sweden

Introduction: The radiosurgical treatment of metastases is limited and potentially complicated by adverse radiation effects (ARE) and local recurrences. So far data to identify quantitative criteria to predict ARE and local recurrence have been lacking.

Objectives: The aim of this study was to analyze both the occurrence of adverse radiation effects and local recurrences after Gamma Knife radiosurgery and to study their clinical significance. Diagnostic options are described and potential dose volume relations are analyzed.

Patients and Methods: 301 consecutive patients with 1217 brain metastases were treated by Gamma Knife radiosurgery at the Karolinska Hospital in 451 treatments. Tumors were followed with MRI in 3 months intervals. Patients surviving more than 9 months (n=105) with tumors larger than 10 mm (n=153 metastases) were selected for the current follow-up and detailed dose volume analysis.

Results: The median survival of this selected group was 21.2 months. There was a secondary enlargement in 30.7% of metastases with a diameter of >10 mm (47 /153): 17% (26/153) were interpreted as ARE and 13.7 % (21/153) as local recurrences. There was no preference of a specific diagnosis and secondary enlargement. 18 % (4/22) patients with ARE and 27 % of patients with recurrences (4/15) were symptomatic. The prescription and maximum doses, tumor volumes, integral doses and conformity index did not differ significantly between ARE or recurrence group. The volume of the 10 Gy isodose (V10Gy) was 24.11 cc in metastases with vs. 14.35 cc in tumors with uncomplicated outcome (p=0.0043). For V10Gy <3.4 cc and for V10Gy >42cc the risk for ARE was 6.3% (1/16) and 64% (7/11) respectively. For treatments with a 10 Gy isodose volume of 3.4 - 42 cc the ratio between V10Gy and tumor volume (KARE factor) was a significant predictor of ARE . When the KARE factor was < 4.09, the risk for ARE was significantly reduced to 3.45 % (1/29) (vs. 26%: 17/65; p=0.0098 Fisher's ExactTest). Due to potential diagnostic difficulties to reliably differentiate between ARE and recurrences in metastases, both negative events were analysed together for an empirical approximation of an effective dose range. For treatments with a V10Gy between 3.4 - 42 cc and prescription doses > 20Gy and a KARE factor <4.09 the risk for any secondary enlargement of the tumor (ARE or recurrence) was significantly reduced to 8.3% (2/24) (vs. 37.9% :33/87; p=0.0057 Fisher's ExactTest).

Discussion: This analysis of longer term surviving patients with metastases covers the latency of 9 months necessary to develop adverse radiation effects. The simplistic KARE factor reflects the

11:30 - 12:30 ORAL SESSION

OS15 FUNCTIONAL 2 - PAIN, MOVEMENT DISORDERS, EPILEPSY

Room: Auditorium

OS15-1 GAMMA KNIFE SURGERY FOR INTRACTABLE PAIN: A ROLE OF PITUITARY RADIOSURGERY BASED ON OUR EXPERIENCE

Motohiro Hayashi¹ Noriko Tamura¹ Masahiro Izawa¹ Yoshikazu Okada¹ Masahiro Izawa¹ Yoshikazu Okada¹

(1) Tokyo Women's Medical University, Tokyo, Japan

Gamma knife radiosurgery for cancer pain: Rationale: Cancer pain has been treated by GKS, targeted to the pituitary gland, as an alternative new pain control method. The purpose of this study was to investigate to prove the efficacy and the safety of this treatment.

Methods and materials: We have treated Twenty one patients, who suffered from severe cancer pain related to bone metastasis, by using GKS. The target was the pituitary gland. The maximum dose was 160-180 Gy with one isocenter of an 8-mm collimator, keeping the radiation dose to the optic nerve less than 10 Gy.

Results: At a follow up of 1 to 12 months, significant pain reduction was observed in 90.5% (19/21) without significant complication. In the effective patients, pain relief was observed within several days, and this effect was prolonged until the day that they died. And no recurrences and no hormonal dysfunction were observed.

Conclusions: This treatment has the potential to ameliorate cancer-related pain, and GKS will play a more important role in the treatment of intractable pain. More experience and additional refined study protocols are needed to evaluate which parameters are important, to determine what treatment strategy is the best, and to clarify the safest option for patients with intractable cancer pain.

Gamma knife surgery for thalamic pain syndrome: Rationale: To evaluate outcomes after pituitary radiosurgery in patients with post-stroke thalamic pain syndrome.

Methods and Materials: twenty four patients with thalamic pain syndrome underwent pituitary radiosurgery and were followed at least 12 months thereafter. The radiosurgical target was defined as the pituitary gland and its connection with the pituitary stalk. The maximum dose varied from 140 to 180 Gy. Mean follow-up after treatment was 35 months (range, 12 to 48 months).

Results: Initial pain reduction, usually within 48 h after radiosurgery, was marked in 17 patients (71%). However, in the majority of cases the pain recurred within 6 months after treatment, and at the time of the last follow-up examination durable pain control was marked in only 5 patients (21%). Ten patients (42%) had treatment-associated side effects. Anterior pituitary abnormalities were marked in 8 cases and required hormonal replacement therapy in 3; transient diabetes insipidus was observed in 2 cases, transient hyponatremia in one case, and clinical deterioration due to increase of the numbness severity despite significant reduction of pain was seen once.

Conclusions: Pituitary radiosurgery for thalamic pain Results in a high rate of initial efficacy and is accompanied by acceptable morbidity. It can be used as a primary minimally invasive management option for patients with severe pain resistant to medical therapy.

11:30 - 12:30 ORAL SESSION

OS15 FUNCTIONAL 2 - PAIN, MOVEMENT DISORDERS, EPILEPSY

Room: Auditorium

OS15-2 GAMMAKNIFE VIM THALAMOTOMY FOR TREMOR. OUTCOME IN A SERIES OF 61 CONSECUTIVE PATIENTS

Romain Carron¹ Tatiana Witzas² Jung Kyo Lee³ Michael C. Park¹ Jean-philippe Azulay² Jean Regis¹

(1) Department of stereotactic and functional neurosurgery La Timone Hospital, Marseille, France (2) Department of neurology, Movement disorders, La Timone Hospital, Marseille, France (3) Department of Neurological Surgery, Asan Medical Center, , Seoul, Korea, Republic of

Introduction: Vim DBS surgery is still regarded as the gold standard for essential or severe intractable Parkinsonian tremor. Vim Gammaknife thalamotomy is a possible alternative still under evaluation. The aim of the present study is to analyse the clinical Results with correlation to the MRI postoperative appearance.

Materiels and methods: Between April 2004 and October 2010, a Vim Gammaknife thalamotomy was performed in 61 patients harbouring an intractable essential or Parkinsonian tremor in Marseille University hospital (45 men and 16 women). Mean age was 72 years. Preoperative imaging work-up consisted of stereotactic MRI including MP-RAGE, axial CISS and coronal TSE sequences (1,5T-Siemens®) and a non contrast CT-scan. From June, 2009 additional diffusion tensor imaging (DTI) sequences were systematically obtained and co-registered with the stereotactic imaging using Leksell GammaPlan (Elekta®). Vim targeting was determined after Guiot scheme on stereotactic MRI ventriculography. Treatment plan consisted of a unique 4 mm isocenter. 130 Gy were delivered to the 100% isodose. In order to improve safety in relation to the capsula interna, the shot was shielded. Follow-up included serial MRIs (MP-RAGE, T2) and clinical evaluation by expert neurologists (Whiget tremor scale, functional scale) at 3, 6 months, 1 and 2 years.

Results: 77% of the 61 Vim thalamotomies were performed on the left side. Follow-up was superior or equal to six months for 51 patients. The mean decrease in the amplitude of tremor at one year was 76%. The overall percentage of patient presenting a good or excellent outcome was 80 %. We report on one hyper-reponder who presented a transient hemiparesia related to an extensive MRI lesion and three hyporesponders with no significant MRI changes and no clinical benefit (6,5% of patients).

Conclusion: In our series, unilateral GKS Vim thalamotomy is a safe and effective alternative to Vim high-frequency DBS for intractable disabling tremor with upper limb involvement. The use of Guiot scheme on stereotactic MR ventriculography enabled to achieve satisfactory targeting and DTI proved helpful to readily identify capsula interna and optimize in fine the outcome. The analysis of the clinical Results and serial postoperative MRIs enabled to identify three subpopulations of hypo, normo- and hyper-responders and their proportions.

11:30 - 12:30 ORAL SESSION

OS15 FUNCTIONAL 2 - PAIN, MOVEMENT DISORDERS, EPILEPSY

Room: Auditorium

OS15-3 LONG-TERM MRI FOLLOW-UP AFTER GAMMA KNIFE RADIOSURGERY FOR TEMPORAL LOBE EPILEPSY

Adyl Melhaoui¹ Michael Park¹ Motohiro Hayashi¹ Fabrice Bartolomei² Patrick Chauvel² Jean Régis¹

(1) Department of Stereotactic and Functional Neurosurgery, Timone University Hospital, A.P.M., INSERM U751, Marseille, France (2) Department of Clinical Neurophysiology, Timone University Hospital, A.P.M., INSERM U751, Marseille, France

Introduction: Gamma Knife radiosurgery (GKR) for selected cases of refractory mesial temporal lobe epilepsy (MTLE) has proven its long-term safety/efficiency [1]. We assessed and evaluated the correlation between the timing of long-term MRI changes and the clinical outcome.

Methods: We reviewed the clinical charts, dose planning and follow-up imaging of 15 patients treated for MTLE at the Timone University Hospital with more than 6 years of follow-up. We evaluated dates of onset of MR changes and resolution of contrast enhancement, mass effect and long-term lesioning effect. We compared the Results of groups based on the Engel classification.

Results: Between 1993 and 1998, 15 patients (6 males, 9 females, mean age 35, range 22-46) were treated for MTLE with mean follow-up of 8 years (6-11) with total of 155 MRIs (10 MRIs/patient). Mean onset of first MRI change was 11.5 months, mean time for maximal change was 15 months, and mean time for MRI resolution was 42 months. In only 60% of patients (9/15), long-term MRI showed a cerebral lesion (mean volume 1.55cc) in the antero-mesio-temporal area. In patients with a lesion on the MRI, its volume was small and represents only 18% of the treatment volume. In 3 cases (20%), a cystic lesion was identified beyond 100 months. In the best-outcome group (Engel Ia), the mean time of MRI change onset is 12.5 months, maximal change 17 months and the resolution 55 months. In the worst-outcome group (Engel III and IV), the mean time of MRI change onset is 9.3 months, maximal change 14 months and the resolution 29 months. The data suggest more delayed the onset of MRI changes and resolution, better the clinical outcome.

Conclusion: GKR is an effective and safe treatment for MTLE with 60% of patients being seizure free at long-term follow-up. Delayed onset of MRI changes and resolution is a good predictor of positive clinical outcome. Long-term MR lesioning is not mandatory for seizure control. Close long-term MRI monitoring is necessary to assess and follow MRI changes and late complications.

1. Bartolomei et al., Neurology 70:1658-63, 2008.

11:30 - 12:30 ORAL SESSION

OS15 FUNCTIONAL 2 - PAIN, MOVEMENT DISORDERS, EPILEPSY

Room: Auditorium

OS15-4 STEREOTACTIC RADIOSURGERY FOR HYPOTHALAMIC HAMARTOMAS

Yuriy Trunin¹ Andrey Golanov¹ Gennadiy Gorchachev¹ Valeriy Kornienko¹ Valeriy Kostuchenko¹ Polina Kudryavtseva¹ Nadezhda Mazerkina¹ Viktor Sorokin¹

(1) Burdenko Neurosurgery Institute, Moscow, Russian Federation

Objective: Radiosurgery plays an important role in the treatment of refractory seizures induced by hypothalamic hamartomas (HHs). These lesions are often associated with catastrophic epilepsy leading to progressive cognitive and behavioral deterioration. Radiosurgery is an emerging treatment modality for HHs, which provides excellent seizure outcomes and minimal risk of complications.

Materials and methods: Between March 2005 and July 2010 9 patients were undergoing radiosurgery. Mean patient age was 8,5 years (range 9 months' 20 years).

All the patients had medically refractory epilepsy (2 patients had secondary generalization).

2 patients with precocious puberty. All patients underwent anticonvulsive conservative treatment during 3 -18 years with temporary positive effect. Two patients have been treated by surgery, one of them had temporary positive effect. In treatment planning we used Axial T2-weighted and 3DSPGR magnetic resonance images to establish the size and location of the HHs. We used « Novalis » (BrainLab) with micro-multileaf collimator and CyberKnife (Accuray) for radiosurgery. The volume of the HHs ranged from 0,3 to 3,3 sm³. Mean marginal dose for radiosurgery was 17,1 Gy (11-18 Gy).

Results: all patients were available for neurological and imaging follow-up. Mean follow-up period was 20,5 month (4-48). Seizure freedom was achieved in 3 patients (33,3%), 6 patients (66,7) had some improvement of seizure frequency, intensity and seizure structure. To date, no serious complications have been discovered.

Conclusion: Radiosurgery is a safe and effective treatment for HHs. Distinct from other surgical treatments, it is noninvasive and virtually free of major complications. Radiosurgery may be a first-line treatment for these lesions when medically refractory epilepsy are present.

11:30 - 12:30 ORAL SESSION

OS15 FUNCTIONAL 2 - PAIN, MOVEMENT DISORDERS, EPILEPSY

Room: Auditorium

OS15-5 IMMEDIATE PAIN RELIEF ELICITED AFTER RADIOSURGERY FOR CLASSICAL AND SYMPTOMATIC TRIGEMINAL NEURALGIA

Alessandra Gorgulho¹ Robert Elashoff¹ Nima Sarani¹ Nzhde Agazaryan¹ Chul Lee¹ Phillip Chow¹ Stephen Tenn¹ Michael Selch¹ Antonio De Salles¹

(1) University of California at Los Angeles, Los Angeles, USA

Introduction: Immediate relief following radiosurgery for trigeminal neuralgia (TN) has been observed in a minority of cases. Our goals were to determine the occurrence of immediate pain relief as real vs. placebo effect and to search for factors associated with this desirable outcome.

Materials and Methods: Between January/2003-June/2008, 150 patients were treated with radiosurgery for classical or symptomatic TN at UCLA. A commercially available linear-accelerator (Novalis®, BrainLAB) device was used to deliver 90 Gy to the root-entry zone with a 4 or 5mm collimator. Pain outcomes were graded using a 4-point scale. Complications were recorded through standardized follow-up evaluations. Treatment plans were retrieved and brainstem/trigeminal nerves were retrospectively re-contoured using standard anatomical landmarks. Dose-volume histograms were used to calculate the volume of brainstem/trigeminal nerve receiving 20%, 30% and 50% of the prescribed radiation doses.

Results: Twenty-five (19.84%) patients presented with immediate pain relief, defined as pain cessation within 48 hours post-radiosurgery. Kaplan-Meier analysis showed that good/excellent pain outcomes were sustained and significantly better in the immediate pain relief group ($p=0.006$) compared to non-immediate relief. Univariate and multivariate logistic regression failed to show correlation between brainstem/trigeminal nerve volumes, trigeminal nerve-pontine angle, prior surgical procedures, TN etiology, age, gender and immediate pain relief. Neither post-radiosurgery complications nor recurrence rates were different between groups.

Conclusion: Immediate pain relief leads to sustained relief and patients present significantly better pain outcomes in comparison to those without immediate relief. The mechanism triggering immediate relief is still unknown and did not correlate with the volume of brainstem/trigeminal nerve receiving pre-specified doses of radiation.

WEDNESDAY, 11 MAY 2011

10:30 - 11:30 ORAL SESSION

OS16 GLIOMAS

Room: La Seine

OS16-1 *RADIOSURGERY FOR RESIDUAL OR RECURRENT GLIOBLASTOMA MULTIFORME*

Ajay Niranjani¹ Hideyuki Kano¹ Tian Wang¹ Oscar F Zorro¹ Javier Lobato-polo¹ Thomas Flannery¹ Douglas Kondziolka¹ John C. Flickinger¹ L Dade Lunsford¹

(1) University of Pittsburgh, Pittsburgh, USA

Purpose: Glioblastoma multiforme is a devastating diagnosis. Resection followed by radiation therapy is the standard treatment. It is disappointing however, that the eventual regrowth of the tumor is routine. The authors analyzed the outcomes of gamma knife stereotactic radiosurgery (SRS) for residual or recurrent glioblastoma multiforme (GBM) and evaluated factors that affected patient survival and tumor control rates.

Methods: Between 1988 and 2007, 299 patients with histologically proven GBM underwent SRS using Gamma Knife at our institution. A total of 323 SRS procedures were performed. The median patient age was 57 years (23-89 years). The median tumor volume was 15.2 cc (0.26-84.2 cc). The median prescription dose delivered to the tumor margin was 15.0 Gy (9-25 Gy). The median maximum dose was 26.0 Gy (range, 20 to 50 Gy). The mean follow-up time was 62.2 months (range, 12 -232 months).

Results: The median patient survival after radiosurgery was 9.2 months. The 1-year and 2-year overall survivals were 40.4% and 16.4% respectively. Univariate analysis suggested that younger age (less than 60 years: $p < 0.0001$), higher dose (15Gy or higher: $p = 0.006$), smaller tumor volume (less than 15cc: $p = 0.002$), higher KPS ($p = 0.005$) were significantly associated with longer patient survival. Prior radiation therapy, prior chemotherapy, prior total tumor resection, and patient sex were not associated with overall survival. Multivariate analysis suggested that younger age ($p < 0.0001$) and smaller tumor volume ($p < 0.0001$) were significantly associated with better patient survival.

Conclusions: Multimodality management including surgery, XRT, Chemotherapy and radiosurgery is needed to improve the outcome of GBM. Radiosurgery is a safe and effective minimally invasive option for management of residual or recurrent GBMs. Radiosurgery is a useful adjuvant treatment for palliating selected patients with GBMs especially the younger patients with smaller tumors.

10:30 - 11:30 ORAL SESSION

OS16 GLIOMAS

Room: La Seine

OS16-2 TUMOR RESPONSE AND CLINICAL OUTCOMES AFTER LINAC RADIOSURGERY IN 50 PATIENTS WITH RECURRENT MALIGNANT GLIOMAS

Toufic Khalil¹ Jean Jacques Lemaire¹ Veronique Dedieu¹ Denise Donnarieix¹ Beatrice Claise¹ Jean Louis Kemeny¹ Michel Lapeyre¹ Bruno Perreira¹ Aurelie Thalami¹ Jean Chazal¹ Pierre Verrelle¹

(1) Service neurochirurgie CHU, Clermont-ferrand, France (2) Département de radiothérapie Centre Jean Perrin, Clermont-Ferrand, France

Background: We evaluate clinical outcome and radiographic response after radiosurgery (RS) in patients with recurrent malignant glioma in a single institution.

Methods: Between 2001 and 2008, 50 patients, 34 glioblastoma multiforme (GBM) and 16 anaplastic oligodendroglioma (AO) were treated with linear accelerator micromultileafs collimator for recurrence after standard fractionated RT. The median interval between diagnosis and radiosurgery was 9 months [4 to 46] for GBM and 24 months [4 to 73] for AO. The median marginal dose was 15 Gy [12 to 16]; and the median gross tumor volume was 6.64 ml [0.13 to 44.5].

Results: Median overall survival after primary diagnosis was 21.5 months [8 to 123] for GBM and 57.9 months [15 to 150] for AO. Median survival after RS was 9.5 months [2 to 49] for GBM and 32.9 months [2 to 73] for AO. Median progression-free survival (PFS) after RS was 6.7 months [2 to 22] for GBM and 22 months [2 to 73] for AO, and PFS at 6 months of 58.6 % for GBM and 72.6 % for OA. Radiographic volume evolution shows a reduction or stable disease in 59 % for GBM and 81 % for AO. Patients who responded to treatment had statistically improved survival compared to non-responders, with median survival of 28.4 months vs 6.1 months ($p < 0.001$).

Conclusion: RS in patients with recurrent malignant glioma was well tolerated and effective. Radiological response was noted in 66% of patients with significant improved of survival for responders.

10:30 - 11:30 ORAL SESSION

OS16 GLIOMAS

Room: La Seine

OS16-3 EFFECTIVE REGIMEN OF FRACTIONATED RADIOSURGERY (8 GY X 4) FOR GLIOBLASTOMA WHO FAILED AFTER SECOND-LINE CHEMOTHERAPY

Samuel Ryu¹ Winston Ning¹ Jinkoo Kim¹ Ren Lei¹ Jin Jian-yue¹ Walls Nicole¹ Tom Mikkelsen¹ Jack Rock¹ Movsas Ben¹

(1) Henry Ford Hospital, Detroit, USA

Approach: Radiosurgery has a limited role in the initial management of glioblastoma. Most patients are doomed to progress and are treated with chemotherapy. However, there is no widely

acceptable treatment for progressive tumors after second-line chemotherapy. We have treated these patients with fractionated radiosurgery (FRS). This study is to demonstrate the efficacy of FRS with the endpoints of local tumor response and time to progression after radiosurgery.

Relevance: There is no standard treatment for progressive tumors after second-line chemotherapy. Our previous pilot study with fractionated radiosurgery showed encouraging tumor response rate. In order to improve the tumor response, we incorporated 4 sessions of radiosurgery 8 Gy in each fraction (Total of 32 Gy).

Innovation: Total of 43 patients with recurrent / progressive GBM who failed second-line bevacizumab-based chemotherapy from 8/08 to 6/10. FRS was given in total dose of 32 Gy to the contrast-enhancing gross tumor → total 4 sessions of 8 Gy fraction twice a week. Average tumor volume of contrast enhancement was 23.7 ± 15.5 cc. Areas of new flair imaging change and abnormal diffusion weighted image were included as clinical target volume for doses of 6 Gy x 4 (total of 24 Gy). After radiosurgery, patients continued with chemotherapy. Clinical and MRI followup were performed every 2 months after radiosurgery.

Results: Overall radiographic tumor response rate was 49% at 2 months. Early sign of imaging progression was outside of the target volume in 13 patients at 2 months. Median time to progression was 4 months (1→12 months). One patient who had the longest progression-free interval survived 15 months after radiosurgery. Overall median survival time 8.5 months (2→15 months) after radiosurgery.

Conclusion: FRS achieved an excellent tumor control in selected group of patients who has an amenable target volume. Radiosurgery can be a viable treatment option for progressive / recurrent tumors after second-line chemotherapy.

10:30 - 11:30 ORAL SESSION

OS16 GLIOMAS

Room: La Seine

OS16-4 SALVAGE RADIOSURGERY FOR RECURRENT HIGH GRADE GLIOMA

Ida Milanese¹ Marcello Marchetti¹ Chiara Falcone¹ Andrea Botturi¹ Livia C Bianchi² Andrea Salmaggi¹ Laura Fariselli^{1, 2}

(1) Fondazione Istituto Neurologico C Besta, Milano, Italy (2) Centro Diagnostico Italiano (CDI), Milano, Italy

Purpose: the aim of the present study was to evaluate the efficacy and feasibility of salvage radiosurgery for patients presenting recurrent High Grade Glioma (HGG) PATIENTS AND **Methods:** 73 patient with recurrent HGG were treated at our institutions between 2004 and 2009. Single shot radiosurgery with mean total dose of 13,7 Gy was performed in 22 lesions; 60 lesions were treated by multisession SRS (mean total dose 24 Gy, 3 fractions). Median age was 53 years (range 20 → 88); mean KPS > 70 (60-100). In all pt a second line chemotherapy was performed before radiotherapy. Cox regression models were used to analyze the influence of age, volume of the treated lesions and the type of SRS (single shot vs multisession) on survival.

Results: Median survival time after retreatment was 9 months. No specific prognostic factors positively affected survival. All pt were able to complete the prescribed dose; RTOG toxicity never

exceeded grade II.

Conclusions: Salvage SRS was safety and well tolerated. The adverse effects were minimal. Survival Results in our series are comparable to reported Results in recent literature. No difference was observed when single fraction or multiple fractions were used.

10:30 - 11:30 ORAL SESSION

OS16 GLIOMAS

Room: La Seine

OS16-5 GKRS IN THE INITIAL MANAGEMENT OF PATIENTS WITH MALIGNANT GLIOMAS: CAN IT REPLACE CONVENTIONAL RT?

Masaaki Yamamoto¹ Takuya Kawabe¹ Bierta E Barfod¹ Yoichi Urakawa¹

(1) Katsuta Hospital Mito GammaHouse, Hitachi-naka, Japan

Background: There is Level I evidence that the use of radiosurgery boost followed by external beam radiotherapy (EBRT) for patients with newly diagnosed malignant gliomas does not confer benefits with respect to overall survival, quality of life, or patterns of failure as compared with EBRT alone (Tsao et al, Int J Radiat Oncol Biol Phys 63: 47-55, 2005). The next question is whether EBRT is necessary for all patients with malignant gliomas. The clinical efficacy of gamma knife radiosurgery (GKRS) alone as initial radiotherapy for patients with malignant gliomas is not yet fully understood.

Patients: We analyzed 54 patients (85 procedures) who underwent GKRS as one of the initial treatment procedures (July, 1998-June, 2008) for histologically-verified malignant gliomas; grade III in 21 and grade IV in the other 33. There were 27 females, 27 males. The mean age was 65, range 31 to 83 years.

Results: As of October of 2009, four patients were alive and the other 50 were confirmed to be deceased. Median survival times (MSTs-months) from the time of the initial treatment were 15.0 in grade III and 11.9 in grade IV patients ($p=.1258$). There was a significant MST difference between the two surgical procedure groups, 30 months in patients who underwent gross total removal and 24 in those undergoing partial removal (15.8 vs. 10.6 months, $p=.0003$). However, MSTs did not differ significantly between the two treatment strategies, GKRS only vs. EBRT plus a GKRS booster (13.2 vs. 14.8, $p=.8435$). Even in grade IV patients, the MST of patients with EBRT plus a GKRS booster did not differ significantly from that of those receiving GKRS only (9.4 vs. 13.2, $p=.7813$). Salvage GKRS was not required in 19 patients (61.3%) with GKRS only and 14 (60.9%) with EBRT plus a GKRS booster ($p=.9750$). In patients with grade IV, the median further GKRS-free time of the GKRS only group (12.7) did not differ significantly from that of the EBRT plus a GKRS booster group (10.6, $p=.8928$).

Conclusion: Our Results failed to demonstrate the superiority of EBRT plus a GKRS booster as compared with GKRS only. GKRS may replace EBRT in the initial management of selected patients with malignant gliomas.

10:30 - 11:30 ORAL SESSION

OS17 MENINGIOMAS

Room: Miles Davis

OS17-1 *GAMMA KNIFE RADIOSURGERY FOR PARASELLAR MENINGIOMAS: LONG TERM RESULTS: INCLUDING COMPLICATIONS, PREDICTIVE FACTORS AND PROGRESSION FREE SURVIVAL*

Jason Sheehan¹ Brian Williams¹ Chun Po Yen¹ Robert Starke¹ Bhuvaneswara Basina¹ James Nguyen¹ David Schlesinger¹

(1) University of Virginia, Charlottesville, United States

Objective: Stereotactic radiosurgery serves as an important primary and adjuvant treatment option for patients with many types of intracranial meningiomas. This is particularly true for those with parasellar meningiomas. In this study, we evaluate the outcomes using stereotactic radiosurgery to treat parasellar meningiomas.

Methods: This is a retrospective review of the outcomes of 138 patients with meningiomas treated at the University of Virginia from 1989 to 2006; all patients had a minimum follow-up of 24 months. There were 32 males and 107 females with a mean age of 54 years (range 19-85). Eighty-four patients had previous surgical resection. The mean pre-radiosurgery tumor volume was 7.5 cc (range 0.2-54.8 cc). Clinical and radiographic evaluations were performed, and factors were assessed related to favorable outcomes in each.

Results: The mean follow-up was 84 months (median 75.5; range 24-216 months). One hundred and eighteen patients (86%) had unchanged or decreased tumor volume at last follow-up. Kaplan Meier analysis demonstrated radiographic progression free survival at 5 and 10 years to be 95.4% and 71%, respectively. Fourteen (10%) patients developed new cranial nerve palsies following Gamma Knife radiosurgery (GKRS). Factors associated with tumor control included younger age, higher isodose, and smaller tumor volume. Longer follow-up was associated with either a decrease or increase in tumor volume. Fourteen (10%) patients experienced new or worsening cranial nerve deficits after treatment. Factors associated with this occurrence were larger pre-treatment tumor volume, lower peripheral radiation dose, lower maximum dose, tumor progression, and longer follow up.

Conclusion: GKRS offers an acceptable rate of tumor control for parasellar meningiomas and accomplishes this with a low incidence of neurological deficits. Radiologic control after radiosurgery is more likely in those with a smaller tumor volume and a higher prescription dose.

10:30 - 11:30 ORAL SESSION

OS17 MENINGIOMAS

Room: Miles Davis

OS17-2 GAMMA KNIFE ROBOTIC MICRORADIOSURGERY FOR SKULL BASE MENINGIOMAS: TUMOR SHRINKAGE MAY DEPEND ON THE AMOUNT OF RADIATION ENERGY DELIVERED PER LESION VOLUME (UNIT ENERGY)

Motohiro Hayashi¹ Noriko Tamura¹ Shoji Yomo¹ Mariko Nagai¹ Masahiro Izawa¹ Yoshikazu Okada¹

(1) Tokyo Women's Medical University, Tokyo, Japan

Background: The objective of the present study was the evaluation of the effectiveness of robotic microradiosurgery of skull base meningiomas using Leksell Gamma Knife model C with an automatic positioning system.

Methods: The Results of the management of 66 tumors were analyzed retrospectively. Their volume varied from 0.3 to 50.6 cm³ (mean = 6.6). The treatment plan was based on the use of multiple small isocenters compactly positioned within the border of the lesion with resultant improved homogeneity of high-dose distribution, increased average dose within the target and sharp dose fall outside the treated volume. The marginal dose varied from 10 to 14 Gy (mean = 12). The length of follow-up ranged from 26 to 80 months (mean = 46).

Results: The overall tumor growth control was 99%. Reduction of the mass volume was marked in 54 patients (82%), and in 15 of them it constituted 650%. In other 11 cases (17%) stabilization of the lesion growth was noted. The shrinkage rate significantly correlated with amount of radiation energy delivered per tumor volume, designated as unit energy ($p = 0.007$). One meningioma (1%) regrew 3.5 years after radiosurgery. The treatment-related morbidity was limited to transient abducens nerve palsy in 1 patient (1%).

Conclusion: Application of the concept of Gamma Knife robotic microradiosurgery for the management of skull base meningiomas may change the paradigm of their treatment from stabilization of growth to reduction of the volume of the neoplasm. The tumor shrinkage rate may depend on the amount of radiation energy delivered per lesion volume (unit energy).

10:30 - 11:30 ORAL SESSION

OS17 MENINGIOMAS

Room: Miles Davis

OS17-3 VISUAL FUNCTION PRESERVATION AFTER MULTI-SESSION GAMMA KNIFE RADIOSURGERY FOR PERIOPTIC MENINGIOMAS. PRELIMINARY RESULTS

Piero Picozzi¹ Antonella Del Vecchio² Alberto Franzin¹ Marzia Medone¹ Angelo Bolognesi³ Pietro Mortini¹

(1) Gamma Knife Unit, Dept. of Neurosurgery, IRCCS San Raffaele, Milano, Italy (2) Dept. of Medical Physics, IRCCS San Raffaele, Milano, Italy (3) Dept. Of Radiation Oncology IRCCS San Raffaele, Milano, Italy

Introduction: The radiation tolerance of the anterior visual pathways represents a challenge for treating adjacent lesions with single-session radiosurgery. Stereotactic multi-session radiosurgery has been introduced as a strategy for the treatment of the tumors near to the optic apparatus. We propose the use of Gamma Knife for multi-session treatment in three consecutive days.

Methods: 38 patients treated between January 2006 and June 2009 were included in this study (7 males, 31 females; mean age 56 years). Of those, 25 patients had cavernous sinus meningioma, 4 patients had optic nerve meningiomas, 7 had tuberculum sellae meningioma, one a small sphenoidal wing meningioma and 1 a spheno-orbital meningioma. All treated tumors were immediately adjacent to a part of the anterior optic apparatus. Preoperative visual acuity deficit was present in 25 patients (11 severe deficit, 14 mild deficit) while, 9 patients had visual fields defects (hemianops/quadranops/). In 9 patients visual field was not evaluable. Cranial nerves deficit were recorded in 8 patients. Gamma Knife radiosurgery was delivered in three sessions with a mean prescription dose to the tumor margin of $6.8 \text{ Gy} \pm 0.1 \text{ Gy}$ per session (range 6-7 Gy) and a mean total prescription isodose of 20.3 Gy (range 18-21 Gy). Mean pre-treatment tumor volume was 8.28 cm³ (median 6.95, range 0.33-29.6). Mean maximum dose to the optic apparatus was always below 7 Gy for each session (mean 5 Gy)

Results: The median follow-up was 24 months (range 7-49). Overall tumor control rate was 100%. Tumor volumetric reduction was observed in 27 patients (71%), whereas in 11 patients (29%) no volumetric variation was recorded. Visual acuity improved in four patients (16%) while visual field improvement occurred in four of these patients (16%). No patient experienced visual deterioration. Cranial nerve function improvement was recorded in one patient (12.5%).

Conclusions: This preliminary experience suggests that multi-session radiosurgery with Gamma Knife can be a safe and effective treatment for tumors immediately adjacent to segments of the optic apparatus.

10:30 - 11:30 ORAL SESSION

OS17 MENINGIOMAS

Room: Miles Davis

OS17-4 STEREOTACTIC RADIOTHERAPY AND RADIOSURGERY FOR PERIOPTIC ANTERIOR AND MIDDLE SKULL BASE MENINGIOMAS

Andrey Golanov¹ Mikhail Galkin¹ Natalija Serova¹ Gennadiy Gorlachev¹ Sergey Ilyalov¹ Valerij Kostuchenko¹ Polina Kudryavtseva¹

(1) Burdenko Neurosurgical Institute, Moscow, Russian Federation

Objective: Surgical treatment of skull base meningiomas is connected with many problems. If meningioma is situated near the optic apparatus, surgical treatment becomes even more complicated. We have conducted retrospective study to evaluate how stereotactic irradiation of anterior and middle skull base meningiomas with perioptic localization can effect tumor growth control and optic nerve function.

Materials and Methods: Between August 2005 and August 2009 101 patients were treated for different anterior and middle skull base meningiomas related to visual paths. Following

localizations were treated - cavernous sinus, parasellar and medial sphenoid wings meningiomas. 32 patients had histological verification due to previous operations of tumor partial removal. Different cranial neuropathies were observed in 89 patients, from these visual disturbances were found in 37 patients. We used Gamma-Knife model C (Elekta) and - α Novalis- (BrainLab) with micro-multileaf collimator for radiosurgery. Radiotherapy was conducted with - α Novalis- (BrainLab). Radiotherapy was performed in cases when visual paths were adjacent to meningioma. In other cases radiosurgery was applied. Mean marginal dose for radiosurgery was 13,8 Gy (10-17,6 Gy), mean marginal dose for radiotherapy was 47,4 Gy (43,2-53,5 Gy). 90 patients have undergone stereotactic radiotherapy. In 24 patients radiosurgery was performed.

Results: 98 patients were available for neurological and ophthalmologic follow-up, 100 patients were available for imaging follow-up (mean follow-up period -> 27 months for both). Among tumors available for follow-up imaging 98% (98 tumors) diminished in size or were stable and 2% (2 tumors) enlarged. In 97% of patients available for follow-up visual functions were stable or improved. Other cranial nerves functions were stable or improved.

Conclusion: Stereotactic irradiation of perioptic anterior and middle skull base meningiomas is capable to control tumor growth effectively, while preserving or even improving visual function.

10:30 - 11:30 ORAL SESSION

OS17 MENINGIOMAS

Room: Miles Davis

OS17-5 STEREOTACTIC RADIOSURGERY OF WHO GRADE II AND III INTRACRANIAL MENINGIOMAS: MANAGEMENT STRATEGY BASED ON A 20-YEAR EXPERIENCE

Bruce Pollock¹ Scott Stafford¹ Michael Link¹ Yolanda Garces¹ Robert Foote¹

(1) Mayo Clinic, Rochester, USA

Objective: To define the variables associated with survival and tumor control after single-session radiosurgery for patients with atypical and malignant intracranial meningiomas.

Methods: Fifty-three patients with WHO Grade II/III meningiomas underwent radiosurgery from 1990 to 2008. Four patients were excluded due to follow-up of less than 6 months. Thirty-six patients (73%) had Grade II tumors and 13 patients (27%) had Grade III tumors. The median patient age was 60 years. The majority of patients had tumors located in the falx/parasagittal region or cerebral convexities (n=35, 71%). Nineteen patients (39%) had progressing tumors despite prior radiation therapy (median dose, 54 Gy). The median treatment volume was 15 cm³; the median tumor margin dose was 15 Gy. Seven patients (14%) received concurrent radiation therapy (median dose, 50.4 Gy). Follow-up (median, 39 months) was censored at last evaluation (n=30) or death (n=19).

Results: The 2-year and 5-year cause-specific survival (CSS), progression-free survival (PFS), and local tumor control (LC) rates were 81% and 61% (CSS), 58% and 40% (PFS), and 77% and 45% (LC), respectively. Tumor grade correlated with CSS (HR 3.4, P=0.008), PFS (HR 2.6, P=0.02) and LC (HR 2.4, P=0.02) on univariate analysis, but not on multivariate analysis. Multivariate analysis showed that having failed prior radiation therapy (HR 3.0, P=0.02) and tumor volume greater than

15 cm³ (HR 4.4, P=0.01) were negative predictors of CSS; having failed prior radiation therapy (HR 3.5, P=0.002) was a negative predictor of PFS, and having failed prior radiation therapy (HR 3.3, P=0.001) and tumor volume greater than 15 cm³ (HR 2.3, P=0.02) were negative predictors of LC. Thirteen patients (27%) had radiation-related complications at a median of 6 months after radiosurgery. No tested factor correlated with post-radiosurgical morbidity.

Conclusions: Although tumor histology relates to survival and tumor control rates for patients with atypical or malignant meningiomas, having failed prior radiation therapy and larger tumor volume may be even more significant negative predictors for patients with WHO Grade II and III intracranial meningiomas. Based on our experience, we recommend complete tumor resection whenever possible and early radiosurgery if residual tumor is noted on post-operative MRI to optimize outcomes for this difficult patient group.

10:30 - 11:30 ORAL SESSION

OS18 VASCULAR 2 – ARTERIOVENOUS MALFORMATIONS MULTIMODALITY & ALTERNATIVE APPROACHES

Room: Auditorium

OS18-1 STEREOTACTIC RADIOSURGERY FOR ARTERIOVENOUS MALFORMATION IN SPETZLER-MARTIN GRADE 1 : CAN RADIOSURGERY BE A FIRST CHOICE OF TREATMENT?

Masahiro Shin¹ Tomoyuki Kouga¹ Shunya Hanakita¹ Nobuhito Saito¹

(1) The university of Tokyo Hospital, Tokyo, Japan

Introduction: Surgery is recommended as the best treatment option for small and easily accessible AVMs, but some patients strongly prefer radiosurgery. To know the Results of radiosurgery in a specific group of AVMs classified as Spetzler-Martine grade 1 (SMG1, size<3cm, non-eloquent location, superficial venous drainage), we retrospectively analyzed our series of the patients with those AVMs.

Materials and Methods: 150 patients with AVMs in SMG1 were radiosurgically treated in our institution. Follow-up periods ranged from 12 to 120 months (median 59 months)

Results: The actuarial obliteration rates on angiography were 95.4 % at 4 years. Factors associated with better outcome on univariate analysis were male patients, younger age, previous hemorrhage, preceding surgical resection, nidus volume less than 2.0 cm³, marginal dose more than 24 Gy, clear nidus margin, and dose planning using angiography with MRI or dynamic CT (not angiography alone). On multivariate analysis, age less than 40 years and no prior endovascular treatment emerged as significant factors (p = 0.0077 and 0.0008). Radiation-induced neuropathy was seen in 3, with all being mild and transient sensory disturbance. Sensory deficit at radiosurgery, the nidus in the parietal lobe or in the paraventricular region negatively affected the outcome. Latency interval hemorrhage developed in 2: the annual bleeding rate was 1.0 %, and the cumulative risk was 3.1 % at 2 years. Age more than 60 years was the only factor associated with the higher risk of latency interval hemorrhage. One patient suffered hemorrhage 1.5 year after angiographic obliteration, and the nidus was surgically removed. At the surgery, the obliterated nidus was well

demarcated, least vascularized, and easily dissected from surrounding brain, which was successfully removed without any neurological deficit.

Discussion: These data indicates that radiosurgery achieves reasonable Results for small and superficial AVMs in the non-eloquent area, which is equivalent to the outcomes of the surgical resection in the past literature. Comparing to microsurgical resection, stereotactic radiosurgery has several benefits besides the therapeutic outcomes, short hospital stay, no need for craniotomy, or slow change of CBF dynamics. Some factors affecting the outcome should be given consideration before offering radiosurgery as an alternative treatment option. According to our recent data, AVMs that show an increase in the size of the enhanced region within 1 year of angiographic obliteration is more susceptible to have late hemorrhage. Therefore, they should be followed with caution and, if possible, we should recommend the surgical resection of the obliterated AVM nidus.

Conclusions: Stereotactic radiosurgery can be a reasonable treatment option for AVMs classified as SMG1. Close observation is necessary even after angiographic obliteration especially when the enhanced nidus shows an increase in the size within 1 year after obliteration.

10:30 - 11:30 ORAL SESSION

OS18 VASCULAR 2 – ARTERIOVENOUS MALFORMATIONS
MULTIMODALITY & ALTERNATIVE APPROACHES

Room: Auditorium

OS18-2 STEREOTACTIC RADIOSURGERY AFTER EMBOLIZATION FOR ARTERIOVENOUS
MALFORMATIONS

Hideyuki Kano¹ Douglas Kondziolka^{1, 2} Huai-che Yang¹ Kyung-jae Park¹ Aditya Iyer¹ Thomas Flannery¹ Ajay Niranjana¹ Josef Novotny Jr.² John Flickinger^{1, 2} L. Dade Lunsford^{1, 2}

(1) Department of Neurological Surgery, University of Pittsburgh, Pittsburgh, United States (2) Department of Radiation Oncology, University of Pittsburgh, Pittsburgh, United States

Introduction: To define the long-term benefits and risks of stereotactic radiosurgery (SRS) for arteriovenous malformation (AVMs) patients who underwent prior embolization.

Methods: Between 1987 and 2006, we performed Gamma knife® SRS on 996 patients with brain AVMs; 120 patients underwent embolization followed by SRS. In this series, 56 patients (47%) had at least one prior hemorrhage. The number of embolizations ranged from 1-4. The median target volume was 6.6 cc (range, 0.2-26.3 cc). The median margin dose was 18 Gy (range, 13.5-25 Gy).

Results: In this series embolization prior to SRS was associated with a lower rate of total obliteration ($p<0.00001$) in comparison to patients without embolization. After embolization, 30 patients (25%) developed symptomatic neurological deficits. One patient hemorrhaged immediately after embolization. The actuarial rates of total obliteration documentation by either angiography or MR were 35%, 53%, 55%, and 59% at 3, 4, 5, and 10 years, respectively. Factors associated with a higher rate of AVM obliteration were smaller target volume, smaller maximum diameter, higher margin dose, and lower Pollock-Flickinger score. Nine patients (8%) had a hemorrhage during the latency interval and five patients died due to hemorrhage. The rate of AVM hemorrhage after SRS was 0.8%, 3.5%, 7.7%, 7.7%, and 7.7% at 1, 2, 3, 5, and 10 years, respectively. The overall annual

hemorrhage rate was 2.7%. Factors associated with associated with a higher risk of hemorrhage after SRS were larger target volume, larger number of prior hemorrhages, and higher Pollock-Flickinger score. Permanent neurological deficits due to adverse radiation effects (AREs) developed in seven patients (5.8%) after SRS and one patient developed delayed cyst formation 210 months after SRS. No patient died due to ARE. Higher Pollock-Flickinger score was associated with higher risk of symptomatic AREs.

Conclusions: Prior embolization was associated with lower rate of total obliteration in this series. However, embolization followed by SRS may reduce the risk of AVM bleeding in the first two years after SRS. In the future the role of embolization after SRS should be explored.

10:30 - 11:30 ORAL SESSION

OS18 VASCULAR 2 – ARTERIOVENOUS MALFORMATIONS MULTIMODALITY & ALTERNATIVE APPROACHES

Room: Auditorium

OS18-3 IS EMBOLISATION OF AVM'S BEFORE GAMMA KNIFE SURGERY A PREFERABLE METHOD OF MANAGEMENT?

Michael Torrens¹ Ioannis Ioannidis¹ Nikos Natsis¹ Christos Stergiou¹ Alexandros Andreou¹
(1) Hygeia Hospital, Athens, Greece

Aim: Recent publications have suggested that embolisation may impair the rate of occlusion of AVM's after radiosurgery. The neurovascular patients in our hospital, whether for open surgery, interventional radiology and/or Gamma Knife radiosurgery, are treated by one surgical team. We conducted a review in order to assess the significance of embolisation in our experience.

Material and methods: Information on 250 cases of AVM, treated between 2004 and 2010, has been collected prospectively. Only 7 cases were operated. The policy of the unit is to protect the patient by primary embolisation with cure as the aim and 203 cases were embolised. 40 cases were treated by primary Gamma Knife radiosurgery. 80 cases were treated by Gamma Knife after embolisation. For radiosurgery planning the target was outlined by CT angiography in all cases as well as MRI and DSA. Occlusion following radiosurgery was defined by DSA at 2 years or later.

Results: In the cases embolised primarily the total occlusion rate was 40% (mortality 0.5%, bleeding rate 2.5%). In primary Gamma Knife treatments the 2 year occlusion rate was 68% (mortality 0%, rebleed rate 0%). In the post-embolisation Gamma Knife treatment group the 2 year occlusion rate was 62% (mortality 0%, rebleed rate 2.5%). The almost total (>98%) occlusion rate on DSA was 81% and these other malformations are expected to close before the 5 year follow up. There was no statistically significant difference in the Results: of cases treated with or without embolisation after correction for target volumes and dosage regimens. The overall 'cure' rate of all AVM's at 2 years, selected only by referral to this unit, was 66%.

Conclusion: Bearing in mind the theoretical risk of recurrent haemorrhage in the latent period after radiosurgery, we will discuss whether these figures justify the policy of primary embolisation with curative intent in all cases where this is possible. Though no deterioration of occlusion rate with radiosurgery is observed after embolisation, the mortality and rebleeding rate after embolisation

(2.5%) is greater than that after radiosurgery (1.6%) and the success rate of embolisation (40%), though high in relation to published series, is less than radiosurgery (66%).

10:30 - 11:30 ORAL SESSION

OS18 VASCULAR 2 – ARTERIOVENOUS MALFORMATIONS MULTIMODALITY & ALTERNATIVE APPROACHES

Room: Auditorium

OS18-4 *THE DOSIMETRIC EFFECTS OF ONYX EMBOLIZATION ON TREATMENT PLANNING: A REASSESSMENT AND VALIDATION OF CURRENT MODELS*

Robert Lieberman¹ Lei Wang² Guoqiang Cui² Steven Chang¹

(1) Department of Radiation Oncology, Stanford University Medical Center, Stanford, Ca, USA (2) Department of Neurosurgery, Stanford University Medical Center, Stanford, Ca, USA

Objectives: Onyx, an intravascular glue containing tantalum, can decrease the size of intracranial AVMs before radiosurgical treatment. The high-Z tantalum, however, may cause dose calculation errors. We sought to evaluate the effect of beam attenuation on CyberKnife treatment planning by using various density calculations and directly measuring incident dose in a phantom containing a model closely simulating an Onyx treated AVM.

Methods: The ball-cube insert of standard head phantom was replaced with a machined Lucite form containing a cylindrical cavity, 2.54 cm in diameter and 2.54 cm in length. The 12.86 cc cavity was loaded with either ground beef, or ground beef containing various concentrations of Onyx, to simulate untreated and treated AVMs. The long axis of the cylinder was oriented in the A-P direction within the phantom and either Gafchromic EBT2 film or thermoluminescent dosimeters (TLDs), with a tested accuracy of at least $\pm 3\%$, were placed in the cylinder's mid-sagittal plane. Treatment was simulated and planned using various Onyx glue/tantalum concentrations and different CyberKnife/Multiplan density models with a ray-tracing algorithm. A calculated, highly homogenous dose of 400 cGy was delivered and actual incident dose was measured using film or TLDs. Data supplied by the manufacturer would indicate that AVMs treated with moderate volumes of Onyx would contain approximately 6.1% weight/volume of tantalum.

Results: When the phantom was loaded with beef without Onyx, the calculated doses, using both the water/air and body standard density models, the measured dose was accurate to within $\pm 3\%$ of the calculated dose. When the phantom was loaded with a beef/Onyx mixture, containing a 6.1% weight/volume of tantalum, the measured dose using water/air density model correlated within an accuracy of $\pm 3\%$. Using the body standard density model, and automatically calculated electron densities the measured dose was approximately 10% lower than the calculated dose. By manually overriding the automatically calculated density of the Onyx-containing volume with different relative electron densities (from 1.03 to 2.23), the measured dose varied from 2% to 9% greater than that of the calculated dose.

Conclusions: The water/air density model in the CyberKnife/Multiplan treatment planning system showed the best agreement between the calculated and the measured doses in the Onyx-containing volume. The actual attenuation due to moderate concentrations of Onyx was less than

that calculated using CT density data. We recommend using an air/water model without density correction when treating Onyx treated AVMs containing moderate quantities of the tantalum containing glue.

10:30 - 11:30 ORAL SESSION

OS18 VASCULAR 2 – ARTERIOVENOUS MALFORMATIONS
MULTIMODALITY & ALTERNATIVE APPROACHES

Room: Auditorium

OS18-5 *LARGE INOPERABLE AVMS TREATED WITH HIPOFRACTIONATED STEREOTACTIC
RADIOSURGERY. EXPERIENCE AT A SINGULAR INSTITUTION.*

Jose Emilio Suarez¹

(1) INNN Mexico, Radiosurgery Unit, Mexico, Mexico

Introduction: Large AVMs remains a controversial problem in daily practice. Medical options must consider sometimes economic aspect considering the cost of embolization or surgery.

Methods: We evaluate 69 patients with a large AVMs considered not candidates for surgery or conventional single dose of radiosurgery, or embolization. All patients diagnosed with conventional angiography, 3T MRI, and contrast CT. The vascular panel decided the treatment with the protocol of fractionated radiosurgery after careful evaluation.

Results: We treated 69 patients, 32 male 37 female with large AVMs, with an average of 36 cc volume. And an average follow up of 37 months. The doses ranged from 35-42 Gy to the 90% isodose line. The fractionation in 5 fractions in 74%, and 6 fractions in 16% 10% received 7 fractions, same dose.

Results: We found that the initial symptoms: headache 79%, epilepsy 21%, past surgery 11%, embolization in 28% CVA in 29%. 54.5% with a decrease in the volume, in the follow up, no bleeding episodes were observed. No complications related were present.

Conclusions: Hypofractionated radiosurgery is a feasible treatment for those not suitable for surgery. The patient is treated in a comfortable fashion with no complications. Longer period of follow up are necessary to evaluate occlusion rate.

14:00 - 15:00 ORAL SESSION

OS 19 SPINE 1

Room: La Seine

OS19-1 *PERSONAL EXPERIENCES OF 428 SPINAL LESIONS TREATED WITH
MICROSURGERY AND/OR RADIOSURGERY*

Hiroshi Inoue¹ Akihiko Nozaki² Kenichi Seto²

(1) Institute of Neural Organization, Fujioka, Japan (2) Kanto Neurosurgical Hospital, Kumagaya, Japan

Objective: Radiosurgery is an established powerful tool for many pathological lesions such as benign tumors, malignant tumors, vascular malformations and functional disorders. Lesions in eloquent areas are good indication for radiosurgery in order to preserve important functions. Benefits of radiosurgery for spinal lesions are evaluated from personal experiences of microsurgery and radiosurgery.

Methods: Microsurgery was indicated for patients with tumors and vascular lesions in accessible areas without damages of spinal functions, and pathology not suitable for radiosurgery. Patients with progressing symptoms were also indicated for direct surgery. Radiosurgery (single or multisession) was used for patients with surgical risks and for functional preservation. Benign lesions were intended to cover with 50-70% isodose of lower marginal doses and malignant lesions with 60-80% isodose of higher marginal doses. Some patients were intended to treat with combination of microsurgery and radiosurgery.

Results: Three hundred and twenty eight lesions were treated with microsurgery. Tumors occupied in 15.9%, vascular lesions 4%, degenerative disorders 54%, and anomalies 26%. Most symptoms were improved or disappeared immediately after surgery. However, complications such as spinal cord dysfunctions, CSF leakage, wound infections, and spinal column dysfunctions were found in small numbers of patients. One hundred lesions were treated with radiosurgery. All were tumors or vascular lesions. Extradural metastases occupied in 51%, intradural extramedullary tumors 19%, intramedullary tumors 19%, vascular lesions 8%, and others 3%. Pain due to metastases diminished or disappeared shortly after radiosurgery. Paresis and sensory disturbances were improved or stable in most patients. Most malignant tumors decreased in size and benign tumors were stable in short term follow-up to 5 years. Dural AVF was disappeared one year after treatment. No adverse effects found up to date. In combination treatment, functional restoration was obtained in patients with intradural lesions.

Conclusions: Radiosurgery is safe and effective treatment for spinal tumors and vascular lesions. Pain relief is obtained shortly after treatment and functional restoration is also possible. However, long term follow-up is required for evaluation of adverse effects on spinal cord, especially for patients with benign lesions. Combination with microsurgery may increase treatment indications of spinal lesions and decrease complications for patients with surgical risks.

14:00 - 15:00 ORAL SESSION

OS 19 SPINE 1

Room: La Seine

OS19-2 CYBERKNIFE FRAMELESS REAL-TIME IMAGE GUIDED STEREOTACTIC
RADIOLOGY FOR THE TREATMENT OF SPINAL LESIONS

Alex Muacevic¹ Markus Kufeld¹ Christoph Fuerweger¹ Berndt Wowra¹ Joerg-christian Tonn²

(1) Cyberknife Center , Munich, Germany (2) University of Munich Hospitals, Munich, Germany

Objective: The role of cranial radiosurgery is well established. Its use for the treatment of spinal lesions has been limited by the availability of effective target-immobilizing devices. The Cyberknife (Accuray, Sunnyvale, CA, USA) is an image guided frameless stereotactic radiosurgery system that

allows for the radiosurgical treatment of spinal lesions. This study evaluated the feasibility and effectiveness of the treatment of spinal lesions with a single fraction radiosurgical technique.

Methods: The Cyberknife system uses the coupling of an orthogonal pair of X-ray cameras to a dynamically manipulated robot-mounted linear accelerator with six degrees of freedom that guides the therapy beam to the intended target without the use of frame-based fixation. Real time imaging allows the tracking of patient movements. Lesions were tracked by bony landmarks without any implanted fiducials. In this prospective cohort evaluation of spine radiosurgery technique, 408 spinal treatments in 337 consecutive patients (265 malignant, 63 benign, 9 vascular lesions) were treated with single fraction radiosurgery technique. All dose plans were calculated on the basis of computed tomographic images acquired from 1.5-mm slices and 1 mm MRI sequences with an inverse treatment planning technique.

Results: The mean follow up time was 14.3 months (range 1 → 54 months). Local control after 12, 24 and 36 months was 97%, 91% and 87%, respectively. Median tumor volume was 21 ccm. 117 patients had received conventional external beam irradiation before radiosurgery. Spinal tracking was also possible after transpedicular screw fixation. Median prescribed tumor dose was 19 Gy (range 12 → 25 Gy) to the 70% isodose line. The overall complication rate was 5% (nausea 4, pain 4, bleeding 1, instability 6, myelopathy 2 patients).

Conclusions: Spinal Cyberknife radiosurgery is a new, safe and effective outpatient treatment method for selected patients with spinal tumors. This technique offers a successful therapeutic modality as a primary treatment, for lesions not amenable to open surgical techniques, in medically inoperable patients, in lesions located in previously irradiated sites, or as an adjunct to multidisciplinary treatment concepts.

14:00 - 15:00 ORAL SESSION

OS 19 SPINE 1

Room: La Seine

OS19-3 INTRADURAL, EXTRAMEDULLARY SPINAL LESIONS. FIVE YEARS, SINGLE-INSTITUTION RADIOSURGERY EXPERIENCE.

Marcello Marchetti¹ Ida Milanese¹ Livia C. Bianchi² Achille Bergantin² Angelo Franzini¹ Sergio Giombini¹ Giovanni Broggi¹ Carlo Lazaro Solero¹ Laura Fariselli^{1, 2}

(1) Dept. of Neurosurgery, Fond. IRCCS Istituto Neurologico "C. Besta", Milano, Italy (2) Centro Diagnostico Italiano (CDI), Milano, Italy

Introduction: At the state of art, surgery represents the first choice treatments for spinal, intradural lesions. The more recent advance in radiosurgery technology made possible treatments also in proximity of radiosensitive structures such as the spinal cord. In this study we report about our own radiosurgery experience in treatment of benign intradural, extramedullary tumours of the spine.

Materials and methods: In this study we analyzed the 32 benign intradural, extramedullary lesions with a minimum follow-up period of 12 months. Five cases were associated to fibromatosis type 1 or 2. The lesions included 19 meningiomas, 11 schwannomas, 1 neurofibroma and 1 paraganglioma. Treatments planning were always CT based (1.25 mm thickness). CT and MR

images were fused to better define the target volume and the critical structures. Planning Tumour Volume (PTV) was defined as the radiographic tumour volume with no margin. All patients were clinically and radiologically evaluated before and after treatment (every 6 months during the first two years and thereafter once per year).

Results: The mean follow up was 38 months (range 12-78, median 36 months). All patients well tolerated the procedures. The mean tumour volume was 10,3 cc (range: 0,2-138 cc, median 2,3 cc). Twelve patients underwent a single fraction treatment, the total dose to the target ranged from 10 to 15 Gy (average: 12.3 Gy) to the 70-80 %. All the others received a hypofractionated radiotherapy treatment (4 to 6 fractions) with a prescribed dose ranging from 14 to 30 Gy (average 22 Gy). The maximum dose to the spinal cord ranged from 9 to 26 Gy. Although these are only preliminary Results, during all the follow-up period, no lesion showed a radiological evidence of progression. Neurological conditions were preserved or improved. No permanent sequelae were registered. A significantly and durable pain relief (where present) was observed.

Nevertheless the present study also underlined an improvement in the quality of life (QoL).

Conclusions: Spinal frameless stereotactic radiosurgery was found to be both safe and effective for extra-axial, spinal lesions. Although surgical excision remains the primary treatment option for most intradural tumours, CyberKnife offers a true alternative therapeutic modality for such lesions, especially in case of recurrent and residual lesions or when surgery is contraindicated.

14:00 - 15:00 ORAL SESSION

OS 19 SPINE 1

Room: La Seine

OS19-4 *PROSPECTIVE EVALUATION OF SPINAL CORD AND CAUDA EQUINA DOSE CONSTRAINTS AND TOXICITY USING THE ELEKTA SYNERGY S FOR SPINE RADIOSURGERY*

John Flickinger¹ Josef Novotny¹ Mubina Quader¹
(1) University of Pittsburgh Medical Center, Pittsburgh, United States

Objective: Our center began a dedicated spine radiosurgery program that utilized cone beam computed tomography (CBCT) image guidance technology for target localization. This study prospectively evaluated the spinal cord and cauda equina doses received during single fraction spine radiosurgery treatments in order to determine a safety profile for this technique.

Methods: One hundred seventy-nine spine lesions were treated using the Elekta Synergy S 6-MV linear accelerator with a beam modulator and CBCT image guidance combined with a HexaPOD couch that allows patient positioning correction in 3 translational and 3 rotational directions. Lesion location included 29 cervical, 76 thoracic, 52 lumbar, and 22 sacral. There were 146 malignant and 33 benign lesions. Twenty-nine lesions (16%) were intradural. One hundred twelve lesions (63%) had received prior conventional fractionated radiotherapy. Radiosurgery was used as a primary treatment modality in 47 cases (26%), for radiographic progression after prior conventional radiotherapy in 91 cases (51%), and adjuvant post-surgery therapy in 41 cases (23%). For each case, the maximum point dose to the spinal cord and/or cauda equina as well as the volume of

those structures receiving greater than 8, 10, and 12 Gy were recorded.

Results: No subacute or long term spinal cord or cauda equina toxicity occurred during the follow-up period (median 21 months). For cases at the level of the spinal cord (105 cases) the mean prescribed dose to the gross tumor volume (GTV) was 14 Gy (range 11-18 Gy). The GTV ranged from 0.37 to 100.24 cm3 (mean 26.1 cm3). The mean maximum point dose to the spinal cord was 10 Gy (range 4-12 Gy), and the mean spinal cord volumes (cm3) receiving greater than 8, 10, and 12 Gy were 0.76 (0-3.45), 0.05 (0-.42), and 0.0, respectively. For cases at the level of the cauda equina (74 cases) the mean prescribed dose to the GTV was 15 Gy (range 10-20 Gy). The GTV ranged from 0.19 to 491.6 cm3 (mean 73.8 cm3). The mean maximum point dose to the cauda equina was 11 Gy (range 5-14 Gy), and the mean cauda equina volumes (cm3) receiving greater than 8, 10, and 12 Gy were 1.4 (0-6.68), 0.26 (0-2.99), and 0.02 (0-.39), respectively.

Conclusions: This study demonstrated that limiting the spinal cord dose to 10 Gy and the cauda equina dose to 11 Gy can be achieved with therapeutic GTV prescription doses for single fraction spine radiosurgery using CBCT guidance. Such dose constraints are associated with both a safe and effective clinical outcome.

14:00 - 15:00 ORAL SESSION

OS 19 SPINE 1

Room: La Seine

OS19-5 *INTRAMEDULLARY SPINAL CORD METASTASES TREATED WITH CYBERKNIFE
RADIOSURGERY: A REPORT OF TEN CASES, A REVIEW OF THE LITERATURE, AND
TREATMENT RECOMMENDATIONS*

Robert Lieberman¹ John Adler¹ Scott Soltys² Iris Gibbs² Steven Chang¹ Steven Chang¹

(1) Stanford University, Department of Neurosurgery, Stanford, Ca, United States (2) Stanford University, Department of Radiation Oncology, Stanford, Ca, United States

Object: Intramedullary spinal cord metastases are uncommon and difficult to treat with surgery or conventional radiotherapy. CyberKnife Stereotactic Radiosurgery (SRS) has been proven effective in the treatment of intraparenchymal brain metastases and a variety of spinal lesions. We sought to determine the safety and efficacy of SRS for spinal cord intramedullary metastases (SCIMs).

Methods: Ten patients with eleven SCIMs were treated with CyberKnife, at Stanford, between 2000 and 2010. With IRB approval, we reviewed their charts for clinical condition, pathological diagnosis, treatment parameters, and outcome. When necessary, we obtained additional information from surviving family members, primary care doctors, or referring doctors.

Results: Patients ranged in age from 39 to 77 years (median 66, SD 15) at the time of treatment. Included were seven women and three men. Tumors ranged in size from 0.12 to 1.98 cc (median 0.39, SD 0.62). Five had metastases from breast, 2 from non-small cell lung cancers, 1 from prostate, 1 of germ cell origin, and 1 from an epithelioid hemangioepithelioma. All presented with multiple other lesions and significant neurological deficits (all CTCAE Grade 3). We delivered doses ranging from 14 to 27 Gy (median 21, SD 4.2) in 2 to 5 (median 3.0, SD 0.9) sessions. Complete follow-up was available for all ten. Three patients remain alive 1.8, 2.2, and 6.0 months after

therapy. Of the seven deceased patients, survival ranged from 2.2 to 27.2 months (median 5.4, SD 8.9). No local recurrences were observed, pre-treatment neurological deficits did not worsen, and there were no complications related to treatment.

Conclusions: This is the largest reported series of patients treated with CyberKnife for SCIMs. Although our patients presented with multiple metastases, and although overall survival was poor, we saw no clinical evidence of local recurrences or treatment related complications. We believe SRS to be safe in this group. Since SRS requires fewer sessions than conventional radiation therapy, and has less acute morbidity than open surgery, we feel that SRS can be an option for the palliative treatment of intramedullary spinal cord metastases.

14:00 - 15:00 ORAL SESSION

OS20 RADIOSURGERY GENERAL

Room: *Miles Davis*

OS20-1 *THE PATIENTS TOLERANCE AND PERSPECTIVE OF A STEREOTACTIC
RADIOSURGERY PROCEDURE*

Smee R¹ Williams J¹ Schneider M¹

(1) Department of Radiation Oncology, The Prince of Wales Cancer Centre, High St, Randwick, Sydney, Australia

Objectives: All medical procedures can have an impact upon the patient. This review will explore the patients tolerance of the procedure of Stereotactic Radiosurgery (SRS).

Methods: All patients with a good command of English who were going to have SRS for an appropriate intracranial condition were invited to participate in this Ethics approved prospective study evaluating the patients reaction to the Radiosurgery procedure. There were 3 phases to the study, each phase involved determining a point on a linear analogue scale as to their reaction to a specific question assessing their physical and emotional (thus quality of life) status at 24 hours, 7 days and 12 weeks post SRS. All questionnaires were filled away from the department, 2 stamp addressed envelopes were provided for responses. Participation of all patients at the 3 time points was encouraged, with all data entered onto an SPSS database for statistical interpretation.

Results: Between March 2005 - October 2010, 506 patients were enrolled on to the study with 347 patients completing all 3 diaries. 24 hours following the SRS, of the 347 patients, 65% had headaches, 43% were having some difficulty in concentrating, 33% had nausea, 37% felt miserable and 90% had fatigue. 99% of patients felt that the SRS team was supportive on the day of their procedure. By 12 weeks post SRS 76% of patients were still experiencing some level of fatigue, headaches still in 56% and 60% were still having trouble concentrating or had some loss of balance. In most parameters there was a progressive improvement over time. From October 2008, pre-treatment fatigue status was included at recruitment phase, thus from October 2008 to July 2010, 69 (44%) had no pre treatment feeling of fatigue, 55 (35.3%) experienced mild fatigue and 32 (20%) due to concurrent medical conditions or advanced age noted moderate to severe fatigue levels.

Conclusion: In the largest series assessing the patients perception over time of a Stereotactic Radiosurgery procedure, there was a high incidence of feeling unwell immediately following the procedure, which slowly but incompletely improves over time.

14:00 - 15:00 ORAL SESSION

OS20 **RADIOSURGERY GENERAL**

Room: Miles Davis

OS20-2 **STEREOTACTIC RADIOSURGERY: THE ROLE OF SAFETY AND THE RADIATION THERAPIST**

Robyn Walker¹ Fang-fang Yin¹ John Kirkpatrick¹

(1) Duke University Radiation Oncology, Durham, USA

Radiation therapists are on the frontline in the battle against cancer. They are also closest to the patient during treatment, performing a key role in ensuring patient safety and intervening if something goes wrong. Rigorous safety practices and policies help them treat with confidence. Safe and effective treatment has always been a guiding principle of oncology, and efforts have redoubled to improve radiation treatment safety. Although everyone is responsible for patient safety, radiation therapists are the final element in a comprehensive system. They perform the final checks before beam-on and, therefore, carry a special weight of responsibility. Radiation therapists must have safety procedures and routines in place so they can treat with confidence in a safe environment.

The Department of Radiation Oncology at Duke University Hospital has an environment of safety built on the pillars of accountability, communication and consistency. These principles are enacted in specific policies, checklists and practices. Radiation therapy is steadily improving in the ability to control and cure cancer. Throughout this presentation, specific focus will be given to safety and quality assurance for special procedures on the Novalis Tx such as Stereotactic Radiosurgery. With single fraction, high dose treatment becoming the standard of care, safety and quality assurance is of utmost importance. Duke has incorporated practices such as a sterile treatment zone and time out procedure to ensure accurate treatment. Individualized checklists have been designed as part of the electronic medical record as a check and balance for verification of treatment. As the technology becomes more complex, safety cannot be taken for granted. Patient safety requires constant vigilance and continual learning, because once the dose is given, it can not be taken back.

14:00 - 15:00 ORAL SESSION

OS20 **RADIOSURGERY GENERAL**

Room: Miles Davis

OS20-3 **MULTISESSION STEREOTACTIC RADIOSURGERY FOR LARGE BRAIN TUMORS OF >3CM**

Azhar Rashid¹ Muhammad Abid Saleem¹ A Sattar M Hashim¹

(1) Pakistan Gamma Knife & Stereotactic Radiosurgery Center, Karachi, Pakistan

Background: Single session Intracranial stereotactic radiosurgery (SRS) is now the full or is the part of treatment for most of the benign and malignant brain tumors having size of 3 cm or less than 3 cm. Clinical dilemma comes in, when the size of the lesion is >3cm and surgery is not possible;

either the tumor is surgically inoperable, medically inoperable, or patient refuses surgery, then single session SRS is not the feasible option because of increased normal tissue toxicity. Multisession stereotactic radiosurgery is the suitable answer to lower down the normal tissue toxicity without compromising the therapeutic benefits.

Objective: To evaluate the feasibility of linear accelerator based multisession stereotactic radiosurgery for large brain tumors of >3cm.

Methods: From 15.06.2009 to 15.08.2010, fifty brain lesions of >3cm were treated by multisession stereotactic radiosurgery with the help of a modern linear accelerator (Synergy-S, ELEKTA: Crawley UK) having micro multileaf collimators, on board imager: cone beam CT (CBCT) and robotic couch. 24 (48 %) were male and 26 (52 %) were females. Mean age was 36.5 years SD \pm 18.79. Five (10 %) patients were of pituitary adenoma, 7 (14 %) were of meningioma, 13 (26 %) were low grade gliomas, 14 (28 %) were of high grade gliomas, 7 (14 %) were other pathologies. Median target volume was 145.7 cm³ (range: 15.9- 718.2 cm³). Up to 5 fractions were used in most of the cases. Acute CNS toxicity was noted up to 6 weeks from the end of SRT and late CNS toxicity was observed at 6 months.

Results: All the patients tolerated treatment very well. No acute toxicity occurred in 46 (92%) of the patients. Two (4 %) patients had grade II acute toxicity and two (4 %) had Grade III acute toxicity. 29 (58 %) patients had no late toxicity at 6 months. Late toxicity was not documented in 14 (28%) patients who had follow-up less than 6 months. 7 (14 %) patients were dead till 6 months. 43 (86 %) patients were alive at the time of analysis. Radiologically, 11 (22%) patients achieved partial response, 32 (64 %) patients were having stable disease and overall control rate was found to be 86 %, progression of disease was documented in 7 (14%) patients. Out of 7 (14%) dead patients, 2 (4 %) were dead because of progression of disease and five (10%) were dead because of other medical causes. Median follow-up time from the end of SRS was 128.5 days (range: 30-407 days).

Conclusion: Linear accelerator based multisession stereotactic radiosurgery for large brain tumors of >3cm is effective and well tolerated.

14:00 - 15:00 ORAL SESSION

OS20 RADIOLOGY GENERAL

Room: Miles Davis

OS20-4 GAMMA KNIFE RADIOSURGERY FOR PATIENTS MORE THAN 80 YEARS OLD

Hidefumi Jokura¹ Jun Kawagishi¹ Kazuyuki Sugai¹ Kou Takahashi¹

(1) Jiro Suzuki Memorial Gamma House, Furukawa Seiryō Hospital, Osaka, Japan

The Japanese have known to have one of the longest life span in the world. The Life expectancy of male and female at the age of 80 are 8.7 and 11.7 years respectively. Without the need of general anesthesia and craniotomy, Gamma Knife radiosurgery (GKRS) can be applied regardless of patient condition including age. In this paper we analyzed our experience of GKRS for patients more than 80 years old.

Between November 1991 and May 2010, 5420 patients had been treated at our site. In which, 228 patients including 174 patients with metastases (6.5% of the total number of metastasis), 20

meningioma (3.9%), 18 trigeminal neuralgia (36.2%), 8 vestibular schwannoma (1.4%), 2 AVM (0.3%), 2 pituitary adenomas (0.6%) and 4 patients with other pathologies are more than 80 years old at the time of first GKRS. The treatment Results of metastases, meningioma, trigeminal neuralgias and vestibular schwannoma are summarized.

Metastasis: median survival after GKRS was 9.0 months and shorter than that of younger patients, but there was no statistical significance. Meningioma: Growth of the tumors had been confirmed all but one patient with symptomatic trigeminal neuralgia before GKRS. Average follow up period was 48.5 (2-111) month and during the follow up only one patient died of senility at the age of 91. All the tumors were smaller or stable at the time of last follow up without new neurological deficit. Trigeminal neuralgia: Average follow up was 46.9 (1.6-120) months and average age at the last follow up was 89.9 years old. No pain with or without medication was attained in 68.8% and adequate control with medication was attained another 18.7%. Trigeminal neuropathy was observed in 18.8%. Vestibular schwannoma: Average follow up period was 73.8 months. No patient died during the follow up period and average age at the last follow up was 88.2 (82.6-98) years old. Ventriculo-peritoneal shunts were needed before GKRS in 2 patients (25%). All the tumors were controlled at the last follow up.

GKRS for the patients more than 80 years old provides same efficacy compared to that for younger patients. We see no complication unique to this age group.

14:00 - 15:00 ORAL SESSION

OS20 RADIOSURGERY GENERAL

Room: Miles Davis

OS20-5 GAMMA KNIFE RADIOSURGERY FOR INTRACRANIAL TUMORS OF PATIENTS WITH FAMILIAL NEOPLASTIC SYNDROMES: NEUROFIBROMATOSIS 2 AND VON HIPPEL-LINDAU

Elena Kusak¹ Nuria Martínez¹ Jorge Gutiérrez¹ Germán Rey¹ Roberto Martínez¹

(1) Gamma Unit. Hospital Ruber Internacional, Madrid, Spain

Introduction: Abnormalities in tumor suppressor genes condition certain tumor prone diseases with successive surgical treatments being a major cause of morbidity and mortality. Neurofibromatosis type 2 (NF2) presents with simultaneous or consecutive development of meningiomas or schwannomas. Bilateral VIII vestibular schwannomas is characteristic. Hemangioblastomas (HGBs) are distinctive of von Hippel-Lindau (vHL) disease. Radiosurgery has become an alternative to repeated surgeries, although concern has been raised in relation to the potential oncogenic effect of radiotherapy.

Objective: The analysis of our Results and those published of Gamma Knife Radiosurgery for intracranial tumors in these patients.

Method: Between 2004 and 2008, 70 treatments in 33 NF2 patients have been performed. Two thirds were females. The mean age was 36.5 years. Forty patients had previous surgery and 22 had received radiotherapy. The mean number of treated lesions in one procedure was 3.9 with a mean marginal dose of 12.7 Gy and a mean volume of 10.4 cm³. One third of patients had a

known family history.

Between 1994 and 2010, 18 treatments for HGBs in 14 patients (7males/7females) with a total of 40 HGBs have been performed. The mean age was 37.4 years. The mean marginal dose was 13.9 Gy, with a mean prescription isodose of 59.4% and a mean treated volume of 4.4 cm³. Six patients had a VHL diagnosis.

Results: In NF2, the mean follow-up has been 4 years, with 20% of patients followed for more than 5 years. The local volumetric control was obtained in 72.8% of cases with reduction in 31%. One hundred and forty nine meningiomas and 62 schwannomas were treated. In 15 cases the treated lesions grew (12 schwannomas and 3 meningiomas). Clinically 28 patients remain stable, in 5 their symptoms improved. Hearing worsened in 11 cases. Three patients died due to progression of NF2. In HGBs the mean follow-up has been 4 years. Local volumetric control was obtained in all but three patients. In all VHL patients other location HGBs appeared during follow-up.

Conclusions: Gamma Knife radiosurgery is an effective option to surgery in the treatment of these patients, especially those with unresectable tumors or with contraindications for new surgical procedures. Due to the genetic condition of these diseases, any therapeutic decision must be evaluated individually. This treatment must be used in those patients with lesions with evident growth or with progressive symptoms, when surgery is not a safe option in an NF2 or VHL experienced neurosurgical unit.

14:00 - 15:00 ORAL SESSION

OS21 OTHER SKULL BASE LESIONS 1

Room: Auditorium

OS21-1 EXCELLENT LONG TERM RESULTS: OF GAMMA KNIFE RADIOSURGERY FOR GLOMUS JUGULARE

Laurie Blach¹ Coy Sammie¹ Bortolletto Pietro¹ Amendola Beatrice¹ Kleinberg Lawrence² Wolf Aizik¹

(1) Miami Neuroscience Center at Doctor's Hospital of Baptist Health Systems, Coral Gables, United States (2) Department of Radiation Oncology, The Johns Hopkins University School of Medicine, Baltimore, United States

Purpose: Gamma Knife Radiosurgery (GKS) is advocated as an alternative to microsurgical resection of Glomus Jugulare. The purpose of this study is to report our long-term Results of GKS for Glomus Jugulare.

Methods: We prospectively collected clinical and demographic data on patients treated with GKS for Glomus Jugulare at a single institution between 1995 and 2009. Patients were interviewed for development of new clinical symptoms and yearly MRI scans were reviewed to evaluate for progression of disease.

Results: 18 patients received GKS for Glomus Jugulare. 19 treatments were given to those 18 patients. There were 16 females treated and 2 males. Median age of patients at the time of first GKS is 60 years (range: 14-83 years). All of the patients presented with at least one cranial nerve deficit. Two patients underwent prior external beam radiotherapy (EBRT) and three patients were treated with GKS after initial surgery. One patient was treated with EBRT, surgery and initial GKS

prior to the GKS delivered at our institution. One patient was treated in a staged fashion. Five patients were lost to follow up.

GKS was delivered for Glomus Jugulare with a mean volume of 13.7 cc (range: 0.1- 40.0cc). The mean treatment time was 1hr 15 minutes (range: 9 min - 3hr 54 minutes) with an average of 7.4 (range: 1-19) isocenter shots utilized.

With median follow up of 64.0 months (range: 11.9-169.1 months), all patients are without radiographic evidence of progression of disease. None of the patients developed complications of GKS. Of the 13 patients with follow up, none reported development of new or progressive cranial nerve deficits.

Conclusions: This data confirms that Gamma Knife Radiosurgery is an excellent treatment for Glomus Jugulare with high long-term local control without significant risk of complications. We continue to follow these patients for very long term outcome data. Gamma Knife Radiosurgery should be considered as an alternative treatment of Glomus Jugularae to surgical resection as local control is maintained and the morbidity profile of this approach remains low.

14:00 - 15:00 ORAL SESSION

OS21 OTHER SKULL BASE LESIONS 1

Room: Auditorium

OS21-2 SINGLE AND MULTI-SESSION RADIOSURGERY A USEFUL TREATMENT OPTION FOR THE PARANGLIOMAS OF HEAD & NECK. SINGLE INSTITUTION 5 YEARS EXPERIENCE

Livia C. Bianchi¹ Marcello Marchetti¹ Ida Milanese¹ Achille Bergantin² Giovanni Broggi¹ Carlo L. Solero¹ Laura Fariselli¹, ²

(1) Dept of Neurosurgery, Fondazione IRCCS Istituto Neurologico C Besta, Milano, Italy (2) Centro Diagnostico Italiano (CDI), Milano, Italy

Introduction: Parangliomas are highly vascular and predominantly benign neoplasms that have traditionally been treated by surgery, embolization and/or external beam radiotherapy (EBRT). The aim of this study was to evaluate the short-term local tumour control and safety of CyberKnife radiosurgery for these lesions.

Materials and methods: In the period between August 2004 and September 2009 twelve patients, eleven with jugular glomus paragangliomas and one with a carotid body paraganglioma, were treated. The mean age at the treatment time was 54 years (range 23-85 years). Ten out of the twelve patients were female and just two were male. The target contouring was performed on merged CT and MR images. PTV was defined as the tumour volume without margins. The target volume ranged from 1,4 to 25 cc (average 8,9 cc; median 6,6 cc)

Nine patients were treated with a mean dose of 12,4 Gy (range 11-13 Gy) in a single fraction. Three patients were treated with a mean dose of 26,3 Gy (range 24-30 Gy) in 3 to 6 fractions. The mean prescribed isodose line was the 79%.

Results: The procedure was tolerated well by all the patients. The mean follow-up period was 47,4 months (range 13-74 months). One patient died from unrelated causes. There were no local

recurrences. All the twelve patients also demonstrated neurological stability or improvement. No cranial nerve palsies have arisen, nor has deterioration beyond baseline been observed.

Conclusion: Single and multi-session radiosurgery appears to be both safe and effective in the treatment of skull base paragangliomas. Preliminary Results were quite promising. Determining both the real growth control and the late toxicity rate will require further investigation.

14:00 - 15:00 ORAL SESSION

OS21 OTHER SKULL BASE LESIONS 1

Room: Auditorium

OS21-3 GAMMA- KNIFE RADIOSURGERY FOR CRANIAL BASE PARANGLIOMAS

Marisa Gandía¹, ² Elena Kusak¹ Nuria Martínez¹ Jorge Gutiérrez¹ Germán Rey¹ Roberto Martínez¹

(1) Gamma Unit. Hospital Ruber Internacional, Madrid, Spain (2) Neurosurgery H. U. La Paz, Madrid, Spain

Introduction: Paragangliomas are highly vascular neuroendocrine tumors, usually benign and well encapsulated. In their cranial base location microsurgery is associated to high morbidity (50%-80%) especially in relation to low cranial nerve damage.

Materials and methods: We present a series of 57 patients bearing cranial base paragangliomas treated with Gamma Knife radiosurgery from February 1995 to January 2010. Forty seven patients with a follow up exceeding 2 years are analyzed in detail. There were 15 males and 32 females, with a mean age of 53,7 years (range 19,9 - 82,3). In 31 cases there was a neuroimaging diagnosis exclusively, the other 16 had been operated on and had a pathological confirmed diagnosis. In the surgical group 3 patients had their lesions previously embolized, and 2 had received fractionated radiotherapy while in the nonsurgical group 5 had received endovascular treatment and 1 had fractionated radiotherapy.

At the time of treatment 6 % of the operated patients were asymptomatic, 81% and 94% had low cranial nerve and VIII cranial nerve deficits respectively. In the nonsurgical group 3% were asymptomatic, with low cranial nerve involvement in 74%, and 71 % and 23% with VIII and V, VI or VII cranial nerve deficits respectively.

The mean tumor volume was 14.2 cm³ (1.4-62.2 cm³), with a mean marginal dose of 13,6 Gy (12-15 Gy) and maximal doses between 20 and 55 Gy.

Results: Mean follow-up was 65.5 months (12-175). Volumetric control was obtained in 93.6% (reduction in 68.1% and stable in 25.5%). In three cases (6.4%) tumors progressed. The volumetric reduction ranged from 0.75cm³ (5%) to 15.55cm³ 60% (mean 5.6 cm³, median 3.4 cm³). No clinical complications were observed.

Conclusions: Gamma- Knife radiosurgery is an effective, safe and efficient therapeutic option in the treatment of these tumors, as a first line treatment or associated to surgery, endovascular treatment and/or conventional fractionated radiotherapy.

14:00 - 15:00 ORAL SESSION

OS21 OTHER SKULL BASE LESIONS 1

Room: Auditorium

OS21-4 LONG TERM RESULTS OF GAMMA KNIFE RADIOSURGERY FOR TREATMENT OF INTRACRANIAL GLOMUS JUGULARE TUMORS

Khalid Abdelkarim^{1, 2} Wael Reda^{1, 3} Amr El Shehaby^{1, 3}

(1) Gamma Knife Center, Nasser Institute, Cairo, Egypt (2) Clinical Oncology Department, Ain Shams University, Cairo, Egypt (3) Neurosurgery Department, Ain Shams University, Cairo, Egypt

Introduction: Glomus Jugulare tumors are benign but locally aggressive ones that represent a therapeutic challenge. Previous studies about the use of Gamma Knife Radiosurgery (GRS) in those tumors have documented good Results that needed larger number of patients and longer follow up periods to be confirmed.

Patients and Methods: Out of 1830 patients treated in the Gamma Knife Center, Cairo between August 2001 and November 2008, 30 patients had glomus jugulare tumors; the data of 26 of them were evaluable. They were 16 females and 10 males, five of them were previously operated, 2 were partially embolized, and 19 had gamma knife as their primary treatment. All the tumors were Fisch Type D except for one Fisch type C and the mean volume was 12.5 cm³ (range 3.7 to 28.4 cm³). The mean prescription dose was 14.5 Gy (range 12 to 18 Gy); while the mean isodose was 44.9% (range 30% to 50%).

Results: The mean follow up period was 59 months (range 24 to 105 months), and by the time of the data analysis, two of the patients were dead (66 and 24 months after GK treatment). None of the tumors continued to grow (100% control rate). Ten tumors became smaller and 16 were unchanged. The symptoms improved in 16 patients, were stable in nine, and worsened in one patient who developed a transient facial palsy. Only six patients had serviceable hearing before the GKR, all of them kept that hearing throughout the follow up period. Symptomatic improvement began before any reduction in tumor volume could be detected, where the mean time to clinical improvement was 6.5 months whereas the mean time to tumor shrinkage was 17.5 months.

Conclusions: This study about the long term follow up of the GKR for the intracranial glomus jugulare tumors confirmed that this is a highly effective and safe treatment. This data shows that the clinical improvement is not correlated with the radiological volume reduction.

Key words: Glomus jugulare tumor, radiosurgery, gamma knife, tumor volume.

14:00 - 15:00 ORAL SESSION

OS21 OTHER SKULL BASE LESIONS 1

Room: Auditorium

OS21-5 GAMMA KNIFE RADIOSURGERY FOR CAVERNOUS SINUS HEMANGIOMAS

Dong Gyu Kim¹ Sang Woo Song¹ Hyun-tai Chung¹ Sun Ha Paek¹ Jung Ho Han² Yong HwY Kim¹ Jin Wook Kim¹ Jung Hun Park² Young-hoon Kim¹

(1) Seoul National University College of Medicine, Department of Neurosurgery, Seoul, Korea, Republic of (2) Seoul National University Bundang Hospital, Department of Neurosurgery, Gyeonggi-do, Korea, Republic of

Objective: Cavernous sinus hemangiomas are rare vascular tumors of cavernous sinus. Microsurgical removal of these neoplasms may be extremely difficult due to massive intraoperative bleeding and possible neurologic deficit. Radiosurgery has emerged as a treatment alternative to microsurgery. We described our experience with 11 cases of cavernous sinus hemangioma treated by Gamma Knife radiosurgery.

Methods: We performed a retrospective analysis of 11 patients with cavernous sinus hemangioma treated by Gamma Knife radiosurgery between 2004 and 2010. The cohort consisted of 2 male and 9 female patients with median age of 59 (range 39-73 years). One patient had undergone previous surgical resection and the remaining 10 patients underwent Gamma Knife radiosurgery as their primary treatment under the radiologic diagnosis. 7 patients were asymptomatic before Gamma Knife radiosurgery whereas 4 had ocular movement disturbances and/or optic nerve impairments. The median tumor volume was 5.1cm³ (range 2.6 -> 32.3 cm³). The median dose to the tumor margin was 14.5Gy (range 11.5 -> 16Gy).

Results: The median follow-up period was 18months (range 6 -> 60 months). Follow-up evaluations revealed a reduction in tumor volume in all patients. Average tumor volume reduction rate at recent MR images was 60.9% (range 13.2 -> 84.5%). Average tumor volume reduction rate within one year after Gamma Knife radiosurgery was 56.1% (range 13.2 -> 84.5%). All patients with symptoms prior to Gamma Knife radiosurgery showed improved clinical status. No radiosurgery-related complications were met during follow-up.

Conclusions: Our study increases the possibility that Gamma Knife radiosurgery is an effective and safe treatment modality for managing cavernous sinus hemangiomas. Considering the potential risk of the surgical removal, Gamma Knife radiosurgery could be a primary treatment strategy in cavernous sinus hemangiomas which have a clear neuroimaging diagnosis.

15:00 - 16:00 ORAL SESSION

OS22 SPINE 2

Room: La Seine

OS22-1 GRADING SYSTEM OF METASTATIC EPIDURAL SPINAL CORD COMPRESSION (MESCC)

Samuel Ryu¹ Jack Rock¹ Rajan Jain¹ Casas Carlos¹ Lonnie Schultz¹ Joseph Anderson¹

(1) Henry Fod Hospital, Detroit, USA

Approach: Treatment of MESCC) consists of steroid, radiation, and surgery. Surgical resection improves ambulatory function. We have demonstrated epidural decompression by spine radiosurgery.

Relevance: While open surgical resection may be effective, many patients are not good candidates for surgery. Spine radiosurgery is non-invasive and convenient. It spares functioning bone marrow which is needed for chemotherapy. A relevant grading system will help treatment decision. This study was performed to validate the grading system for clinical use in the management of MESCC. The proposed grading system has radiographic and neurological components. Radiographic grades; grade 0 is spine bone involvement only, grade I is epidural tumor within epidural fat, grade II abuts dura with mild thecal sac compression, grade III is impingement to spinal cord, grade IV is spinal cord displacement and partial CSF block, and grade V is complete block. Neurological grades (a-e). Grade a is no symptoms. Grade b is focal minor symptom such as pain. Grade c is functional paresis with muscle strength 4/5. The involved muscle is functional and ambulatory. Grade d is non-functional paresis with muscle strength $\leq 3/5$, and Grade e is plegic, urinary or rectal incontinence.

Innovation: The study included 62 patients with 85 MESCC lesions who were treated with spine radiosurgery in the phase II clinical trial. MRIs of the MESCC lesions were retrospectively reviewed by 3 clinicians (radiation oncologist, medial oncologist, neurosurgeon) and 5 neuroradiologists. Tests of inter-observer variation were performed. For statistical analysis, Kendall-[™]s coefficient was calculated for concordance for ordinal response. Score above 0.75 represents high correlation. Kappa coefficient was calculated for nominal response of the observers.

Results: After radiosurgery, patients with neurological grades a-c improved or remained intact in 82%. Overall Kendall-[™]s coefficient of concordance for ordinal response was 0.83 ($p < .0001$). Overall Kappa coefficient for nominal response was 0.38 ± 0.01 ($p < .0001$). This represents good to fair correlation. Among clinicians, Kendall-[™]s coefficient 0.85, and Kappa coefficient 0.33 ± 0.04 ($p < .0001$). Among neuroradiologists, Kendall-[™]s coefficient 0.86, and Kappa coefficient was 0.39 ± 0.01 ($p < .0001$)

Conclusion: Radiographic grade and neurological grade were mutually independent. MRI was not predictive of neurological symptoms. Inter-observer variation was minimal, and there was high correlation among clinicians and radiologists. The grading system is useful for clinical use in patient evaluation and outcome reporting.

15:00 - 16:00 ORAL SESSION

OS22 SPINE 2

Room: La Seine

OS22-2 CERVICO-THORACIC REGION SPINE RADIOSURGERY (SRS) : IMPACT ON ADJACENT ORGANS AT RISK (OAR)

Gazanfar Rahmathulla¹ Toufik Djemil¹ Samuel Chao¹ Todd Emch¹ Lilyana Angelov¹

(1) Cleveland Clinic, Cleveland, United States

Purpose/Objective(s): RTOG protocols have proposed dose constraints to the Organs At Risk (OAR) in SRS. While efforts have focused on evaluating spinal cord tolerance when treating spinal column metastases, no recommendations exist for other adjacent OAR such as the brachial plexus or oropharyngeal region when performing spine radiosurgery (SRS) in the cervico-thoracic region. We evaluated the dosimetry as well as the acute and delayed effects of SRS to these adjacent but less well studied regions.

Materials/Methods: 14 consecutive patients (7males) with cervico-thoracic spine tumors were treated with single fraction SRS using the Novalis® platform between 2006-2009. Mean age at presentation was 61.3 (range 35 - 78); mean KPS 80. No patient had neurological or oropharyngeal deficits at initial presentation. PTV in 6/14 patients involved 1 vertebral body (VB); 3/14 involved 2 contiguous VBs; 3/14 3 VBs; 1/14 4VBs and 1/14 5 VBs to a mean prescribed dose 15.1Gy (range:12 - 16 Gy). Spinal cord, brachial plexus, larynx, trachea and esophagus were delineated as OAR on CT and MRI imaging in the actual treatment plans and dosimetrically evaluated.

Results: Patients were followed closely to assess treatment response. Mean patient follow-up was 9.3 mos (range:1 - 33 mos). Mean cord dose was 6 Gy (max.13.4 Gy) to a mean volume treated (MVT) of 4.1 cc; mean brachial plexus dose 6.1Gy (max 18.2 Gy) with a MVT of 23.2 cc ; mean laryngeal dose 3.3 Gy (max 18.1 Gy) with a MVT of 70.1 cc; mean tracheal dose 3.1 Gy (max 17.0 Gy) to a MVT of 35.9 cc; mean esophageal dose 4.3 Gy (max 18.6 Gy) to a MVT of 9.5cc. For each OAR, dose to 0.1 cc, 1cc, 2 cc, 5 cc and the volume receiving > 10 Gy was assessed to define dose constraints. Clinically, no patient developed any CTC grade 3-5 toxicity.

Conclusions: Data exists evaluating the impact of radiation therapy on OARs in the cervico-thoracic region with conventional fractionated regimens for head and neck, lung and breast cancer. To our knowledge this is the first published report evaluating the impact of single fraction spine radiosurgery on these same anatomic structures. From our analysis, the current SRS doses used at our institution are safe and well tolerated. Further studies are required to define dose constraints to these OAR.

15:00 - 16:00 ORAL SESSION

OS22 SPINE 2

Room: La Seine

OS22-3 SPINE RADIOSURGERY: A DOSIMETRIC ANALYSIS IN 124 PATIENTS WHO RECEIVED 18 GY

Stefano Schipani¹ Jian Yue Jin¹ Winston Wen¹ Samuel Ryu¹

(1) Henry Ford Hospital, Detroit, Mi, USA

Objective: A retrospective analysis was conducted to define the dosimetric characteristics of Spine Radiosurgery (SRS).

Methods: A total of 124 patients with 165 spine metastases were reviewed. Cervical, thoracic and lumbar spine metastases were treated in 13, 75 and 36 patients respectively. Contrast enhanced simulation CT and diagnostic MR were fused to delineate the target and the Organs at Risk (OARs). Spinal cord, oesophagus, trachea and oropharynx were partially contoured as the volume extending from 6 mm above to 6 mm below the target. Kidneys were entirely defined. A dose of 18 Gy in single fraction was prescribed to the 90% isodose line to encompass the periphery of the target. A dose constraint of 10 Gy to the 10% of the spinal cord was used. Dosimetric data for target coverage and OARs were analysed.

Results: Overall average target volume was 52 ± 35 cc and 95% of the volume received 18 ± 0.7 Gy (D95%). The average spinal cord partial volume was 4 ± 2 cc. The maximum dose (Dmax) and the dose to 10% of the spinal cord (D10%) were 13 ± 2 Gy and 8 ± 2 Gy, respectively. D10% was $43 \pm 9\%$ of the prescribed dose.

D95% for the cervical, thoracic, and lumbar spine target was 18 ± 0.8 Gy, 18 ± 0.7 Gy and 18 ± 0.7 Gy respectively. D10% for the spinal cord was 8 ± 1.8 Gy, 8 ± 1.7 Gy and 8 ± 1.7 Gy respectively.

The oesophagus dosimetry was analysed in 58 patients. The average partial volume of the oesophagus was 6 ± 4 cc. The Dmax to the oesophagus was 14 ± 4 Gy and the dose to 50% of the organ (D50%) was 7 ± 3 Gy.

The trachea was assessed in 28 patients and the average partial volume was 14 ± 6 cc. The Dmax and D50% resulted as 9 ± 4 Gy and 4 ± 2 Gy respectively.

The oropharynx was studied in 11 patients and was 25 ± 12 cc. The Dmax and D50% were 14 ± 4 Gy and 5 ± 1 Gy respectively.

The kidneys were analysed in 34 patients. Dmax and D50% resulted as 10 ± 6 Gy and 1 ± 0.9 Gy for the right kidney, and 10 ± 4 Gy and 1 ± 0.9 Gy for the left kidney respectively. There were no clinically detectable complications in any patients.

Conclusions: SRS can cover the target tumour well, while limiting the dose to various OARs. The dosimetric data provide clinical dose guidelines.

15:00 - 16:00 ORAL SESSION

OS22 SPINE 2

Room: La Seine

OS22-4 MINIMAL ACCESS SPINE SURGERY FOR METASTATIC SPINAL TUMOURS
FOLLOWED BY STEREOTACTIC BODY RADIOTHERAPY

Arjun Sahgal¹ Matthew Foote¹ Rajesh Reddy¹ Eric Massicotte¹

(1) University of Toronto, Toronto, Canada

Objective: To report a novel approach in the treatment of spinal metastases with epidural disease causing mechanical instability using a combined minimal access spine surgery (MASS) technique for tumour decompression and reconstruction, followed by spinal stereotactic body radiotherapy (SBRT).

Methods: A retrospective review of the first ten consecutive patients treated with MASS followed by SBRT was conducted. The MASS technique is based on a tubular retraction system to gain access for spinal cord decompression, and mechanical stabilization achieved using methylmethacrylate (MMA). SBRT consisted of one to five high dose per fraction treatments. Eight patients were symptomatic at baseline, and pain, disability, and quality of life prospectively determined using the visual analogue scale, Oswestry disability index and short-form-36 version 2, respectively.

Results: The median follow-up was 13 months (range, 3-18). MASS successfully decompressed each patient, and the median blood loss was 335 ml. The median time to spinal SBRT treatment planning was 6.5 days. Local control was observed in 7 of the 10 patients. Improvement in pain, disability and quality of life was observed post-SBRT. One patient had a complication of a dural tear during MASS. One patient who did not go on to be treated with SBRT, and considered separately in this analysis, suffered acutely from MMA extravasation rendering the patient myelopathic and subsequently died.

Conclusion: Safety and preliminary efficacy is reported with our MASS and SBRT combined approach for patients with spinal metastases and epidural disease, however, local control benefits require confirmation upon long-term follow-up.

15:00 - 16:00 ORAL SESSION

OS22 SPINE 2

Room: La Seine

OS22-5 UNEXPECTED PARALYSIS FROM VERTEBRAL BODY SRS IN SWINE SUGGESTS A
DOSE LIMIT FOR PERIPHERAL NERVES

Paul Medin¹ Ryan Foster¹ Orhan Oz¹ Albert Van Der Kogel²

(1) University of Texas Southwestern Medical Center, Dallas, United States (2) Radboud University, Nijmegen, The Netherlands

A study approved by the Institutional Animal Care and Use Committee is underway to investigate the affects of single-fraction irradiation on vertebral body health. Image-guided spinal radiosurgery

was used to deliver either 16 or 24 Gy to the level 5, 6, and 7 cervical vertebral bodies of ten Yucatan minipigs. Dose distributions were conformal to the vertebral bodies with an emphasis on sparing the spinal cord and esophagus. Bilateral C6-C8 spinal nerves received doses of 24-25 Gy . All five pigs in the 24 Gy dose group experienced unexpected, bilateral frank paralysis in their forelimbs between 10-15 weeks following radiosurgery. Spinal cord injury was presumed so the spinal cords of all five animals were fixed in formalin, sectioned and embedded in paraffin. Five spinal cord sections from each animal were stained with a combination of luxol fast blue and periodic acid-Schiff. Peripheral nerves were harvested from two animals and prepared similarly to the spinal cords. Histopathologic slides were reviewed and no changes were observed in any spinal cord section while peripheral nerves showed a degree of demyelination that could not be quantitated due to the lack of a normal unirradiated nerve. Pigs in the 16 Gy group have normal neurologic status 10 months post-radiosurgery. Although the incomplete histopathologic data from the peripheral nerves is unfortunate, it is believed that radiation injury to the spinal nerve is the only explanation for paralysis of the 24 Gy animals. Dose to the spinal nerve should be considered carefully when prescribing spinal radiosurgery. The unexpected outcome of paralysis in this swine model suggests the upper dose tolerance limit of the spinal nerve lies between 16 and 25 Gy.

15:00 - 16:00 ORAL SESSION

OS23 BRAIN METASTASES 4

Room: Miles Davis

OS23-1 *ISONECROSIS RISK LINE FOR MULTISESSION RADIOSURGERY OF LARGE BRAIN METASTASES: ISODOSE VOLUME OF 14GY (V14) IN SURROUNDING BRAIN*

Hiroshi Inoue¹

(1) Institute of Neural Organization, Fujioka, Japan (2) Kanto Neurosurgical Hospital, Kumagaya, Japan

Objective: Treatment volume of radiosurgery is limited because of radiation injury to the surrounding brain. Kjellberg 1% risk line of necrosis is used to determine marginal doses of radiosurgery depending on lesion volumes. Recently multisession radiosurgery has important roles for treatment of large lesions. However, there are no data for evaluation of radiation necrosis to determine the dose and the number of session. Isonecrosis risk line for multisession treatment was obtained from clinical data of patients with larger brain metastases treated with multisession. **Methods:** Isodoses of brain and tumor tissues in multisession treatment were calculated using L-Q formula with α/β value of 2 and 10, respectively. Isodose volumes of 14Gy in surrounding brain tissue excluding tumor volumes (V14) were measured from dose-volume histograms obtained during dose plan of 79 patients with large brain meastases. **Results:** Isodoses of 14Gy to brain in single session radiosurgery were calculated 23.1Gy in 3 sessions, 26.2 in 4, 28.8 in 5, and 31.2 in 6. The V14 of 79 patients treated with multi-session were 0.5 to 36.9ml (median: 6.6ml). Three patients (3.9%) required resection surgery because of edema or radiation necrosis 7 weeks to 13 months after treatment. The V14 in these patients was

13.5-31.5ml. Four patients received steroid or osmo-steroid therapy because of edema 4 weeks to 12 months after radiosurgery and their V14 were 5 to 16.2ml (median: 13.5ml). Median V14 of patients without edema was 6.6ml. Statistical dominance ($p=0.05$) was found between groups with and without edema. Patients with V14 less than 7ml developed edema in one (2.3%) but not necrosis.

Conclusion: Isonecrosis risk line for multisession radiosurgery has same value of Kjellberg 1% necrosis risk line for single session radiosurgery. The V14 seems to be a good indicator for prediction of radiation injury to surrounding brain in patients with large metastases.

15:00 - 16:00 ORAL SESSION

OS23 BRAIN METASTASES 4

Room: Miles Davis

OS23-2 HYPOFRACTIONATED STEREOTACTIC RADIOTHERAPY USING CYBERKNIFE FOR LARGE BRAIN METASTASES

Taro Murai¹ Hiroyuki Ogino² Shinya Takemoto¹ Yuta Shibamoto¹ Hirochika Suzuki⁴ Terufumi Okumura³ Yasuhiro Matsushita³ Yukiko Tsuji³ Ayano Imafuji⁴ Yuko Omiya⁴

(1) Department of Radiology, Nagoya City University Graduate School of Medical Sciences, Nagoya, Japan (2) Health and Welfare Bureau, Nagoya City Government, Nagoya, Japan (3) Department of Neurosurgery, Tsushima City Hospital, Tsushima, Japan (4) Department of Radiology, Tsushima City Hospital, Tsushima, Japan

Objectives: We evaluated the efficacy and toxicity of hypofractionated stereotactic radiotherapy (HFSRT) for large brain metastases (BM).

Methods: Between August 2006 and December 2009, 33 inoperable patients aged 51-92 years were seen; 5 had recursive partitioning analysis class III status. A total of 37 large BM (> 8 cc in volume) were treated with HFSRT using CyberKnife as a first-line therapy. A marginal dose of 30 Gy in 3 fractions or 35 Gy in 5 fractions were delivered daily on consecutive days in most patients. We evaluated local tumor control (LC), overall survival (OS), and toxicity as endpoints. Neurological examinations and computed tomography or magnetic resonance imaging were performed within 1-3 months after treatment. Each lesion was measured and response was scored according to MacDonald's criteria. LC was defined as complete response, partial response or stable disease. The LC and OS were calculated using the Kaplan-Meier method. Toxicity was recorded according to the National Cancer Institute Common Terminology Criteria for Adverse Events version 4.

Results: The tumor volume before HFSRT was 21.2 ± 17.7 cm³ (mean + SD). Primary tumor site was the lung in 12 patients, colon in 6, breast in 5, hepatocellular carcinoma in 2, bladder in 2 and other in 6. Twenty-two lesions were located in the cortex, 13 in cerebellum, 1 in brainstem and 1 in basal ganglia. The median prescribed dose was 27 Gy (range, 15 -35) and the median fraction number was 3 (range, 2-5). The median OS was 6 months (range, 1-49). Actuarial OS rates at 6, 12 and 18 months were 44%, 28% and 16%, respectively. Four patients died of intracranial disease progression including carcinomatous meningitis. We could measure 34 lesions after HFSRT. The median follow-up interval was 3 months (range, 1-48). One lesion demonstrated complete response, 17 partial response, 9 stable disease, and 7 progressive disease. Actuarial LC rates at 3

months, 6 months and 1 year were 79%, 79% and 72%, respectively. Four patients with a lesion in the cerebellum had to undergo tumorectomy for brain edema within 2 months after HFSRT (Grade IV). One with a basal ganglia tumor died of brain edema 4 months later. One developed Grade IV blindness at 14 months.

Conclusions: HFSRT to large BM provides a high level of LC with acceptable toxicity, although careful observation is necessary within 3 months after treatment.

15:00 - 16:00 ORAL SESSION

OS23 BRAIN METASTASES 4

Room: Miles Davis

OS23-3 RADIOSURGERY FOR LARGE BRAIN METASTASES

Jung Ho Han¹ Dong Gyu Kim² Hyun-tai Chung² Sun Ha Paek² Chul-kee Park² Hee-won Jung²

(1) Department of Neurosurgery, Seoul National University Bundang Hospital, Gyeonggi-do, Korea, Republic of

(2) Department of Neurosurgery, Seoul National University Hospital, Seoul, Korea, Republic of

Background: To find out the efficacy and safety of radiosurgery in patients with large brain metastases (LBM) treated with radiosurgery.

Methods: Eighty patients with LBM ($> 14 \text{ cm}^3$) were treated with radiosurgery between 1998 and 2009. The mean age was 59 ± 11 years, and 49 (61.3%) were male. Neurologic symptoms were identified in 77 (96.3%) patients, and 30 (37.5%) patients exhibited a dependent functional status. The primary disease was under control in 36 (45.0%) patients, and 44 (55.0%) patients manifested single lesion. The mean tumor volume was $22.4 \pm 8.8 \text{ cm}^3$, and the mean marginal dose prescribed was $13.8 \pm 2.2 \text{ Gy}$.

Results: The median survival time from radiosurgery was 7.9 months (95% CI, 5.343-10.46), and the one-year survival rate was 39.2%. Functional improvement within 1 to 4 months or maintenance of the initial independent status was observed in 48 (60.0%), and 20 (25.0%) patients after radiosurgery. Control of the primary disease, a marginal dose $\leq 11 \text{ Gy}$, and a tumor volume $\leq 26 \text{ cm}^3$ were significantly associated with overall survival (HR=0.479; $p=0.018$; 95% CI, 0.261-0.880; HR=0.350; $p=0.004$; 95% CI, 0.171-0.718; HR=2.307; $p=0.006$; 95% CI, 1.274-4.180, respectively). Irreversible radiation-related necrosis developed in 15 (18.8%) patients.

Conclusion: Radiosurgery seems to have a comparable efficacy with surgery for LBM. However, the rate of radiation-related toxicities after radiosurgery should be reduced.

15:00 - 16:00 ORAL SESSION

OS23 BRAIN METASTASES 4

Room: Miles Davis

OS23-4 SINGLE AND MULTI-SESSION RADIOSURGERY TREATMENT FOR BRAIN METASTASES. SINGLE INSTITUTION, 5 YEARS EXPERIENCE ANALYSIS.

Ida Milanese¹ Marcello Marchetti¹ Livia C. Bianchi² Giancarlo Beltramo² Francesco Di Meco¹ Paolo Ferroli¹ Marco Saini¹ Angelo Franzini¹ Sergio Giombini¹ Carlo L. Solero¹ Giovanni Broggi¹ Laura Fariselli^{1, 2}

(1) Fondazione IRCCS Istituto Neurologico C. Besta, Milano, Italy (2) Centro Diagnostico Italiano, Milano, Italy

Introduction: The treatment of brain metastases is in changing. Many technical radiotherapy options are available and actually under clinical evaluation. In the present study, we retrospectively evaluated the efficacy and toxicity of both single and multi-session radiosurgery.

Patients and Methods: In the period between June 2004 and December 2009, 443 patients referred to our Institute for a metastatic disease of the brain. In this period 729 lesions were treated by either single or multi-session radiosurgery with CyberKnife (CK).

The KPS was always higher than 70. A prior WBRT was performed in 107 patients.

Five-hundred-seventy-two patients were treated by single session radiosurgery. The mean dose was 19 Gy, encompassed by the 82 % isodose line. The mean target volume was 2,8 cc (median 1,4). One-hundred-fifty-seven patients were treated by multi-session radiosurgery. The mean dose was 23,4 Gy delivered in 2 to 5 fractions. The mean reference isodose line was the 79 %. The mean tumor volume was 14,6 cc (median 10,3 cc). The number of treatments for each patient ranged from 1 to 9. All patients were evaluated with clinical and radiological follow-up using MRI after 2 months and every 4 months thereafter.

Results: Actuarial overall survival was 69,3%, 51,7%, 31,6% and 23,3% at 6, 12, 24 and 36 months, respectively. The median overall survival was median overall survival 12,7 months (95% CI: 9.0-16.4). The median follow-up period was 46 months (95% CI: 38.1-54.7) According to the McDonald criteria, after six months, CR was achieved in 18,7% of the lesions, PR in 22,7%, and SD in 40%. The 16,7% of the treated lesion showed a progression. The cause of death was the systemic progression of the disease in 68% of the patients and the intracerebral progression in 19%. Only the 10% of the patients died because of the treated lesion. RPA class has been confirmed as a prognostic factor. Upfront WBRT had no impact on survival and local control. Neurological status improved in 65% of pts. Adverse event were rare and usually mild (4 patients had a RTOG toxicity > grade 2).

Conclusion: This experience suggest that both single and multi-session radiosurgery should be proposed as an alternative approach to WBRT in the treatment of one to three metastatic lesions in selected patients

15:00 - 16:00 ORAL SESSION

OS23 BRAIN METASTASES 4

Room: Miles Davis

OS23-5 GAMMA KNIFE RADIOSURGERY FOR THE TREATMENT OF NON-SURGICAL CYSTIC CEREBRAL METASTASES

Pablo Goetz¹ Shelly Lwu¹ Mandana Arayee¹ Monsalves Eric¹ Julius Ebinu¹ Norman Laperriere² Cynthia Menard² Mark Bernstein^{1, 2} Gelareh Zadeh^{1, 2}

(1) Toronto Western Hospital, Toronto, Canada (2) Princess Margaret Hospital, Toronto, Canada

Objective: Treatment options for cystic cerebral metastases include surgical resection, whole-brain radiation therapy (WBRT), and stereotactic radiosurgery (SRS). Larger cystic lesions are regarded as unsuitable for SRS: higher radiation doses required carry an associated risk of radiation toxicity and the non-cellular component may not respond to radiation. Although previous radiosurgical series include tumours with cystic components there are no dedicated studies to date analyzing the use of SRS in cystic lesions that do not require aspiration. The purpose of this study was to assess the role of Gamma Knife Radiosurgery (GKRS) in the treatment of non-surgical cystic brain metastasis.

Methods: We reviewed a prospectively maintained database of brain metastases patients treated at our institution between January 2007 and July 2009. 223 consecutive patients with brain metastases underwent GKRS. Lesions with at least 50% cystic component were identified. Clinical, radiological and dosimetry parameters were reviewed to establish the overall response of cystic metastases to SRS as well as identify potential predictive factors of response. This study had local research ethics board approval.

Results: 57 lesions in 40 patients were analyzed (17 male, 23 female, mean age 57.9 ± 11.6 years, range 30-77 years). 45% patients received upfront GKRS, the remainder received prior WBRT. Lung carcinoma was the primary cancer in 54% of patients, 10% breast, 8% melanoma, 25% other. 52% of the patients were RPA Class I, the remainder class II (none class III). Mean tumour volume was 4.4 ml (range 0.11-23.18 ml). Mean prescription dose was 20.1 Gy (range 15-24 Gy). Mean follow-up was 12.5 months (range 1.8-56). 3 month follow up imaging revealed an average reduction in tumour diameter of 22% (1.7cm to 1.4 cm maximum diameter). Mean RTOG conformity index was 1.6 (range 0.83-3.2). Mean Paddick conformity index was 0.6 (range 0.31-0.89). Local tumour control was achieved in 57% of the treated lesions. Local control rates were 94, 87, 72 and 51% at 3, 6, 12, and 18 months respectively. Local control was superior in lung compared to non-lung subtypes (70 vs 48%). Two (3.5%) of the treated brain metastases required surgical resection as local salvage therapy due to development of symptomatic progression.

Conclusions: The Results of this study support the use of GKRS in the management of non-surgical cystic metastases despite a perceived poorer response in the reported literature. Our local control rates are comparable to a matched cohort of non-cystic brain metastases. Tumour subtype was as predictor of response.

15:00 - 16:00 ORAL SESSION

OS24 OTHER SKULL BASE LESIONS 2

Room: Auditorium

OS24-1 GAMMA KNIFE SURGERY FOR CAVERNOUS SINUS TUMORS: MID-TERM FOLLOW-UP RESULTS: WITH RADIOSURGERY BASED ON MICROANATOMY.

Motohiro Hayashi¹ Noriko Tamura¹ Shoji Yomo¹ Mariko Nagai¹ Masahiro Izawa¹ Yoshikazu Okada¹

(1) Tokyo Women's Medical University, Tokyo, Japan

Objective: Tumors in the Cavernous sinus (CS) involve many vital neurovascular structures and therefore are among the most difficult tumors to achieve cure by surgery. Gamma knife surgery (GKS) has increasingly been in use as a safe and effective treatment for residual, recurrent tumors and those considered to be inoperable. However, its treatment accuracy and clinical Results are often called into question due to the complex intracavernous sinus structures and difficulty in identifying their specific locations. In this report, we review our follow-up of 120 patients treated by GKS based on our original image sequence and precise treatment planning.

Materials and Methods: A total of 120 patients harboring CS tumors (89 pituitary adenomas, 19 meningiomas, 6 cavernous angiomas, 4 abducens nerve, and 2 oculomotor nerve schwannomas) were treated and followed at least 2 years. Median prescription dose was 12Gy at 50% isodose line except for pituitary adenomas; non-functioning adenomas:18(12-25)Gy, functioning adenomas:25(15-35)Gy. We preferred to use gadolinium enhanced 3D heavily T2 WI (SISS/FIESTA) for MR imaging sequence, which enabled clear visualization of the intracavernous sinus structures. Tumors and surrounding nerves were localized and treatment plan was constructed to avoid normal vital structures. 80% high isodose coverage within tumors should be also considered.

Results: The length of follow-up ranged from 24 to 76 months (mean, 36 months). Overall, tumor control rate was 97.5% (pituitary adenomas:97%, meningiomas:100%, cavernous angiomas:100%, schwannomas:100%), and tumor shrinkage rate was 68.3% (pituitary adenomas:64%, meningiomas:79%, cavernous angiomas:100%, schwannomas: 67%). Endocrinological normalization was seen in 39% of the cases with functioning adenomas. There was no pituitary dysfunction in all cases. Complication of cranial nerve was seen in 5% (50% in schwannomas: abducens nerve palsy:5, oculomotor nerve palsy:2, and 2.6% in other tumors) and most of them (83%) were transient.

Conclusions: Clearly, our follow-up period is not enough to evaluate and further prospective studies are required before GKS is established as a standard of treatment for CS tumors. However, even our short-term follow-up resulted in early-phase tumor shrinkage and less radiation-induced complications. We are convinced that GKS will play a bigger role in the treatment of CS tumors in the future.

15:00 - 16:00 ORAL SESSION

OS24 OTHER SKULL BASE LESIONS 2

Room: Auditorium

OS24-2 INTENSITY MODULATED STEREOTACTIC RADIOTHERAPY FOR LOCALLY RECURRENT NASOPHARYNGEAL CARCINOMA

Tc Lam¹ Vyw Wong¹ Tw Leung² Sy Tung¹

(1) Clinical Oncology, Tuen Mun Hospital, Hong Kong, China (2) Clinical Oncology, Queen Mary Hospital, Hong Kong, China

Purpose: To study the treatment outcome in patients with locally recurrent nasopharyngeal carcinoma (NPC) who were treated with intensity modulated stereotactic radiotherapy (IMRT).

Methods and Materials: Thirty six consecutive patients with non-metastatic, locally recurrent NPC who were treated with curative intent between 2002 and 2009 were retrospectively analyzed. Patient immobilization and localization technique had been reported previously (reference 1). IMRT was delivered with 6-MV isocentric, coplanar beams in six fields. The T-stage distribution at recurrence (rT) was as follows: rT1-11, rT2-4, rT3-12, and rT4-9. All patients were treated with SRT with a daily fractional dose of 2-3 Gy (median, 2.5 Gy) to a total dose of 45 - 66 Gy (median, 55Gy). Mean total equivalent dose (TED) delivered to PTV was 57.1 Gy. Concurrent chemotherapy-IMRT was performed in 14 patients.

Results: The median follow-up time was 32 months. Median age of patient receiving IMRT was 51 years old. The median interval between primary radiotherapy and irradiation was 48 months. The 3-year overall survival rate and local failure-free survival (LFFS) rate for the whole group were 54.9% and 69.4%, respectively. Mean TED delivered to rT1-2 and rT3-4 patients were 55.7 Gy and 57.9 Gy respectively. The 3-year LFFS rates of rT1-2 and rT3-4 diseases were improved to 74.3% and 75.8% respectively, compared with previous report with stereotactic conformal radiotherapy (65-67%, reference 2). Concurrent chemo-IMRT was not associated with improvement in LFFS. There was no mortality due to acute treatment complications. However, late toxicity of treatment was high: trismus 47.2%, dysphagia 50.0%, stroke 13.9%, carotid artery stenosis 13.9%, symptomatic osteonecrosis of skull base 2.8%, radiation-induced temporal lobe necrosis 27.8%. Grade 4 or 5 toxicity due to late treatment-related complications occurred in 22% of patients.

Conclusion: IMRT was an effective treatment for locally recurrent NPC. Dose escalation for patients with rT3-4 relapse resulted in satisfactory local control rate but caused high rate of treatment related late morbidity. Further works need to be done to decrease the complication rate.

References:

- 1) VYW Wong. CT Verification of Isocentre Relocatability Using Stereotactic Mask Fixation System. *Clinical Oncology* (2003) 15: 280-287
- 2) TW Leung. Stereotactic Radiotherapy for Locally Recurrent Nasopharyngeal Carcinoma. *Int. J. Radiation Oncology Biol. Phys.*, (2009) 75: 734-731

15:00 - 16:00 ORAL SESSION

OS24 OTHER SKULL BASE LESIONS 2

Room: Auditorium

OS24-3 *RETROSPECTIVE STUDY TO REVIEW THE EFFICACY AND TOXICITY OF FRAMELESS FRACTIONATED STEREOTACTIC RADIO THERAPY (SRT) FOR CHINESE PATIENTS WITH PERSISTENT NASOPHARYNGEAL CARCINOMA*

Yiu Cheong Tse¹ Kam Tong Yuen¹ Joel Cheung¹ Ck Cheng¹ Cc Yau¹

(1) Princess Margaret Hospital, Kowloon, Hong Kong

Aim: To evaluate the efficacy and toxicity of stereotactic radiotherapy (SRT) for Chinese patients with persistent nasopharyngeal carcinoma (NPC), after primary radiotherapy.

Method: Between July 2008 and January 2010, 14 patients (10 men and 4 women, median age 54.5, range 35-85) with locally persistent NPC, after primary radiotherapy, were treated by SRT. 3 patients had squamous cell carcinoma and 11 patients had undifferentiated carcinoma. All patients were treated with Intensity-Modulated Radiation Therapy (IMRT) technique, using Eclipse™ planning system, localized by ZMed Optical Guidance Platform (OGP) with FramelessArray® bite block and mounted Reference Fiducial Frame, giving 18Gy in 3 fractions, prescribed at 100%IL, given on Day 1, 4 and 8. Biopsy in post-SRT week 12 was performed to assess clinical response. Median follow up period was 17.2 months.

Results: After SRT, 8 (57%) of 14 patients had complete regression of tumour. 5 (35.7%) of 14 patients had persistent tumour. 1 patient had defaulted follow up. Among those 3 patients with squamous cell carcinoma, all patients had proven persistent disease after SRT. 2 (20%) of 10 patients with undifferentiated carcinoma had proven persistent disease after SRT. 2 (14%) of 14 patients were succumbed so far, one died of clinical sepsis with multiple distant metastasis, while the other one had defaulted our follow up and noted death in Mainland China. For patients with complete regression (CR), their survival period ranged from 9-28 months (mean = 18 months). None of them had cancer relapse till the day of analysis. For patients with persistent tumour, their survival period ranged from 5-26 months (mean = 14.4 months). One died of sepsis. There was no statistical significant difference in survival in both groups of patients ($p=0.157$). Time to start SRT after diagnosis was 4.7-8.7 weeks (mean = 6.5 weeks) in CR group and 2.7-5.7 weeks (mean = 4.6 weeks) in persistent tumour group. There was no statistical significant difference of clinical response in relation to time to start SRT ($p=0.054$). 7 (50%) of 14 patients had G3/4 hearing symptoms. One patient had visual impairment and one patient had osteonecrosis of mandible. No patient had newly developed cranial nerve palsy, G3/4 xerostomia, temporal lobe necrosis during follow-up period.

Conclusion: Our study shows frameless SRT is an effective and well tolerable salvage treatment for persistent undifferentiated NPC.

15:00 - 16:00 ORAL SESSION

OS24 OTHER SKULL BASE LESIONS 2

Room: Auditorium

OS24-4 POST-OPERATIVE TREATMENT OF SKULL BASE CHORDOMAS WITH PHOTON-BASED FRACTIONATED STEREOTACTIC RADIOTHERAPY

Darlene Bugoci¹ Michael Girvigian¹ Joseph Chen¹ Joseph Hastings¹ Jeannie Han¹ Javad Rahimian¹

(1) Southern California Permanente Medical Group, Los Angeles, United States

Objectives: Skull base chordoma is a slow growing tumor that ultimately leads to the death of the patient as the tumor progresses locally. Standard treatment involves surgical resection and post-operative radiation therapy, often with proton beam. We report our updated Results of skull base chordoma patients who underwent surgical resection followed by photon-based Fractionated Stereotactic Radiotherapy (FSRT) with image guidance.

Methods: Between December 2002 and February 2009, 12 patients with skull base chordomas and no history of prior radiation therapy were treated with adjuvant or salvage radiation therapy at Kaiser Permanente Los Angeles Medical Center. The patients initially were treated with FSRT using dynamic conformal arc with static beam Intensity-Modulated Radiation Therapy (IMRT) boost. Since 2006, patients have been treated with image guided intensity modulated FSRT. The median age was 55 years (range, 10-79). There were 6 males and 6 females. The median isocenter dose of 74 Gy (range, 54-76) was delivered in 200 cGy fractions and prescribed to the 90% isodose line that covered the PTV (target volume with a median 2 mm margin).

Results: Median follow up period was 42 months (range, 1-81). Median time from surgery to the start of radiation therapy was 3.6 months. The overall survival was 76.4% at 5 years, and 46.9% and 37.5% of patients were free of progression after radiation at 24 and 60 months respectively. There was no correlation between disease progression and age, tumor volume, or time to start radiation ($p = 0.0732$, $p = 0.53$, and $p = 0.07$ respectively). Six patients had progression of disease after radiation with a median time to progression of 17.3 months (range 2.3-27.7). One patient died of respiratory failure and sepsis unrelated to disease less than 1 month after completing 54 Gy. One patient was salvaged with radiosurgery and surgical resection, with stable disease after almost 7 years since diagnosis. Two patients have received small molecule tyrosine kinase inhibitors for salvage therapy, with stable disease at 20 months and 23 months. At last follow up, 9 patients had stable or reduced disease.

Conclusions: Our updated Results demonstrate FSRT as post-operative treatment for skull base chordomas is safe and effective with overall survival comparable to other less available treatment modalities. Our patients experienced fewer complications and neurologic function was preserved despite increased local progression with longer follow up. These Results give credence to the possibility of dose escalation for future patients with image guided, intensity modulated FSRT.

15:00 - 16:00 ORAL SESSION

OS24 OTHER SKULL BASE LESIONS 2

Room: Auditorium

OS24-5 *CYBERKNIFE RADIOSURGERY CAN CONTROL RECURRENT EPIDERMOID CYSTS OF THE CENTRAL NERVOUS SYSTEM*

Maziyar Kalani¹ Robert Lieberman¹ Jan Eckermann¹ Steven Chang¹ Iris Gibbs² John Adler¹ Steven Chang¹ Steven Chang¹

(1) Department of Neurosurgery, Stanford University Medical Center, Stanford, Ca, United States (2) Department of Radiation Oncology, Stanford University Medical Center, Stanford, Ca, United States

Objectives: Epidermoid cysts of the central nervous system (CNS) may be difficult to resect and recur if removed incompletely. Recurrent lesions may be impossible to control and can be associated with poor outcomes. We sought to investigate the safety and efficacy of stereotactic radiosurgery (SRS) for recurrent CNS epidermoids.

Methods: Three patients treated with CyberKnife recurrent CNS epidermoid cysts were identified. With IRB approval, we reviewed their charts for clinical history, SRS treatment parameters, and outcomes. The patients were contacted for additional follow-up.

Results: Patient DL, now 63, presented in 2002 with an epidermoid of the conus medullaris. Nine open resections and percutaneous aspirations since 1999 had failed to control either symptom progression or radiographic growth. In May 2002, 18 Gy was provided to the margin of the 3.7 cc recurrence in a single session. Although two percutaneous aspirations were required for increased pain in the months following SRS, the most recent MRI of 2009, showed no residual and pre-SRS symptoms remained stable. Patient JL, now 69, presented in 2004 with an L3-L4 lesion which recurred following open resections in 1991, 1995, 1999, and 2002. Following an open debulking of February 2004, a 39.6 cc residual remained and SRS to a marginal dose of 22 Gy was provided in two sessions. When most recently seen in April 2008, the MRI was benign and the pre-treatment pain was stable. Patient NB, now 52 years old, presented in 2007 with a middle fossa lesion. The epidermoid had reappeared after craniotomies in 2000 and 2006. In November 2007, the symptomatic 4.5 cc recurrence was treated to a marginal dose of 24 Gy in three sessions. The most recent MRI of August 2010, showed no residual and the patient remains asymptomatic.

Conclusions: Each of our three patients had lesions which had recurred and required multiple open surgeries, including operations 12, 17, and 24 months before additional symptomatic recurrences required treatment with SRS. Following SRS, we documented clinical or radiological local control 36, 48, and 102 months after SRS. Lesion related symptoms remained stable and we did not observe treatment complications. We believe that stereotactic radiosurgery can be safe and effective in the treatment of epidermoid cysts of the CNS and should be considered for select individuals with recurrent or unresectable lesions.

16:30 - 17:30 ORAL SESSION

OS25 OTHER CRANIAL MALIGNANCIES

Room: La Seine

OS25-1 PROTON-BASED STEREOTACTIC RADIOTHERAPY IN PEDIATRIC TUMORS.

Jl Habrand¹, ³ S Bolle¹, ² J Datchary¹, ³ C Alapetite¹, ² S Petras² S Helfre¹, ² L Feuvret¹ V Calugaru¹, ² L De Marzi¹ A Beaudre³ R Dendale¹, ² J Grill³ F Doz³

(1) Centre de protonthérapie of the Institut Curie, Orsay, France (2) Institut Curie, Paris, France (3) Institut Gustave Roussy, Villejuif, France

Background: Protontherapy (PT) seems to provide a real benefit to young patients due to its unique ability to spare close and distant normal organs even compared with advanced photon techniques, and to escalate doses in locally aggressive processes. Preliminary dosimetrical investigations have pointed its potential role in medulloblastomas, rhabdomyosarcomas, Ewing' s sarcomas, neuroblastomas....We update here the initial clinical experience of the Orsay group (Fr) in children, using stereotactic PT in head and neck malignancies.

Patients and Methods: 135 children (19% intra cranial conditions) were managed between 1991 and 2009 with protons for part, or full (since 2007) radiotherapeutical course. Children were referred from 3 different institutions (IGR: 68%, I Curie: 29%, Paris public hosp: 3%). Selected indications mainly concerned low-grade malignancies located close to critical structures in the brain, orbit, and head and neck regions that were classified in 5 subgroups: craniopharyngiomas (CR): 40, bony sarcomas (BS):40, cerebral gliomas (CG):19, soft tissue sarcomas (STS): 16, others (O):20. Children (med. age: 11 years, range: 2-17.5) were treated to a mid 50 to 70 Cobalt-Gray Equivalent (CGE) according to the tumor type (range: 43-72) using conventional fractionation (i.e. 5 weekly sessions of 1.8 Gy CoEq per day). Stereotactic alignment based on the implantation of intra cranial metallic fiduciaris was used in all. General anaesthesia was required in younger cases.

Results: With a median follow-up of 35 months (range: 3-165), % 5-Y OS/DFS are 86/74. By subgroups, % 5Y-OS/DFS were 100/69 in CR, 89/86 in BS, 100/48 CG, 63/68 in STS, 67/64 in O, respectively. Immediate and late toxicities were extremely low, including a subgroup of 26 children treated at the highest dose-levels (i.e. 760 CGE).

Conclusion: This highly encouraging clinical experience, based on «first generation equipment (201 MeV synchrocyclotron and two fixed beam lines with passive double-scattering beam diffusion), has motivated the design of a new upgraded facility (240 MeV isochronous cyclotron and 3 beam lines, with one isocentric gantry and pencil beam scattering) that will become fully operational in 2011. This might allow the implementation of new clinical studies including extra cranial sites such as spinal/para spinal sarcomas, cranio-spinal irradiation, intra thoracic and intra abdominal sarcomas and neuroblastomas.

16:30 - 17:30 ORAL SESSION

OS25 OTHER CRANIAL MALIGNANCIES

Room: La Seine

OS25-2 STEREOTACTIC RADIOSURGERY FOR PINEAL TUMOURS

John Yianni¹ Jeremy Rowe¹ Gabor Nagy¹ Matthias Radatz¹ Andras Kemeny¹

(1) National Centre for Stereotactic Radiosurgery, Sheffield, UK

Objectives: Pineal tumours continue to present considerable clinical dilemmas and challenges. We were therefore interested to review our cumulative experience with a view to formulating a potential treatment strategy.

Methods: A retrospective analysis of all patients treated with Stereotactic Radiosurgery (STRS) for pineal tumours in one centre between 1987 and 2009. Forty-four patients (66% male) were treated with a mean age(1sd) of 33.6(16.4) years. Eleven had biopsy-proven pineal parenchymal tumours, six astrocytomas, three ependymomas, two papillary epithelial tumours and two germ cell tumours. Twenty (45%) patients had no definitive histology despite attempted surgical biopsy in 11. Prior to radiosurgery 17 had undergone craniotomy, 10 radiotherapy and four chemotherapy. Nine patients were referred for primary STRS.

Results: Fifty Gamma knife treatments were performed on 44 patients prescribing 18.1(4.2) Gy with a treatment volume of 3.8(3.8) cm³. Routine clinical and MRI assessments were reviewed to calculate control rates. Mean follow up was 62.5(52.9) months. Five patients (two ependymomas and three pineal parenchymal tumours) died at 36.2(36.7) months after initial radiosurgical treatment. Overall progression-free survival Results were 93% at one year, 77% at five years, 67% at 10 and 20 years. Log-rank analysis revealed that higher initial tumour grade ($p=0.04$), previous radiotherapy ($p=0.002$) and radiological evidence of necrosis ($p=0.03$) were associated with worse outcomes. The five year progression-free survival for patients who possessed these «aggressive» features was 47.1% compared with 91% for those patients who did not have these features. No persistent complications were attributed to STRS.

Conclusions: These Results demonstrate an increasing role for STRS in managing pineal tumours. Based on our findings we propose a possible treatment strategy to rationalize the use of radiosurgery in managing these difficult tumours.

References: Kano H. et al. Role of Stereotactic Radiosurgery in the Management of Pineal Parenchymal Tumours. *Prog Neurol Surg.* 2009;23:44-58.

Mori Y. et al. Stereotactic Radiosurgery for Pineal and Related Tumours. *Prog Neurol Surg.* 2009;23:106-18.

16:30 - 17:30 ORAL SESSION

OS25 OTHER CRANIAL MALIGNANCIES

Room: La Seine

OS25-3 MEDULLOBLASTOMA IN CHILDREN AT THE NATIONAL INSTITUTE OF ONCOLOGY IN RABAT

Hanane Chenna¹ Hanane El Kacemi¹ Khalid Hassouni¹ Karima Nouni¹ Fatima Zahra El M'rabet² Omar El Mesbahi² Hanane Berhil¹ Tayeb Kebdani¹ Noureddine Benjaafar¹ Brahim Khalil El Gueddari¹

(1) National Institute of Oncology, Rabbat, Morocco (2) Service of Oncology, CHU of Fes, Fes, Morocco

Introduction: Medulloblastoma accounts for approximately 30% of childhood brain tumors. This is one of the most frequent brain tumors in children.

Objectives: To study the epidemiological, clinical, histological, therapeutic and prognosis of medulloblastoma in children.

Materials and Methods: Retrospective study in a series of 47 children, aged under 16 years treated in our department between 1999 and 2008.

Results: The median age of patients was 8 years (3-15 years). Males were slightly dominant and sex ratio was 1.5. The average period of consultation was 4 months (1 month - 11 months). The circumstances of discovery were dominated by a neurological deficit in 39 cases (83%), a syndrome of intracranial hypertension in 36 cases (76%) and visual disturbances in 13 cases (27%). All patients underwent brain imaging (CT and or MRI). The tumor was infratentorial in 99% of cases. Histological diagnosis was made by surgical biopsy in 11 cases and stereotactic biopsy in 2 cases. The clinicopathological study concluded medulloblastoma. 40 patients underwent surgery, resection was complete in 21 cases (45%), subtotal in 7 cases (15%) and incomplete in 8 cases (17%). Postoperative imaging (MRI or CT) was performed in 13 patients (28%), the median time was 14 days (2-48 days) including 2 cases made in the first 48 hours. Residual tumor was found in 19 cases (40%). 29 patients (62%) received radiotherapy with a mean time between surgery and radiotherapy of 40 days. 8 patients (17%) received adjuvant chemotherapy. The median is 10 months (3 - 66mois). 10 patients (21%) are alive and are followed by disease, 2 patients (4%) died and 13 patients (27%) were lost to view.

Conclusion: Early diagnosis of medulloblastoma strongly influences the prognosis and risk of postoperative sequelae. Therefore ICHT should be considered in tables imposes atypical and, in emergencies, conducting a brain imaging. The diagnosis, the staging must be complete (craniospinal imaging pre-and postoperatively, completeness or otherwise of the resection, CSF study) in order to better tailor treatment.

16:30 - 17:30 ORAL SESSION

OS25 OTHER CRANIAL MALIGNANCIES

Room: La Seine

OS25-4 *A TREATMENT TECHNIQUE FOR PEDIATRIC RETINOBLASTOMA USING TOMOTHERAPY-BASED STEREOTACTIC RADIOTHERAPY*

Emilie Soisson¹, ² Selvan Rajakesari¹ Horacio Patrocinio¹, ² Carolyn Freeman¹

(1) McGill University Health Center, Montreal, Canada (2) McGill University, Montreal, Canada

The purpose of this work was to develop a technique for the treatment of pediatric retinoblastoma patients using a fractionated stereotactic approach on a Tomotherapy treatment unit. A unique patient positioning system was developed, which includes components of a commercially available stereotactic frameless mask system, an in-house designed Tomotherapy specific tabletop docking device, and a plastic suction contact lens to provide immobilization of the globe. Stereotactic localization was then achieved using volumetric image fusion between the planning CT and daily megavoltage CT (MVCT) acquired on the Tomotherapy unit. The use of an image-guided patient positioning system avoids using a frame-based coordinate system, which cannot account for interfraction variation in the rotation of the globe. Two 2 year-old patients with intraocular retinoblastoma have been treated using this method at our clinic. Both patients had prior disease in the contralateral eye and radiation therapy was chosen to avoid enucleation of both eyes. The Tomotherapy treatment planning system was used to generate a conformal intensity modulated treatment plan to deliver 45Gy in 25 fractions which allowed for sparing of the lens, lacrimal gland and orbital bone. Patient 1 had a 0.71cm³ target volume in the nasal retina. The average dose to the lacrimal gland was 1.6 Gy and the maximum dose to the orbital bone was <20Gy, which are below the suggested tolerances for dry eye and orbital bone growth retardation respectively. Lens sparing was not possible for this patient due to the proximity of the disease to the lens. Patient 2 had a 0.97cm³ target volume in the posterior retina. The average dose to the lacrimal gland was 17.9Gy, 20% of the orbital bone received a dose greater than 20Gy, and the maximum dose to the ipsilateral lens was 8.85Gy, again minimizing the risk of treatment related toxicity. Both patients were treated under anesthesia and tolerated the treatment well with no acute side effects. Any interfraction variability in the rotation of the eye could be verified on daily MVCT. On follow-up examination, flattening of the tumor was observed in both cases.

16:30 - 17:30 ORAL SESSION

OS25 OTHER CRANIAL MALIGNANCIES

Room: La Seine

OS25-5 GAMMA KNIFE STEREOTACTIC RADIOSURGERY FOR HEMANGIOPERICYTOMA

Takahiko Tsugawa¹ Yoshimasa Mori¹ Tatsuya Kobayashi¹ Chisa Hashizume¹ Yuta Shibamoto² Toshihiko Wakabayashi³

(1) Nagoya Radiosurgery Center, Nagoya Kyoritsu Hospital, Nagoya, Japan (2) Department of Radiology and Radiation Oncology, Nagoya City University Graduate School of Medicine, Nagoya, Japan (3) Department of Neurosurgery, Nagoya University Graduate School of Medicine, Nagoya, Japan

Introduction: Hemangiopericytoma is a rare intracranial tumor that composes under 0.5% of all primary brain tumor. This tumor is notable for local aggressiveness, high rate of recurrence and proclivity for extracranial metastasis. For the management of recurrent intracranial tumors, we applied Gamma Knife radiosurgery (GKRS) in case tumors are localized and treatable in size. In this study we evaluated the efficacy and the role of GKRS for control of the recurrent hemangiopericytomas.

Method: Between April 2004 and July 2010, we treated 7 patients with intracranial hemangiopericytoma by GKRS. All patients underwent operation before GKRS. The mean age of these patients at first GKRS was 43.4 (range 29-68) years. One patient was treated with fractionated external beam radiotherapy before GKRS and another patient was treated with linac-based radiosurgery before GKRS. One to 9 (median 1) tumors were treated at one session of GKRS. The mean volume of the tumors was 3.8 ml (range 0.3-11.4 ml) and the mean prescription dose to tumor margin was 16.7 Gy (range 13-20 Gy).

Result: The median follow-up time was 38.6 months (range 1-70 months). Of 6 patients who were followed up more than 36 months, the treated tumor was decreased in size in 3, remained unchanged in 1, progressed in 1, and in one patient the tumor regressed then developed repetitive recurrence. Extracranial metastasis was observed in one case. The progression free survival rate was 100, 67, and 50% at 12, 24, and 36 months after the initial GKRS respectively.

Conclusion: GKRS is a reasonable management option for patient with recurrent hemangiopericytoma.

16:30 - 17:30 ORAL SESSION

OS26 PHYSICS 2

Room: Miles Davis

OS26-1 *DOSIMETRY OF A NOVEL ROTATING GAMMA SYSTEM FOR STEREOTACTIC RADIOSURGERY*

Ronald Young¹ Kuang-ming Yang^{3, 5} Ching Chen² Steen Madsen⁴

(1) Rotating Gamma Institute - Orange County, Anaheim, Ca, United States (2) Dept. of Radiation Oncology, Good Samaritan Hospital, Los Angeles, Ca, United States (3) Dept. of Radiation Oncology, Tungs' Metroharbor General Hospital, Wuci, Taiwan (4) Dept. of Health Physics and Diagnostic Sciences, University of Nevada, Las Vegas, Nv, United States (5) Dept. of Biomedical Images and Radiological Sciences, National Yang-Ming University, Taipei, Taiwan

Approach: This is the first report of the basic dosimetric properties of a new rotating gamma system: the RGS Vertex360 (TM).

Innovation: Dosimetric properties were compared to those measured with traditional rotating gamma systems and with the Leksell Gamma Knife. The RGS Vertex360 is similar to the original rotating gamma system developed by OUR New Medical Technology Development Co., Ltd. (Shenzen, China), however, there are a few notable differences including the angular arrangement of the sources. Basic dosimetric properties of the RGS Vertex360 were measured including: absorbed dose rate, output factors, mechanical and radiation center accuracy and dose profiles.

Results: A significant discrepancy was observed for the 4 mm output measured from the RGS Vertex360 compared to those obtained from previous rotating gamma units: the 4 mm output from the RGS Vertex360 (0.807) was 32-38% higher than those measured from previous units. This is somewhat surprising considering the excellent agreement in 4 mm outputs from the RGS Vertex360, the corresponding outputs specified by the manufacturer of the original OUR unit and those measured for the Leksell Gamma Knife. The mechanical accuracy was similar to previous rotating gamma systems while the 50-90% penumbra was narrower. Dose profiles compared favorably with the Leksell Gamma Knife: in many instances the measured penumbra was narrower for the RGS Vertex360.

Conclusions: Notwithstanding the 4 mm output factor, the dosimetric properties of the RGS Vertex360 compared favorably with those of previous rotating gamma systems. The 4 mm output discrepancy was attributed to suboptimal alignment of the primary and secondary collimators in previous studies. The dosimetric properties of the RGS Vertex360 and the Leksell Gamma Knife were similar and, taken together, the Results suggest that the new rotating gamma system is well suited for stereotactic radiosurgery procedures.

16:30 - 17:30 ORAL SESSION

OS26 PHYSICS 2

Room: Miles Davis

OS26-2 GLOBAL ACCURACY OF HEAD FRAME STEREOTACTIC PROCEDURE

Stefania Pallotta^{1, 2} Fabiola Paia² Silvia Scoccianti² Cinzia Talamonti^{1, 2} Giampaolo Biti^{1, 2} Marta Bucciolini^{1, 2}

(1) Department of Clinical Physiopathology- University of Florence, Florence, Italy (2) Radiotherapy Unit AOU Careggi, Florence, Italy

Objective: Geometrical accuracy is required in stereotactic treatment, especially when a single fraction of a very high radiation dose is delivered to a small target. The purpose of this study was to assess the global accuracy of a stereotactic procedure evaluating the contributions due to the: stereotactic transformation, target localisation and head frame repositioning.

Methods: The Elekta HeadFix stereotactic frame and Odyssey (PerMedics Inc, CA, USA) TPS were considered in this study. The accuracy of the stereotactic transformation implemented in the TPS was evaluated using a synthetic phantom generated using Analyze (Biomedical Imaging Resource, MN) software package. The stereotactic localisers of the HeadFIX frame and 10 structures were generated and sent to the TPS. Sampling the localisers, the TPS evaluates the stereotactic transformation and calculates the centroid coordinates of the 10 structures. The differences between the known and measured centroids' coordinates represent an estimate of the accuracy of the stereotactic transformation.

The accuracy in target localisation was estimated using a plastic phantom with 8 glass spheres inserted in known positions. The phantom, fixed to the stereotactic frame, was CT scanned (0,68mm pixel size, 2mm slice thickness). The mean differences between known and measured spheres positions represent an estimate of the imaging contribution to the target localization.

Finally the stereotactic frame repositioning was assessed on 6 patients comparing the distances between markers fixed on the patients' head and on the stereotactic frame, measured in two repeated CT scans. The mean differences between correspondent distances represent an estimate of the HeadFix frame reposition.

Results: The accuracy of the stereotactic transformation evaluated by the TPS and assessed using a synthetic phantom was less than 0,5 mm along x,y and z directions. The accuracy in target localization Results less than 1 mm in x-y plane but higher than 1mm along the z direction (slice thickness). Finally the mean accuracy of the HeadFIX frame repositioning, evaluated on 6 patients, was about 1mm. Larger values related to the stress of the tray used to fix the patient to the stereotactic frame were observed for some patients.

Conclusions: In our experience the larger contribution to the geometrical accuracy of the considered stereotactic procedure is the stereotactic frame repositioning which could be improved by adopting a stereotactic frameless approach [Keshavarzi, Takakura].

Keshavarzi S, et al. Initial clinical experience with frameless optically guided stereotactic radiosurgery/radiotherapy in pediatric patients, Childs Nerv Syst. 2009;25(7):837-44.

Takakura T et al The geometric accuracy of frameless stereotactic radiosurgery using a 6D robotic couch system, Phys. Med. Biol. 2010; 55:1-10

16:30 - 17:30 ORAL SESSION

OS26 PHYSICS 2

Room: Miles Davis

OS26-3 INITIAL EXPERIENCE WITH HYBRIDARC RADIOSURGERY PLANNING FOR INTRACRANIAL TARGETS

Frank Lagerwaard¹ Gilian Simons¹ Johan Cuijpers¹ Ben Slotman¹

(1) VU University medical center, Amsterdam, The Netherlands

HybridArc (BrainLab, Feldkirchen) is a recently developed radiosurgery planning technique, which integrates aperture-optimized dynamic conformal arcs (DCA) with discrete intensity modulated radiotherapy beams (IMRT). It allows for both coplanar and non-coplanar planning and is initially evaluated for use in intracranial and spinal radiosurgery. The ratio of the dose objectives for the arc aperture optimization and IMRT beam optimization can be adjusted using a slider. For standard radiosurgery treatment without adjacent organs at risk, planning without IMRT contribution might already be sufficient. For more complex planning cases, the relative contribution of IMRT beams may be increased stepwise to obtain optimal dosimetry. We performed an initial dosimetric comparison of HybridArc planning with our current clinical radiosurgery technique consisting of 5 non-coplanar DCA for a number of intracranial indications.

Materials and Methods: Radiosurgery plan comparisons were performed for cases with brain metastases, vestibular schwannomas, hypothalamic hamartomas, pituitary tumors and meningiomas using iPlan radiosurgery planning software (RT dose 4.5, BrainLab). Plans consisting of 5 DCA were compared to HybridArc plans with a standard configuration of 3 (aperture-optimized) DCA and 2 IMRT fields per arc. The weighting of DCA and IMRT for this planning study varied per case, however, was usually in the range of 80-90% (DCA) versus 10-20% (IMRT).

Results: Both standard and complex HybridArc planning could be completed within one hour planning time. The combination of aperture-optimized DCA and dose painting by IMRT beams allows for fast relative sparing of adjacent organs at risk. In comparison with 5DCA plans, HybridArc planning showed similar target conformity for small round or oval shaped lesions such as brain metastases or AVMs. For irregular lesions such as vestibular schwannomas or meningiomas, however, target conformity obtained with HybridArc was consistently better. Radiosurgery planning with DCA for large intracranial lesions resulted in non-conformal dose distributions and relatively high PTV-inhomogeneity. HybridArc plans substantially improved both the target conformity and dose homogeneity for these larger tumors, similarly as what can be obtained using more time-consuming IMRT planning.

Conclusion: HybridArc offers a rapid and powerful radiosurgery planning option for improving target conformity and/or homogeneity, particularly in irregularly shaped and larger lesions. For round or oval-shaped smaller lesions, Results of HybridArc were comparable to planning with multiple DCA. Examples of HybridArc planning for several intracranial indications will be presented.

16:30 - 17:30 ORAL SESSION

OS26 PHYSICS 2

Room: *Miles Davis*

OS26-4 *EVALUATION OF DOSE CALCULATION ALGORITHMS FOR STEREOTACTIC RADIOTHERAPY TREATMENT MODALITY USING TLD*

Mahmoud Hegazy¹

(1) ROV, Mebourne, Australia

Aim: To investigate if the Pencil Beam (PB) algorithm takes the disturbance of the dose distribution due to tissue inhomogeneities sufficiently into account in dynamic arc and static conformal treatment beams modalities for fractionated stereotactic radiotherapy of head & neck, and liver tumors.

Materials and Methods: A treatment plan using the dynamic arc and static conformal treatment modalities of an oropharynx and liver lesions on a humanoid phantom (Rando) were evaluated. The same plans were calculated with two different calculation algorithms: Clarkson and Pencil Beam algorithms (both available on the planning system of BrainSCAN treatment system, v 4.03 and v 5.02).

The resulting plans are compared using isodose distributions and cumulative dose volume histograms (CDVH). An inter-comparison of the results of the two algorithms was performed to investigate how accurately each of them takes the influence of tissue inhomogeneities into account such as bony structures and air cavities often appearing in the head and neck region. Additionally, the resulting plans were compared with absolute dosimetric measurements of the treatment plan on the Rando phantom with TLD.

Results: All calculated doses show a good agreement with the measured doses except in the planning target volume (PTV) in and at the border of the air cavities. The two algorithms overestimated the doses in PTV at the boundary with low density tissue with 12%, and 9% for Clarkson and Pencil Beam respectively. The correspondence between the calculated doses is reflected in the graphs of the CDVHs. They show similar curves for PTV and the structures.

Conclusions: The Pencil Beam algorithm of BrainSCAN TPS calculates a treatment plan for the dynamic arc and static conformal treatment beams modalities adequately for fractionated stereotactic radiotherapy of head and neck tumors, except in the PTV in and at the border of the air cavities where the actual dose is over-estimated. Care needs to be taken in clinical cases where it is critical to irradiate the air tissue boundary to a sufficient dose.

Keyword: Conformal radiotherapy, Stereotactic radiotherapy, dose calculation algorithms, head & neck, TLD.

16:30 - 17:30 ORAL SESSION

OS26 PHYSICS 2

Room: Miles Davis

OS26-5 DESIGN OF 3D PHANTOM METHOD FOR QUALITY ASSURANCE OF IMAGING SYSTEMS & TREATMENT DELIVERY IN GAMMA KNIFE RADIOSURGERY PROCEDURES

Sajeev Thomas¹, ² Sampath Somanna¹ Musthafa M M²

(1) National Institute Of Mental Health & Neuro Sciences , Bangalore, India (2) University of Calicut, Kozhikode, India

Aim: To design and develop a novel method for verifying the accuracy of Stereotactic imaging and treatment delivery in stereotactic Radiosurgery procedures.

Materials and Methods: A 3D octagonal phantom has designed using acrylic slabs of varying thickness connected using nylon rods with acrylic bolts. The phantom has drilled holes of varying length from 2 mm to 14 mm with 1.3mm diameter separated at equal distances .Volume chambers are designed for simulating Target volumes (Teflon for CT imaging and filled these chambers with gels for MR Imaging) . plates were designed for placing of 0.125 cc and pin point ion chambers. Plates of 3 cm x 3cm were designed for inserting Films for Dosimetry provisions are made for placing TLD dosimeters for dose measurements.

A special plate has been fixed with lead balls of 1mm diagonally for assessing the geometrical accuracy of stereotactic Angiographic imaging.The assembly may be attached to the Leksell frame using a base plate and was tightened using platinum screws.

CT,MRI,DSA images of the phantom has been acquired using Philips Brilliance 16 CT scanner , Siemens Magnetom vision 1.5 Tesla MR unit and Siemens Neurostar DSA unit with appropriate indicator boxes using routine protocols used in gamma knife procedures.The images were exported to the Leksell Gammaplan through hospital network . Images were defined and registered in Gammaplan and stereotactic coordinates are evaluated.Skull frame measurements are taken and treatment plans are generated for Known doses .The phantom with Ion chamber and films are irradiated using APS system in Leksell 4c and measurements are repeated for a period of time. Using IAEA ->TRS 398 protocol dose measurements were performed and FWHM were compared with known stereotactic valuesin Leksell Gamma Plan.

Results: Mean value of absolute maximum error estimated for MR images from Siemens Magnetom vision MR unit were 0.41 mm(X-Axis),1.53 mm(Y-Axis) and 2.02 mm(Z-Axis).Mean of absolute maximum error estimated using CT images from Philips Brilliance 16 CT scanner were 0.34mm (X-axis), 0.43mm (Y-Axis) and 0.75mm (Z-Axis).The mean maximum error in estimating the vector distances from the centre of the Leksell system(100,100,100) to known Targets were 0.22 mm and 0.80 mm for CT and MR images respectively. The percentages of maximum error in volume calculations were assed separately and FWHM deviation for different Isocentric positions are tabulated and analyzed along with absolute doses at different Isocentric positions.

Conclusion: This phantom may be used for verifying the accuracy of complete Radio surgical procedure which includes imaging and treatment delivery .This technique is simple and may be adopted even in small clinical set-ups.

16:30 - 17:30 ORAL SESSION

OS26 PHYSICS 2

Room: Miles Davis

OS26-6 *DEVELOPED TECHNIQUE OF EXTRA-CRANIAL FRACTIONATED STEREOTACTIC RADIOTHERAPY WITH BRAINLAB EXAC TRAC AUTO-POSITIONING SYSTEM*

Mahmoud Hegazy¹

(1) ROV, Mebourne, Australia

Developments in radiotherapy treatment techniques provide new options and treatment opportunities for patients. one of these is the Extra-cranial Stereotactic Radiotherapy Fractionation which is available in Kasr El-Eini Center of Radiation Oncology and Nuclear Medicine(NEMROCK) . Several clinical cases have shown that a radiotherapy treatment allows delivery of higher total doses to the tumor. However, damage to healthy tissues as side effects caused from excess radiation, is a factor to be consider. Extra-cranial Stereotactic Radiotherapy, with its precise tumor definition, exact patient localization, and immobilization can reduce the damage of healthy tissue surrounding the tumor, while still allowing higher total doses to be delivered to the planning target volume (PTV). In this study, development of BrainLab cranial software system is achieved to be applicable for the Extra-cranial lesions using the circular collimators arc-based radiosurgery . By this technique a good dosimetric

Results were obtained , with minimum doses delivered to health tissues and maximum target dose .The best of treatment is based on dose distribution, conformity index, and dose volume histograms for the patient.

16:30 - 17:30 ORAL SESSION

OS26 PHYSICS 2

Room: Miles Davis

OS26-7 *DOSIMETRIC IMPLICATIONS OF MLC MARGINS AROUND PTVS FOR DYNAMIC CONFORMAL ARC CRANIAL RADIOSURGERY: A PLANNING STUDY*

James Tanyi¹, ² Lu Meng¹, ² Debra Monaco¹ Anna Simeonova³ Martin Fuss¹

(1) Oregon Health and Science University, Portland, USA (2) Oregon State University, Corvallis, USA (3) Heidelberg University, Heidelberg, Germany

Purpose: To assess the effect of multileaf collimator margin on target and normal tissue dose-volume metrics for intracranial stereotactic radiosurgery (SRS).

Methods: One-hundred and eighteen intracranial lesions of eighty-three SRS patients formed the basis of the current study. For each planning target volume, four separate treatment plans were generated with MLC margins of 0, 1, 2, and 3 mm, respectively. Each plan employed identical treatment planning parameters for a dynamic conformal arc technique using 5 arcs shaped by a high-resolution MLC (HD-MLC, 2.5 mm at isocenter, Novalis TX, BrainLAB). Prescription isodose coverage was normalized such that a prescription dose of 22 Gy covered 95% of the PTV. Dose-

volume comparative metrics including conformity index, heterogeneity index and normal tissue dose falloff. Furthermore, dose-response criteria including tumor control probabilities (TCP) and normal tissue complication probabilities (NTCP) were computed for plan comparison purposes.

Results: Target dose heterogeneity decreased with increasing MLC margin ($p < 0.001$); average heterogeneity index decreased from 145% to 110%. Target dose conformity generally decreased with increasing MLC margin (mean conformity index ranged from 1.38 to 1.53, optimal value observed at 1 mm margin). TCP decreased with increasing MLC margin ($p < 0.001$). Normal tissue dose fall-off increased with margin ($p < 0.001$) with lucid planning target volume dependence ($\text{tau-beta} \geq 0.7$). NTCP increased with larger margins ($p < 0.001$). Despite likely increase in NTCP with synchronous increase in PTV volume for any given MLC margin, no clear correlation was observed between NTCP and PTV volume ($\text{tau-beta} < 0.7$).

Conclusions: Use of narrow MLC margins for radiosurgery resulted in superior normal tissue sparing with consequential target dose heterogeneity. Clinical significance of the current findings warrants further investigation.

16:30 - 17:30 ORAL SESSION

OS27 VASCULAR 2 – ARTERIOVENOUS MALFORMATIONS & OTHER VASCULAR LESIONS

Room: Auditorium

OS27-1 DID THE ADVENT OF THE GAMMAPLAN SYSTEM CONTRIBUTE TO BETTER TREATMENT **RESULTS:** IN GKRS FOR AVMS?

Masaaki Yamamoto¹ Bierta E Barfod¹ Yoichi Urakawa¹

(1) Katsuta Hospital Mito GammaHouse, Hitachi-naka, Japan

Background: During the 40-year history of gamma knife radiosurgery (GKRS) for patients with arteriovenous malformations (AVMs), the most important development is widely considered to be a dose-planning technique, the GammPlan (GP) system, introduced in 1995. But has this development contributed to better treatment Results?

Patients: A consecutive series of 181 AVM patients who underwent GKRS during the 1978 through 2002 period were studied. The mean patient age was 37 years, range 7 to 78 years. There were 107 males and 74 females. The mean and median nidus volumes were 4.34 cc and 1.40 cc, range 0.02 to 55.80 cc. The most common presentation was bleeding (115 patients), followed by seizure (31) and others (7). In the remaining 28 patients, AVMs were diagnosed incidentally. The Pollock-Flickinger score ranged from 0.23 to 6.42, the median and mean being 1.14 and 1.24. The AVMs were located centrally in 50 patients, non-centrally in 130 and both in one. Also, the AVMs were located at the supra-tentorium in 155 and at the infra-tentorium in 26. Before GKRS, surgical intervention was performed in 11 patients and trans-arterial embolization in 17. The 181 patients were divided into the two groups; Group-A included 55 treated before 1994 (before GP was available), group-B the 126 treated after 1995.

Results: Excluding 17 deceased patients, the median and mean follow-up period were 8.7 and 10.3 years, range 5.4 to 30.6 years. Among these 181 patients, post-GKRS angiography was performed

in 152 (52 in group-A, 100 in group-B). Although there was a tendency for the obliteration rate in group-B (70.0%) to be higher than that in group-A (61.5%), this difference did not reach statistical significance ($p=.2922$). The incidences of complications were 20.0% in group-A and 3.2% in group-B ($p=.0004$). The actuarial complication rates were 3.7% in group-A and 1.6% in group-B at the fifth post-GKRS year and 12.6% and 4.8%, respectively, at the 10th post-GKRS year ($p=.1424$). **Conclusions:** Evidence accumulated to date does not indicate that introduction of the GP system has significantly increased obliteration rates relative to the old systems. However, the GP system has significantly reduced long-term complication rates.

16:30 - 17:30 ORAL SESSION

OS27 VASCULAR 2 – ARTERIOVENOUS MALFORMATIONS & OTHER VASCULAR LESIONS

Room: Auditorium

OS27-2 LONG TERM RESULTS: OF GAMMA KNIFE RADIOSURGERY OF CAVERNOMAS

Roman Liscak¹ Dusan Urgosik¹ Vilibald Vladyka¹ Gabriela Simonova¹ Jitka Semnicka¹ Tomas Chytka¹ Josef Vymazal¹

(1) Hospital Na Homolce, Prague, Czech Republic

Object: The radiosurgery of cavernomas remains a controversial indication. The only proof to verify the positive effect of the treatment is the clinical observation during the longer follow up, where the decreased annual risk of rebleeding should be observed after the latent interval inherent to radiosurgery. Besides that also improvement of clinical symptoms (e.g. secondary epilepsy) and regression of the treated lesion could be also observed. Long term Results from our centre were evaluated.

Methods: 112 patients with brain cavernomas were treated using the gamma knife in Prague between 1993 and 2000. The marginal dose was a median of 16 Gy. Follow-up ranged 5-184, median 84 months. The risk of bleeding before radiosurgery was 2% annually and decreased to 0,5% after 2 years latent interval. 39% of patients suffered from epilepsy before radiosurgery and this improved in 45% of them. An increase in the volume of the cavernoma was observed in 6,4% of patients and a decrease in 53% after the treatment. Collateral oedema after radiosurgery was detected in 27% of patients, which caused temporary and persistent morbidity 14,6%, resp. 0,9%. Rebleeding had temporary and permanent morbidity 0,9% resp. 5,6% and 2% mortality. Rebleeding can be expected more frequently where the dose to the cavernoma margin was less than 14 Gy. Edema occurrence after gamma knife treatment was more frequent for patients who have undergone prior surgery, for patients with a larger cavernoma volume and where the dose to the cavernoma margin was higher than 13 Gy.

Conclusions: Decreased risk of rebleeding after the latent interval of two years was observed after radiosurgery of cavernomas. The risk of permanent complications after radiosurgery was lower than 1% and temporary morbidity can be reduced by lower marginal dose. Controversial issues (incomplete knowledge of natural course of disease and absence of diagnostic tool, which could proof elimination of the risk of rebleeding) led us gradually to reserve radiosurgery for

selected group of patients with repeated bleeding or progressive impairment of neurodeficit, where alternative treatment (microsurgical resection) represent unacceptable risks.

16:30 - 17:30 ORAL SESSION

OS27 VASCULAR 2 – ARTERIOVENOUS MALFORMATIONS
& OTHER VASCULAR LESIONS

Room: Auditorium

OS27-3 *RADIOSURGERY FOR SYMPTOMATIC CAVERNOUS MALFORMATIONS LONG-TERM FOLLOW UP AND COMPARISON WITH THE NATURAL HISTORY*

Yoshihisa Kida Yoshi¹ Toshinori Hasegawa¹

(1) Komaki City Hospital, Komaki, Japan

Purpose: Long-term Results: of radiosurgery to cavernous malformations(CMs) are reported, and compared with the symptomatic cases treated conservatively.

Cases and methods: There are 152 cases of symptomatic CMs, either by hemorrhage, neurological deficits or by epilepsy, which were treated with gamma knife(A). There are another 40 cases with conservative treatments(B).

Results: Majority of lesions in Group (A) are located in eloquent areas like brainstem or basal ganglia, followed by lobar and cerebellar lesions. With the mean maximum and marginal dose of 26.4 and 14.9 Gy respectively, 30% of them showed a shrinkage and the others were unchanged in the mean follow-up of 55.4 months. Hemorrhage rate after radiosurgery are far decreased to 3.2%/year/case, which is almost one tenth of the one during 5 years before gamma knife (31.8%). Hemorrhage rate showed 8% in the first year, then apparently decreased to less than 5% subsequently and finally reached near to 0% in the 7th year. In contrast, the hemorrhage rate in Group (B) was 7.6 %/year/case during 62 months of mean follow-up, which is more than double than Group A. Convulsive seizures associated with CM either disappeared or decreased in almost 70% of patients, who were treated with gamma knife.

Conclusion: Because of markedly decreased rate of hemorrhage and epilepsy with acceptable rate of complications, radiosurgery for cavernous malformation is warranted and advisable. In the report, very long-term follow-up Results: more than 10 years will be presented

16:30 - 17:30 ORAL SESSION

OS27 VASCULAR 2 – ARTERIOVENOUS MALFORMATIONS
& OTHER VASCULAR LESIONS

Room: Auditorium

OS27-4 *RADIOSURGERY FOR BRAINSTEM CAVERNOUS MALFORMATIONS: A META-ANALYSIS ON OUTCOMES*

Joaquin Camara-quintana¹ Sachin Batra¹ Daniele Rigamonti¹

(1) Johns Hopkins Hospital, Department of Neurosurgery, Baltimore, United States

Relevance and Innovation: Surgery is the preferred treatment option for brainstem cavernous malformations, while treatment using stereotactic radiosurgery remains controversial. Radiosurgery for lesions located in deep eloquent locations such as the brainstem is perceived to be promising, yet the evidence is limited to few studies with small sample size. A meta-analytic method was undertaken for brainstem cavernous malformations to better define outcomes seen with radiosurgery.

Approach: A systematic search of the Medline electronic database, Embase database, and Scopus database was conducted to identify articles published that examined brainstem cavernous malformations treated with radiosurgery. Data was extracted on morbidity, mortality, and improvement rates for this treatment modality. The meta-analysis was performed by transforming proportions into the Freeman-Tukey variant of the arcsine square root transformed proportions and calculating pooled proportions by back transforming the weighted mean. Between the studies, heterogeneity was assessed and random effects model was used when found to be significant.

Results: The outcomes for brainstem cavernous malformations treated by radiosurgery was determined from a pooled analysis from 7 studies with 182 cases. This pooled proportion resulted in a transient deficit rate of 13.3% (95% CI, 4.4-26.1%), new deficit rate of 15.7% (95% CI, 10.8-21.2%), a mortality rate of 7.1% (95% CI, 3.9-11.2%), and a stabilization/improvement rate of 73.1% (95% CI, 66%-79%).

Conclusions: This meta-analysis demonstrates that radiosurgical management of brainstem cavernous malformations Results in favorable outcomes with minimal morbidity/mortality to patients.

16:30 - 17:30 ORAL SESSION

OS27 VASCULAR 2 – ARTERIOVENOUS MALFORMATIONS
& OTHER VASCULAR LESIONS

Room: Auditorium

OS27-5 GAMMA KNIFE RADIOSURGERY FOR CAROTID-CAVERNOUS FISTULA IN ELDERLY
PATIENTS

Brigitte Gatterbauer¹ Harald Standhardt¹ Adolf Ertl² Josa Frischer¹ Engelbert Knosp¹ Klaus Kitz¹

(1) Medical University Vienna, Vienna, Austria (2) General Hospital, Vienna, Austria

Object: In the treatment of carotid cavernous fistula (CCF) spontaneous cure or regression of symptoms are reported but a therapeutic approach is warranted in patients presenting with elevated intraocular pressure, visual deterioration, progressive or severe cranial nerve palsy and exophthalmia. The most common therapeutic approach is endovascular embolisation. However, neurologic complications of cerebral angiography and embolisation are reported and seem to be significantly more common in elderly patients.

The aim of our study is to present Gamma Knife radiosurgery (GKN) as treatment possibility for CCF in elderly patients, leading to a rapid improvement of symptoms.

Methods: In a retrospective study we analysed all patients presenting with CCF and treated

with GKN in our department between 2000 and 2009. 11 elderly patients underwent 13 GKN procedures. The mean age of patients was 67.3 years (6.9 years SD). Detailed clinical chart review was performed for all patients. The current clinical status of the patients was assessed via a neurological examination, resulting in a mean follow up time of 2.9 years (2.6 years SD). The patient´s outcome was rated according to their residual symptoms. Descriptive statistical analysis included mean values and standard deviation (SD).

Results: All patients presented with a broad spectrum of symptoms. In detail, ciliary injection (n=8), exophthalmia (n=7), chemosis (n=8), diplopia (n=5), headache (n=8), visual symptoms (n=6), tinnitus (n=2), elevated intraocular pressure (n=4) but no intracranial haemorrhage occurred. Five patients underwent endovascular embolisation before GKN. However, symptoms persisted. GKN was performed with 4 and 8mm collimators, respectively. The irradiated mean volume was 0.5ccm (0.3ccm SD). The mean prescription radiation dose was 17 Gy (0.8 Gy SD) and the central dose 35.5 Gy (3.2 Gy SD). In two patients a second GKN treatment was necessary. At the time of follow-up, clinical symptoms were improved substantially in 27.3% and disappeared completely in 72.7% of patients. In more detail, already two months after GKN controls of intraocular pressure showed normalisation in all four patients. Therefore, angiography for demonstration of occlusion was relinquished to avoid the higher risk of complications in elderly patients. Residual symptoms were minor and included ciliary injection (n=2) and mild exophthalmia (n=1).

Conclusion: GKN is an effective treatment for CCF in elderly patients with low risk of complications. Intraocular pressure normalises rapidly. Improvement of clinical symptoms seems to be a sufficient outcome measure in patients with CCF, thus rendering post-radiosurgery angiography an unnecessary risk.

12.30 – 13.30 LUNCHEON SEMINAR sponsored by ELEKTA

SPINE RADIOSURGERY: TODAY AND TOMORROW

Gerszten, PC**Peter E. Sheptak Professor**

Neurological Surgery and Radiation Oncology, University of Pittsburgh Medical Center, Pittsburgh, PA, United States of America

Objective: The goals of spine radiosurgery parallel those of intracranial radiosurgery, namely to improve local control beyond the capabilities of conventional fractionated radiotherapy and to be an effective treatment for previously irradiated lesions with an acceptable safety profile.

Methods: Spine radiosurgery is an evolution of the concept of intracranial radiosurgery, giving tumoricidal doses of radiation to vertebral, intradural extramedullary, and intramedullary lesions that limits radiation doses to normal structures. In some ways, spine radiosurgery is more complex than intracranial radiosurgery due to the need for frameless image guidance, issues of spinal instability, spinal cord radiation sensitivity, issues of organ motion, and the radiobiological implications of larger treatment volumes.

Results: The current indications for spine radiosurgery include as a primary treatment modality, in previously irradiated sites, in medically inoperable patients, as an adjunct to surgery, and for lesions not amenable to open surgery. Spine radiosurgery parallels the way in which radiosurgery has been incorporated into the multimodality approach to intracranial lesions. Spine radiosurgery allows for open surgery to be avoided, alters the actual surgery performed, (i.e. extent of resection or approach), may be integrated into systemic therapy, and used as a radiation boost after conventional radiotherapy for radioresistant tumors. There is substantial evidence that radiosurgery is safe and effective with durable symptomatic response and local control for even radioresistant histologies, regardless of prior fractionated radiotherapy. Radiosurgery should be considered over conventional fractionated radiotherapy for the treatment of solid tumor spine metastases in the setting of oligometastatic disease and/or relatively radioresistant histology. Radiosurgery has altered the way in which we approach patients with oligometastatic spine disease. Radiosurgery has also become more widely used as a treatment option for benign intradural tumors. Its role in patients with neurofibromatosis will also be further defined. In the future, radiosurgery will be used to treat degenerative conditions of the spine as well as pain syndromes by targeting specific areas of the spinal cord, stellate ganglion, and dorsal root ganglion. Radiosurgery also will be used for functional spine surgery. At the moment, there is a need for better consensus regarding defining target volumes, dose prescriptions, safe doses to the spinal cord and other critical structures, and the indications and contraindications for spine radiosurgery.

Conclusions: In a similar fashion to the way that radiosurgery is today an essential part of the treatment paradigm for intracranial tumors, radiosurgery will become an essential tool in the multimodality treatment of spine tumors. There will be a greater use of radiosurgery to treat both benign tumors as well as degenerative conditions of the spine.

COST EFFECTIVENESS OF GAMMA KNIFE RADIOSURGERY**Bodo Lippitz**

Dept. of Neurosurgery Karolinska Hospital Stockholm, Sweden; Gamma Knife Centre, Bupa Cromwell Hospital, London,

Health expenditures both in Europe and in the US are rising continuously. In 2008, European Union countries used 8.3% of their GDP on average on health care while the US devoted 16% of their GDP for health. Although further increasing costs are expected, substantial recessions may result in long-term reductions of health expenditures in order to decrease public deficits. The health care system in Europe is predominantly based on publicly provided or publicly controlled medicine with an urgent need for cost reduction and without interest in economic profits. One consequence of increasing cost awareness in all European countries is the general tendency to reduce the number of hospital beds (by 22% between 1995 and 2008) and the shortening of the length of the hospital stay by an average of 13% since 2000. Hence minimal invasive treatment techniques have come into the focus of recent developments. Within neurosurgery, radiosurgery and Gamma Knife in particular, are part of the evolution towards shorter hospitalisation and lower treatment related morbidity.

Cost calculations do not necessarily influence the individual therapeutic decisions, but are crucial for the planning of treatment options for hospitals and insurers. The cost for any therapeutic intervention varies considerably depending on time and geography. Cost/benefit calculations should ideally comprise direct and indirect costs including capital and operating costs, length of hospital stay, imaging, diagnostics, follow-up and ancillary treatments. Factors such as procedural morbidity and even mortality influence the cost/benefit ratio significantly. Indirect costs from a socio-economic aspect comprise lost workdays and the need for rehabilitation. Reliable cost comparisons are virtually impossible, due the multitude of these often interrelated factors with major variations.

The direct costs of a Gamma Knife treatment depends on the number of patients treated per unit and can therefore vary considerably. The closer to the potential maximum output the radiosurgical unit operates, the lower the costs per patient. Direct radiosurgical cost can vary between €17.300 and €6,500, when annually 150 or 500 patients are treated, respectively. Direct costs for complex neurosurgical interventions on the other hand, show similar variations and are calculated at \$5800 in Taiwan, ca \$30.000 in the US and 15.000 € in Germany and Canada.

The implementation of radiosurgery resulted in local institutional cost reductions of 12-25% for craniotomies in the Swedish public system, which is reflected by similar results from several studies that calculated Gamma Knife surgery had a 25-30% cost advantage over surgical resection. On the other side of the cost/benefit spectrum there is fractionated whole brain radiotherapy (WBRT) for brain metastases, which represents a relatively inexpensive treatment with low specificity. However, due to the limited therapeutic efficacy of WBRT, radiosurgery achieves significantly lower costs per year of median survival.

Analyses of treatment of brain metastases, AVM and acoustic neuroma demonstrate that Gamma Knife radiosurgery represents all advantages of a minimal invasive method including lower direct costs due to reduced staff requirements and shorter hospitalization. The indirect costs for radiosurgery were lower due to lower treatment-associated morbidity and the socio-economic impact is positive due to lower amount of lost workdays.

12.30 – 13.30 LUNCHEON SEMINAR sponsored by VARIAN

VISION FOR RADIOSURGERY

John Adler (US)

Radiosurgery (SRS) is the future of nearly all therapeutic radiation, period! Ever better imaging and radiobiologic understanding will only reinforce this inevitable future. How will these trends influence SRS equipment design? After more than a decade of widespread use, it is clear that image-guided targeting is every bit the equal of, and possibly even superior to, frame-based targeting; given the potential for seemingly impossible to measurable mechanical displacements of a patient's head within a stereotactic frame, the actual application accuracy of frame-based radiosurgery in individual patients is unknowable. This contrasts with image-guidance where it possible to calculate measurement errors in phantoms and in some situations, even patients, albeit always after the fact. Nevertheless, as a result of these new understandings, the era of stereotactic frames will likely soon be history. One practical consequence of this move towards image-guided targeting is that the emerging concept of applying SRS to functional and psychiatric diseases is intrinsically more palatable if invasive frame can be avoided.

Most of the exciting new clinical applications in radiosurgery involve either very large doses to extremely small regions of the brain, such as functional disorders, or require extremely high output to target larger lesions that move throughout the respiratory cycle or which are deep in the pelvis. Significant increases in radiation output combined with continuously improving multi-leaf collimators, makes such procedures ever more practical by shortening treatment times.

Radiosurgery has profoundly changed the treatment of a number of diseases over the past three decades. However, even in the brain, where clinical applications are best established, anecdotal evidence suggests that radiosurgery is underutilized and not living up to its full potential. Why? Sometimes this situation clearly stems from the need for better clinical studies, or in some regions of the world, the absence of suitable radiosurgical equipment. Numerous medical societies including the ISRS and the CKS, as well as a range of vendors, including Varian, are seeking to address both such concerns. However, perhaps the biggest challenges to growing radiosurgery as a discipline are not scientific or equipment related?

Patient referrals for radiosurgery represent the final step in a complex physician-centered process. At each step the evaluating physician seeks, if only for simplicity, to address a patient problem themselves. Oftentimes the referring doctor is a surgeon who has at their disposal a range of tools for managing most of the diseases in question. Consequently, for many (most?) surgical specialists in such a position, any excuse to not refer a patient onto a radiosurgical center of excellence is seized upon. The clinical data to support an existing or an emerging clinical application has to be truly compelling or a patient needs to be extremely assertive for a radiosurgical referral to happen. Truly flawless clinical studies can change this dynamic, but does such perfection really exist anywhere in the clinical realm? Instead I suggest that a more practical solution to expanding the clinical availability of radiosurgery maybe to address the training, cultural, political and financial barriers that prevent wider physician, and especially surgeon, participation in radiosurgery. By removing the disincentives for recommending or using radiosurgery, clinical outcome can become the sole

arbitrator by which referring physicians make a recommendation. Some specific ideas for realizing such a vision will be discussed. If the barriers to true interdisciplinary treatment can be overcome, radiosurgery could dominate the therapeutic landscape for many decades to come.

THE RADIOSURGERY PROGRAM AT VUMC AMSTERDAM

Frank J. Lagerwaard, Ben J. Slotman (NL)

Linear accelerator-based stereotactic radiosurgery (SRS) and fractionated stereotactic radiotherapy (SRT) for intracranial lesions has been performed at the VU University medical center Amsterdam since 1991. Most common indications for SRS include brain metastases, vestibular schwannomas, arteriovenous malformations and trigeminal neuralgia, while fractionated SRT has commonly been used for base of skull meningiomas. Occasionally, SRS has been used in high/grade glioma patients, either as a boost or for treatment of recurrent disease.

The frameless SRS/SRT approach has largely replaced frame-based treatments, with the exception of SRS for AVM's and trigeminal neuralgia. A recently published in-house analysis of the accuracy of the BrainLAB frameless mask system using measurements on both phantoms and patients showed an accuracy of 0.3 mm (1 SD) in each direction and an intrafractional positional stability of 0.35 ± 0.21 mm. The maximum observed intrafractional shift was 1.2 mm, underscoring the safety for frameless radiosurgery procedures.

The Novalis linear accelerator, which has been in use since mid-2002, has recently (2009) been replaced by the Novalis TX. The clinical introduction of the Novalis TX has greatly increased the available options for patient setup and treatment delivery. The Novalis TX offers the possibility to perform online patient-setup using the ExacTrac system and 6D Robotics couch, on-board kV-imaging, or kV CBCT scans. Because of the speed, high accuracy and user friendliness of the ExacTrac system, this is generally used for SRS/SRT of intracranial lesions. For SRT of extracranial lesions, e.g. lung cancer, online CBCT-based setup on the tumor has largely replaced patient setup on bony anatomy.

The controversy whether brain metastases should be treated with SRS as a single modality or combined with upfront WBRT is still unresolved. We have implemented an intermediate approach between both policies. Patients with 1-2 brain metastases on high-resolution planning MRI scan are treated with SRS without upfront WBRT. Patients with 3-5 brain metastases, who are in good clinical condition without rapidly progressing extracranial tumor, are treated with a combination of WBRT (5x4 Gy) and a simultaneous integrated boost to the brain metastases (boost 5x4 Gy) using RapidArc intensity-modulated volumetric arc therapy. The use of an integrated boost technique allows for much steeper dose gradient than with a conventional summation of WBRT and subsequent stereotactic boost. Preliminary outcome data of this approach, which can be delivered within 3 minutes per fraction, show that high local control rates and favorable survival can be obtained when appropriate patients are selected.

POSTER SESSION 1

P1001

GAMMA-KNIFE RADIOSURGERY FOR VESTIBULAR NEUROMAS: AN ANALYSIS OF 279 PATIENTS FOLLOWED MORE THAN 4 YEARS. A SINGLE INSTITUTION'S EXPERIENCE

Gustavo Touzet¹ Vincent D'hardemare¹ Nicolas Reyns¹ Christophe Vincent¹ Frédérique Dubrulle¹ Thierry Sarrazin¹ Eric Lartigau¹ Serge Blond¹

(1) GammaKnife Center, Department of Stereotaxy and Functional Neurosurgery, Hospital Roger Salengro, Centre Hospitalier Régional Universitaire, Lille, France

Purpose: The aim of this study is to assess the impact of Leksell Gamma Knife Radiosurgery for vestibular schwannomas on the quality of life following radiosurgery by analysing the tumor control rate, the preservation of hearing and the variables modifying the treatment outcomes.

Material Methods: The retrospective study pertains to 279 patients who underwent a Leksell 4C Gamma-Knife Radiosurgery (Elekta Instruments, Stockholm, Sweden) for a vestibular schwannoma at the Hospital of Lille (France) from 2004 to 2007. Follow-up lasted at least 4 years including regular clinical, audiometry and MRI evaluations. For each lesion, the anatomical analysis of the images was realised with the Gammaplan Software and was later measured serially using standard volumetric software of a radiological workstation.

Results: On average, the observation lasted 59 months (range 48-72 months) for patients aged from 24 to 79 years. The lesions were irradiated at the 50% isodose line for the tumor margin with an average dose of 12 Gy (range 10-13 Gy) at the periphery. The neuroma-™'s volumes were 0,11 to 2,8 cm³ (median: 1,3 cm³) and transient increases of the tumor were detected for 39% of the patients, with a maximum transient increase volume identified at 6 to 30 months after radiosurgery. Tumor control at last follow-up was 95,3% with only 3% of patients undergoing surgery after radiosurgery. When the tumor was treated with a marginal dose of 12 Gy or less with no previous treatment, serviceable hearing was preserved in 61% of the cases, when the facial nerve function was adversely injured in 2,5%. These findings were dependent of marginal dose and of the tumor-™'s size

Conclusion: In the treatment of vestibular schwannoma, contemporary radiosurgical techniques and the use of marginal doses below 13 Gy appear to represent an excellent compromise between controlling the disease and preserving the auditory function. Patients should be informed about the benefits and risks of radiosurgery and microsurgery before choosing an intervention. Further analysis of post-treatment outcomes should be encouraged as follow-up times increase, and the treatments protocols must evolve.

P1002

TUMOR PSEUDOPROGRESSION FOLLOWING RADIOSURGERY FOR VESTIBULAR SCHWANNOMA: A VOLUMETRIC ANALYSIS

Caroline Hayhurst¹ Gelareh Zadeh¹

(1) Toronto Western Hospital, Toronto, Canada

Objective: Transient expansion, or pseudoprogression following radiosurgery for vestibular schwannoma (VS) is becoming increasingly recognised, but remains poorly understood in terms of natural history and pathophysiology. Failure to recognise pseudoprogression will lead to unnecessary second intervention. This study aims to characterize pseudoprogression to assess the incidence, causative factors and its association with radiation induced adverse effects.

Methods: A single institution retrospective study of 200 VS treated with Gamma Knife radiosurgery between 2005 and 2009. 75 patients had at least 24 months clinical and radiographic follow-up (median 29 months) and were included. Tumor response was calculated volumetrically using Gammaplan software on consecutive MR FIESTA imaging. Tumor response was categorised as stable, regression, pseudoprogression or sustained growth. A significant change in tumor volume was defined as a 10% change. All treatment plans were reviewed for dosimetry characteristics; including homogeneity, gradient index, conformity index, isocentre number and dose rate.

Results: 49 (65%) of VS were stable or regressed after treatment. 17 (23%) underwent pseudoprogression, with onset of enlargement at 6 months. 7 (9%) remained larger than initial treatment volume at last follow-up. 9 (12%) demonstrate persistent growth. 3 patients underwent subsequent microsurgery. One patient required urgent intervention at 3 months for cystic enlargement, otherwise all patients with progressive enlargement had stable VS until at least 24 months. 26 (34.7%) patients developed non-auditory adverse radiation effects following treatment. There was no statistical association between onset of clinical deterioration and tumor response. There was no significant correlation between patient age, tumor size and morphology, or radiosurgical dosimetry parameters and tumor response on multivariate analysis.

Conclusion: Pseudoprogression should be an expected phenomenon after radiosurgery for VS. Volume changes in the first 24 months following radiosurgery rarely herald treatment failure and follow-up imaging can be safely delayed until 24 months. There are no tumor related or dosimetric variables which predict tumor response in this series.

P1003

COMPARISON OF INTENSITY MODULATED STEREOTACTIC RADIOSURGERY WITH CONVENTIONAL STEREOTACTIC CONFORMAL BEAM RADIOSURGERY IN VESTIBULAR SCHWANNOMAS

Niteen More¹ Vijay Anand Reddy¹ Karthikeyan Srinivasan² Kausik Bhattacharya¹ Vinitha Reddy¹ Revathy Kesavan² Sajal Kakkar¹ Padma Ganesan² Tamilselvan Kasirajan² Muthulingam Shunmugavel²

(1) Dept of Radiation Oncology, Apollo Health City, Hyderabad, India (2) Dept of Medical Physics, Apollo Health City, Hyderabad, India

Objective: To compare the treatment plans using conventional stereotactic conformal beams and intensity modulated beams with inverse planning software on BrainLab, iPlan planning system for the stereotactic radiosurgery treatment of vestibular schwannomas.

Methods: Five patients of vestibular schwannomas with intracanalicular extension were treated with stereotactic radiosurgery on Novalis Tx linear accelerator. All patients had non-serviceable hearing loss. Volumetric MR imaging and high resolution CT scans were fused on BrainLab, iPlan planning system. Initially conformal beam radiosurgery (CBRS) planning was done using non-coplanar stereotactic conformal beams. Subsequently, intensity modulated radiosurgery (IMRS) plans were generated using inverse planning Methods. Constraints were given for adjacent structures such as brain stem and cochlea. Additionally a wall of 2 to 3 mm was created around the target and constraints were given to achieve better conformity. Dose distribution of the optimum IMRS plans were compared with the CBRS plans.

Results: Mean volume of the target was 2.26cc (range 0.3-3.9cc). Four patients were treated with 12Gy and one with 13 Gy in single fraction. Mean value of isodose chosen for dose prescription was 90%. Six to nine beams were used in both types of plans. Mean value of maximum dose in PTV in CBRS and IMRS plans was 14.69Gy and 13.96Gy, respectively. Mean dose to the PTV in CBRS and IMRS arm was 13.63 and 13.22Gy, respectively. Conformity index for PTV dose coverage was 1.74 and 1.28 in CBRS and IMRS plans, respectively. Mean and maximum doses to brainstem were 1.73 and 6.35Gy in CBRS and 1.42 and 5.79Gy in IMRS plans respectively. Mean of maximal dose to cochlea was 12 and 10Gy in CBRS and IMRS plans respectively.

Conclusions: Intensity modulated radiosurgery plans were better as compared to conformal beam radiosurgery plans in terms of homogeneity and conformity of the prescribed dose to PTV. There was minimal improvement in doses to normal structures such as brainstem and cochlea.

P1004

MR IMAGING FOR VESTIBULAR SCHWANNOMA: COMPARISON OF MR IMAGING SEQUENCES USED FOR SRS PLANNING

Meg Schneider¹ Robert Smee¹ Karl Chan¹

(1) Department of Radiation Oncology, The Prince of Wales Cancer Centre, High St, Randwick, Sydney, Australia

Objectives: MR imaging is used to identify the target volume used when planning vestibular schwannoma cases for stereotactic radiosurgery [SRS] treatment. At Prince of Wales Hospital we have been delivering SRS to selected patients since 1990. We use an MRI data set which is fused to a stereotactically localised CT scan. The MR sequence that we use is MPRAGE, a volumetric T1 weighted sequence with contrast. Recently, we were advised that a CISS sequence would give better definition of the target volume. The purpose of this study is to compare the volume marked on each of the data sets and determine volumetric and positional differences to decide whether to incorporate this data set when planning cases for SRS.

Methods: Two MRI data sets were acquired for a patient with a small vestibular schwannoma with a maximum dimension of 14mm. The MPRAGE data set covers the entire skull with slices reconstructed at 3mm spacing. The CISS data set is a 20mm block centred on the target with slices at 0.5mm spacing. The localised CT data set includes the entire skull at 3mm spacing. These two

MR image sets were fused to the localised CT scan and the target was outlined on both MR data sets. These 3D volumes for the targets were then compared for coincidence of position and volume. It is important to ensure that the CISS scan was acquired with the head tilt at the same angle as the CT scan. If this was not achieved then the fusion was not possible. This is not important if only an MPRAGE data set was used for planning.

Results: The CISS scan definitely demonstrated the schwannoma much more clearly than the MPRAGE which we have used for planning in the past. This is because it is a T2* weighted volume gradient echo sequence which takes advantage of the inherent high signal from the bright CSF.

Conclusion: There was a difference in the volumes generated from the MPRAGE and CISS data sets. We intend to repeat this approach of comparing the volumes on patients in the future so that we can make definitive recommendations as to which volume we will use as the target volume. We will continue to use the MPRAGE to volume the organs at risk (OAR) within the skull and hopefully use the CISS for contouring the target.

P1005

SPORADIC VESTIBULAR SCHWANNOMAS TREATED BY LINAC-BASE RADIOSURGERY AT THE PONTIFICIA UNIVERSIDAD CATÓLICA DE CHILE: TUMOUR CONTROL AND CRANIAL NERVE FUNCTION PRESERVATION

José Lorenzoni¹ Pablo Vizhñay¹ Adrián Zárate¹ Pablo Albiña¹ Juan Delgado¹ André Vieira¹ Patricio Tagle¹ Pelayo Besa¹

(1) Pontificia Universidad Católica de Chile, Santiago, Chile

Objective: To evaluate the Results of radiosurgery for the treatment of sporadic vestibular schwannomas at the P. Universidad Católica de Chile.

Methods: Between March 2006 and May 2010, 42 patients harbouring sporadic vestibular schwannomas were treated by linac-based radiosurgery. The treatment was performed with linear accelerator Varian Clinac 21 Ex end equipment for radiosurgery Varian Z-Med. Conic collimators were used for all treatments. The mean marginal dose administered was 12.5 Gy. (12-13) normalized at the isodose curve 70 or 80%.

Results: 25 men and 17 women with a mean age of 49 years (28-71) were treated. Ten patients were previously operated and in 32 radiosurgery was the first treatment. There was not mortality; the tumour control at the last follow-up was 97.6% (only one treatment failure) with an actuarial control of 93.7% at 4 years. No malignant transformation has been observed. Useful hearing preservation was in 65% in those patients with useful hearing at the time of treatment, with an actuarial value of 62% at 4 years. Facial nerve function preservation was in 100%, Trigeminal nerve preservation was in 95%. No compromise of any lower cranial nerve was documented.

Conclusions: These Results obtained using the recommended dose nowadays (12-13 Gy.) are according with the information available in the literature concerning tumour control and cranial nerve function preservation, Linac-based radiosurgery is an option for radiosurgical treatment of vestibular schwannomas.

P1006

LINAC-RADIOSURGERY IN THE TREATMENT OF VESTIBULAR SCHWANNOMA.

Christine Kopp¹ Claudius Fauser² Michael Molls¹ Anca-ligia Grosu³

(1) Klinik und Poliklinik für Strahlentherapie und Radiologische Onkologie, Klinikum rechts der Isar, Technische Universität München, Munich, Germany (2) Hals-Nasen-Ohrenklinik und Poliklinik, Klinikum rechts der Isar, Technische Universität München, Munich, Germany (3) Klinik für Strahlenheilkunde, Universität Freiburg, Freiburg, Germany

Objective: To evaluate tumor control, hearing function and side effects associated with radiosurgery (RS) for Vestibular Schwannoma (VS) in a group of patients treated at the same institution.

Patients and Methods: Between 1997 and 2007, 68 patients with VS have been treated with LINAC-RS at our department of radiation oncology. These patients have been functionally evaluated at the head and neck department of our hospital before, 6 weeks and every 6 months after treatment. The mean follow-up time was 30.1 months. The group included 32 females and 36 males, the median age was 63.2 years. Treatment was performed using an adapted Siemens-LINAC with 6 MeV photons and the BrainLab system. A total dose of 12 Gy on 100% isodose on the tumor margins was delivered in one session. Evaluation included serial magnetic resonance imaging (MRI), neurological and otorhinolaryngological examination: pure tone audiogram, speech audiogram, vestibular function tests, assessment of facial and trigeminal function.

Results: Tumor control, defined as no tumor progression on follow-up MRI, was 98.5%. Good or serviceable hearing was present before treatment in 39/68 (57%) patients. Pure tone audiogram measurements revealed a mean hearing loss of 10 dB one year after treatment. Later during follow up, at 2 and 3 years after RS, hearing function according to pure tone audiograms did not worsen any further. We found an improvement of hearing in 4/68 (6%) patients.

At presentation, 44/68 (65%) patients reported vertigo, whereas on the last follow-up visit only 33/68 (49%) patients still had this symptom.

Facial nerve function remained mostly unaffected by RS, 3/68 (4%) patients reported complete recovery of the initial facial nerve dysfunction, 4/68 (6%) patients developed new facial nerve dysfunction, one of them being transient. New trigeminal nerve dysfunction occurred in 9/68 (13%) patients, 5/68 (7%) patients reported restoration of preexisting trigeminal neuropathy.

Conclusions: LINAC-based stereotactic radiosurgery for VS offers good tumor control rates and acceptable side effects. Hearing function can be potentially preserved. Additional follow-up will allow more Conclusions regarding long term tumor control, hearing function and cranial nerve function after RS.

P1007

A CALL FOR A BETTER DEFINITION OF SUCCESS AND FAILURE IN RADIOSURGERY FOR VESTIBULAR SCHWANNOMAS (VS)

Daniele Rigamonti¹ Sachin Batra¹ Sumit Kapoor¹ Kathryn Carson² John Shuck¹ Siddharth Kharkar¹ Rahul Gandhi¹ Juan Jackson¹ Jan Wemmer¹ Stephanie Terazakis¹ Ori Shokek¹ Lawrence Kleinberg¹ Luigi Marchionni¹

(1) Johns Hopkins School of Medicine, Baltimore, USA (2) Johns Hopkins School of Public Health, Baltimore, USA

Approach and relevance: In the Radiosurgery literature of VS, success is defined as lack of «salvage surgery». We assessed clinical outcome and long-term tumor control after fractionated stereotactic radiotherapy (FSRT) for unilateral VS.

Methods: 385 of 496 patients, treated at Johns Hopkins Hospital between 1995 and 2007, had adequate radiological follow-up to meet inclusion criteria. The primary endpoint was surgical resection. Secondary endpoint was radiological progression and clinical outcome.

Results: Eleven patients (3%) required surgery. Radiological progression was observed in 116 (30.0%) patients, in 35 (9%) patients the treatment volume more than doubled during the follow-up period, although nobody has required surgery to date.

Innovation/Discussion: According to VS radiosurgery literature, our success rate would be 97%, because only 11 patients (3%) needed «salvage surgery».

We see three problems with this definition of success.

1-The term «salvage» surgery is improperly applied.

«Salvage» surgery, in trauma, aims at controlling major vascular injuries that are immediately life-threatening and otherwise likely to produce the deadly triad of hypothermia, acidosis, and coagulopathy. Once bleeding is controlled, patients are best served by cessation of the operation, and transfer to the ICU, where the physiologic derangement is corrected, before the patient can undergo definitive operative procedures.

In Oncology, «Salvage» surgery for recurrent cancer, especially when original therapy included irradiation, generally refers to major destructive procedures providing only modest benefit at high personal cost to the patient.

In the management of VS, surgery necessary to address tumor growth after Radiosurgical treatment is generally very successful, hardly «salvage»

2- In Radiation Oncology, Progression Free Survival (the length of time a patient has survived without noticeable growth of the cancer from the treatment) and Primary Tumor Control (absence of a documented tumor recurrence or progression at the primary site) measure success. In the management of VS, if we use the above definition, we cannot call success post-treatment growth, even if it has not required surgery during the period of follow-up.

3- Our present definition of success is not transparent and potentially misleading.

Conclusion: It behooves the radiosurgical community to make a concerted effort to improve its definition of success in adherence to accepted standards.

P1008

THE CLINICAL OUTCOME AND EFFICACY OF GAMMA KNIFE RADIOSURGERY FOR VESTIBULAR SCHWANNOMAS. A STUDY OF 75 SUCCESSIVE CASES. KARACHI EXPERIENCE.

Abid Saleem¹ Azher Rashid¹ M Hashim A Sattar¹

(1) Pakistan GammaKnife and Stereotactic Radiosurgery center.NMI, Karachi, Pakistan

Objective: To evaluate the clinical outcome and efficacy of gamma knife Radiosurgery for vestibular schwannoma.

Material and Methods: Since May 2008 till August 2010, 75 patients with vestibular schwannoma (excluding neurofibromatosis II) were treated with Leksell Gamma Knife 4c at Pakistan Gamma Knife and Stereotactic Radiosurgery Center, Karachi. There were 31 females and 39 male patients. The patients age ranged from 24 to 71 (median 42 .8 yrs).Thirteen patients (17%) had undergone partial or total excision of their tumor prior to gamma knife surgery. The size ranged from 448.2mm³ to 38.7 cm³ (median 16.85cm³). Multiisocenter dose planning placed a prescription dose of 10 -14 Gy on the 45 -50% isodose located at the tumor margin. Median prescription dose at 50 % isodose is 12 Gy. Follow up ranged between 1 to 27 months (median 14 months).Clinical and magnetic resonance (MR) imaging follow up evaluations were routinely performed every 6 months.

Results: A loss of central enhancement (central necrosis) was demonstrated on MR imaging in 86.5 % of the patients. At the latest MR imaging assessment decreased or stable tumor volume was demonstrated in 95% of the patients. No facial nerve toxicity was observed. Temporary non specific vestibulo-cochlear symptoms were reported in 13% of patients. Of patients with discernible hearing Gardner- Robertson grades were unchanged in 80 % patients. Imbalance improved in 60 % patients. One patients had to undergo surgery because of increase in cystic portion of the tumor. Two patients had to undergo V.P shunt.

Conclusion: Gamma Knife Radiosurgery is a safe and effective treatment option for the management of vestibular schwannomas. The complications and morbidity after radiosurgery are far less frequent than those encountered after surgery. This, combined with its noninvasive nature is making radiosurgery increasingly the treatment of choice for such lesions.

P1009

RADIOSURGERY (SRS) FOR ACOUSTIC NEUROMAS - WHAT HAPPENS LONG TERM?

Daniel Roos¹

(1) Royal Adelaide Hospital, Adelaide, Australia

Objectives: Long term follow-up data on SRS for acoustic neuromas is limited. This report summarises the Results of the Royal Adelaide Hospital experience for patients treated with linac SRS at least 10 years ago.

Methods: Data was collected prospectively in the SRS clinic for 51 patients treated between 1994 and 2000. Four patients with NF2 and three treated for post-operative recurrence were excluded. For the remaining 44 patients, the median age was 63 (range 33-75), 26 were male and the median tumour diameter was 21 mm (range 11-34 mm). The marginal dose was 14 Gy (4 patients)

or 12 Gy (40 patients).

Results: No patient required surgical salvage. For the 35 patients with at least 10 years of potential follow-up (eight died and three were lost to follow-up before 10 years), 5 tumours remained stable and 30 decreased in size (median shrinkage 5 mm, range 3-15 mm). Of 22 surviving patients with serviceable hearing at presentation (pure tone average ≤ 50 dB), 5 patients (23%) have retained serviceable hearing at 107-183 mo follow-up, while 17 patients (77%) lost it at a median of 25 mo (range 8-77 mo). Five patients had new or worsened trigeminal neuropathies (14 Gy = 2, 12 Gy = 3), one of whom also had a facial neuropathy (12 Gy), all transient. Three patients required ventriculo-peritoneal shunting at 5, 6 and 27 mo (two with pre-existing ventriculomegaly). There were no second tumours attributable to the SRS.

Conclusions: Long term follow-up of SRS for acoustic neuromas confirms excellent tumour control (100% freedom from surgical salvage), but few patients preserve useful hearing. Late morbidity is very rare.

P1010

FRACTIONATED STEREOTACTIC RADIOSURGERY FOR LARGE ACOUSTIC NEUROMAS: HEARING PRESERVATION AND COCHLEAR DOSE

Maged Ghaly¹ Jana Fox¹ Ajay Kapur¹ Mihaela Marrero¹ Lili Vijeh¹ Diana Schettini¹ Petrina Zuvic,¹ Michael Schulder¹

(1) Departments of Radiation Oncology and Neurosurgery, Hofstra North Shore-LIJ School of Medicine, New York, USA

Introduction: Hearing preservation after stereotactic radiosurgery (SRS) in patients with large acoustic neuromas (AN) has been correlated with cochlear dose. Fractionated SRS (FSRS) offers the potential of preserved hearing despite coverage of the cochlea with therapeutic doses.

Materials and methods: Seven consecutive patients (5 female, 2 male, median age 63 years) were treated with FSRS for large ANs. The median tumor volume was 3.79cc (range, 2.075- 8.349 cc) with MRI showing mass effect on the brain stem in all patients. Symptoms at presentation included decreased hearing in all patients, facial numbness in four, ataxia in three and, dysphagia in one patient. Two patients underwent neurosurgical intervention (surgical resection or shunt placement) prior to radiation. A noninvasive, repeat-fixation mask was used for simulation by way of spiral CT (2 mm slice thickness), and for treatment. Patients received 25 Gy in 5 consecutive daily fractions of 5 Gy. All treatments were prescribed to the 90% isodose and given using a dedicated 6 MeV linear accelerator and stereotactic positioning system (Novalis, BrainLAB, Munich). Differential collimation and beam weighting achieved conformality. Volume maximum dose and maximum point dose to brain stem were 22 Gy to < 0.5 cc, 25 Gy respectively. Cochlea maximum point dose was 25 Gy in all patients.

Results: At a median follow up of 12 months (range, 6- 24 months), all patients have stable baseline hearing loss; audiometry was unchanged in the immediate post treatment period. Two patients developed transient tinnitus. There were no other new deficits related to cranial nerve, brainstem or cerebellar function. In all patients followup MRI demonstrated tumor control with central necrosis.

Conclusion: FSRS can be used to treat patients with large acoustic neuromas with preservation of pre-treatment hearing levels despite delivery of therapeutic dose to at least part of the cochlea. We will continue follow up to validate these Results over a longer time period.

P1011

RADIOSURGERY FOR NFII TUMORS LONG-TERM OUTCOMES AND THE ROLE OF RADIOSURGERY

Yoshihisa Kida Yoshi¹ Toshinori Hasegawa¹

(1) Komaki City Hospital, Komaki, Japan

The definite roles of radiosurgery and microsurgery for NFII tumors are not settled yet. Very long term outcomes for them after gamma knife treatment are reported.

Cases and Methods: There are 35 cases of NFII bearing bilateral acoustic tumors, including 18 males and 17 females. The ages are ranging from 7 to 71 years with a mean of 40 years at radiosurgery. Tumors ranged from 10 to 44 mm(mean 24.3 mm) in mean diameter, and were treated with 9.9 to 15 Gy (mean 12.6 Gy). Total outcome concerning tumor control, functional outcome and adverse effect were evaluated.

Results: The actuarial tumor control and response rate are 97.8% and 57.8% respectively in the mean follow-up more than 8 years. In contrast 60% of contralateral tumors were unchanged, and 40% were enlarged. Hearing preservation for treated and non-treated contralateral tumors were 64% and 77% respectively. As adverse effects, perifocal edema, hydrocephalus, facial spasm, encapsulated hematoma were reported in each one case. Total outcomes were worse than other schwannoms because of deteriorating hearing.

Conclusion: It is apparent that radiosurgery can control the NFII acoustic tumor for a very long time. However it is required to improve hearing preservation in order to guarantee the good quality of life for the patients.

P1012

CANCELLED

P1013

GAMMA KNIFE RADIOSURGERY FOR LOW CRANIAL NERVE SCHWANNOMAS

Dong Gyu Kim¹ Sang Woo Song¹ Hyun-tai Chung¹ Sun Ha Paek¹ Jung Ho Han² Yong Hwuy Kim¹ Jin Wook Kim¹ Jung Hun Park² Young-hoon Kim¹

(1) Department of Neurosurgery, Seoul National University College of Medicine, Seoul, Korea(2) Department of Neurosurgery, Seoul National University Bundang Hospital, Gyeonggi-do, Korea

Objectives: Low cranial nerve schwannomas are uncommon intracranial tumors. For some patients, complete surgical resection is possible but may be associated with significant morbidity. Gamma Knife radiosurgery is a minimally invasive alternative or adjunct to micro surgery for such tumors. The purpose of this study is to evaluate the effect on tumor growth and symptom relief in patients with low cranial nerve schwannomas after undergoing gamma Knife radiosurgery.

Methods: Thirty-six patients underwent Gamma-knife radiosurgery between December 1997 and November 2009. Fourteen patients had undergone previous tumor resection and the others underwent Gamma Knife radiosurgery as their primary treatment. There were 12 men and 24 women. The mean tumor volume was 4.7ml (range 0.5 - 13.7ml). A median of nine isocenters were used. Median marginal and maximal doses were 13 and 26 Gy, respectively.

Results: Four patients were lost to routine follow-up. The median duration of follow-up was 36 months(range 6-148 months). Tumor size decreased in thirteen patients, remained stable in thirteen, and increased in six patients. Overall volume control rate was 81.3%. Solid tumors showed statistically more effective volume control than tumors including cystic portion. Eleven patients improved and nineteen patients remained at their pre-GKS clinical status. Two patients had experienced clinical deterioration and underwent surgical intervention. Hoarseness was improved at 57% (8/14) and swallowing dysfunction was improved at 64% (7/11). Loss of central enhancement was occurred at 22 patients (69%).

Conclusion: Gamma Knife radiosurgery is very effective and safe treatment modality for solid low cranial nerve schwannoma. But caution should be paid in Gamma Knife radiosurgery for low cranial nerve schwannomas including cystic component. Loss of enhancement is common phenomenon in Gamma Knife radiosurgery for low cranial nerve schwannomas and we need a understanding of their usual clinical course.

P1014

FIRST YEAR OUTCOME OF PATIENTS WITH VESTIBULAR SCHWANNOMA AFTER ROTATING GAMMA SYSTEM TREATMENT.

Géza Mezey¹ József Dobai¹, ² Gábor Csiky¹ Imre Fedorcsák¹, ² László Bognár¹, ²

(1) Debrecen University, Dept of Neurosurgery, Debrecen, Hungary (2) Debrecen University, Gamma Radiosurgery Center, Debrecen, Hungary

Purpose: Today, in the management of vestibular schwannoma the radiosurgery is worldwide accepted. Different radiosurgical systems are used, but there is a little information with use of rotating gamma system (RGS). We decided to collect and compare our result to the literature and evaluate the efficiency of RGS in the treatment of vestibular schwannoma.

Methods: Between September 2007 and February 2010, 186 patients with vestibular schwannoma (<3cm) underwent radiosurgery with RGS (GammaART 6000NT Rotating Gamma System, American Radiosurgery, San Diego, CA). The mean marginal dose was 12Gy (10-13Gy). Data was collected at time of RGS treatment and 6, 12 months after. At time of treatment and time of clinical controls, MRI scans were done also to evaluate the morphological changes. 76 of 186 patients were excluded, because of short term follow-up (<1yr) or lack of further information.

Results: In the first year 1 patient had complete tumor regression. After 6 months, 7 patient's tumor size increased. Progression was noticed on MR images in 4 cases by the end of first year. In other cases the tumor morphology was unchanged or central hypointensity was observed with different volume reduction. Within the first 48hrs after treatment 34% of patients had acute complaint, mostly headache (22%), nausea or vomiting (10%) and vertigo (5). Later, complication was mentioned by 28% of patients (12% headache, 7%vertigo, 2% tinnitus, 2% trigeminal symptoms etc.). Facial neuropathy was noticed in 3 cases, 2 weeks, 6 and 10 months after irradiation. 2 of 3 cases remained partial, and 1 has passed away. Hearing preservation was not evaluated because most of the patients had no effective hearing at time of treatment. The mean hospital stay was average 1.2 days (1-4days). The mean time lost from work after treatment was 16days (1-160days). 96 patients had jobs before radiosurgical treatment. 94 of 96 patients returned to their job, 66% within 1 week, 78% within 2 weeks and 95% in the first month. Two patients who did not return to work had continuous discomfort feeling because of tinnitus.

Conclusion: Within the first year good tumor control was observed. Side effects are relatively rare and well tolerable so patients have good chance to return to their work and continue the same quality of life. Short term Results suggest that treatment of vestibular schwannoma with RGS is safe and it might as effective as use of other radiosurgical systems (1) but further clinical study is warranted with larger patient groups and a longer follow-up period.

(1) Lunsford LD. et al: Radiosurgery of vestibular schwannomas: summary of experience in 829 cases. J Neurosurg 2005;102 Suppl:195-9.

P1015

STEREOTACTIC RADIOSURGERY OF CRANIAL NERVE NEURINOMAS

Omelian Trompak¹ Miron Šramka¹ Martin Chorvath¹ Mario Rattaj¹ Gabriel Kralik¹ Augustin Durkovsky¹ Štefan Galbavy¹

(1) Clinic of stereotactic Radiosurgery St. Elisabeth Oncological Institute, Bratislava, Slovakia

¹Trompak O. ¹M.Šramka, ¹Rattaj M., ²Chorváth M., ³Králik G., Durkovský A., ⁵Galbavý Š.

1Clinic of Stereotactic Radiosurgery St. Elisabeth University of Health and Social Work, Bratislava, Slovakia -

2Clinic of Radiotherapy St. Elisabeth Cancer Institute - 3Department of Radiation Physics St. Elisabeth Cancer Institute - 4Clinic of Radiodiagnostics Medical Faculty, Comenius University - 5Institute of Laboratory Medicine St. Elisabeth University of Health and Social Work

We are presenting a retrospective evaluation and Results of LINAC based stereotactic radiosurgery (LINAC SRS) of vestibular schwannomas treated during the period of 8 years (2000 ->2008) at the Clinic of Stereotactic Radiosurgery of St. Elisabeth University of Health and Social Work, Bratislava, Slovakia.

Methods: We analysed 210 patients, 206 patients with acoustic neurinomas, 3 patients with trigeminal nerve schwannomas and one patient with glossofaryngeal nerve neurinoma. 34.7 % were males, 65.3% females, median age was $48.6 \pm 2.04(14-83)$. 33.2% of patients had prior microsurgery(18.4% with relapses and 14.8 % with residual tumours). The median dose to the tumour margin was $12.5 \text{ Gy} \pm 0.5$. Treatment safety: the maximal dose to the brain stem was 12.0Gy, to the optical structures 8.0Gy, lens 0.6 Gy. For visualisation of target volume and critical structures CT and MR fusion for each patient was done. Treatment was performed on linear accelerator (Clinac 600C/D, Clinac 2100 CD) with the use of rigid stereotactic ring, treatment planning was done by Leibinger STP 3.4 and intensity modulated stereotactic radiosurgery (IMSRS) by MIMiC (Nomos).

Results and conclusion: 5 years tumour control was 93.8%; in 8.2% of treated patients by LINAC SRS growth progression was detected during the follow-up. In our experience LINAC based SRS of cranial nerves neurinomas represents treatment of choice for tumours with volumes less then 10 cm³ without significant acute and late neurological complications with acceptable hearing preservation. Volumetric MR study is a precise tool for local control evaluation. For larger tumours fractionated radiotherapy or combination of neurosurgical extirpation with stereotactic radiosurgery might be a reasonable treatment option.

P1016

LONG TERM FOLLOW UP OF LINEAR ACCELERATOR RADIOSURGERY FOR VESTIBULAR SCHWANNOMA: EVALUATION OF 3-D VOLUMETRIC CHANGES OVER 10-YEAR TREATED IN A SINGLE INSTITUTION.

Kensaku Kamada¹ Shiro Baba¹ Kenta Ujifuku¹ Takayuki Matsuo¹ Kazuhiko Suyama¹ Izumi Nagata¹

(1) Department of Neurosurgery, Nagasaki University School of Medicine, Nagasaki, Japan

Purpose: Because of the benign behavior of vestibular schwannomas (VSs), long-term follow-up after the treatment is required. So many studies reported about radiosurgery for VSs. Among them, almost all mentioned about tumor control, however, a few studies referred 3-D volumetric changes. It is very important to evaluate precise tumor volume particularly in order to detect the tumor progression. However, up to now no long-term follow-up of 3-D volumetric change over 10-year after radiosurgery has been reported. We report on retrospective study with the administration of LINAC radiosurgery followed over 10-years in 20 patients harboring VSs in our single institution. Moreover, we estimated the precise tumor volumetric change.

Materials and Methods: Between October 1993 and October 1999, VSs had been diagnosed in 45 patients who underwent LINAC radiosurgery in our unit. Data for analysis were obtained in 20 consecutive patients (6 men and 14 women) in this study. The median age was 54 years (range 21-63 years). Six patients (30%) had previously undergone resection. All cases involved unilateral tumors with a median volume of 2.1 ml (range 0.5-8.9 ml). Depending on the tumor size and configuration, 1 to 4 isocenters (median 2 isocenters) were targeted. The median radiation dose directed to the tumor margin was 14 Gy (range 10-14 Gy), and the median maximal dose was 23 Gy (range 17-36 Gy). To measure tumor volume, we obtained 3D-SPGR MR imaging sequences.

Results: The median duration of the follow-up MR imaging studies was 150 months (range 124-192 months). Of 20 patients, 18 obtained tumor shrinkage. Two (10%) patients underwent second radiosurgery. No neurosurgical resection was needed. The actuarial 10-year progression-free survival rate was 90%. Serial volumetric changes revealed that eight (40%) of 20 patients demonstrated tumor shrinkage even after the 10th year. Radiation injury on MR images occurred in two patients. No patient experienced malignant transformation.

Conclusion: LINAC radiosurgery proved to be a safe and effective treatment for patients followed longer than 10 years who presented with tumors with a volume of less than 10 cm³. Additional tumor shrinkage may occur continuously over 10-year after radiosurgical treatment for VSs.

P1017

OUR EXPERIENCE OF GAMMA KNIFE RADIOSURGERY OF SAMII T4 VESTIBULAR SCHWANNOMAS

Sergey Ilyalov¹ Svetlana Zolotova¹ Valery Kostjuchenko¹ Marina Zotova¹ Natalia Nikonova¹ Igor Pronin¹ Andrey Golanov¹

(1) Burdenko Neurosurgical Institute, Moscow, Russian Federation

Gamma Knife radiosurgery is effective treatment of vestibular schwannomas. However indications to the GKRS of large tumors and Results of treatment are controversial.

Methods: 165 patients with VS were treated during 2005-2008 period. Local compression of brain stem have been observed in 80 cases, include 29 cases with deformation of 4-th ventricle (Samii T4b) among them. There were not symptomatic brain stem compression or intracranial hypertension. Male-female ratio was 1:2,6. Median age was 46. Neurofibromatosis II has been found in 5 cases. 25 patients have been operated previously. Tumor median volume was 6,9 cc (maximum 13,8 cc). Deafness founded in 27 of 69 patients whom-TMs audiograms were carrying out. Marginal dose was 12 Gy.

Results: after GKRS stable hearing founded in 33 of 42 patients (76,8%), functional hearing preserved in 16 (38%). Facial palsy (House-Brackmann 2-5) founded in 7 cases (8,7%). Complete

or partial recovery of facial nerve function was observed in 6 patients with corticosteroids in use. Open hydrocephalia was observed in 3 patients. Shunt operation was needed in only 1 of this. Continuing growths of tumors founded in 3 cases and then 1 patient was operated, two of this -> both reirradiated. There were not postirradiation brain stem edema. Total tumor growth control make up 96%.

Conclusion: GKRS is effective and safety alternative Methods of treatment of the large schwannomas without symptomatic brain stem compression

P1018

GAMMA KNIFE RADIOSURGERY FOR KOOS STAGE 4 VESTIBULAR SCHWANOMA -THE TREATMENT STRATEGY AND MIDDLE TERM RESULTS

Mariko Nagai¹

(1) Tokyo Women's Medical University, Tokyo, Japan

Introduction: In general, a surgical removal is selected for a treatment of Koos stage 4 vestibular schwannoma. In case of stage 1, we simply observe, and for stage 2 and 3 radiosurgery or operation, sometimes both of them. But in fact we sometimes find some cases that we can not select the surgical approach because of their age or general conditions. This time we analysed our cases that were Koos stage 4 and were treated by just only gamma knife. Then we will report about their suitable treatment strategy.

Materials and Methods: In our institute, we have experienced 133 vestibular schwannoma cases between Jan.2003 and Oct.2009. Among them we have 4 Koos stage 4 cases. There were 3 women and 1 man. Ages have ranged between 30 y.o. and 70 y.o. (average 64.5 y.o.) Tumor volumes have ranged between 2.3 cc and 3.9 cc (average 3.05 cc) For hearing ability before radiosurgery, we have 1 GR class 1, 1 GR2, 1 GR3 and 1 GR5. And we have not experienced any facial palsy (All of them present HB grade 1). As treatment, we selected 11-12 Gy for 50% prescription isodose.

Result: During 2 years after radiosurgery, all cases presented volume shrinkage more than 20%. Then we never needed a additional surgery. 75% of the patients could conserve their hearing activity, and only 1 patients presented hearing loss. There were no patients who presented trigeminal nerve disturbance, brain stem edema and so on.

In general surgical removal is the first strategy in case of Koos stage 4 vestibular schwannoma. But we should approach radiosurgery much more in any special cases. We need long-term follow-up.

P1019

THREE DIMENSIONAL TUMOR SEGMENTATION PROVIDES HIGHLY ACCURATE VOLUMETRIC ASSESSMENT OF VESTIBULAR SCHWANNOMAS FOLLOWING GAMMA KNIFE RADIOSURGERY

David Q Chen¹ Danielle D Desouza^{2, 3} Udi Blankstein¹ Karen Davis^{1, 2, 3} Normand Laperriere⁴ Mojgan Hodaie^{1, 2}

(1) Division of Neurosurgery, University of Toronto, Toronto, Canada (2) Institute of Medical Science, University of Toronto, Toronto, Canada (3) Toronto Western Research Institute, University of Toronto, Toronto, Canada (4) Radiation Medicine Program, University of Toronto, Toronto, Canada

Magnetic resonance imaging (MR) assessment of vestibular schwannomas (VS) is traditionally done by evaluating changes in two dimensional parameters, as a correlate of the overall volumetric change. 2D linear measures therefore provide an estimate of the 3D volume of an irregular shape (Varughese et al., 2010). There are however inherently unavoidable errors with 2D measurements. We have previously demonstrated the feasibility of visualizing accurate 3D relationships between acoustic neuromas and surrounding cranial nerve fibers using combined 3D tumor volume definition and tractography of the cranial nerves (Chen et al., 2010). In this study we explore the technique of manual segmentation of VS and comparison with 2D assessment of tumor size. Several time-points, before and after GK radiosurgery were used, to identify changing trends of tumor volume and how these compare between the two Methods.

1.5 Tesla T2 FIESTA MR sequences of three patients (ages 41-56) with VS were studied. Segmentation was performed using the 3D Slicer software. The volume of the tumor was contoured on anatomical images and 3D representations were constructed from the contoured segmentation mask and overlaid onto the anatomical T1 for visualization. Volume statistics were computed for each timepoint. At the same time, two dimensional measures of the tumor were undertaken, and the change in size with time compared with both Methods.

Segmentation can depict the tumor volume with accuracy, and allows for more detailed measure of volume change with time. The estimated spheracle constructed from 2D measurements was inaccurate in one case since it suggested no significant change in tumor size, while 3D segmentation showed an increase of 4% in tumor size, likely in keeping with early tumor pseudoprogression. While the trend of change in tumor size was relatively similar for both Methods, the actual tumor volumes differed significantly, confirming that 2D measures are inherently inaccurate as 3D correlates. Segmentation may be the best tool for assessment of the phenomenon of tumor pseudoprogression and change in tumor volume with time.

References: Chen DQ, Quan J, Guha A, Tymianski M, Hodaie M (2010) Three dimensional in vivo imaging of cranial nerve fibers associated with vestibular schwannomas using diffusion based tractography. Neurosurgery

Varughese JK, Wentzel-Larsen T, Vassbotn F, Moen G, Lund-Johansen M (2010) Analysis of vestibular schwannoma size in multiple dimensions: a comparative cohort study of different measurement techniques. Clinical otolaryngology : official journal of ENT-UK ; official journal of Netherlands Society for Oto-Rhino-Laryngology & Cervico-Facial Surgery 35:97-103

P1020

LOCAL CONTROL AND SATISFACTION SURVEY OF PATIENTS FOLLOWING LINAC RADIOSURGERY FOR BENIGN INTRACRANIAL TUMORS.

Maria Aggeliki Kalogeridi¹ Paraskevi Georgolopoulou² Kleanthi Doukakis³ Konstantinia Sotiriadou⁴ Vassilis Kouloulis¹ Anastasia Sotiropoulou⁵ John Kouvaris¹ George Pissakas³

(1) Radiotherapy Unit, Medical School, National University of Athens, Athens, Greece (2) Department of Medical Physics, St Savvas Anticancer Hospital, Athens, Greece (3) Alexandras' General Hospital, Athens, Greece (4) University Hospital of Larissa, Larissa, Greece (5) Radiotherapy Department, St Savvas Anticancer Hospital, Athens, Greece

Approach: To investigate local control, toxicity, patients'-™ satisfaction and quality of life after radiosurgery in a group of consecutive patients treated with linear accelerator (Linac) radiosurgery for intracranial benign tumors.

Relevance/Innovation: Between 2000 and 2004, 34 patients (median age 65.5 years, range 50-84) with unilateral acoustic neuroma or benign meningioma were treated with linear accelerator-based stereotactic radiosurgery. Six patients were referred for treatment of residual or recurrent tumor after surgical resection, while 28 patients were offered radical radiosurgery. Median tumor volume was 5.95cm³. The dose for neuroma and meningioma patients was 11-12 Gy and 12-15.5 Gy, respectively. On the treatment day a Brown-Roberts-Wells stereotactic head-frame was screwed onto the patient-™s skull under local anesthesia. The whole procedure was carried out in 8-9 hours. The follow-up consisted of imaging studies and clinical examinations with assessment of facial and trigeminal nerve function at 6 and 12 months after the intervention and yearly thereafter. Any deterioration of preexisting symptoms or new symptoms interfering with quality of life after radiosurgery was also recorded.

Results: Follow-up time ranged from 76 to 125 months (median 101 months, mean 100.5 months). Nineteen (59%) tumors decreased in size and 13 (41%) remained stable. None of the tumors increased in size in the long-term follow-up. No patient developed permanent neurological toxicity or deterioration of preexisting symptoms. All patients rated the experience convenient since the procedure was completed in a few hours and in an outpatient basis. Most of them reported minor to moderate pain while the stereotactic frame was being attached but no discomfort for the rest of the procedure. Quality of life was unchanged or higher after radiosurgery and the vast majority of patients (97%) would recommend linear accelerator-based stereotactic radiosurgery.

Conclusions: After a median follow-up of more than eight years, linear accelerator-based radiosurgery for neuromas and meningiomas is found to be not only highly effective, but also a convenient, minimally invasive radiotherapeutic procedure that does not reversely affect the patients'-™ quality of life.

P1021

SPHENOORBITAL MENINGIOMAS (INTRAOSSEOUS MENINGIOMA): RADIOSURGERY 10 YEARS AND 41 PATIENTS EXPERIENCE

Luis Larrea¹ Enrique Lopez¹ Jose Bea² Maria C Baños² Maria A Garcia² Conrado Pla²

(1) Hospital NISA Virgen del Consuelo. Servicio de Oncología Radioterapica., Valencia, Spain (2) Hospital NISA Virgen del Consuelo. Sevcio de Fisica Medica., Valencia, Spain

Sphenoorbital meningiomas are complex tumours involving the sphenoidal wing, orbit, cavernous sinus, frontal and temporal lobes, have a difficult clinic diagnostic, only when they have symptomatic intracranial tumour or orbitary symptoms. Their complete resection is very difficult or impossible. After patients re-evaluation they can be classified also as intraosseus meningiomas. Surgery is the usual treatment and sometimes with pre-operative embolization, but postoperative morbidity and a high recurrence rate are common. Post-operative radiotherapy has low effect and high difficulty because of the low tolerance of proximal organs. We describe our experience with radiosurgery for relapse, post-operative treatment or exclusive treatment.

Objectives: Evaluation the radiosurgery treatment, that is one effective option for those patients have. Surgery is the usual treatment.

Methods: Between February 2000 and February 2010 we had treated 41 patients (19 male and 22 females between 29 and 82 years old) with Sphenoorbital meningiomas, 10 post-operative, 19 after surgery relapse after 30 months (3-230 months). 71% patients have symptoms. We performed MR and CT scans to verify the osseous involvement. The treatment target involves the entire tumour, including the osseous component. The stereotactic procedure has been performed with the Elekta G frame, and both CT and MR scans and RTPS SIMUPLAN. Arctherapy with cones and Elekta SL75/5 linac was used. The marginal dose we had planned is 15 Gy in 36 cases, 12 Gy in 3 cases, and 3 cases with 10 Gy after 40 Gy conventional radiotherapy. All of them included the tumour, affected bone and intraorbital component for a median volume of 9,4 ml (1,6-30,7 ml). Maximum significant dose to the optic nerve was less than 12 Gy, and less than 8 Gy to the optic chiasm. The number of isocenters used was 1 to 6 including 92,5% tumour volume.

Results: Median follow up 34 month (6-105 months).

Side effects, acute and chronics: 57% had retroocular pain after radiosurgery during 6-18 months. 2 patients had epilepsy episode. 35% show oedema in follow up MR.

Tumour control with no growing in 95%, tumour necrosis and shrinking in 43%, symptoms relieve in 92%.

Conclusions: Radiosurgery is a good and safe treatment for these rare tumours that involve sphenoorbital bone. We had excellent symptoms relief. We have observed very low toxicity, auto limited, and low incidence of side effects and very good tolerance and local control.

P1022

LONG-TERM OUTCOMES OF STEREOTACTIC RADIOSURGERY FOR THE TREATMENT OF CAVERNOUS SINUS MENINGIOMAS.

Marcos Santos¹ Jose Salcedo¹ Jose Diaz¹ Felipe Calvo¹ Jose Samblas¹ Hugo Marsiglia¹ Kita Sallabanda¹

(1) Grupo IMO, Madrid, Spain

Background: Patients with cavernous sinus meningiomas (CSM) have an elevated risk of surgical morbidity and mortality. Recurrence is often observed after partial resection. Stereotactic radiosurgery (SRS), either alone or combined with surgery, represents an important advance in CSM management, but long-term Results are lacking.

Patients and methods: Eighty-eight CSM patients, treated from January 1991 to December 2005, were retrospectively reviewed. The medium follow-up was 86.8 months (range: 17.1 to 179.4). Among them, 22 were followed for more than 10 years. There was a female predominance (84.1%). The age varied from 16 to 90 years (medium: 51.6). Forty-seven patients (53.4%) received SRS alone, and forty-one patients (46.6%) had undergone surgery before SRS. A dose of 14 Gy was prescribed to isodose curves from 50% to 90%. In 25 patients (28.4%), as a result of the proximity to organs at risk, the prescribed dose did not completely cover the target.

Results: After SRS, 65 (73.8%) patients presented tumor volume reduction; 14 (15.9%) remained stable, and 9 (10.2%) had tumor progression. The progression-free survival was 92.5% in 5 years, and 82.5% in 10 years. Age, sex, maximal diameter of the treated tumor, previous surgery and complete target coverage did not present significant associations with prognosis. Among the 88 treated patients, 17 presented morbidity that was related to SRS, and 6 of them spontaneously recovered.

Conclusions: SRS is an effective and safe treatment for CSM, feasible either in the primary or post-surgical setting. The incomplete coverage of the target did not worsen the outcome. More than 80% of the patients remained free of disease progression in long-term follow-up.

P1023

STEREOTACTIC RADIOSURGERY AS A SALVAGE TREATMENT OPTION FOR ATYPICAL/ANAPLASIC MENINGIOMAS

Marcos Santos¹ Kita Sallabanda¹ Jose Salcedo¹ Jose Diaz¹ Felipe Calvo¹ Hugo Marsiglia¹ Jose Samblas¹

(1) Grupo IMO, Madrid, Spain

Background: Non-benign meningiomas (NBM) are characterized by aggressive behavior. Surgery is the initial treatment of choice, but in cases of recurrence, options become more limited. Due to the rarity of the disease, the optimal management of recurrences is not well defined. We present our Results from salvage treatment with stereotactic radiosurgery (SRS) in previously surgically treated patients after long-term follow up.

Patients and methods: Seventeen patients treated between 1993 and 2007 were retrospectively reviewed. There were 16 atypical and 1 anaplastic meningiomas, with a mean follow-up of 64.8

months (range: 8.4 to 170.1 months). There was a male predominance (70.6%). Ages varied from 16 to 76 years (mean: 48.7). The most frequent tumor sites were the convexity of the skull and the parasagittal region (36% each). Five patients had undergone another surgical resection before being considered for SRS, and 4 patients had received radiotherapy as an adjuvant to surgery, two after the second resection. At the time of recurrence, most of the patients (78.9%) presented a single tumor nodule, while 4 presented multicentric disease (21.1%). Lesion volumes varied from 0.8 to 12 cm³ (mean: 5.3 cm³). A total of 22 tumors were treated. The most frequent symptom leading to the diagnosis of recurrence was epileptic seizures (7 patients), followed by various degrees of hemiparesia (6 patients). A dose of 12 to 16 Gy (mean: 14.1 Gy, median: 14 Gy) was prescribed according to isodose curves from 50 to 90%.

Results: After SRS, 3 of the patients (17.6%) presented with tumor volume reduction (one complete response), 7 (41.2%) remained stable, and 7 patients presented with tumor progression. Two patients (11.8%) developed new lesions. The Kaplan-Maier-estimated progression-free survival (PFS) and overall survival (OS) were 65.9% and 81.6% at 5 years and 35.2% and 43.5% at 10 years. Age, sex, site and tumor volume were not significantly associated with the prognosis. A tendency toward worse OS was detected among patients presenting with multicentric disease ($p=0.06$). No relevant toxicity was described after SRS.

Conclusions: SRS provided an effective and safe treatment for this group of patients with recurrent NBM. Patients who present with multicentric disease will probably fare more poorly.

P1024

STEREOTACTIC RADIOSURGERY AND RADIOTHERAPY FOR MENINGIOMAS: PREDICTORS OF PATIENT OUTCOME AND RESPONSE TO THERAPY

Randy Jensen¹ Dennis Shrieve¹ Annabelle Shrieve¹

(1) Huntsman Cancer Insitutie, University of Utah, Salt Lake City, USA

Relevance and Innovation: We explore outcomes of patients with intracranial meningiomas treated with stereotactic radiotherapy (SRT) or radiosurgery (SRS) in regards to patient and treatment characteristics, tumor histology and hypoxia-related biomarker analysis.

Approach: Outcomes of 155 patients with 165 intracranial meningiomas treated with 172 treatments of either SRT (80 treatments) or SRS (92 treatments) are reviewed. Median follow-up was 36 months. Patient gender, age, tumor volume, tumor grade, prior therapies, and select set of tumor hypoxia-regulated biomarkers were correlated with tumor local control and overall survival. Median tumor volumes for SRS treated patients was 2.72 cm³ (range 0.8-43.4) treated to a median dose of 1500 cGy and 12.54cm³ (range 0.5-78.85) treated to median of 5400 cGy for SRT patients. Histology was available in 78 patients, 48 WHO I, 27 WHO II, and 3 WHO III. Tissue was available for immunohistological biomarker analysis in 52 patients (20 receiving SRT and 32 SRS) for Hypoxia-inducible factor-1 (HIF-1), vascular endothelial growth factor (VEGF), glucose transporter-1 (Glut-1), and carbonic anhydrase-IX (CA-IX). We also examined this tissue for microvascular density (MVD) and proliferative index using MIB-1 staining.

Results: Ten patients received more than one treatment session; six patients for recurrent disease and 4 for separate tumors. Local control was 67/74 (91%) for SRT treated patients and 81/87 (93%) for SRS treatment. Six SRS failures and 2 SRT failures required surgery, 2 were pre-SRS mistaken

for metastatic disease. There was no correlation between tumor volume and local control. The majority of treatment failures occurred in patients with WHO II tumors. In fact, tumor histology, which correlated with MIB-1 staining, was predictive of both progression-free survival (PFS) and overall survival (OS). Our preliminary examination has yielded no predictive value for response to radiation therapy in regards to HIF-1, VEGF, Glut-1, CA-IX, or MVD. Thirty-three patients were treated with surgery before SRT, with SRT used as a salvage therapy in 13 patients as a post-op adjuvant in 20. Sixty patients were treated with surgery before SRS, with 25 treated up front and 35 as salvage therapy. There was no statistical difference in local control between adjuvant and salvage therapy in either group.

Conclusions: SRS and SRT are very successful in controlling intracranial meningioma growth. Tumor histology appears to be the only predictive marker for response to stereotactic radiation therapy. Our study is limited by low numbers of treatment failures and with longer follow-up more correlations may be found.

P1025

FRACTIONATED STEREOTACTIC RADIATION (FSR) FOR MENINGIOMAS IMPINGING ON THE OPTIC APPARATUS.

Raphael Pfeffer¹ Uzi Nissim¹ Iris Gluck¹ Dror Alezra¹ Roberto Spiegelmann¹

(1) Sheba Medical Center, Tel Hashomer, Israel

Objectives: To assess the clinical and radiological Results of FSR in the treatment of optic nerve sheath or skull base meningioma impinging on optic apparatus treated at Sheba Medical Center from initiation of our program in November 2002 until November 2009.

Methods: 159 patients with meningioma presenting with visual symptoms or with lesions impinging on optic apparatus have been treated on a standard protocol of stereotactic irradiation receiving a total dose of 50.4 Gy in 1.8 Gy fractions calculated to the 90% isodose line. The PTV included the GTV with 3 mm margins. The prescription dose covered the entire GTV and at least 95% of the PTV and maximum dose to optic nerve was 56 Gy. 23 patients had optic nerve sheath (ons) meningioma and 136 patients had skull base meningioma (96 predominantly cavernous sinus, 13 petroclival, 21 parasellar). Age ranged from 26-79 years (median 56 years). 59 patients with non ons meningiomas had undergone previous surgery. Patients were immobilized in a removable frame and underwent MRI and CT planning after image fusion. Treatment was delivered with on a Varian linear accelerator using 4-5 dynamic arcs with the M3 micro-multileaf collimator. Median follow up is 45 months (range 12- 92 months). Follow up was by clinical symptoms, ophthalmologic exam and annual MRI.

Results: Acute toxicity was mild and limited to fatigue (29 patients) headaches (11 patients) and nausea (3 pt) and in all patients responded to low dose dexamethasone. 49 patients presented with vision impairment attributed to the meningioma (non-surgical). Vision improved in 34, was stable in 12 and worsened in 3 patient. Visual impairment was seen in only one patient presenting without visual symptoms. 21 patients reported subjective visual improvement on completion of their radiotherapy course and improved vision was noted within 6 months of completing radiotherapy in most responding patients. Long term tumor control was achieved in 94% of patients..

Conclusions: For patients with optic nerve sheath or skull base meningioma impinging on the

optic pathway FSR is well tolerated with little acute toxicity. Early improvement of visual symptoms is commonly seen and most patients have long term tumor control.

P1026

MENINGIOMATOSIS AND STEREOTACTIC RADIOSURGERY

Kita Sallabanda¹ Nicolas Isa¹

(1) IMO Group, Madrid, Spain

Introduction: Multiple intracranial Meningiomas are infrequent. Are benign tumors that usually are asymptomatic and the diagnosis in many cases is incidental and the treatment is postponed. In 1938 Cushing and Eisenhard (4) defined this entity as "something more than one meningioma and less than a diffusion of them-. Even now, cases reported as multiple meningiomas (MM) include a variety of conditions from which these lesions must be well differentiated. We reviewed our data base searching for meningiomatosis, multiple meningiomas possibly associated with neurofibromatosis type II (NF2).

Purpose: Multiple intracranial meningiomas are infrequent. Usually the main treatment has been surgery, but the surgical approach involves multiple procedures with a high risk of neurological complications. Recently stereotactic radiosurgery (SRS) has evolved as a valuable option. We retrospectively analyzed the prognostic factors and outcomes of the patients treated with SRS in our institution.

Material and Methods: Between September 1993 and September 2008, 73 patients with the diagnosis of meningiomatosis have been treated with SRS, 12 of them had a clinical diagnosis of NF2. Median age at diagnosis was 48 years (range 13-85), 78% were women. All underwent SRS treatment with photons, LINAC 6 MV, with a high-precision positioning system and mechanical fixation of the tertiary collimator (SR200-University of Florida), 3D planning with image fusion in our Radiosurgical Unit.

Results: The 73 patients have different previous treatments: Surgery 34 (46,7%), Surgery + SRS 18 (24,6%), SRS 3 (4,1%), and 18 (24,6%) patients didn't receive any treatment . We treat with SRS a total of 182 Meningiomas, with a median of 2 treatments per patient (range 1-10). Only 53 patients (72,6%) have biopsy, resulted in Meningiomas WHO type I in 49 patients, type II 3, and type III 1. The size of the Meningiomas treated with SRS <2cms 87 tumors, 2 to 4 cms 86, >4cms 9. The median marginal dose given was 14 Gy (range 10-16 Gy), median maximal dose of 16 Gy (range 12-28 Gy), median isodose of 90% (range 50-105%), median of isocenters was 2 (range 1-5). Only 70 patients were considered in the analyses, for 3 missed in the follow up. At the first evaluation, we found neurological disorders in 40 patients (57%). The median follow-up was 50,5 months (range 3-198). At the last follow up, the treated Meningiomas were controlled in 66 (94,2%) of 70 patients. Only 27 patients (38,5%) have neurological disorders. We did not have treatment complications.

Conclusions: In Meningiomatosis, SRS is an effective treatment, were multiple treatments can be performed in each patient, controlling the lesions, obtaining improvement and/or clinical stabilization of the patient, with low morbidity.

P1027

FRACTIONATED STEREOTACTIC CONFORMAL RADIOTHERAPY FOR LARGE BENIGN SKULL BASE MENINGIOMAS

Giuseppe Minniti¹ Enrico Clarke¹ Mattia Falchetto Osti¹ Luigi Cavallo² Paolo Cappabianca² Riccardo Maurizi Enrici¹

(1) Department of Radiation Oncology, Sant' Andrea Hospital, Università degli Studi di Roma "La Sapienza", Roma, Italy (2) Department of Neurological Sciences, Division of Neurosurgery, Università degli Studi di Napoli Federico II, Napoli, Italy

Purpose: to assess the safety and efficacy of fractionated stereotactic radiotherapy (FSRT) for large skull base meningiomas.

Methods and Materials: Fifty-two patients with large skull base meningiomas aged 34-74 years (median age 56 years) were treated with FSRT between June 2004 and August 2009. All patients received FSRT for residual or progressive meningiomas more than 4 centimeters in greatest dimension. The median GTV was 35.4 cm³ (range 24.1-94.9 cm³), and the median PTV was 47.6 cm³ (range 33.5-142.7 cm³). Treatment volumes were achieved with 5-8 noncoplanar beams shaped using a micromultileaf collimator (MLC). Treatment was delivered in 30 daily fractions over 6 weeks to a total dose of 50 Gy using 6MV photons. Outcome was assessed prospectively.

Results: At a median follow-up of 34 months (range 9-70 months) the 3-year and 5-year progression-free survival (PFS) rates were 96% and 90%, and survival was 100%. Three patients required further debulking surgery for progressive disease. Hypopituitarism was the most commonly reported late complication, with a new hormone pituitary deficit occurring in 10 (19%) of patients. Clinically significant late neurological toxicity was observed in 3 (5.5%) patients consisting of worsening of pre-existing cranial deficits.

Conclusion: FSRT as a high-precision technique of localized RT is suitable for the treatment of large skull base meningiomas. The local control is comparable to that reported following conventional external beam RT. Longer follow-up is required to assess long term efficacy and toxicity, particularly in terms of potential reduction of treatment-related late toxicity.

P1028

GAMMA KNIFE RADIOSURGERY FOR CEREBELLOPONTINE ANGLE MENINGIOMA EXTENDING INTO INTERNAL ACOUSTIC CANAL: TOLERABLE COCHLEAR RADIATION DOSE FOR HEARING PRESERVATION

Dong Gyu Kim^{1, 2} Young-hoon Kim^{1, 3} Hyun-tai Chung^{1, 2} Sun Ha Paek^{1, 2} Jung Ho Han^{1, 3} Yong HwY Kim^{1, 2} Jin Wook Kim^{1, 2} Sang Woo Song^{1, 2}

(1) Seoul National University College of Medicine, Seoul, Korea (2) Seoul National University Hospital, Seoul, Korea (3) Seoul National University Bundan Hospital, Seongnam-si, Korea

The purpose of current study was to evaluate the efficacy and the tolerable radiation dose to ipsilateral cochlea after Gamma knife radiosurgery (GKRS) for cerebellopontine angle (CPA) meningiomas extending into internal acoustic canal (IAC). Between 1998 and 2009, a total of 50 patients with follow-up over 1 year were enrolled. There were 5 male and 45 female patients whose median

age was 55 years (range, 15-75). At diagnosis 8 patients (16%) presented with non-serviceable hearing. The median pre-GKRS volume of tumor was 5.2 cm³ (range, 1.0-19.0), the median length of extending portion into IAC was 6.6 mm (range, 1.3-13.3), and the median prescribed marginal dose was 13 Gy (range, 10-15) at an isodose line of 50%. The median follow up duration was 39 months (range, 12-122). Radiological tumor control rate was 92% including unchanged 17 cases and decreased 29 cases. Only 2 patients (4%) underwent additional interventions because of a tumor control failure and an aggravated facial pain. After GKRS, preoperative cranial nerve dysfunction symptoms were relieved in 30 - 50% of the presented patients; tinnitus 53%, dizziness 56%, facial spasm 50%, facial palsy 33%, facial numbness 33%, and facial pain 38%. Of the 42 tumors with serviceable hearing, the hearing preservation rates were 98% at the last follow up. The mean radiation dose to cochlea of these cases was 5.8 Gy \pm 0.3 Gy. The tumor control rate of GKRS for CPA meningioma was very excellent, and the symptom improvement rate was reasonable. A 5.8 Gy was the tolerable radiation dose to cochlea not inducing hearing disturbance of GKRS for CPA meningioma extending into IAC.

P1029

SCRT OF MENINGIOMAS. A LONG-TERM FOLLOW-UP STUDY WITH REGARD TO LOCAL CONTROL, SURVIVAL AND MORBIDITY

Inge Compter¹ Kathrin Zaugg² Ruud Houben¹ Jim Dings³ Geert Bosmans¹ Claudia Buescher² Brigitta Baumert¹

(1) Dept. of Radiation-Oncology (MAASTRO), GROW (School for Oncology & Developmental Biology), Maastricht University Medical Centre (MUMC), Maastricht, The Netherlands (2) Clinic and Polyclinic of Radiation-Oncology, University Hospital Zurich (UHZ), Zurich, Switzerland (3) Dept. of Neurosurgery, Maastricht University Medical Centre (MUMC), Maastricht, The Netherlands

Purpose: To analyze the long-term Results in terms of efficacy of patients with a meningioma treated with fractionated stereotactic radiotherapy (SCRT).

Patients and Methods: Seventy-two patients treated with fractionated stereotactic radiotherapy between 1996 and 2008 at MAASTRO clinic (n = 45) and in Zurich (UHZ) (n = 27) were included. Patients received SCRT either as primary treatment (n = 46), as an adjuvant therapy following a subtotal resection (n = 19) or for recurrent tumours after a complete primary resection (n = 7). 49 of 72 tumours (68%) (21 UHZ, 28 MAASTRO) were located in the skull base region (cavernous sinus and pontine angle). Others were located in the brain lobes, in the pineal, suprasellar and cerebellar region, at the sinus sagittalis superior or the falx. The mean target volume was 31,0 ml (range 3 - 115ml). The median total dose was 54 Gy (range 50,4 - 59,4). Follow-up examination included MR-imaging and clinical work-up. Radiological control was defined as either complete response, partial response or stable disease according to the RECIST-criteria v1.1. Data were analyzed using univariate survival analyses.

Results: The median follow up was 4,13 years (range 0.66 - 11 years). Overall survival for patients with a WHO grade I and II meningioma was 92% and 75% at 3 years and 79% and 75% at 5 years, respectively. Progression-free survival for benign (grade I) meningiomas was 95% at 3 years and 95% at 5 years, and for atypical meningiomas 40% at 3 years. 98,4% of patients had either stable or improved (51,6%) clinical symptoms after radiotherapy. Late toxicity was observed in 17 (23,6%)

patients, of which 3 (4,2%) patients had grade IV toxicity. No deaths were related to treatment.

Conclusions: SCRT is a viable and successful therapy. Moreover, it is a safe and reliable non-invasive treatment for tumours that cannot be resected due to high risks involved.

P1030

CAVERNOUS SINUS MENINGIOMAS: GAMMA KNIFE RADIOSURGERY AS A FIRST LINE TREATMENT

Elena Kusak¹ Nuria Martinez¹ Jorge Gutiérrez¹ Germán Rey¹ Roberto Martínez¹

(1) GAMMA UNIT. HOSPITAL RUBER INTERNACIONAL, Madrid, Spain

Introduction: In spite of microsurgical and endoscopic advances, Cavernous Sinus Meningioma resection is usually subtotal and associated to high morbidity. In recent years, Radiosurgery has emerged as an important non invasive management option for treatment of these lesions, with excellent clinical and volumetric Results.

Object: To analyze our Results with Gamma Knife radiosurgery in this group of patients, and compare them with those previously published.

Methods: and Patient Profile: From October 1993 to January 2009, 141 patients with sporadic Cavernous Sinus Meningiomas have been treated and followed at our Gamma Knife Unit. Those tumors with known anaplastic or atypical features confirmed at a previous surgery were excluded. Mean age was 53.3 years, 73% being females. Seven patients had been previously operated on and 2 had received previous radiotherapy. The mean marginal dose was 12.9 Gy, ranging from 10 to 16.5 Gy. The mean volume was 11.6 cm³

Results: The mean follow-up has been 53.7 months (5-184 months), with 51 and 8 patients followed for more than 5 and 10 years respectively. The local volumetric control has been 97.9 % of which 77.3% were reductions and 20.6% stabilizations. In 2.1 % of tumors, progression was observed. In 8 patients clinical symptoms were alleviated, and 2 have had a clinical progression. No new treatment related symptoms have been observed. Asymptomatic edema was seen in 2 cases. One patient died in the postoperative period of a subsequent surgery after tumor progression.

Conclusions: Our experience confirms that Gamma Knife Radiosurgery is safe and effective in the treatment of cavernous sinus meningiomas as a first line treatment option, especially for cranial nerve function preservation

P1031

VISUAL OUTCOME AFTER SINGLE-SESSION GAMMA KNIFE RADIOSURGERY FOR PERIOPTIC MENINGIOMAS

Amr El-shehaby¹ Wael Reda¹ Khaled Abdel Karim¹

(1) Gamma Knife Center, Cairo, Cairo, Egypt

Aim: Perioptic meningiomas present a challenge for single-session stereotactic radiosurgery due to the low radiation tolerance of the anterior visual pathway. Fractionated radiation therapy and multisession stereotactic radiosurgery are sometimes proposed to reduce radiation toxicity to the visual pathway, when treating these tumors. This retrospective study aims at assessing the visual

outcome after single-session gamma knife radiosurgery (SSGKS) for meningiomas in direct contact with the anterior visual pathway.

Methods: Between August 2001 and December 2006 123 consecutive patients with skull base meningiomas were treated by single-session GKS. Seventy-three patients had meningiomas that were either in direct contact or displacing the anterior visual apparatus. The mean age was 50 years (21-80 years). Twenty patients had had previous surgery and one patient was previously treated by conventional fractionated radiotherapy. The mean follow up period was 34 months (12-72 months). The tumor volumes ranged from 0.95-34.2 cc (median 10.1 cc) with 39 patients having tumor volumes more than or equal to 10 cc. The marginal dose was between 6 and 12 Gy (mean 11.3 Gy) and the maximum dose to visual pathway was from 2 to 13.7 Gy (mean 9.3 Gy). Formal visual testing and clinical examination was performed before treatment and at follow up intervals beginning at 6 months.

Results: The visual field improved in 30 patients (42%), remained stable in 39 (53%) and worsened in 4 (5%). Ocular nerve palsy improved in 10 (56%) out of the 18 patients with pre-treatment palsy. Tumor volume after SSGKS was stable in 46 patients (60%), decreased in 26 (36%) and increased in 3 (4%). Out of the 30 patient with visual field improvement, 15 patients (50%) had no radiologically-proven tumor shrinkage.

Conclusion: Single-session gamma knife radiosurgery may be a safe and effective treatment for tumors in contact with the optic apparatus, with the possibility of visual and ocular nerve function improvement. Tumor shrinkage is not a pre-requisite for functional improvement.

P1032

SURGICAL APPROACH TO COMPLEX SKULL BASE MENINGIOMAS WITH THE AID OF GAMMA KNIFE SURGERY

Masaru Aoyagi¹ Kaoru Tamura¹ Yoshihisa Kawano¹ Kikuo Ohno¹ Masaaki Yamamoto²

(1) Department of Neurosurgery, Tokyo Medical and Dental University, Tokyo, Japan (2) Department of Neurosurgery, Katsuta Hospital Mito GammaHouse, Hitachinaka, Japan

Objectives: The primary goal of treatment of complex skull base meningiomas is a long-time tumor control over his or her life span. Sufficient removal with least morbidity is essentially required followed by Gamma knife surgery (GKS). We reviewed 103 consecutive cases of skull base meningiomas since 1991, particularly 62 cases during the recent 8 years since radiosurgery has been used intentionally.

Patients and Methods: The subjects include parasclerotic (n=38, clinoidal, cavernous sinus etc.), frontal base (n=26, tuberculum sellae, olfactory groove etc.), and petrous (n=39, apex and ridge, jugular foramen, foramen magnum) meningiomas. Tumor size, vascularity, and the relation of tumors to perforators, cranial nerves, and the brain stem were investigated. The operative Results were compared before and after radiosurgery has been used intentionally.

Results: Surgical removal was performed using skull base technique, and the dissection plane near the critical structure in the recent series has been set between tumors and the tumor capsule including marginal vessels. GKS was performed on 4 of 41 previous cases and 17 of 62 recent cases. Critical complications were markedly decreased in the recent series: involvement of perforators (3 vs. 0), cranial nerves (7 vs. 4), and the brain stem injury (1 vs. 0). Regrowth was found in 6 of 41

previous cases and 1 of 62 recent cases.

Conclusions: Skull base technique and the tumor membrane dissection could avoid neurovascular complications, facilitate maximal resection with minimum morbidity, and thus contribute to the success of the management of complex skull base meningiomas with the aid of Gamma Knife surgery.

P1033

PATTERNS OF FAILURE AFTER GAMMA KNIFE RADIOSURGERY IN MENINGIOMAS: MULTIPLE MENINGIOMAS AND PATIENTS WITH RECURRENT MENINGIAL DISEASE

Vincent Bulthuis^{1, 2} Patrick Hanssens¹ Suan Te Lie¹ Guus Beute¹ Jeroen Verheul¹ Sieger Leenstra¹ Hendrik Piersma¹ Koo Van Overbeeke¹

(1) St.Elisabeth Hospital, Tilburg, The Netherlands (2) Maastricht University Medical Center, Maastricht, The Netherlands

Introduction, relevance and innovation: Gamma Knife® Radiosurgery (GKRS) is a well accepted treatment modality for patients with intracranial meningiomas. A interesting group of patients is those who have multiple meningiomas or had extensive previous treatment. In order to assess local control after GKRS, we evaluated patients who were treated for multiple meningiomas, or had multiple surgeries, radiotherapy or Gamma Knife treatments. We believe that this study is of relevance to show Results of Gamma Knife Radiosurgery for this group of complex patients.

Materials and Methods: Between December 2002 and July 2009, 12 patients with a median age of 50,5 years (35-75) with initially 30 meningiomas were treated in our center. The mean tumor volume was 3, 70 cc (range 0,095 -11,3 cc). The mean prescribed dose was 13 Gy (range 12-13 Gy.) The mean dose given to 100% of the tumor volume was 10,55 Gy (range 9,5- 12,3 Gy). The mean period of follow up was 62,5 months (range 35-87 months). Eleven patients with 28 tumors had undergone surgery earlier ranging from one to four times. Of these tumors, 21 (75,0%) were benign (WHO grade 1), 4 (14,3%) were atypical (WHO grade 2) and 3 (10,7%) were malignant (WHO grade 3). The median time between the last surgery and first GKRS was 64,5 months (10-248 months). Six patients received GKRS elsewhere before our first treatment. Nine patients underwent radiotherapy before the first GKRS.

Results: Local progression was found in 7 tumors in 7 patients. Of these, 2 meningiomas were WHO grade 1 tumors (local control of 90,5%) , 4 WHO grade 2 tumors and 1 WHO grade 3 tumor, yielding specific local control rates of 0% and 66,7% respectively. All recurrences showed a central growth pattern. In two patients, five new meningiomas were found during follow-up. Ten patients received multiple GKRS treatments due to progressive disease, ranging 2 to 8 times, leading to tumor control.

Conclusions: In this group of complex patients a high local control is found for WHO grade 1 tumors. Lower local control is found for WHO grade 2 and 3 meningiomas. We show that multiple benign tumors can be treated with GKRS. Also, after progression GKRS can be used multiple times to get local control. The data of these patients will be discussed with emphasis on growth pattern, site of recurrence and relationship with dose and volume.

P1034

STEREOTACTIC RADIOSURGERY FOR MENINGIOMAS: EARLY EXPERIENCE FROM A UK LINAC CENTRE

Deva Jeyaretna¹ Geoffrey Tipper¹ James Palmer¹ Sarah Pascoe¹ Stephen Kelly¹ William Adams¹ Peter Whitfield¹

(1) Southwest Stereotactic Radiosurgery Centre, Plymouth, UK

Objectives: Characterise our early experience using LINAC-based stereotactic radiosurgery for intracranial meningiomas.

Methods: Data was prospectively collected on patients with intracranial meningiomas treated with conformal stereotactic radiosurgery or fractionated stereotactic radiotherapy using a M3 LINAC based system at a regional UK neurosurgical unit. Localisation was frame (n=35) or mask based (n=23). Blinded pre and post-treatment volumetric measurements of tumours were undertaken. Tumour regression was defined as a reduction in volume by 20% or greater, stable disease as a reduction of less than 20% to an increase of less than 20% and progression as an increase in volume by 20% or greater.

Results: 58 tumours were treated in 54 patients (42 female 12 male). The majority of tumours were located at in the skull base. Histological grading of the tumours revealed 45%, 21% and 2% were respectively WHO Grade I, II and III. In 33% the histological samples were not taken.

The median gross tumour volume (GTV) at the start of treatment was 5.1ml (interquartile range 2.5ml to 9.4ml). The mode dose to the isocentre for frame based stereotactic radiosurgery was 15Gy and for mask based fractionated stereotactic radiotherapy treatment it was 1.8Gy, typically in 25 to 28 fractions. The mode dose to the tumour was 12Gy and 1.62Gy respectively for frame and fractionated therapy. The median follow up period was for 24 months. At most recent follow the median GTV was 2.5ml (interquartile range 1.2ml to 6.5ml). The median volume change was a reduction in size by 43% (interquartile range, reduction by 63% to reduction by 8%). 69% of tumours demonstrated regression, 23% stable disease and 8% progression. There were 3 deaths in this series. 2 deaths from disease progression in atypical and anaplastic tumours respectively and one death from causes unrelated to the primary disease or treatment.

Conclusions: Early follow up of meningioma patients undergoing stereotactic radiosurgery demonstrates good tumour control. This evidence indicates that stereotactic radiosurgery is a valuable treatment in the management of meningiomas. Longer term follow up of this cohort is required to evaluate whether these treatments can be considered as first line approaches in patients with surgically curable meningiomas.

P1035

GAMMA KNIFE RADIOSURGERY FOR MALIGNANT TYPE MENINGIOMA - EFFICACY AND PATHOLOGICAL FINDINGS -

Tamura Manabu¹ Kenji Kubo² Ryuji Okita³ Mitsuhiro Ogura³ Naoyuki Nakao³ Yuji Uematsu³ Toru Itakura³ Mikhail Chernov¹ Yoshihiro Muragaki¹ Hiroshi Iseki¹

(1) Institute of Advanced Biomedical Engineering and Science, Tokyo Women's Medical University, Tokyo, Japan (2) Gamma Knife Center, Koyo Hospital, Wakayama, Japan (3) Department of Neurological Surgery, Wakayama Medical University, Wakayama, Japan

Objective: To analyze the efficacy of Gamma Knife Radiosurgery (GKS) for malignant type meningioma (WHO grade II or grade III) focusing on pathological findings after GKS.

Material and Methods: Among 85 patients of meningiomas treated by GKS in Koyo Hospital from 1995 to 2008, 14 patients were diagnosed as an atypical or anaplastic meningioma before GKS. We can follow all 14 clinical courses for 17 lesions at least 1 year after GKS. Three patients were treated for a distant lesion at a different time. Their pathology revealed as a grade II (atypical) in 7 patients and grade III (anaplastic) in 7. The average of patients' age is 60.3 and the number of male is 8 (57.1%). The average of marginal dose at 17 lesions is 18.1 (6.0-23.0) Gy and maximum dose is 35.4 (12.0-46.0) Gy. Tumor volume is calculated 7.8ml (0.4-28.5) at average.

Results: In 17 lesions, 6 lesions were followed with no recurrence for 28.0 months (average) after GKS (Good-control group). The other 11 lesions resulted in 7 recurrent tumors and 4 patients' death (Poor-control group). Good-control tumor was treated 20.2/40.3 (marginal/maximum) Gy at dose for 3.1ml volume at the average, while poor-control was 16.9/32.6Gy, 10.3ml respectively. Smaller ($p=0.056$) and higher maximum dose ($p=0.036$) at GKS have a chance to a good tumor control. Overall, in 14 patients, only 2 patients were followed satisfactorily with no-recurrence after GKS. Five patients (6 lesions) suffered from the resection of re-growth tumor in 13.5 months (median) after GKS. Five pathological findings were tumor recurrence (marginal dose: 17.4Gy, average) and one was mainly tumor necrosis for which we had treated in 23Gy at a marginal dose.

Conclusion: GKS for malignant type meningioma could have possibility to avoid tumor recurrence with smaller volume (less than 3.0ml) and higher dose (over 40Gy at maximum dose). However a high-dose irradiation may cause tumor necrosis as well as tumor control relatively earlier after GKS.

P1036

GAMMA KNIFE STEREOTACTIC RADIOSURGERY: AN INSTITUTIONAL REVIEW IN THE TREATMENT OF CAVERNOUS SINUS MENINGIOMAS

Frederick Zeiler¹ Anthony Kaufmann¹ Derek Fewer¹ Garry Schroeder² Patrick Mcdonald¹ Michael West¹

(1) University of Manitoba, Dept of Neurosurgery, Winnipeg, Canada (2) University of Manitoba, Dept of Radiation Oncology, Winnipeg, Canada

Introduction: Cavernous sinus meningiomas encompass complex lesions with difficult direct surgical access, classically affording high morbidity and mortality. Stereotactic Radiosurgery poses a unique and effective means of controlling tumor progression with low complications.

Methods: We retrospectively reviewed all cavernous meningiomas treated with Gamma Knife (GK) radiosurgery between November 2003 and Oct 2010. Clinical data, treatment parameters, and radiographic and clinical outcomes were evaluated.

Results: We treated 30 patients, 4 of which were lost to follow up. Presentations included: headache (9), 5th nerve dysesthesia/paresthesia (13), 6th nerve palsy (11), 3rd nerve palsy (8), Horner's (2), blurred vision (9), relative afferent papillary defect (1), asymptomatic/incidental (1). Treatment planning consisted of MRI and CT in 17 of 30 patients (56.7%), the remainder were planned with MRI (44.3%). Average follow up time was 36.1 months, with mean age of 55.1 years. There were 8 males (26.7%) and 22 females (74.3%). Meningioma locations include right cavernous sinus (17), left cavernous sinus (13), Meckel's cave (5), prepontine cistern (4), sellar/suprasellar (7), and temporal lobe (3). Internal carotid artery encasement was entire in 10 patients, partial in 12. Twelve patients had previous surgical debulking prior to radiosurgery. Average diameter and volume was 3.4cm and 7.9 cm³ respectively. Average dose at the 50% isodose line was 13.5 Gy, with the range from 12.5 to 16 Gy. Tumor size post GK decreased in 9 patients (30.0%), remained stable in 19 patients, and continued to grow in 2. Overall 28 out of 30 (93.3%) of patients achieve tumor regression or stasis. Of the two patients with growth follow up is ongoing while one is asymptomatic, and the other has ongoing issues with persisting facial numbness and occipital neuralgia. Minor transient complications occurred in 17 patients, all resolving. Serious permanent complications occurred in 4 patients: new onset trigeminal neuralgia (1), occipital neuralgia (1), atypical facial pain (1), and panhypopituitarism (1).

Conclusion: GK offers an effective treatment Methods for halting meningioma progression in the cavernous sinus, with low serious permanent complication rate.

P1037

CYBER KNIFE RADIOSURGERY (CKRS) TREATMENT FOR PATIENTS WITH INTRACRANIAL MENINGIOMAS

Nuria Martinez¹ Elena Kusak¹ Jorge Gutierrez¹ German Rey¹ Roberto Martinez¹

(1) Gamma Unit. Hospital Ruber Internacional, Madrid, Spain

Introduction: Treatment of meningiomas with radiosurgery is already common practice. With new radiation techniques this therapeutic option is extended to a larger number of patients and now include others cases that required a fractionated treatment or a lower dose to diminish irradiation effects on healthy tissues with old Methods: those with large lesions or patients not subsidiary of surgery.

Objectives: To analyze the preliminary Results of treatment using CKRS in this group of patients.

Methods: Between October 2006 and Mars 2010, 26 patients with intracranial meningiomas using CKRS with a tracking system based on skull contour were treated. Five of them required a prior ventriculoperitoneal shunt for hydrocephalus. Eleven cases (42 %) had been previously operated (mean of surgeries: 1'4. Range: 1-3) and none had received previous radiotherapy. Mean age was 66 years (range: 40-87), 56 % being females. In the followed patients group (88%), they all have a single lesion. The treatment was delivered in three sessions, with a mean marginal dose of 6'8 Gy

by session (total marginal dose: 20'4 Gy) with a range of 6-8 Gy by session (range of total marginal dose: 18-24 Gy). The mean volume was 35'9 cc (range: 12'4 - 127 cc).

Results: The mean follow-up has been 22'5 months (range: 6'8 - 46). The local volumetric control has been 90'9 % of which 35% were reductions in size (mean of reduction 23 % compared to the previous volume). In 2 patients a volumetric progression was observed. Three patients have had a clinical progression (one of them due growing tumor and the other two patients have suffered a mild increase of previous deficits). No new symptoms in relation to the treatment have been observed. In 72 % steroids were administrated daily during irradiation.

Conclusions: Although the follow-up is short, preliminary Results in these patients are very positive considering the advanced age and the large treated volume. CKRS it is a simple and well tolerated technique with high efficacy and low morbidity.

P1038

10-YEAR FOLLOW-UP AFTER GAMMA KNIFE RADIOSURGERY OF MENINGIOMA

Bodo Lippitz^{1, 2}

(1) Gamma Knife Centre, Bupa Cromwell Hospital, London, UK (2) Karolinska Gamma Knife Center, Stockholm, Sweden

Background: In 11 published Gamma Knife series comprising 1336 meningioma patients the local tumor control ranges between 90 and 98%. However, sufficient data describing the long-term outcome of meningiomas have been lacking so far and 82 % of patients were in series with a median follow-up of less than 5 years. Hence it appears crucial to investigate if the Results of short term follow-up studies can be reproduced in the long-term perspective. Objectives: The current study describes the clinical and radiological long-term outcome of meningioma patients treated with Gamma Knife radiosurgery.

Patients and Methods: Between 3/91 and 5/2001 86 consecutive Swedish patients with meningiomas were treated with Gamma Knife radiosurgery at the Karolinska Hospital Stockholm. A total of 130 tumors were treated radiosurgically in 115 treatment sessions. The median prescription dose was 15 Gy (7-35 Gy), the median maximum dose 30.7 Gy (17-70 Gy). The median tumor volume was 2.5 cc (0.05-50.4cc). The median radiological and clinical follow-up period after GKS was 10 years (1.8-16.5y) and 9.4 years (2.1-17.4y) respectively. Follow-up was available in 94.6% (123/130 meningiomas)

Results: After a median follow-up period of 10 years, tumor control was achieved in 87.8 % of meningiomas (108/123 tumors). The median time between initial treatment and recurrence (n=15) was 5.8 years (1.9-11.5 years). In 15.1% of patients (13/86) out of field recurrences were documented at a median of 7.5 years (1.3-15.7). New meningiomas were seen in 10.5% after a median of 5.4 years (0.9-10.8). 72% of patients did not require further treatment, in 23.3% (20/86) underwent a second Gamma Knife treatment, 10.5% (9/86) required later open surgery, 5.8% (5/86) required both secondary treatments. 86% of patients were neurologically unchanged or improved. Meningiomas treated with a prescription dose of > 13.4 Gy experienced a significantly lower rate of local recurrences (7.1% vs 24% p=0.0096).

Discussion: The current retrospective analysis comprises one of the longest available follow-up investigations in a larger series after radiosurgery of meningiomas. It documents a persistent

high local tumor control after Gamma Knife treatment, which is only slightly lower than in after published observations with shorter follow-up. The current series allowed an estimation of a necessary minimum dose for tumor control in meningiomas. A significant number of meningioma patients did develop tumor recurrences outside the radiation field and even new tumors and these tumor recurrences appeared late after treatment which explain the slightly better outcome in series

P1039

LONG-TERM RESULTS OF A PROSPECTIVE NON-RANDOMIZED STUDY ABOUT THE ASSESSMENT OF QUALITY OF LIFE DURING AND AFTER STEREOTACTIC RADIOTHERAPY OF MENINGIOMAS.

Martin Henzel¹ Helmut Sitter² Rita Engenhardt-cabillic¹

(1) Department of Radiation Oncology, Philipps University Marburg, Marburg, Germany (2) Department of Theoretical Surgery, Philipps University Marburg, Marburg, Germany

Introduction: Stereotactic radiotherapy (SRT) is delivered for primary therapy and additionally after incomplete resection of skull base meningiomas with a long-term control >90%. Treatment-related side effects were very low, but nothing is known about quality of life (QoL) during and after SRT.

Methods: Between 2005 and 2007 67 patients were treated with SRT. 15 patients must be excluded of the study because of non-compliance filling-out the questionnaire consequently during follow-up. 42/52 patients underwent previous operations and 10/52 primary SRT.

QoL was assessed with the questionnaire SF36, comprising 36 items measuring patient's response in 8 health domains summarized in Physical Component Summary (PSC) and Mental Component Summary (MCS). Patient's response was evaluated before, at the end and half-yearly after SRT (endpoint 24 months after SRT). Treatment was delivered by a LINAC with 6 MV photons. Median fraction dose was 1.8 Gy, total dose 54.0 Gy. Local control, toxicity (CTC score, LENT SOMA) and symptomatology were evaluated half-yearly by clinical examinations and MRI scans.

Results: Follow-up data reaching the endpoint were available from 44 patients. 3 patients died from senile decay and one patient died from a metastasized breast cancer. 2 patient did not fill out further questionnaires because of dementia and further 2 patient because of non-compliance. Patients undergoing previous operations had statistically significant better values for MCS ($p=0,004$) before and after SRT than patients undergoing primary SRT. These patients started from a higher value level not being affected by the treatment. For PCS patients treated with primary SRT had worse values before and at the end of SRT. 6 months after treatment the values rose up and assimilated to the values of patients undergoing previous operations, but this was not significant ($p>0,05$). Comparing gender, age and symptomatology according to MCS and PCS there were no significant differences before and after SRT ($p>0,05$). Local control was 98%. Clinically severe acute or any late toxicity was never seen. 9/52 patients showed an improvement of their main symptoms and 43/52 were stable. None developed any worsening.

Conclusion: The SRT offers a treatment option of high efficacy with only low side effects. Patients undergoing previous operations started from a higher value level not being affected by the treatment. Delivered as primary treatment SRT may improve QoL according to PCS. There was no significant correlation between age, gender, improvement of symptoms and QoL.

P1040

GAMMA KNIFE RADIOSURGERY FOR MENINGIOMAS: POST-IRRADIATION CHANGES ON CT SCANS

Yasushi Nagatomo¹ Masaaki Yamamoto² Takuya Kawabe² Bierta E. Barfod² Yoichi Urakawa²

(1) Katsuta Hospital Mito GammaHouse , Hitachi-naka, Japan (2) Takai Hospital, Tenri, Japan

Purpose: In recent years, with MR imaging being widely used for post-radiosurgical evaluation of meningiomas, little information has been available about density changes on CT scans after radiosurgery.

Material and Methods: Among 303 patients who underwent gamma knife radiosurgery (GKRS) for meningiomas at Mito GammaHouse from July 1998 to March 2007, 83 were selected for this study. These 83 patients were followed at least 3 years and were periodically assessed using CT scans as well as MR imaging at Mito GammaHouse. There were 71 females and 12 males. Ages at the time of GKRS ranged from 26 to 89 years (mean; 60 years). The tumor was located at the skull base in 59 patients and at other sites in the remaining 24.

Results: Significant CT density increases of tumors were demonstrated in 36 (43%) of the 83 patients 3-11 years after GKRS; density increase were not apparent 2 years after GKRS. In most patients, density increases occurred in relation to tumor growth control. We experienced an autopsy case with a meningioma, in which a postmortem examination was performed 42 months after GKRS. In this patient, sequential follow-up CT scans showed gradual tumor shrinkage as well as remarkably increased tumor density. On postmortem studies, the tumor microscopically showed a diffuse area with numerous psammoma bodies.

Conclusion: A density increase due to psammomatous change can be regarded as having been produced by GKRS. This GKRS-induced change reflects tumor growth control.

P1041

LOW DOSE GAMMA KNIFE RADIOSURGERY FOR NONFUNCTIONING PITUITARY ADENOMAS

Wael Reda¹ Amr El-shehaby¹ Khaled Abdel Karim¹ Sameh Roshdy¹

(1) Gamma Knife Center, Cairo, Cairo, Egypt

Aim: The main concerns when performing GKS for pituitary adenoma is visual and pituitary function preservation while achieving tumor growth control. Higher prescription doses are typically correlated with a higher incidence of postradiosurgical hormonal deficiencies. The goal of the study was to retrospectively analyze the feasibility of using a lower prescription dose in the treatment of nonfunctioning pituitary adenomas and its effect on vision, pituitary function and growth control.

Patients and Methods: The study was carried out on 38 patients with nonfunctioning pituitary adenomas treated between January 2002 and July 2008. Twenty one patients were available for follow up for at least 2 years (13 males and 8 females). Nineteen patients were previously operated. Three cases developed pituitary dysfunction after surgery. One patient had an abnormal pituitary hormone profile before radiosurgery due to an attack of pituitary apoplexy. Visual field defects were present in 14 patients. The prescription dose was 12 Gy in all patients. The tumor volume ranged from 0.5 to 11.8 cc (mean 4.8 cc). The maximum dose to the visual pathway was kept below 10 Gy. The mean maximum dose to the visual pathway was 7.9 Gy.

Results: The patients were followed up for a period of 24 to 90 months (mean 44 months). The tumor size decreased in 11 (52%) patients and remained stable in 9 (43%) patients. In one patient there was tumor growth outside the previous radiation field. Of the 14 patients with visual field defects, 10 (71%) experienced an improvement and the rest remained stable. In only four patients was the visual improvement associated with tumor shrinkage. The hormonal profile remained normal in all except the 4 patients with preradiosurgical pituitary dysfunction.

Conclusion: The 12 Gy prescription dose used in this study seems to be sufficient at producing tumor control sparing the patient from radiation-induced pituitary dysfunction. This is even supported by the visual improvement reported in a number of cases. A larger series and longer follow up is required to confirm these Results.

P1042

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P1043

USEFULNESS OF 3.0 TESLA-MRI IN PLANNING OF STEREOTACTIC RADIOSURGERY AND STEREOTACTIC RADIOTHERAPY FOR BRAIN LESIONS

Yoshimasa Mori¹ Takahiko Tsugawa¹ Tatsuya Kobayashi¹ Chisa Hashizume¹ Hisato Nakazawa¹
(1) Nagoya Radiosurgery Center, Nagoya Kyoritsu Hospital, Nagoya, Japan

Precise identification of the target lesion and the surrounding normal structures is most important in treatment planning of image-guided stereotactic radiosurgery (SRS) and stereotactic radiotherapy (SRT). Usefulness of 3T-MRI compared with 1.5T-MRI during treatment planning of SRS and SRT in 51 patients is presented.

3T-MRI visualizes anatomical structures much better in details than 1.5 T-MRI. 3T-MRI was taken in relation to treatment planning of Gamma Knife SRS and Novalis SRT in 51 patients. Diagnosis includes meningioma in 19 patients (parasellar, 14; petroclival, 5), pituitary adenoma in 14, craniopharyngioma in 5, metastasis in 5, and others in 8. In 38 patients with sellar and parasellar tumors, the spatial relationship between tumors and optic pathways were evaluated by 3T-MRI. In 4 patients with other skull base tumors, tumors and other cranial nerves were observed in details by 3T-MRI. In 7 patients, location and extension of the tumor was investigated by 3T-MRI. In one patient with glossopharyngeal neuralgia, the glossopharyngeal nerve in the cistern was visualized. In one patient with pituitary micro-adenoma 3T-MRI disclosed growth hormone-secreting pituitary micro-adenoma, located anterior-inferiorly, and anterior lobe and posterior lobe of normal pituitary gland more clearly than 1.5 T-MRI. The tumor with delayed contrast enhancement, after enhancement of the posterior lobe and then the anterior lobe, was identified well by dynamic MRI. In some patients with parasellar tumors, the whole route of the involved optic pathway could not be visualized even in 3T-MRI. However, the affected optic nerve was identified longer by 3T-MRI than by 1.5 T-MRI, especially the portion in the optic canal, which made us easier to estimate where the optic nerve fibers, most vulnerable to radiation, were located on the tumor.

In conclusion, 3T-MRI enables better visualization of the target and adjacent critical normal structures to be spared and may make planning of SRS and SRT better.

P1044

PITUITARY GERMINOMA

Fatima Zahra El M'rabet^{1, 2} Hanane Chenna² Karima Nouni² Hanane El Kacimi² Khalid Hassouni² Lamiae Kanouni² Taib Kebdani² Omar El Mesbahi¹ Nourddine Benjaafar² Brahim Khalili Gueddari²

(1) university hospital Hassan II, departement of medical oncology, Fez, Morocco (2) national institut of oncology , radiotherapy unit, Rabat, Morocco

Introduction: germinal tumors are embryonal tumors, localized essentiellemnt in the gonads, cerebral localization is rare, representing less than 1% of intracranial neoplasms. The pure germinoma or seminoma accounts for 60% of cerebral germ cell tumors. Located preferentially at the pineal gland and the supra sellar region, and mainly affects children and adults jeune. Germinoma are the chemo and radiosensitive tumors, therefore, their prognosis is very favorable.

Materials and Methods: we report two cases of pituitary germinomas in two children who are treated in National institut of oncology to Rabat.

CASE 1: 14 year old child, who presented five months before admission, intracranial hypertension is headache, vomiting and diplopia, complicated by motor deficit. The review had found an hemiplegia with papilledema on funduscopy. Brain MRI had objectified the presence of a tumor of the supra sellar region with mass effect and hydrocephalus. After the ventriculo peritoneal shunts, a stereotaxic biopsy confirmed the diagnosis of pituitary germinoma. Subsequently, he received a neoadjuvant chemotherapy (4 cycles of Cis-platinum, Etoposide) with a partial radiological response and improved foil, followed by conventional cerebral radiotherapy (50 Gy). The evolution was favorable with a decrease of 10 years

CASE 2: 11 year old child, who presented six months before admission, a syndrome of increased intracranial pressure with a decrease in visual acuity, and deterioration of general condition. Physical examination of the nervous system is typically normal apart from the presence of papilledema. Brain MRI showed a tumor of the pituitary region with active hydrocephalus without mass effect. The stereotaxic biopsy showed a pituitary germinoma , which was successfully treated by neoadjuvant chemotherapy based on 6 cycles of BEP followed by cerebral radiotherapy (50 Gy) with a favorable outcome on a decline of 2 years.

Conclusion: the cerebral germinoma are tumors with good prognosis, the treatment is based on combined chemotherapy and radiotherapy with higher survival rates.

P1045

PITUITARY TUMOURS: A CENTRES RETROSPECTIVE REVIEW

Robert Smee¹ Peter Wilson¹ Janet Williams¹ Katie De-loyde¹

(1) Department of Radiation Oncology, The Prince of Wales Cancer Centre, High St, Randwick, Sydney, Australia

Summary: Pituitary tumours active/inactive can have a significant impact on patients. This Ethics approved review evaluates patients treated with stereotactic irradiation for a radiological/ endocrinologically active pituitary tumour and there outcomes. 287 were treated, 192 by SRS, 86 by SRT determined by the proximity to the optic chiasm. Tumour volume was the discriminatory

feature between the 2 treatments. 96 acromegalic patients treatment comprised of 86 by SRS, 10 by FSRT. Reduction in GH and IGF-1 levels occurred over many months. 37 Cushings patients had >90% tumour control, however modest impact on hormonal levels. Tumour control >90% resulted in good-modest hormonal reduction.

Objectives: Pituitary tumours hormonally active and inactive can have a significant impact on any patient. This review will evaluate the value of stereotactic irradiation on tumour and endocrine outcomes.

Methods: This retrospective Ethics approved study evaluated all patients who received stereotactic irradiation for a radiological / endocrinologically active pituitary tumour. The pituitary tumour database was audited for all patients referred between 1990-2008 with a pituitary tumour. The data was aggregated into patient, tumour and treatment characteristics. All patients were treated stereotactically with 6Mev photons. The absolute discriminatory feature between single and multiple fractions was contact with the optic chiasm. All data was evaluated on an SPSS (Statistical Package for the Social Sciences) database with Kaplan-Meier evaluation of statistical endpoints.

Results: During this timeframe 278 patients were treated, 192 by SRS (Stereotactic RadioSurgery) and 86 with with fractionated stereotactic treatment (FSRT). 118 had a non-functioning tumour with respective volumes of 2.96cmm and 8.49cmm for local progression rates of 0% and 9%. Of the 96 acromegalic patients, 86 had SRS and 10 had SRT (volumes of 2.59 and 10.39cmm), with reduction in GH and IGF-1 levels occurring over many months. There were 37 Cushing patients treated, only 1 by SRT with >90% tumour control but only modest impact on hormonal levels.

Conclusion: Tumour volume was a significant discriminatory feature between delivery of SRS and SRT. Tumour control was >90% with modest to good hormonal reduction for the specific functioning tumours with low likelihood of new hormonal deficit post treatment.

P1046

PINEAL REGION TUMORS : A RETROSPECTIVE STUDY OF SEVEN CASES

Fatima Zahra El M'rabet¹, ² Hanane Chenna² Karima Nouni² Hanane El Kacimi² Khalid Hassouni² Lamiae Kanouni² Taib Kebdani² Omar El Mesbahi¹ Nourdine Benjaafar² Brahim Khalil El Gueddari²

(1) university hospital hassan II , departement of medical oncology, Fez, Morocco (2) national institut of oncology , radiotherapy unit, Rabat, Morocco

Introduction: Tumors of the pineal region are rare, (0,4 à 1% for all intracranial tumors), known by their histological variability. they are dominated by the germ cell tumors (germinoma and teratoma), followed by the pineal parenchymal tumors. their prognosis is favorable improved by new chemotherapy regimens and techniques of surgery and radiotherapy.

Purpose : Retrospective analysis of seven patients with pineal region tumors in national institut of oncology in Rabat and a literature review.

Materials and methods: Seven patients were treated from 1999 to 2010, for histologically verified primary pineal region tumors.

Resultats: Median age was 8 years, (range : [2-15]), 68% of the patients were male. The median time of consultation was 7 months. All patients were presented an intracranial hypertension and papilledema on funduscopy. Brain MRI had objectified the presence of a tumor of the pineal region

with mass effect and hydrocephalus .stereotaxic biopsy performed in seven patients showed two cases of pineal germinoma , two cases of pineal teratoma and tree cases of pinealoblastoma . All the patients received a curative treatment: Surgery was performed in one patient who has a pineal teratoma , four patients received chemotherapy (BEP) , and brain radiotherapy (50 Gray) for seven patients. The evaluation of the treated patients went up that five tumors were in complete response, two patients have kept no-evolutive residuel disease. The median follow up was 60 month.

Conclusion: Actually, in condition with an adequate and adapted treatment strategy, the pineal tumors can be totally controlled.

P1047

STEREOTACTIC RADIOSURGERY WITH THE CYBERKNIFE FOR PITUITARY ADENOMAS

Chul Bum Cho¹ Kyung Jin Lee²

(1) Hallym University Sacred Heart Hospital, Gyeonggi-do, Korea(2) Catholic University Saint Mary's Hospital, Seoul, Korea

Objectives: In recent years, CyberKnife has emerged as an important treatment modality in the management of pituitary adenomas. Treatment Results after performing CyberKnife and the complications of this procedure are reviewed.

Methods: Twenty-six patients with pituitary adenomas received stereotactic radiosurgery with the CyberKnife (CKRS). The follow-up periods ranged from 7 months to 47 months (mean \pm SD: 30 \pm 12.7 months). The patients consisted of 17 with non-functioning adenomas, 3 with prolactinomas and 6 with acromegaly. The change in the tumor volume, visual acuity, hormonal function, and complications by this therapy were analyzed in each case.

Results: The tumor control rate was 92.3 %. Hormonal function improved in all of the 9 (100%) functioning adenomas. Hormonal normalization was observed in 4 of the 9 (44%) patients with a mean duration of 16months. In two patients (7.6%), visual acuity worsened due to cystic enlargement of the tumor after CKRS. No other complication was observed.

Conclusions: CyberKnife is a safe and effective therapy in selected patients with pituitary adenomas. However, longer follow-up is required for a more complete assessment of late toxicity and treatment efficacy.

Key words: CyberKnife, Pituitary adenoma

P1048

ELECTROPHYSIOLOGICAL ASSESSMENT OF TREMOR RESPONSE AFTER GAMMA KNIFE THALAMOTOMY IN PATIENTS WITH MEDICALLY REFRACTORY ESSENTIAL TREMOR

Soha Al-omar¹ Robert Chen² Elena Moro² Normand Laperriere³ Mojgan Hodaie¹

(1) Division of Neurosurgery, University of Toronto, Toronto, Canada (2) Division of Neurology, University of Toronto, Toronto, Canada (3) Radiation Medicine Program, University of Toronto, Toronto, Canada

Objective: Gamma thalamotomy is a non-invasive Methods of lesioning of the motor thalamus, and is typically used to treat intractable tremor in patients that have surgical contraindications to open thalamotomy or neuromodulation procedures. The onset of benefit is delayed, and reports vary in range of time to effective tremor relief. Objective tremor assessment criteria in this group are lacking, however these patients form a unique group since they provide the possibility of studying the process of gradual improvement in tremor. The objective of this study is to investigate the timing and extent of tremor response after Gamma Knife radiosurgery (GKT) in essential tremor (ET) patients using objective electrophysiological measures and correlation between electrophysiological and clinical response.

Methods: Four patients with longstanding essential tremor (age range 63-78, average age 70) who underwent unilateral GKT were assessed clinically (using the Fahn-Tolosa-Marin Tremor Rating Scale - TRS) and electrophysiologically (EMG and accelerometry) in the pre-operative period and serially in the post-operative period, up to 24 months post treatment. Tremor was assessed in the both arms outstretched position with accelerometer and surface EMG.

Electrophysiological recordings were captured and analyzed using the Spike 2 software. Surface EMG activity was recorded in 3 muscles were assessed on each side (Deltoid, biceps and extensor carpi radialis, ECR); For each muscle, 2 time points of 20sec intervals were analyzed; the first peak amplitude for a frequency between 3-10 Hz was chosen for analysis at each time point. The amplitude of muscle activity was recorded. A logarithmic graph of tremor amplitude vs. the time of follow up in months was constructed for each muscle and timepoint.

Results: Initial electrophysiological response could be seen as early as 3 months. However the decrease in tremor continued with time, and in some, the maximum response could be observed as late as 13 months after treatment. 2 out of the 4 patients had sustained response 24 and 26 months after radiosurgery. In cases where clinically effective tremor benefit was observed, a nearly 1000 fold decrease in tremor amplitude was observed.

Conclusion: Electrophysiological assessment provides a quantitative and objective measure of tremor, and can document improvement in tremor early as 3 months after GKRS. There may be however significant delay in treatment effect, in some cases up to one year post treatment. The delay to benefit must be taken into account when discussing Gamma thalamotomies as a treatment option.

P1049

FRAMELESS IMAGE-GUIDED RADIOSURGERY FOR INITIAL TREATMENT OF TYPICAL TRIGEMINAL NEURALGIA

Joseph Chen¹ Javad Rahimian¹ Michael Girvigian¹ Michael Miller¹

(1) SCPMG, Los Angeles, USA

Objective: To review retrospectively initial experience at a single institution using frameless image-guided radiosurgery (IGRS) for trigeminal neuralgia employing the Novalis linear accelerator (LINAC) with ExacTrac robotic patient positioning device.

Methods: Over an 18-month period, 44 patients (27 women and 17 men; median age 65 years) were treated with frameless IGRS for typical trigeminal neuralgia. 14 cases involved left-sided pain and 30 cases involved right-sided pain. All were responsive to anticonvulsant medications. All

had initial Barrow Neurological Institute Pain Scale (BNI-PS) scores of 4 or 5. All cases were initial radiosurgery treatments with an isocenter dose of 90 Gy delivered via a 4-mm circular collimator forming a spheroid dose envelope. Intrafraction positioning data were collected for all patients. The median follow-up was 15 months.

Results: Overall intrafraction positioning error was 0.49 mm \pm 0.44. After treatment, 40 patients achieved a BNI-PS score of IIb or better; 19 patients achieved a BNI-PS score of I. The median time to pain relief was 4 weeks. Overall, new hypoesthesia was seen in five patients. No other complications were seen.

Conclusions: Use of frameless IGRS Methods s for treatment of trigeminal neuralgia showed Results similar to the authors-™ prior experience with frame-based treatment Methods. IGRS using frameless Methods s is a suitable treatment Methods for patients with trigeminal neuralgia and may be applicable to other functional indications.

P1050

OUTCOME FOR PATIENTS WITH ESSENTIAL TRIGEMINAL NEURALGIA TREATED WITH LINAC STEREOTACTIC RADIOSURGERY

Marcos Santos¹ Jose Salcedo¹ Jose Diaz¹ Gerardo Flores¹ Felipe Calvo¹ Jose Samblas¹ Hugo Marsiglia¹ Kita Sallabanda¹

(1) Grupo IMO, Madrid, Spain

Background: Trigeminal neuralgia is a pain syndrome that affects the fifth cranial nerve. Stereotactic radiosurgery (SRS) is one option for treatment, after conservative approaches have been unsuccessful.

Objectives: The objective of this study was to retrospectively evaluate our institutional Results in the management of patients with essential trigeminal neuralgia treated with Linac SRS.

Methods: Sixty patients were treated between January 1998 and December 2009. Among them, 52 were followed for more than 6 months (median: 26.6 months; range: 6.3 to 99.9 months). Forty-seven patients (90%) had undergone previous surgery before SRS. The target dose ranged from 50 to 80 Gy.

Results: Forty-two patients (80%) reported pain relief of at least 50%. Fifteen of these patients (35.7%) reported recurrence, after an average period of 20 months (range: 4-47 months). Results were better in patients older than 60 years ($p=0.019$). Nineteen patients presented facial numbness after SRS, with a trend toward favorable treatment response ($p=0.06$).

Conclusion: SRS is an effective alternative to the treatment of essential trigeminal neuralgia, with long-lasting pain relief in more than 50% of the patients. Better Results were seen with age >60 years. Facial numbness may be an indication of a good response to the treatment.

P1051

LATENCY PERIOD UNTIL PAIN RELIEF AFTER GAMMA KNIFE STEREOTACTIC RADIOSURGERY FOR TRIGEMINAL NEURALGIA

Chisa Hashizume¹ Yoshimasa Mori¹ Tatsuya Kobayashi¹ Yuta Shibamoto² Yuta Shibamoto²

(1) Nagoya Radiosurgery Center, Nagoya Kyoritsu Hospital, Nagoya, Japan (2) Department of Radiology and Radiation Oncology, Nagoya City University Graduate School of Medicine, Nagoya, Japan

Stereotactic radiosurgery (SRS) using Gamma Knife has been reported to be excellent treatment option to improve trigeminal neuralgia. However, after the procedure there is reported to be some latency period until pain relief. This study was aimed to evaluate latency period between SRS and pain relief in detail.

Thirty-five patients with trigeminal neuralgia were treated by Gamma Knife. The mean age of the patients was 71.3 years. The median interval between onset of trigeminal neuralgia and SRS was 5 years. Twenty patients were under medication of carbamazepine at SRS. In most cases, a maximum dose of 80 Gy was delivered around the root entry zone of the ipsilateral trigeminal nerve.

The median follow-up time was 23 months (range, 7 to 57 months) in all 35 patients. In 23 of 35 patients (66%), improvement of pain (less than half pain comparing that before treatment in visual analogue scale) was developed within 1 month after SRS. However in 3 cases, the latency period was long up to 7 months. In 28 cases, complete pain relief was obtained but the latency period from SRS to complete pain relief was various length, from immediately to 15 months (median 3 months). In 5 cases, though pain was relieved once and recurred at 2 to 5 months after SRS, the pain was relieved again at 3 to 18 months after SRS without retreatment.

Pain relief rate (less than half pain comparing before SRS) at 2 years after SRS was 84%. That at 3 years was 83%. Overall pain relief rate at 3 years including pain relief by retreatment (second SRS) was 92%. Micro-vascular decompression surgery was done additionally after SRS only in 1 case. No severe complication was observed during follow-up period in any patients.

SRS using Gamma Knife is thought to be safe and excellent treatment for trigeminal neuralgia but the latency period until pain relief in each patient is various length up to more than half a year. In some patients pain relief showed biphasic effect. If pain recurs after temporal relief, observation might be a reasonable option especially when the follow-up period at recurrence is not more than half a year.

P1052

FRAMELESS STEREOTACTIC RADIOSURGERY FOR TRIGEMINAL NEURALGIA IN A COMMUNITY BASED CENTER - THE PALO ALTO MEDICAL FOUNDATION'S (PAMF) EXPERIENCE

Pauling Chang¹ Chantal Audet¹ Brett Poffenbarger¹ Paul Jackson¹ Stephen Ryu¹ Robert Lundahl¹ Gordon Ray¹

(1) Palo Alto Medical Foundation, Palo Alto, USA

Objectives: To present PAMF's experience with frameless stereotactic radiosurgery (SRS) treatments of trigeminal neuralgia.

Methods: Between November 2009 and March 2010, six patients with trigeminal neuralgia who failed conservative therapy or who were not candidates for decompressive surgery were treated with frameless SRS. Immobilization was accomplished using a custom BrainLab thermoplastic radiosurgery mask. Treatment planning was performed using CT scans with 1.25 mm slice thickness, MRI fusion using fast imaging employing steady state acquisition (FIESTA) sequence with 0.4 mm slice thickness, and the iPlan planning system (BrainLab). Each trigeminal nerve

root was identified and treated with a single fraction maximum dose of 80 Gy. Treatment was delivered using a 4 mm cone and the 6 MV beam of a Novalis Tx linear accelerator (Varian). Repeated end-to-end tests confirmed that the uncertainties introduced by CT scanning, planning, Exactrac image-guidance and couch positioning (BrainLab), intra-fraction motion corrections, and the linac radiation delivery provides accurate dose delivery and sub-millimeter targeting accuracy. Verification of patient position during treatment delivery was performed using repeated x-ray images that are automatically and instantly analyzed for setup error. Pain assessment was made using the Barrow Neurological Institute (BNI) pain scale.

Results: Five patients had BNI scores of III and one patient had a score of IV prior to SRS. The shortest follow-up after SRS was four months and the longest eight months. Two of the patients with a score of III prior to SRS achieved a score of I, three of the five were maintained at III however. The one patient who had a BNI score of IV decreased her score to III and was gradually weaning herself off her medication. We did not see any treatment related toxicity during the follow-up period and we are continuing to follow the patients.

Conclusions: Although our patient numbers are small and the follow-up is short, we show that frameless stereotactic radiosurgery can be safely delivered in a community based practice. We are considering raising our dose to 90 Gy as our current treatment has not shown any toxicity with the hope that the response rates can be improved.

P1053

RADIOSURGERY FOR TRIGEMINAL NEURALGIA, TREATMENT OUTCOME AND PREDICTORS OF RESPONSE

Hussein Alahmadi¹ Gelareh Zadeh¹ Shobhan Vachhrajani¹ Mojgan Hodaie¹ Mojgan Hodaie¹ Normand Laperriere¹ Normand Laperriere¹ Mojgan Hodaie¹

(1) Toronto Western Hospital, Toronto, Canada

Background: gamma knife radiosurgery is an established treatment for trigeminal neuralgia. With the availability of other treatment modalities, understanding the predictors of good response and delayed recurrence will provide guidance in patient selection.

Methods: we conducted a retrospective review of all patients treated with gamma knife radiosurgery for trigeminal neuralgia at our institution from 2005 to 2009. All patients were treated with a single isocenter with maximum dose of 80 gray targeting the cisternal segment of the trigeminal nerve. Baseline clinical features of the patients and treatment details were reviewed. Regression analysis was carried to identify predictors of response and recurrence. Survival analysis was used to predict recurrence rate.

Results: a hundred and fifty four patients were treated. The average age of the patients was 67 years (range 30-89 years). Ninety-three patients (60%) were female. V3 and V2-V3 were both the commonest pain distribution with each occurring in 40 patients (26%). Average duration of pain was 9 years. Sixteen patients had multiple sclerosis and 9 patients had tumors as a cause of the trigeminal neuralgia. Fifty-seven patients underwent previous surgical treatment (rhizotomy or microvascular decompression). Sixteen patients had previous gamma knife treatment.

Forty-eight patients (31%) became pain free with no medications. Fifty-four patients (35%) were pain free with medications. Thirty patients (20%) had pain after the treatment with significant

reduction in their pain severity. Twenty-two patients (14%) did not have any significant pain reduction. Among the patients with trigeminal neuralgia secondary to multiple sclerosis or tumors, 56% became pain free (with or without medications). Mean interval between treatment and response was 6 weeks. Recurrence occurred in 54 patients (35%). Mean time to recurrence was 10 months. Mean follow up period was 24 months (range 6-56 months). Idiopathic trigeminal neuralgia and the development of numbness after treatment were statistically significant predictors of good response.

Conclusions: gamma knife radiosurgery for trigeminal neuralgia has an initial good response rate. The relatively high recurrence rate should be considered when offering this treatment to young patients with low surgical risks. Idiopathic trigeminal neuralgia and post treatment numbness are associated with good response.

P1054

GAMMA KNIFE RADIOSURGERY FOR INTRACTABLE GLOSSOPHARYNGEAL

Marc Lévêque¹ Constantin Tulesca¹ Romain Carron¹ Jean Régis¹

(1) Department of Stereotactic and Functional Neurosurgery, Timone University Hospital, Marseille, France

Objective: Although Gamma Knife Radiosurgery (GKR) is widely recognized as an effective and minimally invasive treatment for intractable trigeminal neuralgia its role in glossopharyngeal neuralgia (GPN) has not been yet determined.

Methods: Between January 2002 and October 2010 ten patients with medical intractable GPN were treated using GKR. Indication for GKR was the presence of medically intractable GPN and patient's refusal or contraindication to microvascular decompression. Patients underwent preoperative investigation and were evaluated postoperatively with periodic assessment of pain relief.

Results: Ten patients (7 males, 3 females, age range 49- 83) presented with symptoms for an average of 28 months (8- 72). Five patients had a vasculo-nervous conflict. Patients were treated with a dose ranging 60 to 80 Gy, targeted on the cisternal segment (n=2) or glossopharyngeal meatus (n=8). Outcome was favorable with cure of GPN in 8 of 10 patients in the short term (3 months) and 4 of ten patients in the long term (20 months). One patient required two treatments because of a recurrence of symptoms and was treated with maximum doses of 60 and 70 Gy, respectively. There were no neurological complications.

Conclusion: All patients with GPN as a target that received a dose greater than 75 Gy were cured at long term follow up. The two patients with cisternal segment as a target and received a dose significantly lower than 70 Gy were not cured of their GPN. There were no neurological deficits involving the lower cranial nerves. It will be necessary to investigate the optimal radiation dose and target of GKR for GPN in order to achieve long-term pain relief.

P1055

NOVALIS TX RADIOSURGERY FOR TRIGEMINAL NEURALGIA: PRELIMINARY RESULTS

Alessia Pica¹ Alexander Stibal² Marco Malthaner³ Ernst Born³ Ethan Taub⁴ Luigi Mariani⁴ Andreas Raabe² Daniel M Aebbersold¹

(1) Department of Radiation Oncology, Inselspital, University Hospital Bern, Bern, Switzerland (2) Department of Neurosurgery, Inselspital, University Hospital Bern, Bern, Switzerland (3) Medical Physics, Department of Radiation Oncology, Bern, Switzerland (4) Department of Neurosurgery, University Hospital Basel, Basel, Switzerland

Purpose: Gamma Knife radiosurgery (RS) for idiopathic trigeminal neuralgia (ITN) has shown a high rate of pain control, with 68% to 97% of patients having either a good or an excellent response. We report preliminary Results from four patients with TN whom we treated with frame-based radiosurgery using the Novalis Tx LINAC system.

Material and Methods: Four patients with TN underwent Novalis Tx high-definition collimator frame-based radiosurgery from July 2009 to April 2010. All four were women; two of them had ITN, and two had symptomatic trigeminal neuralgia due to multiple sclerosis (MS). The two patients with ITN had undergone microvascular decompression (MVD) without pain relief and one MS patient had undergone radiofrequency thermocoagulation without relief. Using fused MRI and CT scans (3D T1-weighted and 3D T2-weighted images with 1-mm cuts, 1.5-mm CT cuts), we outlined a planning target volume (PTV) 5 mm in diameter in the retrogasserian trigeminal sensory root in order to spare 3-4 mm of the trigeminal dorsal root at the brainstem. Seven to 8 dynamic arcs were used. The maximal dose, prescribed to the 100% isodose line, ranged from 74 to 82 Gy (median, 79 Gy). The median target volume was 0.03 cm³ (0.02-0.10 cm³), and the mean 12-Gy radiosurgical volume (12-GyV) was 3.8 cm³ (1-7 cm³). The Dmean and Dmean integral delivered to the volume of the retrogasserian part of the trigeminal nerve root were 30 Gy (16 - 39 Gy) and 1.36 mJ (0.6-2.6 mJ), respectively.

Results: The median duration of follow-up was 5 months (range, 3-12 months). Pain outcomes were assessed with the Barrow Neurological Institute (BNI) scale before and after RS and at each follow-up visit. Three patients reported initial pain relief, which was excellent in one patient with ITN (from grade IV to grade I) and moderate in the two patients with MS (from grade IV to grade III). One patient with ITN had no pain relief (Dintegral = 0.6 mJ). No complications were encountered other than transient dizziness in one patient 3 months after treatment.

Conclusions: These preliminary Results suggest that Novalis Tx RS for TN can be performed safely and effectively with the parameters that we used (Dmax 79 Gy; Dmean to the volume of the retrogasserian part of the nerve root of 30 Gy)

P1056

DELAYED COMPLICATION AFTER GAMMA KNIFE RADIOSURGERY FOR MESIAL TEMPORAL LOBE EPILEPSY

Kenichi Usami¹ Kensuke Kawai¹ Tomoyuki Koga¹ Masahiro Shin¹ Hiroki Kurita² Ichiro Suzuki³ Nobuhito Saito¹

(1) The University of Tokyo Hospital, Tokyo, Japan (2) Kyorin University Hospital, Tokyo, Japan (3) Japanese Red Cross Hospital, Tokyo, Japan

Objective: Despite a controversy in the clinical significance of gamma knife surgery (GKS) for refractory mesial temporal lobe epilepsy (mTLE), it has been attracting attention owing to its less invasiveness. We report long-term outcome of our 7 patients particularly focusing on its complication.

Methods: During 1996 and 1999, 7 MTLE patients underwent GKS. The 50% marginal dose covering the medial temporal structures was 18 Gy in 2 patients and 25 Gy in 5.

Results: High-dose treatment abolished or significantly reduced seizures (2 patients each, 1 lost to follow-up). However, two patients presented with symptomatic radiation necrosis (SRN) necessitating surgical resection after 5 and 10 years. One patient was drowned to death during sea bathing after one year before seizure disappeared completely.

Conclusion: The high-dose treatment brought sufficient seizure control but carried a significant risk of SRN after several years. Drawbacks such as a delay in seizure control and risk of SRN should be weighed when the clinical significance of this treatment is evaluated.

P1057

SELECTION OF TREATMENT STRATEGY OF GAMMA KNIFE RADIOSURGERY FOR SECONDARY TRIGEMINAL NEURALGIA

Hiroyuki Kenai¹ Masanori Yamashita¹ Akira Yamada¹ Tomoshige Asano¹ Yukihiro Wakabayashi¹ Hirofumi Nagatomi¹

(1) Nagatomi Neurosurgical Hospital, Oita, Japan

Introduction: Gamma Knife radiosurgery (GKRS) is a widely used treatment option for essential trigeminal neuralgia (TN) now. There are few reports, however, of GKRS being performed for secondary TN caused by a tumor, arteriovenous malformation, etc. Generally, GKRS targeting the lesion Results in faster control of pain in the case of secondary TN than in the case of essential TN. We have also encountered some cases of secondary TN. Here, we have summarized the Results of the cases studied by us and reviewed the strategy for application of GKRS in the treatment of secondary TN.

Methods: From January 2001 to December 2009, 24 patients suffering from secondary TN were treated by GKRS at our institution. Of them, 20 patients (7 men and 13 women; age range, 41-82 years; mean age, 69.7 years) who could be followed up for a minimum of 6 months were retrospectively examined. The mean follow-up duration was 34.6 months.

Results: In 15 of the 20 cases, pain could be controlled by GKRS targeting only the lesion. But in some cases, pain could not be controlled in spite of the lesion control by GKRS. In these cases, the pain could be controlled by performing an additional GKRS directly targeting the fifth cranial nerve, using for treating essential TN. And, in cases of emergency or in cases where GKRS was not suitable for treatment of the lesion, from the first, adding or using the same GKRS for treating essential TN was effective.

Conclusions: On the basis of cases studied by us, we reviewed the strategy of performing GKRS for secondary TN. In some secondary TN cases, pain could not be controlled only through lesion control by GKRS. Although GKRS for secondary TN should be directed to the lesion rather than the trigeminal nerve originally, in such cases, it was indicated that adding or using the same

GKRS for treating essential TN was effective and safe for the treatment of secondary TN. Thus, we recommend that GKRS should be directed to the trigeminal nerve in the following cases: 1. when GKRS targeting the lesion has not been effective for pain relief. 2. when pain relief is urgently needed. 3. when the lesion is deemed not amenable to GKRS.

P1058

RADIOSURGICAL CAPSULOTOMY RESULTING IN RAPID SYMPTOMATIC IMPROVEMENT OF OBSESSIVE COMPULSIVE SYMPTOMS IN A PATIENT WITH OCD AND ASPERGER SYNDROME

Konstantin Slavin^{1, 2} Anthony D'agostino³ Patrick Mcgrath³ Jason Washburn³ Jagannath Venkatesan¹

(1) Illinois Gamma Knife Center, Elk Grove Village, USA (2) University of Illinois at Chicago, Chicago, USA (3) Alexian Brothers Behavioral Health Hospital, Hoffman Estates, USA

Objective: To discuss benefits of stereotactic radiosurgical capsulotomy in a patient with refractory disabling obsessive-compulsive disorder (OCD) and Asperger syndrome (AS).

Case Description: 18 year old man with known AS and high level of functioning developed significant worsening of previously mild OCD symptoms 30 months prior to the treatment. The obsessions primarily focused on collecting things that were being thrown away followed by compulsive gathering and retention of all kinds of needless things with subsequent development of aggressive and violent behavior aimed at those who would try to interfere with his aberrant behavior or dissuade him from pursuing these activities. The patient was referred for surgical treatment after failure of medical and behavioral treatment and after evaluation in several prominent centers nationwide concurring with his diagnosis and treatment-refractoriness. Given the choice between deep brain stimulation, radiofrequency capsulotomy and radiosurgical capsulotomy, the patient and his parents chose to proceed with stereotactic radiosurgery (SRS).

Procedure: The SRS treatment was performed in April 2010. Treatment was delivered in one session using Gamma Knife 4C (Elekta). Radiation dose of 140Gy was delivered to 4 isocenters, 2 on each side, targeting the anterior limb of the internal capsule according to previously described target locations.

Results: There were no changes in the patient's condition following the treatment. About 2 months following SRS, the patient started showing signs of improvement and by 4 months after treatment, his symptoms of obsessive behavior almost completely resolved (85% improvement). He maintained obsession-free status after his 4 medications were stopped and was able to return to attending school on regular basis reaching and exceeding his pre-morbid level of functioning. Post-operative MRI obtained 6 months after surgery showed large (larger than expected) lesions in the anterior limb of the internal capsule. No cognitive side effects were noted during post-surgical follow up.

Conclusions: Based on the literature review, this appears to be the first description of SRS capsulotomy in patient with OCD and AS. The rapid symptomatic improvement and the lack of observed side effects should encourage clinicians to consider SRS capsulotomy as a valid treatment option for disabling OCD in patients that prefer to avoid more invasive open destructive interventions or the neuromodulation implants. The destructive nature of the procedure should be carefully weighed against non-destructive neuromodulation approaches.

P1059

RADIOSURGERY FOR INTRACTABLE CLUSTER TIC

A. Vargas¹ A. Donnet² J.-m. Regis¹

(1) Department of Neurosurgery, Timone Hospital, Marseille, France (2) Department of Neurology, Timone Hospital, Marseille, France

Introduction: The association of cluster headache with trigeminal neuralgia has been called cluster-tic syndrome. The tic and cluster components of this syndrome can occur concurrently or separately in time, in the same patient. Patients are usually treated with drug associations for trigeminal neuralgia and cluster headache, or with microvascular decompression of the trigeminal nerve.

Material & Methods: A 58-year-old woman presented with a 5-year history of two main types of head pain. The first type of pain had an usual duration of 5-60 s. The pain was strictly unilateral, being localized to the right orbit, forehead and was described as a sudden, sharp, severe, stabbing headache. The jabs were both spontaneous and triggered by washing the face or brushing the teeth. There was no trigger zone. The second type of pain followed immediately the first one. The headache was ipsilateral, described as a very severe, penetrating periocular pain, associated with right lacrimation, rhinorrhea and eyelid swelling, and lasting about 30-60 minutes. This latter pain cannot be triggered. She described about 20 attacks/day. The patient became intractable with multiple daily paroxysms and was unable to eat and drink. Radiosurgery with a GammaKnife (RS) was performed by delivering a 4mm shot both on the cisternal portion of the V Nerve (90Gy max) and a the sphenopalatin ganglion.

Results: Immediately following RS, the patient experienced relief of pain. She stopped taking medical treatment three months after radiosurgical treatment without recurrence of the pain. Six months after GKS, she developed paresthesia and sensory loss (V1&V2). Eighteen months after radiosurgical treatment, the patient has always a complete pain relief (Grade I: pain free, no use of medication). The onset of a marked hypoesthesia, rare in our experience with trigeminal neuralgia (Regis) and frequent in cluster headache (Donnet, Kano) is in favor a physiopathology similar to CHH.

Conclusion: To the best of our knowledge, our patient is the first one treated with TN and SPG GKS for a cluster-tic syndrome. The response to gamma knife surgery was excellent. Longer follow-up periods and additional studies are required to determine the long-term efficacy and late side effects of this strategy both in cluster headache and in cluster-tic syndrome.

P1060

REPEAT RADIOSURGERY FOR INTRACTABLE OBSESSIVE-COMPULSIVE DISORDER

Sait Sirin³ Kaan Oysul¹ Ferrat Dincoglan¹ Mehmet Ak² Ali Bozkurt² Bahar Dirican¹ Murat Beyzadeoglu¹

(1) Department of Radiation Oncology, Gulhane Military Medical Academy, Ankara, Turkey (2) Department of Psychiatry, Gulhane Military Medical Academy, Ankara, Turkey (3) Department of Neurosurgery, Gulhane Military Medical Academy, Ankara, Turkey

Purpose: To evaluate the safety and efficacy of repeat radiosurgical capsulotomy in intractable

obsessive-compulsive disorder (OCD).

Material and Methods: A 34-year-old female patient with a diagnosis of OCD for 10 years presented to our center. Her history includes failed first-line pharmacological and psychotherapeutic treatments, intractable comorbid major depression, two suicidal attempts, electroconvulsive therapy. Bilateral gamma capsulotomy was performed using one isocenter and 180 Gy of maximum dose at a different hospital. Before radiosurgery, Yale-Brown Obsessive-Compulsive Scale (Y-BOCS) score was 40 and Hamilton Depression Rating Scale -17 (HDRS-17) score was 36. In the follow-up, while depression symptoms improved slightly with some alteration in medication, symptoms of OCD showed no improvement. Forty months after radiosurgery Y-BOCS score was 39, Clinical Global Impressions (CGI) scale score was 7 and HDRS-17 score was 35. On magnetic resonance (MR) images, no definitive lesions were observed. A repeat radiosurgery was planned at our institute. Bilateral anterior capsulotomy was performed using 85 Gy of maximum dose (70 Gy of periphery at 85% isodose) with linac-based radiosurgery system.

Results: Mild nausea and dizziness disappeared on the fifth day of radiosurgery. At one-month follow-up with the usual medication, the scores of Y-BOCS, CGI and HDRS-17 were 31, 5, 25 respectively. On MR images, bilateral capsulotomy lesions were seen without adverse radiation effect.

Conclusion: Repeat stereotactic radiosurgery may be a safe and effective option for failed previous radiosurgery in intractable OCD.

P1061

OUTCOME AFTER LOW-DOSE GAMMA KNIFE RADIOSURGERY FOR PRESUMED DURAL SKULL BASE LYMPHOMA IN IMMUNOCOMPETENT PATIENT

Pavel Ivanov¹ Mikhail Chernov^{1, 2} Georgiy Andreev¹ Andrey Lybinsky¹ Anna Kalesnik¹ Irina Levashkina¹ Aleksander Kuzmin¹ Nikolay Vorobjev¹ Anton Kubasov¹ Irina Sergeeva¹

(1) International Institute of the Biological Systems, Saint-petersburg, Russian Federation (2) Tokyo Women's Medical University, Tokyo, Japan

Summary: A 78-year-old women presented with complaints on the facial pain. MRI revealed skull base tumor, which was initially diagnosed as sphenopetroclival meningioma. Its volume was 8.0 cm³. Gamma Knife radiosurgery with a marginal dose of 10 Gy was done. Fourteen months later MRI disclosed complete disappearance of the neoplasm. Search for possible primary cancer was negative, and possibility of the metastatic intracranial disease was ruled out. It was presumed that the lesion was, in fact, primary dural skull base lymphoma. Such tumors can be easily confused with meningiomas, but low-dose radiosurgery seems to be very effective option for their management.

Objective: Evaluation of the outcome after low-dose Gamma Knife radiosurgery for presumed skull base lymphoma.

Case Description: A 78-year-old women presented with complaints on pain over the left side of the face. MRI demonstrated solitary extraaxial mass lesion, located in the left cerebellopontine angle, petrous apex, and cavernous sinus. The lesion had isointense signal both on T1- and T2-weighted MRI and showed prominent contrast enhancement. Its size was 23.1 - 42.6 - 19.7 mm. The initial diagnosis was sphenopetroclival meningioma. Taking into account the advanced age of the patient and high surgical risk it was decided to perform radiosurgery using Leksell Gamma

Knife model C with Automatic Positioning System.

On the day of treatment the Leksell stereotactic frame was attached to the patient head and thin-sliced MRI as well as CT were performed. Multi-isocenter treatment planning was done. In total 38 isocenters of 8-mm and 4-mm collimators were used. The marginal dose corresponding to 50% isodose line was 10 Gy, the maximum dose was 20 Gy.

Fourteen months after radiosurgery MRI disclosed complete disappearance of the neoplasm, which was associated with significant relief of the preexisting clinical symptoms. Due to complete response of the lesion to low-dose radiosurgery within several months after treatment it was presumed that the neoplasm was, in fact, primary dural skull base lymphoma while no clinical or laboratory signs of immunodeficiency were disclosed.

Discussion: Primary dural lymphoma is an extranodal non-Hodgkin lymphoma. The tumor is extremely radiosensitive, therefore complete and fast response to irradiation is usually observed. Taking into account the outcome in the present case low-dose radiosurgery may be considered as a preferable primary treatment option for large dural skull base lymphoma, since it permits to avoid inadvertent irradiation of the functionally-important adjacent cerebral structures, such as brainstem and cranial nerves.

Conclusion: Dural lymphomas located on the skull base can be easily confused with meningiomas. Nevertheless, low-dose radiosurgery seems to be very effective option for their management.

P1062

FORMATION AND RUPTURE OF THE CAROTID ARTERY PSEUDOANEURYSM AFTER REPEATED SRT FOR SKULL BASE EWING PNET: CASE REPORT

Manabu Tamura¹ Osamu Masuo² Yoshinori Oura² Hiroyuki Matsumoto² Koji Fujita² Naoyuki Nakao² Yuji Uematsu² Toru Itakura² Mikhail Chernov¹ Yoshihiro Muragaki¹ Hiroshi Iseki¹

(1) Institute of Advanced Biomedical Engineering and Science, Tokyo Women's Medical University, Tokyo, Japan

(2) Department of Neurological Surgery, Wakayama Medical University, Wakayama, Japan

Objective: Description of the rare case of pseudoaneurysm formation after repeated SRT for malignant skull base tumor.

Case description: The patient was a 29-year-old man. At the age of 25, he had suffered nasal bleeding and progressive visual field loss on the right eye. Clinical investigation revealed the tumor of the right ethmoid sinus. Because of the rapid progressive loss of visual acuity on the right eye, emergency surgical resection of the neoplasm was performed. Histopathological investigation revealed Ewing PNET. Postoperatively the patient underwent adjuvant chemotherapy and SRT using NOVALIS with delivery of 15 fractions 3.5 Gy each for a target volume of 158 cm³, which resulted in complete tumor response.

Two years later recurrent neoplasm was revealed in the right maxillary sinus. The patient was treated with the second SRT with delivery of 15 fractions 3.7 Gy each for a target volume of 59 cm³, which resulted in complete tumor response. However, one year later new recurrence was disclosed in the right orbit and third SRT was done with delivery of 15 fractions 3.7 Gy each for a target volume of 67 cm³, which resulted in partial response. The patient practically lost his vision on the right eye and suffered from severe headache due to radiation injury of the right temporal lobe beyond the SRT target area.

Four years after an initial manifestation of the disease the patient experienced profound nasal bleeding resulted in a hypovolemic shock. Angiography revealed right C4-5 carotid pseudoaneurysm and irregular stenotic changes of the carotid artery. Investigation was complicated by re-rupture of the lesion, therefore life-saving coiling of the right carotid artery was urgently done. The procedure was complicated by pneumocephalus, which resolved spontaneously. The patient died one year later due to new recurrence of the tumor.

Discussion: It may be difficult to achieve total surgical resection of malignant skull base tumors. As it shown in the present case SRT may be very effective in control of the residual disease as well as new recurrences. However, there is a risk of radiation injury to adjacent neuronal structures. Moreover, in the present case exposure of C4-5 carotid artery to irradiation (in total 220 Gy) resulted in life-threatening vascular complication.

Conclusion: Possible development of carotid stenosis and pseudoaneurysm formation should be considered in cases of repeated SRT for malignant skull base tumors.

P1063

SALVAGE REIRRADIATION USING THE CYBERKNIFE FOR RECURRENT HEAD AND NECK CANCER AT THE SKULL BASE

Hiromitsu Iwata¹, ² Kengo Sato² Naoki Yokota² Koshi Tatewaki² Mitsuhiro Inoue³ Kosaku Inada³ Yuta Shibamoto¹

(1) Department of Radiology, Nagoya City University Graduate School of Medical Sciences, Nagoya, Japan (2) Department of Neurosurgery, Yokohama CyberKnife Center, Yokohama, Japan (3) Division of Quality Management with Radiation, Yokohama CyberKnife Center, Yokohama, Japan

Purpose: To evaluate the clinical outcome of reirradiation using the CyberKnife in the treatment of recurrent skull base head and neck tumor.

Methods and Materials: From July 2005 to December 2009, 71 patients with recurrent skull base head and neck tumor were reirradiated with stereotactic radiotherapy using the CyberKnife. Forty patients were male and 31 were female. Patient age ranged from 11 to 91 years (median, 61 years). Patients who had not undergone conventional radiotherapy as first radiotherapy were excluded. Tumor volume ranged from 3.1 to 204.9 ml (median, 37.2 ml). The dose of previous conventional radiotherapy ranged from 26-70 Gy (median, 60 Gy). Interval between first radiation and reirradiation ranged from 2.5 to 260 months (median, 19 months). The median follow-up period for living patients was 13.5 months (range: 6-44.5 months). The beam energy was 6 MV. Patients were lightly restrained with a custom-made thermoplastic face mask, and the 6D automated skull-tracking tracking Methods was utilized in all cases for patient alignment and target position correction during treatment. Stereotactic radiotherapy was given in 1-5 fractions. Radiation doses were prescribed at the margin (95% volume line of planning target volume). The marginal doses were 20-41.5 Gy in 1-5 fractions (median, 35 Gy). Toxicities were evaluated with the Common Terminology Criteria for Adverse Events version 4.0.

Results: The 1-year overall survival, locoregional control rates and progression-free survival were 65%, 70% and 45%, respectively. The median overall survival and local control were 12 and 10 months, respectively. There were no significant differences in the treatment Results among tumor

volume and interval from previous radiotherapy. Grade 3 or higher adverse events were observed in 20% of the patients. Grade 4 dermatitis was observed in 4 patients receiving trimodal combination therapy. There were 3 brain necrosis cases presenting with clinical symptoms.

Conclusions: Salvage reirradiation using the CyberKnife is acceptable and effective for recurrent skull base head and neck tumor. To protect the normal brain tissue, hypofractionated stereotactic radiotherapy seems preferable. To further improve overall survival and local control, exploration of better planning, dose fractionation and concurrent chemotherapy appears worthwhile. Further investigation of reirradiation using stereotactic radiotherapy for recurrent skull base head and neck tumor is warranted.

P1064

SKULL BASE PARAGANGLIOMA WITH LOCAL SPREAD TO CERVICAL VERTEBRAE.TREATMENT APPROACH-COURSE OF DISEASE

Ioanna Kantzou¹

(1) Attikon Hospital, Athens, Greece (2) Metaxa Hospital, Piraeus, Greece

Paragangliomas are low grade tumors of the base of skull. Tumors that may develop from paraganglia are most commonly found in the temporal bone or cervical region. Paragangliomas are collections of neuroepithelial cells, that probably have their origin in the neural crest. From a therapeutic perspective, they can be treated with surgery or irradiation. We present the case of a patient with skull base paraganglioma with local spread to the first cervical vertebrae, irradiated with lack of progression of the mass and permanent improvement in clinical signs and symptoms initially; later, the patient underwent treatment with radioactive indium due to progression of disease. Due to new progression of disease, six years later, the patient underwent treatment with radioactive yttrium.

P1065

JUGULO TIMPANIC GLOMUS TUMOR, TRIDIMENSIONAL CONFORMAL AND INTENSITY MODULATED RADIATION THERAPY, COMPARATIVE DOSE GRADIENT AND FLAT DOSIMETRY IN FRAMELESS STEREOTACTIC IMAGE GUIDED FRACTIONATED TREATMENT

Vinicio Toledo¹ Porfirio Diaz¹ Xerxes Dominguez¹ Johana Garnica¹ Mariana Leon-q¹

(1) HOSPITAL SAN JAVIER, Guadalajara, Mexico

Statement of study: Compare tridimensional conformal and intensity modulated image guided technics in frameless fractionated stereotactic external beam radiation treatment in jugulo-timpanic glomus tumor verified with cone beam computed tomography and fluence maps in planar dosimetry Objectives.

Confirm dose gradient and stereotactic precision in these technics using 6 an 10 MV X rays

Methods: Two cases were planned with PrecisePlan, thermoplastic mask was used and helical tomography with IV contrast enhance performed, treatment plans were defined after GTV and

a 2mm margin outlined in coronal and axial images. Case 1 3DCRT -11 coplanar, 1 no coplanar segments- previous embolization 6MV and case 2 IMRT, -8 coplanar segments- 10MV linac was used and a cone beam verification protocol implemented in both cases. Embolization material computed tomography density was integrated in the calculation algorithm in case 1. Verification protocol with volumetric in site scan was performed everyday the first five days and then twice a week during the rest of the treatment on both. Deviations were corrected if needed to be. Dosimetric verification -IBA dosimetry- was performed also in both cases, mean prescription dose was 56.29 Gy in 30 1.97 Gy/fraction.

Results: Corrected deviations were 5.7 mm for 3DCRT technic, and 2.6 mm for IMRT technic standard deviation in XYZ axis. Dose distribution analysis for IMRT showed equivalent homogeneous dose in two dimensional distribution measured for flat field verification and, XY dose profiles fluence map showed a better dose gradient than 3DCRT. Calculation algorithm neglected lateral electronic equilibrium in modeling but no CT density file variations. DVH had a stepper curve in IMRT as related to treatment volume.

Conclusions: The cone beam CT performed previous to treatment delivery showed minor standard deviation in IMRT, this positioning image guided quality control scan decreased inter-fraction uncertainty. Dose volume histogram showed better coverage of GTV with the prescription dose to the percentile cumulative volume with IMRT, and proved to be more accurate in the treatment volume homogeneity prescription dose than 3DCRT technic. Leakage and scatter radiation did not seem to represent a significant problem in peripheral dose as measured in fluence maps on both cases despite the X ray energy. IMRT should be the selected technic for fractionated stereotactic image guided external beam irradiation of jugulo-timpanic glomus tumor.

P1066

GAMMA KNIFE RADIOSURGERY FOR JUGULER FORAMEN SCHWANNOMAS

Selcuk Peker¹ Meric Sengoz² Necmettin Pamir¹

(1) Acibadem University Department of Neurosurgery, Istanbul, Turkey (2) Acibadem University Department of Radiation Oncology, Istanbul, Turkey

The aim of this study is to review the Results of the Gamma Knife radiosurgery (GKRS) for jugular foramen schwannomas.

Between 1997-2010, 17 patients with jugular foramen schwannomas has been treated with GKRS. There were 9 female and 8 male patients with the age range of 19-64. The volume of the tumors were between 1.1-12.3 cc (mean 5.9 cc). The median marginal dose was 13 Gy (10-16 Gy). In five patients the primary treatment was with GKRS.

The mean follow-up time was 64 months (6-133 months). Tumor growth control rate was 100%. In twelve patients central necrosis of the tumor was found in MR. The tumor was smaller in 13 and stable in 4 patients. One patient demonstrated temporary voice problems.

Gamma Knife radiosurgery can be used for the treatment of primary or recurrent/residual jugular foramen schwannomas. We think that it should be used as primary treatment in small sized schwannomas.

P1067

COMPARISON OF MACROSCOPIC PATHOLOGY MEASUREMENTS WITH MAGNETIC RESONANCE IMAGING AND ASSESSMENT OF MICROSCOPIC PATHOLOGY EXTENSION FOR COLORECTAL LIVER METASTASES

Alejandra Mendez Romero¹ Yvette Seppenwoolde¹ Joanne Verheij² Roy S. Dwarkasing² Cornelis Verhoef¹ William K. Redekop³ Peter J.c.m. Nowak¹ Jan Ijzermans² Peter C. Levendag¹ Ben J.m. Heijmen¹

(1) Erasmus MC-Daniel den Hoed Cancer Center, Rotterdam, The Netherlands (2) Erasmus MC, Rotterdam, The Netherlands (3) Institute for Medical Technology Assessment. Erasmus University, Rotterdam, The Netherlands

Purpose: To compare pathologic macroscopic tumor dimensions with magnetic resonance imaging (MRI) measurements, and to establish the microscopic tumor extension for colorectal liver metastases.

Materials and Methods: In a prospective pilot study we included patients with colorectal liver metastases planned for surgery and eligible for MRI. A liver MRI was performed within 48 hours before surgery and included a T2-weighted fast spin echo (FSE) single shot sequence, a T1-weighted gradient echo sequence, a T1-weighted gadolinium-enhanced sequence, and a T2-weighted FSE fat saturation sequence. Directly after surgery, an MRI of the specimen was acquired to measure the degree of tumor shrinkage since the specimen had been removed from the liver. After the specimen was fixed in formalin for 48 hours, another MRI was performed to assess possible tumor/specimen shrinkage. All MRI sequences were imported into our radiotherapy treatment planning system where the tumor and the specimen were delineated. For the macroscopic pathology analysis photographs of the sliced specimens were used to delineate and reconstruct the tumor and the specimen volume. Microscopic pathologic analysis was conducted to assess the infiltration depth of tumor cell nests.

Results: Between February 2009 and January 2010 we included 13 patients for analysis with 21 colorectal liver metastases (11 previously treated with chemotherapy and 10 not). We observed almost no shrinkage through the different stages. The smallest mean difference between the tumor assessed on an MRI sequence and the macroscopic pathology was found in the T1-weighted echo gradient sequence. All MRI sequences correlated well with the pathology. The best correlation was for the T1-weighted echo gradient sequence, T2-weighted FSE single shot sequence, and the T2-weighted FSE fat saturation sequence (correlation 0.99), followed by the T1-weighted gadolinium-enhanced sequence (correlation 0.98). We observed 39 tumor cell nests beyond the tumor border in 12 metastases. Microscopic extension (ME) was found between a range of 0.2 and 10 mm, with 10% of the cases being located at a distance of at least 6 mm. No significant relationships were found between ME and tumor or patient characteristics, including preoperative treatment with chemotherapy.

Conclusions: MRI tumor dimensions showed a good agreement with the macroscopic pathology suggesting that MRI can be used for accurate tumor delineation. However, microscopic extensions found beyond the tumor border indicate that caution is needed in selecting appropriate tumor margins.

P1068

UNIVARIATE ANALYSIS OF FACTORS CORRELATED WITH TUMOR CONTROL AFTER SBRT FOR HEPATIC TUMORS

Sylvain Dewas¹ Xavier Mirabel¹ Andrew Kramar¹ Hajer Jaraya¹ Thomas Lacornerie¹ Claire Vautravers-dewas¹ Ingrid Fumagalli¹ Eric Lartigau¹

(1) Centre Oscar Lambret, Lille, France

Objective: CyberKnife® allows the treatment of hepatic tumors while performing real-time tumor tracking. This radiation therapy technique appears to be well tolerated with encouraging local control rates. We have studied the factors correlating with better local control of primary or secondary hepatic lesions.

Patients and Methods: Since 2007, 153 stereotactic liver treatments were administered for 120 patients. Ninety-nine liver metastases (in 72 patients), 48 hepatocarcinomas (in 42 patients) and six cholangiocarcinomas were treated. On average, three to four sessions were delivered over 12 days. Forty to 45 Gy was prescribed to the 80% isodose line. Margins consisted of 5 to 10 mm for CTV, and 3 mm for PTV. A local control analysis by Log-rank and Cox regression was performed.

Results: The median size of the targets was 33 mm (range, 5-112 mm). The median GTV volume was 32.38 cm³ (range, 0.2-499.5 cm³). The mean duration of sessions 107 minutes (range, 36-199 minutes). The mean number of beams per treatment was 152 (range, 25-276 beams). The median total dose delivered was 45 Gy (15 Gy per session). The median minimum dose delivered was 27 Gy (9 Gy per session). With a median follow-up of 15.0 months, the local control rates at one and two years were 84% and 74.6 %, respectively. The overall local control rate was 83.7%. The factors associated with better local control were lesion size <50 mm ($p=0.019$), GTV volume ($p<0.05$), PTV volume ($p<0.01$), and two treatment factors, namely, a total dose of 45 Gy and a dose per fraction of 15 Gy ($p=0.019$). The GTV and PTV volumes were strongly correlated with the diameter of the target ($p<0.001$).

Conclusion: This has been, to our knowledge, the largest series of stereotactic liver treatments. We were able to demonstrate the role of the dose, the size, and the tumor volume in local control. It appears that the Results of our study should be considered in order to obtain a maximum therapeutic efficacy.

P1069

ROBOTIC STEREOTACTIC RADIATION THERAPY FOR LIVER METASTASES OF BREAST CANCER

Ingrid Fumagalli¹ Sylvain Dewas¹ Xavier Mirabel¹ Hajer Jarraya² Thomas Lacornerie¹ Eric Lartigau¹

(1) Academic Radiation Therapy Department, Comprehensive Cancer Center Oscar Lambret,, Lille, France (2) Radiology Department, Comprehensive Cancer Center Oscar Lambret, Lille, France

Objective: With progress in the treatment of breast cancer, patients with liver metastasis remaining in good health represent a new and increasing population. These women represent a new medical challenge since most of the time an invasive treatment such as surgery cannot be considered for them. Stereotaxic radiosurgery (SRS) Therapy could be used to treat these patients.

The purpose of this study was to evaluate the feasibility, tolerance and efficacy of a such irradiation.

Patients and Methods: Eight patients had a SRS irradiation in our center for liver metastasis. Patients had one (6 patients), two (1 patient) or three lesions (1 patient). Median age was 62 years old (47 to 80). All patients were PS 0 or 1, and asymptomatic before treatment.

Average evolution time between primitive tumor diagnostic and treatment for the liver metastasis was 8 years. Initial breast tumor treatment consisted of tumorectomy followed by radiation therapy. 2 patients had adjuvant chemotherapy.

Three to four fiducials (radio markers) were inserted inside or near the metastasis for real-time tumor tracking. The treatment delivered was hypofractionnated : 3 sessions of 15 Gy or 4 sessions of 10 Gy. The constraints at organs at risk were: for the sane liver $V15 < 50\%$, $V21 < 33\%$ and $(V_{total} - V17) > 700 \text{ cm}^3$; for the Stomach $V21 < 5 \text{ cm}^3$ and D_{max} at 24 Gy ; for the duodenum $V15 > 5 \text{ cm}^3$ and D_{max} at 24 Gy ; and for the bowel $V16 < 5 \text{ cm}^3$ and D_{max} at 27 Gy. Early toxicity was evaluated using CTCAE v 3.0.

Results: Mean follow-up was 15 months, with more than 35 months for the first treated patients. All patients finished their treatment. 7 patients were treated in 3 sessions of 15 Gy and one with 4 sessions of 10 Gy. The average duration of treatment sessions was 100 min.

Early toxicity was low: 3 patients had nausea grade I in CTC-3.0. One patient presented a duodenal ulcer after treatment without any long-term consequences.

One patient died of complication due to bone metastasis (hypercalcemia). The seven other patients are still in good health.

Conclusion: SRS treatment was feasible and well tolerated. This hypofractionnated treatment could sterilize the liver metastasis of these patients and should be considered for them more frequently when the number of lesions doses not exceeds three.

P1070

STEREOTACTIC RADIOSURGERY FOR TREATMENT OF PULMONARY METASTASES: OUTCOMES AND TOXICITY

Stefano Masciullo¹ Franco Casamassima¹ Claudia Menichelli¹ Laura Masi¹ Ivano Bonucci¹ Rafaela Doro¹

(1) U.O. Radiobiologia Clinica - University of Florence - Casa di Cura S. Chiara, Florence, Italy

Purpose: To evaluate the effectiveness of image-guided stereotactic radiosurgery (SRS) for the treatment of metastatic pulmonary nodules with diameter $\leq 3 \text{ cm}$ and peripherally located ($\geq 2 \text{ cm}$ around large bronchi).

Materials and Methods: Seventy-one patients (median age 71 years, range 31-84) were treated in our Institution for pulmonary metastases. All patients had lungs as the only metastatic site and primary tumor controlled. The number of metastatic nodules was one in 34 Pts, two in 18, ≤ 4 in others. All detectable lesions in these oligometastatic patients were treated by single-fraction SRS (n=98) when $< 3 \text{ cm}$ and peripheral, or by three fraction stereotactic radiotherapy (n=37) when $> 3 \text{ cm}$ and/or centrally located. Primary tumor was colorectal in 24 Pts, NSCLC in 33, other in 14. Among NSCLC patients, thirty were M1a (according latest AJCC definition) and maximum interval between primary tumors and nodules appearance was three years. Twenty-four patients received prior or following chemotherapy within six months of radiotherapy. For lesions treated by

SRS, PTV ranged from 1.3 to 39 cc (median 8). GTV was delineated on two CT scans acquired in breath hold expiration and inspiration, in order to obtain an ITV. Patients were instructed to take shallow breaths during image acquisition and treatment, the latter performed in free breathing. A spirometer (Elekta ABC) was used for respiratory motion management. No margins were added from ITV to CTV. PTV was obtained with an isotropic margin of 3 mm added to ITV. A number of 3-8 coplanar arcs were utilized for delivery a single dose of 26 Gy, generally prescribed at isocenter with the 90% isodose line including the whole target. A Cone-Beam CT was acquired before the treatment for setup corrections and target localization. A 6-MV Elekta Synergy equipped with dynamic mMLC was employed. CTCAE v.4 and modified RECIST criteria was used for toxicity and response evaluation.

Results: With median follow-up of 16.8 months (3-84), the 1- and 2-years actuarial local control for radiosurgery was 91% and 80.5%. There were 9 local failure in 8 Pts (7 colorectal + 2 NSCLC) and a significant difference was found between colorectal and the other histologic types ($p=0.02$), without influence of target dimension. For fractionated SBRT the 1- and 2-years LC was 86% and 72%. The 1- and 2-years OS was 89% and 76%. No acute or late toxicity of grade > 2 was observed.

Conclusions: In our experience image-guided radiosurgery for pulmonary metastases is a safe and effective therapeutic option. The worse local control of colorectal metastases suggest the need of dose escalation for this histologic type.

P1071

IS STEREOTACTIC BODY RADIOTHERAPY WARRANTED IN MEDICALLY OPERABLE STAGE I NSCLC? A MARKOV MODEL BASED DECISION ANALYSIS

Alexander Louie¹ George Rodrigues^{1, 2} Malek Hannouf² David Palma¹ Jeffrey Cao^{1, 3} Brian Yaremko¹ Richard Malthaner⁴ Joseph Mocanu³ Gregory Zaric^{2, 3}

(1) Department of Radiation Oncology, London Regional Cancer Program, London, Canada (2) Department of Epidemiology and Biostatistics, University of Western Ontario, London, Canada (3) Richard Ivey School of Business, University of Western Ontario, London, Canada (4) Division of Surgery, London Health Sciences Center, London, Canada

Approach: To compare the quality-adjusted life expectancy (QALE) and overall survival in patients with Stage I non-small cell lung cancer (NSCLC) treated with either stereotactic body radiation therapy (SBRT) or surgery. Innovation: A growing body of evidence suggests that SBRT is the standard of care option for medically inoperable stage I NSCLC patients. Relevance: Two randomized control trials are ongoing to determine the role of SBRT in medically operable patients.

Materials and Methods: We constructed a Markov model to simulate the clinical history of medically operable patients with stage I NSCLC that undergo either SBRT or lobectomy for a 5-year timeframe. Recurrence rates and Markov state utilities, consistent with the four stages of the AJCC staging system, were extracted and adapted to monthly time intervals from the literature. Age- and sex-specific rates of death from all other causes were extracted from standard life tables from the Centre for Disease Control and Prevention and were varied according to smoking habit. Surgical outcomes from the model were compared to Adjuvant! Online (AO). We report various treatment strategy overall and quality adjusted survival outcomes stratified by age, sex, and pack-

year history of smoking. Sensitivity analyses on the quality of life of SBRT, treatment related death, and proportion of patients with recurrent disease receiving radical treatments were performed to determine thresholds for treatment modality preference.

Results: Overall survival, cancer specific survival, and other causes of death as predicted by our model correlated closely with those predicted by AO ranging from 0.0% to 3.8%, 0.1% to 1.0%, and 0.1% to 3.5% respectively, thus validating our model. Mean QALE ranged from 3.28 to 3.78 quality adjusted life years (QALYS) after surgery and 3.35 to 3.87 QALYS for SBRT. Differences in overall survival ranged from 2.2% to 3.0% and 0.07 to 0.09 QALYs for all patient cohorts. The utility threshold for preferring SBRT over surgery was 0.90. Outcomes were sensitive to quality of life, the proportion of local and regional recurrences treated with radical versus palliative treatments, and the surgical and SBRT treatment related mortalities.

Conclusions: The role of SBRT in the medically operable patient is yet to be defined. SBRT may offer comparable overall survival and quality adjusted life expectancy as compared to surgical resection. Well powered prospective studies comparing surgery versus SBRT in early lung cancer are warranted to further investigate the relative survival, quality of life and cost characteristics of both treatment paradigms.

P1072

STEREOTACTIC RADIOTHERAPY IN LUNG NEOPLASTIC LESIONS: ANALYSIS OF 68 PATIENTS TREATED AT RADIOTHERAPY UNIT OF FLORENCE UNIVERSITY

Vieri Scotti¹ Stefania Pallotta¹ Ciro Franzese¹ Bendetta Agresti¹ Icro Meattini¹ Silvia Bertocci¹ Lorenzo Livi¹ Paolo Bastiani² Marta Bucciolini¹ Giampaolo Biti¹

(1) Radiotherapy-Azienda Ospedaliero-Universitaria Careggi, Florence, Italy (2) Radiotherapy-ASL10, Florence, Italy

Objective: to analyze feasibility and outcome of stereotactic radiotherapy (SRT) with non-dedicated Linac on primary and secondary lung neoplastic lesions. To correlate local control to dose-escalation.

Methods: from May 2004 to January 2010 68 patients (46 males and 22 females) affected by primary non small cell lung cancer (NSCLC) (n: 46) or metastatic lesions (n: 22) were treated at the Radiotherapy Unit of Florence University. Performance status was 0 in 17 patients, 1 in 26, 2 in 21 and 3 in 2 patients. Majority of patients had pulmonary comorbidities (BPCO GOLD scale > than 1 in 69%). 12 patients were affected by central (0.5-2 cm from the carina), 56 by peripheral lesions (2.5-9 cm). Target lesions were measured on CT scan and median dimension was 25.9 mm (range 10-50). Immobilization was achieved by using a customized body vacuum bag (Bodyfix, Medical Intelligence, Schwabmunchen, Germany). CT images obtained under normal breathing and with breath holding during the expiratory and inspiratory phases, were send to Odyssey (PerMedics Inc, CA, USA) treatment planning system. Dose was prescribed to the lowest isodose line covering 95% of the PTV. SBRT was planned using multiple co-planar 6-MV photon beams and delivered with an Elekta Precise linac equipped with a micro multileaf collimator (Direx Systems Corp. MA, USA) and with an Elekta Synergy Beam Modulator. Prescribed dose and fractionations have changed all over the time; to compare different fractionations the Biological Equivalent Dose (BED) was calculated. 29 patients were treated with a single application (medium delivered BED 74.1 Gy), 39 patients

with 2 to 5 applications (medium BED 82.2 Gy).

Results: 67/68 patients were available for response and vital status. We registered stable disease in 30 patients, partial response in 28, complete response in 7 patients. In 2 patients the treated lesion was grown at the first evaluation post-SRT. BED was correlated to response: most of complete response was observed in patients with BED > 100Gy; the two progressive disease were observed in patients with BED < 60 Gy. SRT-related toxicity was observed in 5/67 patients (7.4%); we observed one case of grade 3 pneumonitis.

Conclusions: in our experience SRT is a safe and feasible treatment in limited stage NSCLC with pulmonary comorbidities and in oligometastatic patients. We believe that active-breathing Methods ologies allow us a further safe dose escalation.

P1073

STEREOTACTIC RADIOTHERAPY FOR THORACIC LESIONS AFTER PNEUMONECTOMY: RETROSPECTIVE ANALYSIS

Gaia Piperno¹ Gianpiero Catalano² Raffaella Cambria¹ Cristina Garibaldi¹ Daniela Alterio¹ Roberto Orecchia¹

(1) European Institute of Oncology, Milan, Italy (2) Multimedica , Castellanza, Italy

Aim: To evaluate toxicity and outcome of stereotactic radiotherapy of intrathoracic lesions after pneumonectomy.

Materials and Methods: From November 2005 to April 2010 sixteen patients who underwent pneumonectomy were referred to our department for the treatment of new thoracic lesion; In all patients surgery was excluded. There were 12 males and 4 females; median age was 64 years old (range 52-77). Previous pneumonectomy (11 left and 5 right) was performed in all cases for non small cell lung cancer. The lesions treated were parenchymal lung nodules in 8 cases and mediastinal nodes in 8; all patients but two were staged with PET scan; (in all PET-studied patients, the lesion was PET positive). In all patients the lesion treated was the only site of disease. Four patients received chemotherapy before radiotherapy; three patients were previously treated with adjuvant radiotherapy to the mediastinum. Stereotactic treatment consisted of 1 to 3 isocentric non-coplanar 6MV-photon arcs, conformed to the PTV by mean of a BrainLABTM dynamic micromultileaf collimator. GTV was detected by mean of a 3 mm-thickened CT scan, with margins of 5-10 mm added for PTV definition. Margins for the PTV definition were defined according the tumor motion assessed by contouring the lesion on different repeated CT series performed during different respiration conditions. Contours were then superimposed by fusing the different CT series. Lesions sizes varied from 7 mm to 4 cm; mean GTV volume was 13.6 (range 0.49-40.5) and mean PTV was 50.9 cm³ (range 10.2-103 cm³).

Dose prescription ranged from 24 to 45 Gy in 3-5 fractions (dose fractions ranged from 6 Gy to 15 Gy). Median dose was 36 Gy in 3 fractions.

Results: All patients completed treatment; one patient had a respiratory distress 2 months after treatment requiring hospitalization followed by full recovery; one patient had esophageal fistula 5 months after treatment.

No other serious (\leq G2) acute nor late side effects have been recorded.

All but one treated lesions were stable or downsized at first CT follow up (60-70 days after treatment). In six patients PET scan become negative on the treated lesion.

After a mean and median follow up of 18 and 8 months (range 5-60) 6 patients are alive and free of disease; 4 patients died of progressive disease (not local); 1 patient died for a cause not related to cancer and 5 are alive with disease; 8 patients had metastatic spread. Only 1 patient had progression of the treated lesion.

Conclusions: Stereotactic radiotherapy is feasible, well tolerated and effective also in patients after pneumonectomy. Lung toxicity does not seems worrying, however, a larger number of patients is warranted

P1074

STEREOTACTIC RADIOTHERAPY FOR PRIMARY LUNG CARCINOMA AND STEREOTACTIC RADIOSURGERY FOR BRAIN METASTASIS IN PATIENTS WITH LUNG CARCINOMA WITH DISTANT METASTASIS ONLY IN THE BRAIN.

Chisa Hashizume¹ Yoshimasa Mori¹ Tatsuya Kobayashi¹ Takahito Tsugawa¹ Yuta Shibamoto² Shinya Otsuka²

(1) Nagoya Radiosurgery Center, Nagoya Kyoritsu Hospital, Nagoya, Japan (2) Department of Radiology and Radiation Oncology, Nagoya City University Graduate School of Medicine, Nagoya, Japan

Purpose: Stereotactic body radiation therapy (SBRT) is highly expected to be a standard treatment for patients with localized primary or metastatic lung tumors. We started SBRT using a stereotactic linear accelerator, Novalis equipped with micro-multi-leaf collimator and accurate patient setup system, ExacTrac in July 2006. In patients suffering from lung carcinoma with metastasis only in the brain, classified to stage IV (T1or2 N0M1), we treated primary lung tumors by SBRT after brain metastasis was treated by stereotactic radiosurgery (SRS).

Patients: We treated 12 patients (5 men and 7 women) with a median age of 72 years (range: 61-83) with lung carcinomas in stage IV with brain metastasis by SBRT using Novalis. All patients had received SRS by Gamma Knife or CyberKnife for brain metastasis. Eight patients had T1N0M1 lung carcinoma and 4 had T2N0M1 when treated by SBRT. Ten of 12 patients had adenocarcinoma and the other 2 had alveolar cell carcinoma or non small cell lung cancer (NSCLC).

Methods: We delineated CTV for lung tumors on CT taken at 3 phases (expiratory, inspiratory and spontaneous breathing) and PTV with a margin of 5-7mm. We planned 3D non-coplanar 7-beam stereotactic irradiation. The targets were covered at 95% or higher isodose level. Prescription dose was 48 Gy to 52 Gy in 4 fractions over 2 weeks in all patients except for in one patient 60 Gy in 8 fractions because of central location of the tumor. Chemotherapy was also done in four patients after the SBRT.

Results: The treatment Results were evaluated with a median follow-up period of 10 months (range, 2 to 46 months) in all patients. Local control (CR+PR+SD) rate of primary lung lesions at two years was 100%. The overall survival rate at 2 years was 92% and cause-specific survival rate at 2 years was 100% in this series. Progression-free survival was 62% at 2 years. Grade 1 radiation pneumonitis developed in 8 of 12 (66%) patients but other side effects was not seen during the follow-up time.

Conclusions: For the patients with stage IV lung carcinomas, if metastasis is only in the brain, SBRT for the primary lung tumor might be a safe and effective treatment. Long-term follow-up data are awaited to determine late complications and long-term tumor control rate.

P1075

STEREOTACTIC BODY RADIOTHERAPY FOR PRIMARY LUNG CANCER: A NON INVASIVE TREATMENT APPROACH IN MEDICALLY INOPERABLE PATIENTS

Giancarlo Beltramo¹ Achille Bergantin¹ Anna Martinotti¹ Paolo Bonfanti¹, ² Livia Bianchi¹

(1) Centro Diagnostico Italiano, Milan, Italy (2) Specialization School in Medical Physics, Milan, Italy

Introduction: Although surgical resection remains the mainstay of therapy for early stage non-small cell lung cancer (NSCLC), unfortunately, many patients with resectable early stage disease are unable to tolerate pulmonary resection because of compromised cardiopulmonary function. We evaluate the efficacy and feasibility of Cyberknife image-guide stereotactic body radiation therapy in patients with early-stage (Stage IA - IB) non small cell lung cancer (NSCLC).

Materials and Methods: between April 2006 to April 2010, 34 patients, 2 female 32 male with a median age of 74 years (range 55 - 89 years) with pathologically proven NSCLC (squamous cell carcinoma, adenocarcinoma, large-cell carcinoma, bronchoalveolar cell carcinoma, or NSCLC not otherwise specified), diagnosed as 16 stage IA and 18 Stage Ib were referred to our Radiotherapy Department for Cyberknife stereotactic radiotherapy treatment. Before study enrollment, patients underwent physical examination, computed tomography (CT) of the chest and upper abdomen, pulmonary function testing, and whole-body 18F-fluorodeoxyglucose positron emission tomography (PET)/CT fusion study. In all patients one or three gold fiducial seeds were implanted in or next to the lung cancer and to allow fiducials stabilization CT simulation was performed one week later. Multiplan (version 2.0.5, Accuray, USA) was employed. The planning treatment volume (PTV) included the GTV expanded by 5 mm isotropic margin. CK stereotactic radiosurgery protocol provide a prescribed PTV dose of 45 - 60 Gy given in 3 daily fractions of 15 - 20 Gy, with > 95% of the PTV encompassed within the prescription isodose volume. Patients were followed with CT and PET scan to detect disease recurrence. Local recurrence was defined as an increase in size of tumor following treatment as most tumors shrunk following radiation.

Results: Median follow-up was 19 months (range, 4-48 months). Kaplan-Meier local control at 1 and 2 years was 84.9% and 84.9% respectively, overall survival (OS) at 1 and 2 years was 89.8% and 83.4%, disease free Survival (DFS) at 1 and 2 years was 84.9% and 78%. We detected a late radiation-induced local fibrosis using CT imaging in most patients, but, till today, none of patients had any chronic symptoms.

Conclusions: CyberKnife-based SRT is a feasible approach for primary lung cancer, offering excellent in-field tumor control and low toxicity profile. Further experience and longer follow-up are needed to evaluate the role of CK and to identify patients most likely to benefit from it.

P1076

PRELIMINARY EXPERIENCE IN IMAGE GUIDED STEREOTACTIC BODY RADIOTHERAPY TREATMENTS FOR LUNG CANCER WITH TOMOTHERAPY

Ruth Rodríguez Romero¹ Patricia Sánchez Rubio¹

(1) Servicio de Radiofísica. Hospital Universitario Puerta de Hierro, Madrid, Spain

Objective: Pulmonary irradiations involve location and dosimetric inaccuracies due to respiratory motion and inhomogeneity tissue, even more for high dose fractionations in case of small lung lesions where the reduction of normal tissue volume included in the PTV becomes essential. Although respiratory gating treatments are available at our facility, its use has been dismissed for lung tumors because of inaccuracy dose calculation algorithm for heterogeneous media. Tomotherapy provides enough dose accuracy, however there is no control of respiratory motion (no gating or tracking), so abdominal diaphragmatic compression is the only option. The purpose of this work is to study the feasibility of hypofractionated stereotactic body treatment of lung lesions with Tomotherapy.

Methods: Three real patient cases have been studied. To assess dampening use benefit, CT studies were performed with and without CIVCO Body Pro-Lock system, at inhalation and exhalation to determine GTV shifts. Also a slow CT images set was obtained during free breathing in each case to use it for planning as an approach to the actual treatment situation (an averaged density). A virtual GTV was defined as a sum of GTV delimited at each respiratory phase.

The recommendations of RTOG-0236-0618 protocols for margins expansion (0.5cm in axial plane and 1.0cm in longitudinal direction) were followed, slightly modified to avoid nearby OARs such as bronchial tree or ribs. Dose prescriptions were also based in these protocols (20Gy x 3 fractions).

Results: A reduction of 2cc in GTVs volumes (13%-20% for small lesions) was obtained applying diaphragmatic compression. Great differences are due to displacement in longitudinal axis that can be reduced from 1.5-2.0cm to 1.0-1.5cm (in axial plane shifts <0.3cm).

Dose distributions obtained show great dose homogeneity (overdosage <4%, subdosage <3%). Treatment times were about 22 minutes.

Patient treatment verifications were agree to dose calculations, even using heterogeneity phantom setup. Daily MVCT showed small lateral and longitudinal shifts <3mm but vertical displacement >7mm because of couch sag.

Conclusions: Pulmonary SBRT treatments are feasible in Tomotherapy even without respiratory control: GTV movements can be taken account, dose distributions satisfy RTOG protocols and are truthful, treatment times are reasonable and IGRT is suitable.

References:

- Dunlap et al. InterJournalRadOncBiolPhys. 2010.76(3)796-801.
- Hodge et al. Acta Oncologica 2006;45:890-896
- Holmes et al. MedDosim 2008.33(2)135-148.
- Kanagaki et al. PhysMedBiol.52-243

P1077

EVALUATION OF LOCAL CONTROL AND TOXICITY IN THE TREATMENT OF LUNG NODULES WITH STEREOTACTIC RADIOTHERAPY

Manuel Llorente¹ Natalia Carballo¹ Cristina Garrán¹ Juan Carlos Viera¹ Amparo Baíllo²

(1) MD Anderson España, Madrid, Spain (2) Universidad Autónoma, Madrid, Spain

We present an analysis of the Results in the treatment of lung lesions (metastasis and primary T1 tumours) using Stereotactic Radiosurgery. We evaluate local control as a function of dose delivered and the toxicity produced by the treatment.

Methods and materials: Patients are immobilized using a stereotactic body frame with a diaphragm compressing device to avoid deep breath. Two images sets are acquired: One in normal breathing and another one in breath hold. Gross tumour volume (GTV) is contoured in both and a 7 mm margin is added to create the planning target volume (PTV) Treatment plan is made with 9 static coplanar beams and calculated in a planning system with convolution calculation algorithm. Prescribed dose covers at least 95% of the GTV. Doses range from 18 Gy (3 fractions) and 62.5 Gy (5 fractions) Lesion size ranges from 4 to 16 cm³.

Follow up is performed with CT images for at least one year. Local control is positive if, after one year, tumour size is stable or smaller.

Results: From January 2005 to December 2009, 67 lesions in 56 patients have been treated with a follow up of at least one year.

Physical dose is converted to standard fractionation equivalent dose using the linear quadratic model and $\alpha/\beta=10$. Dose is correlated with local control and can be separated in 2 groups with a 90% confidence level. One, with doses up to 50 Gy and a local control of 66% and another one with doses higher than 50 Gy and 90% of local control.

Only 5 patients suffered complications linked to Radiotherapy: Pneumonitis grade IV: 1, grade III: 1; esophagitis grade IV: 1 and grade III: 1.

Conclusion: Treatment of lung lesions using Stereotactic Radiosurgery present good Results in terms of local control for doses higher than 50 Gy with a moderate and acceptable toxicity.

P1078

PRELIMINARY EXPERIENCE IN IMAGE GUIDED STEREOTACTIC BODY RADIOTHERAPY TREATMENTS FOR LUNG CANCER WITH TOMOTHERAPY

Ruth Rodríguez Romero¹ Patricia Sánchez Rubio¹

(1) Servicio de Radiofísica. Hospital Puerta de Hierro Majadahonda., Madrid, Spain

Objective: Pulmonary irradiations involve location and dosimetric inaccuracies due to respiratory motion and inhomogeneity tissue, even more for high dose fractionations in case of small lung lesions where the reduction of normal tissue volume included in the PTV becomes essential. Although respiratory gating treatments are available at our facility, its use has been dismissed for lung tumors because of inaccuracy dose calculation algorithm for heterogeneous media. Tomotherapy provides enough dose accuracy, however there is no control of respiratory motion (no gating or tracking), so abdominal diaphragmatic compression is the only option. The purpose of

this work is to study the feasibility of hypofractionated stereotactic body treatment of lung lesions with Tomotherapy.

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- Dunlap et al. International Journal Radiation Oncology Biology Physics. 2010 76(3)796-801.
Hodge et al. Acta Oncologica 2006;45:890-896
Holmes et al. Medical Dosimetry 2008.33(2)135-148.
Kanagaki et al. Phys Med Biol.52-243

P1079

THREE YEARS' EXPERIENCE IN LUNG TUMOURS STEREOTACTIC RADIOTHERAPY/ RADIOSURGERY

Davide Di Gennaro¹ Giuseppe Bove² Bruno Curcio¹ Girolamo Spagnoletti² Losco Arturo¹ Scimone Giuseppe¹ Lazlo Diana¹ Verile Valentina² Plotino Giovanni² Pilotti Immacolata¹
(1) SALERNO UNIVERSITY HOSPITAL, Salerno, Italy (2) FOGGIA UNIVERSITY HOSPITAL, Foggia, Italy

A joint program for Encephalic and Body radiotherapy / radiosurgery treatments started in 2008, in Foggia and Salerno University Hospitals, that irradiate more than 1400 patients/year, with 4 Elekta Linacs.

Radiosurgery is largely approved in the clinical course of oncologic patients, when affected by primitive lung tumours or few (1-3) lung metastases from other sites. Patients had Karnofsky Status > 80, primitive/metastatic lung tumors, diameter < 4 cm and were unsuitable for surgery. Since the beginning, patients were treated with 3-6 fractions (Stereotactic Body Radiotherapy - SBRT), while in 2008 we decided to use also a single fraction (Radiosurgery - SBRS) like other centers in Germany and Japan, for lesions that were 2 cm afar from mediastinum. We used a BRAINLAB Micro-multileaf; Radiological Physics Center (RPC) at the MD Anderson Cancer Center, Houston, Texas, made the external monitoring of photon beams dosimetry. Results we have treated 23

patients with a minimum follow-up of 6 months (range: 6-27 months; mean: 15 months). The CTVs varied from 1.37 to 27.48 cm. The CTV - PTV margin expansion was 5-8 mm in antero-posterior and latero-lateral direction and 10-13 mm in cranio-caudal direction. Patients were irradiated with 9-19 coplanar or 8-12 non-coplanar fields. Radiation dose was prescribed to the peripheral isodose of 80%. Five metastatic lesions received 36-37.5 Gy in 3 fractions, 2 primitive tumours received 50 Gy in 5 fractions, 2 lesions in the immediate proximity of mediastinal vessels (<3 cm) received 42 Gy in 6 fractions. Otherwise, 10 patients were treated with a single fraction of 26 Gy in 8 cases and of 27 Gy and 18 Gy in the remaining 2 cases. Moreover SBRT or SBRS was used as boost technique to treat 4 patients, 3 T3N1 cancer and 1 sarcoma metastasis, diameter 5 cm. Twenty-two lesions were controlled, until now (96% local control). The only local progression was observed on the first patient, treated for a metastasis, but with the primary tumour still present. There were no acute or late clinical complications. In 3 patients CT examination revealed radiological signs of radiotherapy pneumonitis after 6-8 months. Two patients went to surgery and the histological examination revealed no tumour in the >100 Gy (BED10) treated volume. In our first experiences Stereotactic Body Radiotherapy/ Radiosurgery is a safe and practical option to treat lung tumours.

P1080

STEREOTACTIC BODY RADIOTHERAPY FOR OLIGOMETASTATIC LUNG TUMORS

Giancarlo Beltramo¹ Achille Bergantin¹ Anna Martinotti¹ Paolo Bonfanti¹, ² Livia Bianchi¹

(1) Centro Diagnostico Italiano, Milan, Italy (2) Specialization School in Medical Physics, Milan, Italy

Introduction: the standard treatment for metastatic cancer is systemic therapy. The curative treatment of oligometastases with radiotherapy remains an area of active investigation. In a subset of patients with limited lung metastases we hypothesise that Cyberknife Stereotactic Body Radiotherapy can improve treatments outcome.

Materials and Methods: between February 2007 to May 2010, 27 patients, 10 female, 17 male with a median age of 68 years (range 57 - 84 years) with 29 pathologically proven pulmonary metastases not amenable to surgery, (colorectal 10, lung 9, Kidney 7, , pancreas 1, Breast 1, Parathyd 1) with a median volume of 42.38 cc (range 3.55 -240.06 cc) were referred to our Radiotherapy Department for Cyberknife stereotactic radiotherapy treatment. In all patients 1-3 gold fiducials were implanted inside and or in the vicinity of tumor for targetting purpose except for patients who were eligible for fiducialless x sight option. The planning treatment volume (PTV) included the GTV plus 5 mm isotropic margin, Cyberknife stereotactic radiosurgery protocol provide a prescribed PTV dose of 48-54 Gy with 12-18 Gy/fraction for centrally located lesions, and 23 -27 Gy in single fraction for peripheral lesions. Patients were followed with CT and PET scan to detect disease recurrence Local recurrence was defined as an increase in size of tumor following treatment as most tumors shrunk following radiation

Results: Median follow-up was 13 months (range, 4-43 months). Kaplan-Meier local control at 1 and 2 years was 89.1% and 89.1% respectively. We observed an overall survival (OS) at 2 Years of 95.5% . Disease free Survival (DFS) at 1 and 2 years was 85.8% and 57.2% respectively

Conclusions: Cyberknife stereotactic radiotherapy, in patients with pulmonary metastases has been shown to be a promising treatment with high local control and low toxicity profile, but a longer follow up and a higher number of patients are mandatory to evaluate effectiveness.

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EASIBILITY AND EARLY OUTCOME OF ROBOTIC STEREOTACTIC REIRRADIATION IN RELAPSED NON-SMALL CELL LUNG CANCER

Pierre-yves Bondiau¹ Jerome Doyen¹ Michel Poudenx¹ Gaelle Angelier¹ Nicola Venissac²

(1) CAL, Nice, France (2) CHU pasteur, Nice, France

Stereotactic body radiotherapy is now considered as a therapeutic option in the management of non medically operable stage I non-small cell lung cancer and lung metastases when tumour growth is slow and with the control of primary tumour. In order to investigate feasibility of lung reirradiation in primary and secondary adenocarcinomas and epitheliomas treated by robotic stereotactic body radiotherapy, we conducted a retrospective study from December 2006 until April 2010. Inclusion criteria where: Stage I NSCLC (T1 or T2 N0 M0), histology proven tumor, maximal diameter: 6 cm, exclusion if pulmonary atelectasis, infection or pneumonitis.

Patients and Methods: 16 patients with one or two lung lesions were treated with cyberknife[®] (CK). Toxicity was evaluated according to Common Toxicities Criteria (CTC) version 3.0. Other endpoints were local free relapse, progression free survival (PFS), overall survival (OS) evaluated by Kaplan Meier analysis.

Results: Sixteen patients were identified in our database and presented initially with stage I (3), IIA (4), IIB (8) and IV (1) disease. Median follow-up was 12 months, the 2 year OS rate was 39.2%, the 2 year PFS rate was 32.3% and the 2 year local control rate was 69.3%. No patients experienced grade 3, 4 or 5 toxicities. Most frequent toxicities were asthenia (4), radiological asymptomatic alveolitis (9), oesophagitis (4) and chest pain (5). Fifty-four % of complications were grade 2 and worsening of quality of life (persistent toxicity) occurred in 4 patients. One rib fracture appeared next to the relapsed site but was manageable with analgesic.

Conclusions: This study confirmed feasibility of SBRT in limited relapsed NSCLC with a good local control rate. Imaged guided intra-fractions SBRT toxicities in this setting were mild and easily manageable with no high grade toxicities.

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FEASIBILITY OF 3-D CARDIAC CONTOURING AND TREATMENT PLANNING FOR CARDIAC ABLATION OF ATRIAL FIBRILLATION (CYBERHEART)

Takushi Dokiya¹ Kazuo Matsumoto¹ Hiroshi Sekine¹ Yu Kumazaki¹ Paul Zei² Patrick Maguire³ Edward Gardner³ Alice Jack³ Thomas Fogarty³

(1) Saitama Medical University, Saitama, Japan (2) Stanford University School of Medicine, Stanford, California (3) CyberHeart, Portola Valley, USA

Objectives: Minimally invasive cardiac ablation using robotic radiosurgery potentially represents a new alternative to standard catheter-based Methods for the treatment of atrial fibrillation. The purpose of the study was to determine the feasibility of creating clinically acceptable treatment plans utilizing CyberHeart 3-D contouring software (CardioPlan) developed to contour complex (shape and intrinsic motion) cardiac targets and MultiPlan treatment planning.

Methods: Cardiac treatment plans were created from cardiac gated CT imaging studies from

patients with atrial fibrillation (N=20+). Target lesions and critical structures were contoured with CardioPlan software (CyberHeart Inc., Portola Valley, CA) based on the input of electrophysiologists. The contoured lesion set represented an anatomic target lesion routinely ablated with radiofrequency catheters for the treatment of atrial fibrillation, that isolates pulmonary veins from the antrum of the left atrium. There is flexibility to adjust the ablation volumes based on differential patient anatomy. MultiPlan (Accuray, Sunnyvale, CA) treatment planning software was used to demonstrate these contours and create treatment plans. Dosimetry requirements were derived from preclinical animal data and dosimetry guidelines for critical structures followed standard human clinical guidelines.

Results: It was demonstrated that acceptable treatment plans can be created with the aid of 3-D cardiac contouring software (CyberHeart) and MultiPlan treatment planning software. Doses of 25-30 Gy conformally delivered can be planned with consideration of other mediastinal organs at risk such as the esophagus, bronchi and coronary arteries. Respiratory motion is tracked by Synchrony software (Accuray Inc.). There is compensation for the cardiac motion of the target.

Conclusion: After review of cardiac-gated CT images, and considering deformation and differential motion of the cardiac targets, appropriate treatment plans can be constructed. Knowledge of the complicated cardiac ablation volumes and their relationship to organs at risk, is critical. It is therefore feasible to create safe and deliverable cardiac treatment plans to treat atrial fibrillation with robotic radiosurgery. This represents a new and less invasive approach to treating this disabling cardiac arrhythmia.

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STEREOTACTIC EXTERNAL BEAM RADIOTHERAPY VERSUS BRACHYTHERAPY FOR CERVICAL CANCER: RADIOBIOLOGICALS ASPECTS

Valentina Pinzi¹ Federica Cattani⁴ Roberta Lazzari³ Roberto Orecchia³ Valeria Landoni²

(1) Dept. Radiotherapy Regina Elena National Cancer Institute IFO, Rome, Italy (2) Dept Physics Regina Elena National Cancer Institute IFO, Rome, Italy (3) Dept. Radiotherapy, IEO, Milan, Italy (4) Dept Physics, IEO, Milan, Italy

Purpose: The standard of practice for the radiotherapeutic management of locally advanced cervical cancer is the whole pelvis irradiation followed by brachytherapy (Intracavitary Brachytherapy, ICBRT). When brachytherapy cannot be administered for technical or clinical reasons, may external beam stereotactic irradiation be a valid substitute? In this work radiobiological and dosimetric differences between these two schedules of treatment were analyzed.

Methods and materials: 15 patients were treated with the standard 3DCRT technique (four fields) to give 45-50.4 Gy plus a boost dose of 12-30 Gy administered with ICBRT; High Dose Rate (HDR) modality for adjuvant treatment and Pulsed Dose Rate (PDR) modality for adjuvant and exclusive treatments. For each patient a treatment with IMRT was performed to mimic the intracavity therapy and the two different treatment schedules were compared. Target volumes were generated with identical margins for whole pelvis treatment and different margins for boost treatment. Radiotherapy plans were analyzed in terms of dose conformity index (CI) and conformation number (CN), Tumor Control Probability (TCP) and Normal Tissue Complications Probability (NTCP).

Results: The median planning target volume (PTV) for whole pelvis was 1291 cm³ (range 1051-1762 cm³). The median PTV for ICBRT was 37.4 cm³ (range 12.0 - 87.6 cm³), the median PTV for

IMRT boost was 94.5 cm³ (range 36.1 - 244.7 cm³).

The median CI for whole pelvis was 0.99 (range 0.91-1) for 3DCRT technique and 0.96 (range 0.93 - 0.99) for IMRT. The median CI was 0.73 (range 0.35 - 0.91) for ICBRT boost and 0.97 (range 0.95 - 0.99) for IMRT boost.

The median CN for whole pelvis was 0.47 (range 0.39 - 0.55) for 3DCRT technique and 0.85 (range 0.80 - 0.88) for IMRT. The median CN was 0.24 (range 0.03 - 0.55) for ICBRT boost and 0.78 (range 0.62 - 0.99) for IMRT boost. Mean TCP value calculated on boost volume was 80 % for 3DCRT plus ICBRT and 99% for IMRT. Mean NTCP values were 28% and 5% for rectum; 1.5% and 0.1% for bladder and 8.9% and 6.1% for bowel for the two techniques respectively.

Conclusions: Especially when in presence of large cervical tumors HDR brachytherapy is not able to provide adequate target coverage unless a very high dose is administered to organ at risks. In this study the possibility to irradiate cervical cancer with IMRT has been radiobiologically and dosimetrically demonstrated, thus giving a chance to manage these patients also in those departments where brachytherapy procedures are not achievable.

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STEREOTACTIC BODY RADIOTHERAPY FOR OLIGOMETASTATIC ELDERLY PATIENTS AGED MORE THAN 75 YEARS

Stefano Masciullo¹ Franco Casamassima¹ Ivano Bonucci¹ Claudia Menichelli¹ Laura Masi¹ Rafaela Doro¹

(1) U.O. Radiobiologia Clinica - University of Florence - Casa di Cura S. Chiara, Florence, Italy

Purpose: To evaluate outcomes of stereotactic body radiotherapy (SBRT) in elderly oligometastatic patients (< 5 lesions) aged more than 75 years.

Materials and Methods: Sixty-eight elderly oligometastatic patients (median age 78 years, range 75-86) underwent SBRT. Total number of treated lesions was 105. Forty patients had single metastasis, twenty had two metastases, others ≤ 4 mts. In all cases metastases were confined to a single organ (35 lung, 16 liver, 9 lymph nodes, 6 bone, 2 adrenal glands). Primary tumor was NSCLC in 25 Pts, colorectal in 18, prostate in 6, other in 19. Patients with uncontrolled primary tumor were excluded. Median Karnofsky PS was 100 (70-100). All patients were treated with curative intent (all detectable lesions treated with SBRT) and 4 underwent second course of SBRT for new metastases. Twelve received prior/following chemotherapy within six months of SBRT. The treated lesions were located in lung (n=56), liver (n=29), lymph nodes (n=10), bone (n=8), adrenal gland (n=2). PTV ranged from 1.7 to 242 cc (median 26.2). For lung metastases median PTV was 15.6 cc (1.8-90), for liver metastases median PTV was 29 cc (5-242). For adrenal and the majority of pulmonary and hepatic lesions, GTV was delineated on two CT scans acquired in expiration and inspiration, in order to obtain an ITV. For these Pts, spirometer (Elekta ABC) was used for breath monitoring during image acquisition and treatment. Most used prescription dose schemes were 26 Gy x 1 and 10-12 Gy x 3 for lung metastases, 10-12.5 Gy x 3 for hepatic metastases, 10 Gy x 3 for others. A Cone-Beam CT was acquired before the treatment for setup corrections and target localization. A 6-MV Elekta Synergy equipped with dynamic mMLC was employed.

Results: With median follow-up of 12 months (2.3-84), 46 Pts are alive (28 with controlled disease,

12 without evident disease). Kaplan Meier 1- and 2-years overall-survival was 72% and 47%. There were 7 local failure in 6 patients, 5 lesions were salvaged by a second-course SBRT. Kaplan Meier 1- and 2-years local control was 92% and 79% (re-treatments not considered). 1- and 2-years distant progression-free-survival was 63% and 45%. No acute or late toxicity grade >2 was observed.

Conclusions: In our series OS rates were comparable to those of other published studies with lower median age. For elderly oligometastatic patients with good performance status and without severe co-morbidities the SBRT could be offered as non invasive, well tolerated and locally effective therapeutic option, without excluding a possible survival improvement.

P1085

STEREOTACTIC BODY IRRADIATION WITH 3D AND RAPID ARC FOR ABDOMINAL LYMPH-NODE METASTASES: FEASIBILITY AND PRELIMINARY CLINICAL RESULTS.

Angelo Tozzi¹ Simona Castiglioni¹ Filippo Alongi¹ Paola Lattuada¹ Piera Navarria¹ Francesca Lobefalo¹ Carmela Galdieri¹ Sara Pentimalli¹ Pietro Mancosu¹ Elena Clerici¹ Giacomo Reggiori¹ Marta Scorsetti¹

(1) Istituto Clinico Humanitas, Milano (Rozzano), Italy

Objective: Stereotactic body radiation therapy (SBRT) has proved its efficacy in several patient populations with metastatic limited tumors. We have evaluated the clinical effectiveness of SBRT for patients with solitary or non-solitary oligo-metastases from different tumors to abdominal lymph-nodes. Medium term local control and acute/late toxicity were considered as main endpoints.

Materials/Methods: Between 01/06 and 06/09, 19 consecutive patients with unresectable nodal metastases in the abdominal retroperitoneal region were treated with SBRT. Eleven patients had a solitary nodal metastasis, 8 had a dominant nodal lesion as part of oligo-metastatic disease, defined as up to five metastases. Dose prescription was 45 Gy to Clinical Target Volume (CTV) in 6 fractions and Plan Target Volume (PTV) was covered at least by 80% of the prescribed dose. First 12 patients were treated with 3D-conformal technique (3DC), the 7 following by volumetric modulated arc therapy using RapidArc technique. For organs at risk the following objectives were used: maximum dose to spinal cord <18Gy; V15Gy<35% (volume receiving more than 15Gy should be limited to 35%) for both kidneys, V36Gy<1% for duodenum, V36Gy<3% for stomach and small bowel, V15Gy< [total liver volume - 700 cm³].

Results: Median follow-up was 1 year. In 6 cases treated with 3D-CRT prescription was downscaled by 10%-20% in 6 cases in order to keep within dose/volume constraints. Both acute and chronic toxicities were minimal. A complete response was found in 2 patients. A partial response was achieved within 3 months in 9 patients (overall response rate 58%). The actuarial rate of freedom from local progression was 77±14% at 24 months. The 12 and 24 months progression free survival rates were 30±13% and 20±12.0%. The number of metastases (solitary vs non solitary oligo-metastases) was the only variable related to progression free survival (p<0.01). Two patients had local progression, but associated to concomitant systematic disease.

Conclusions: SBRT for metastatic abdominal lymph-nodes could be considered feasible with good clinical Results in terms of medium term local control and toxicity rates. Even if most patients eventually show progressive disease at other sites, local control achieved by SBRT may be potentially significant for preserving quality of life and delaying further chemotherapy.

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CYBERKNIFE HYPOFRACTIONATED RADIOTHERAPY TREATMENT FOR PATIENTS WITH ISOLATED SINGLE LYMPH NODE RECURRENCE FROM PROSTATE CANCER

Giancarlo Beltramo¹ Barbara Jerezek-fossa³ Andrea Vavassori³ Achille Bergantin¹ Federica Locatelli¹ Anna Martinotti¹ Paolo Bonfanti^{1, 2} Dario Zerini³ Roberto Orecchia³ Livia Bianchi¹

(1) Centro Diagnostico Italiano, Milan, Italy (2) Specialization School in Medical Physics, Milan, Italy (3) European Institute of oncology, Milan, Italy

Purpose: Isolated lymph node recurrence, in patients with prostate cancer, is considered an unfavourable situation and systemic hormonal therapy is indicated as the gold standard treatment. Otherwise recent reports on resection of solitary prostate cancer metastasis show a durable increase disease control. Our aim was to evaluate the outcome of Cyberknife hypofractionated radiotherapy (SRT) treatment for patients with isolated lymph node recurrence from prostate cancer.

Methods and materials: Between May 2007 and June 2010, 27 patients with a median age of 68 years (range 56 - 83) with isolated lymph node recurrence with a median volume of 11.47 cc (range 1.10 - 39.00 cc) were treated with Cyberknife stereotactic radiosurgery as primary therapy at our institution. In order to exclude other sites of disease a total body and a positron emission tomography/computer tomography [11C]choline PET/CT).was performed in all patients. No biopsy confirmation was required If feasible a radio-opaque fiducial marker was introduced in the target lesion. One week after fiducial implantation . Axial CT images and MRI T1-T2 sequences were acquired and fused to accurately differentiate the lymph node and the organ at risk. The planning treatment volume (PTV) included the GTV expanded by 2 mm in all other directions The treatment regimen consists of a total dose of 30-36 Gy delivered at 10-12 Gy per fraction, with > 95% of the PTV encompassed within the prescription isodose volume. In 15 lesions Cyberknife SRT was performed as a re-irradiation (the recurrent lesion was situated in the previously irradiated volume) .Toxicity analyses was performed using the Radiation Therapy Oncology Group/European Organization for Research and Treatment of Cancer (RTOG-EORTC) acute and late radiation morbidity scoring system.

Results: The Cyberknife treatment was well tolerated and all patients completed planned SRT. . No acute and late > grade 2 toxicity was observed. no in field clinical progression was observed. 5 patients experienced clinical out field progression ,4 showed regional lymph node progression and one developed bone metastases At the time of the analysis all patients are alive.

Conclusions: Cyberknife-based hypofractionated SRT is a feasible approach for isolated single lymph node recurrent prostate cancer offering excellent in field local control and low toxicity profile. Further investigation is warranted in order to identify the patients that benefit most from this treatment modality. The optimal combination with androgen deprivation should also be defined

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IMAGE-GUIDED ROBOTIC RADIOSURGERY TREATMENT AS SALVAGE THERAPY FOR LOCALLY RECURRENT PROSTATE CANCER

Giancarlo Beltramo¹ Andrea Vavassori³ Barbara Jereczek-fossa³ Achille Bergantin¹ Federica Locatelli¹ Anna Martinotti¹ Paolo Bonfanti^{1, 2} Dario Zerini³ Roberto Orecchia³ Livia Bianchi¹

(1) Centro Diagnostico Italiano, Milan, Italy (2) Specialization School in Medical Physics, Milan, Italy (3) European Institute of Oncology, Milan, Italy

Purpose: Despite improvements in external beam irradiation for prostate cancer, a significant number of patients develop locally recurrent disease. Salvage local therapy may well induced a prolonged biochemical remission and, possibly, even cure. We evaluate the feasibility of re-irradiation with Cyberknife for intra-prostatic recurrence after external beam radiotherapy (EBRT).

Material and Methods: Between September 2007 and June 2010, 26 patients diagnosed with biopsy confirmed locally-recurrent prostate cancer after EBRT and with absence of severe chronic late toxicity were referred to our Radiotherapy Department for salvage treatment with CK stereotactic radiosurgery. The EBRT median dose was 78 Gy (range 70-80 Gy). The median age of the patients at the time of CK was 72 years (range 58-82 years). In all patients three gold fiducial seeds were implanted in the prostate gland through an ultrasound-guided trans-perineal pre-loaded needle and one week later a CT scan and a MRI T1-T2 sequence was performed to elaborate treatment plane after placement of a Foley catheter to show the urethra. Multiplan (version 2.0.5, Accuray, USA) was employed. The planning treatment volume (PTV) included the GTV expanded by 5 mm in all directions except posteriorly where 3 mm were added. CK stereotactic radiosurgery protocol provide a prescribed PTV dose of 30 Gy given in 5 daily fractions of 6 Gy, with > 95% of the PTV encompassed within the prescription isodose volume while keeping the maximum doses to urethra and rectum lower than 125% and 75% of the prescribed dose, respectively Failure was defined as the first failure event and could be categorized as biochemical, clinical or both (if time interval < 2 months). Biochemical failure was defined as two PSA increases over pre-CyberKnife SRT PSA value.

Results: All patients completed planned CyberKnife SRT with a total irradiation time of 5 days (from Monday to Friday). No protocol violation was registered. After a median follow up of 10 months (range 3-33 months) two patients developed severe urinary acute toxicity (grade 3) and 2 developed grade 3 urinary late toxicity. No patients experienced grade 3 acute or late gastro intestinal toxicity. We registered 6 biochemical failure with 2 patients with clinical progression (lymph node and bone metastases).

Conclusions: CyberKnife-based SRT is a feasible approach for locally recurrent prostate cancer, offering excellent in-field tumor control and low toxicity profile. Further experience and longer follow-up are needed to evaluate the role of CK in the treatment of local recurrences and to identify patients most likely to benefit from it.

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ROLE OF TC-RM IN THE DEFINITION OF PROSTATE CANCER VOLUMES FOR THE RADIOTHERAPY PLANNING

Giancarlo Beltramo¹ Achille Bergantin¹ Federica Locatelli¹ Livia Corinna Bianchi¹ Anna Stefania Martinotti¹ Paolo Bonfanti^{1, 2}

(1) Centro Diagnostico Italiano, Milan, Italy (2) Specialization School of Medical Physics, Milan, Italy

Purpose: Following advances in conformal radiotherapy, a key problem now facing radiation oncologists, is target and organ at risk definition. This study was performed to evaluate the suitability of MR (T1w and T2w sequences) with CT to provide improved definition of pelvic treatment volumes for Cyberknife prostate radiotherapy.

Material: Twelve patients with low and selected intermediate risk prostate cancer were treated with Cyberknife stereotactic radiosurgery at our institution. Anatomic countouring of the prostate and organ at risk (rectum, bladder, urethra, penile bulb, femoral heads) were done with image fusion of CT and MR T1w and T2w sequences. Four treatments planning were generated for each patients: a plan based on CT-delineated GTV, one based on T1w-TC-delineated GTV (case 2), one based on T2w -TC-delineated GTV (case 3) and one based on all image- delineated GTV (case 4). Dose was prescribed to the planning target volume (PTV) that consisted of a volumetric expansion the prostate 5 mm, reduced to 3 mm in the posterior direction. The treatment regimen consists of a total dose of 38 Gy delivered at 9.5 Gy per fraction, with > 95% of the PTV encompassed within the prescription isodose volume with bladder and urethra maximum dose <120% of prescribed dose, rectum maximum dose < 100% prescribed dose and rectum V85< 2cm3. We analyzed bladder and urethra D10 and urethra D50. Other organ at risk were only used for dose evaluation. Wilcoxon signed rank test was used for analysis of the different target volumes and doses distributions to OAR.

Results: For each patients targets were compared with CT-delineated GTV (reference imaging). GTV volumes were smaller when MR was used for delineation (case 2: -15.6%±10; case 3: -20.4%±21; case 4: -8.86%±7.9, for all p=0,005). We decided to compare treatment plans prepared using all MR sequences with CT because T1w and T2w information are complementary and so both useful. We could not always respect rectum dose limit in particular in case 1. Mean of rectum maximum doses was significantly higher (p=0,007) in case 1 than in case 4 (40.79Gy vs 38.19Gy; +7.01% with a maximum of +24%). Mean rectum V85 was 4.17 cm3± 2.3 in case 1 and 2.04 cm3±1.1 in case 4 Bladder and urethra D10 were 2.72% and 2.2% higher in case 1, respectively; urethra D50 was 1.71% higher.

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STEREOTACTIC RADIOTHERAPY FOR PRIMARY HEPATOCELLULAR CARCINOMA AND METASTATIC LIVER CANCER

Yoshiaki Okamoto¹ Keiko Takahara¹

(1) Osaka Police Hospital, Osaka, Japan

Purpose: The aim of this review is to evaluate the linear effect, tolerance and toxicity of stereotactic radiotherapy (SRT) for the patients of primary hepatocellular carcinoma or metastatic liver tumors, who were not eligible for surgery, embolization, chemotherapy, or radiofrequency ablation.

Materials and Methods: We reviewed the records of 12 patients treated by SRT to the liver at our hospital. Of twelve patients, 9 had a primary hepatocellular carcinoma and the others had solitary metastatic liver tumors from pancreas cancer, cholangiocellular carcinoma and gastric cancer, respectively. Of nine patients with hepatocellular carcinoma, 2 were irradiated to the primary lesion, 5 to the portal vein tumor thrombus and the other to the inferior vena cava tumor thrombus. Karnofsky performance status scale were as follows; 100: 2, 90: 4, 80: 5, 70: 1 and Child-Pugh classification were as follows; A: 9, B: 3, C: 0. A total dose of iso-center of Planning target volume ranged from 36 to 60Gy in 4-8 fractions of 5-12Gy each.

Results: Median over all follow-up time was 10 months (range, 2-18 months). Tumor response was observed in 11 of 12 (Complete Response: 3, Partial Response: 8), Local (within a treatment field) control rate was 90% at 6 months after SRT. The overall survival after SRT was 75% at 1-year, with a median survival of 8.8 months. Two patients died of primary disease and one patient of renal failure. Median V20 for liver (the volume of normal liver receiving 20 Gy or more) was 30% (range, 24-38%). Grade 2 deterioration in liver function was observed in two patients (15%) and Grade 2 gastrointestinal acute toxicity in one patient. No Grade 2 or more acute or late toxicity was observed.

Conclusion: Based on his review, SRT for the patients of primary hepatocellular carcinoma or metastatic liver tumors who were not eligible for other treatment modalities should be considered a safe treatment Methods and can promise a certain level of effect.

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STAGE I NON SMALL CELL LUNG CANCER (NSCLC) IN OCTOGENARIANS: CLINICAL OUTCOMES AFTER STEREOTACTIC RADIOTHERAPY USING REAL TIME TUMOUR TRACKING.

Alessandro Testolin¹ Cristina Baiocchi¹ Maria Silvia Favretto¹ Sara Galuppo¹ Gianpaolo Bolzicco¹

(1) «San Bortolo» Hospital, Department of Radiation Oncology, Vicenza, Italy

Purpose/objective: The number of octogenarians who present with a stage I non small lung cancer (NSCLC) is increasing. Patients aged 80 years and older often have significant comorbidity and only selected patients (pts) are surgical candidates. In recent years stereotactic Body Radiation Therapy (SBRT) has emerged as a curative treatment alternative in patients with stage I NSCLC who are medically inoperable. However, the tolerance and outcomes of SBRT in pts aged > 80 years with high comorbidity rates is less well characterized. In this work we evaluated the local tumour

control rate, and treatment related toxicity after SBRT using real-time tumour tracking technique in octogenarians pts with stage I NSCLC.

Methods and materials: 17 octogenarians pts (range 80-85) with stage I lung tumour were treated with SBRT. All pts were considered medically inoperable. The median Charlson score was 3(range 1-7). Of the 17 pts 9 had T1 tumour and 8 T2a. The median tumour diameter was 3 cm (range 1.2-4.1). All pts were treated using a CyberKnife System with Synchrony® Respiratory Tracking System (SRTS) device. Five pts were treated with a single fraction (f) of 26 Gy and 10 with 3 f of 17 Gy. A risk adaptive schedule of 32-44 Gy in 3-4 f was used for central tumours (2 pts). The dose was prescribed to the isodose line of 80%. Median FU was 12 months(range 3-49).

Results: Of the 17 pts 3 showed evidence of local recurrence (at 7, 12, 17 months). No local recurrence occurred in pts treated with biologically effective dose (BED) > 100Gy10. The actuarial local progression free probability(LPFP) at 2 years was 59%. The LPFS at 1 and 2 years for pts treated with BED < 100 Gy10 vs > 100 Gy10 was respectively 71% and 51% vs 100% and 100%. Overall and disease free survival at 1 and 2 years were 100-81% and 85-58%, respectively. Treatment was well tolerated. Early side effects were: fatigue in 3 pts (17%) and local chest wall pain in 1 pts (6%). No clinically symptomatic pneumonitis was observed. One pts (6%) developed rib fracture. Subjective symptoms of increased dyspnoea during FU occurred in 1 pts. Asymptomatic radiation induced lung fibrosis was detected in 6 pts (35%).

Conclusion: SBRT with SRTS in octogenarians appears to be a safe and minimally invasive modality for treating pts with medically inoperable stage I NSCLC. Despite the significant presence of medical comorbidity (Charlson score > 4 in 34.5% of pts) an aggressive treatment, with doses of > 100 Gy BED, can be justified. Longer FU will be required to fully establish toxicity as well as probability

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PLANNING 4D-CT FOLLOWED BY IG-IMRT TO TREAT SOLITARY LUNG METASTASIS FROM WILMS TUMOR IN A CHILD: A CASE AT THE RADIOTHERAPY UNIT OF MODENA

Paola Barbieri¹ Filippo Berton¹ Alessio Bruni¹ Elisa Cenacchi² Giuseppina De Marco¹ Patrizia Giacobazzi¹ Gabriele Guidi² Biancaluisa Lanfranchi¹ Manuela Parmiggiani¹ Giorgio Tolento¹ Enrico Turco¹

(1) Radiotherapy of Modena, Modena, Italy (2) Medical Physics of Modena, Modena, Italy

Purpose: Recently we observed a technical improvement in radiotherapy such as the introduction of IG-IMRT and now we are able to deliver very high doses to targets with better accuracy, saving surrounding normal tissues. These improvements give us an important therapeutic choice for several pediatric neoplasms such as Wilms tumor. We present a pediatric case with solitary lung metastasis from kidney Wilms tumor. He underwent surgery and adjuvant chemotherapy followed by stereotactic radiotherapy to the lung lesion using IG-IMRT technique with Tomotherapy instead of a surgery approach.

Materials and Methods: Two-years old patient with right kidney Wilms tumor and synchronous single lung metastasis submitted to right nephroureterectomy on February 2010 followed by chemotherapy (AIEOP Stage IV protocol). The patient was proposed to us for radiotherapy on the single lung lesion. We used 4D-planning CT with Vision RT system, body thermoplastic mask with abdominal compression, both arms hanged up over the head; all the planning CT was obtained

using a deep sedation. All the images obtained were divided in ten different breathing phases and retrieved on TPS; ROIs (GTV4D, CTV4D and PTV4D) and OARs in each scan of the 4D-CT were contoured. After having identified «Sum» Volumes we planned the Radiotherapy treatment using IG-IMRT technique with Tomotherapy. The total dose delivered to target was 14 Gy in two fractions (7 Gy/day).

Results: The GTV4D obtained resulted 0,20 mL while PTV4D 1.39 mL. The 95% of GTV4D and of PTV4D received 100% of prescribed dose; the mean dose to PTV4D was 14.59 Gy and the median dose 14.66 Gy. About the OARs right lung received a mean dose of 0,91 Gy, left lung of 0,19 Gy, heart of 0,04 Gy, the spinal cord had a Dmax of 2,92 Gy. The treatment was well tolerated, no acute side effect was evaluated. One month after radiotherapy the restaging CT scan showed no evidence of disease. Six month's restaging total body CT scan showed persistent complete response.

Conclusions: The use of the newest stereotactic radiotherapy techniques allows us to obtain a very high precision in target delineation and identification before treatment, giving us the chance to achieve higher biological doses and better clinical outcome. The planning using 4D-CT allows us to obtain a better definition of treatment volumes saving surrounding normal tissues with less acute and late side

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STEREOTACTIC RADIOTHERAPY AND PELVIC RECURRENCE IN PREVIOUSLY IRRADIATED AREA

Sylvain Dewas¹ Jean Emmanuel Bibault¹ Xavier Mirabel¹ Philippe Nickers¹ Bernard Castelain¹ Thomas Lacommerie¹ Hajer Jaraya¹ Eric Lartigau¹

(1) Centre Oscar Lambret, Lille, France

Objectives: The first-line treatment of a pelvic recurrence in a previously irradiated area is surgery. Unfortunately, few patients are deemed operable, often due to the location of the recurrence, usually too close to the iliac vessels, or the associated surgical morbidity. The objective of this study is to test the viability of robotic image guided stereotactic body radiotherapy (SBRT) as an alternative treatment in inoperable cases.

Materials and Methods: Sixteen patients previously treated with radiotherapy were retreated with SBRT (CyberKnife®) for lateral pelvic lesions. Recurrences of primary rectal cancer (4 patients), anal canal (6), uterine cervix cancer (4), endometrial cancer (1), and bladder carcinoma (1) were treated. The median dose of the previous treatment was 51.9 Gy (range, 20 to 96 Gy). A total dose of 36 Gy in six fractions was delivered with the CyberKnife over three weeks. The responses were evaluated according to RECIST criteria.

Results: Median follow-up was 10.6 months (1.9 to 20.5 months). The actuarial one- and two-year survival rates were, respectively, 71% (95% CI: 57 to 85%) and 33% (95% CI: 5 to 61%). The actuarial local control rate was 70% (95% IC: 56 to 84%) at both one and two years. Median disease-free survival was 8.3 months after CyberKnife treatment. Acute tolerance was good. No grade 3 or 4 acute or late toxicity was observed.

Conclusion: Robotic stereotactic radiotherapy can offer a short and well-tolerated treatment for lateral pelvic recurrences in previously irradiated areas in nonoperable patients otherwise not treatable. Efficacy and toxicity need to be evaluated over the long term, but initial Results are encouraging.

P1094

STEREOTACTIC RADIOTHERAPY AND ELDERLY PATIENTS

Sylvain Dewas¹ Claire Vautravers-dewas¹ Véronique Servent¹ Xavier Mirabel¹ Bernard Prevost¹ Bernard Coche¹ Bernard Castelain¹ Philippe Nickers¹ Eric Lartigau¹

(1) Centre Oscar Lambret, Lille, France

Objective: The relatively recent introduction of CyberKnife® in the field of radiotherapy has prompted the question of accessibility and usefulness of this technique for seniors.

Patients and Methods: From June 2007, we treated 345 patients of all ages with CyberKnife as part of a single-center study. The study compared potential differences between those over 70 and younger patients with regard to feasibility, relevance of technical features, and other potential impact factors. The impact of age was compared with Student test, and univariate analysis was performed using Chi-2 and Fisher exact tests.

Results: Median age was 61 years (range, 8-86 years). Ninety-eight patients were over 70 and 17 were older than 80. The treatment could not be completed with 2% (2/98) patients over 70 versus 3.6% (9/247) among the younger (no significance). The two patients with incomplete treatments were over 80. Physiologic or psychologic problems in maintaining position for a long time, such as coughing, dyspnea, pain, or anxiety were not more frequent among those over 70. The same was true with those over 80. Mean fraction times were 66.8 and 76.2 minutes in patients under and over 70 years of age, respectively ($p = 0.019$). Analyses in sub-groups based on tumor location or the technique used did not demonstrate any significant difference.

Conclusion: Patients over 70 do not present any more difficulties in maintaining treatment position, nor are their fractions longer than younger patients. Age does not influence feasibility of irradiation. Access to innovative therapies should not be restricted arbitrarily for those over 70. In fact based on our treatment data, CyberKnife treatment appears preferable for this age group and above.

P1095

TREATMENT OF PROSTATE CANCER WITH CYBERKNIFE BODY RADIOSURGERY: THE VALUE OF COMBINED T2-W, DIFFUSION AND DCE IMAGES FOR LOCALIZATION AND STAGING.

Effie Petinelli¹ Nikos Papadakis¹ Andreas Papadopoulos¹ Kosmas Verigos¹ Christos Antypas¹ Nikolaos Salvaras¹

(1) IATROPOLIS- CYBERKNIFE DEPT., Athens, Greece

Objectives: The role of Magnetic Resonance Imaging (MRI) in diagnosis and staging of prostate carcinoma is rapidly increasing. The current study evaluates the combination use of high resolution anatomical T2-weighted (T2W) imaging and advanced haemodynamic MRI techniques, namely dynamic contrast-enhanced MRI (DCE-MRI) and diffusion-weighted imaging (DWI) which, further increase the sensitivity and specificity for prostate cancer (PC) detection [1]. In this regard, the improvements in imaging have in turn allowed the optimal treatment for each patient with PC leading to accurate TNM staging and treatment strategy. Cyberknife (CK) body radiosurgery as monotherapy for low- to intermediate- stage PC enables excellent dose conformation to the target,

whilst minimizes dose to surrounding normal tissues.

Materials and methods: From July 2009 to October 2010, a total of 33 male patients, aged 50 to 80 years, with clinically low- to intermediate- stage PC were evaluated by MRI prior to treatment with CK body radiosurgery. MRI was performed in a Siemens Tim Trio 3Tesla clinical scanner with phased array body coil. The entire prostate was covered in 3.5mm-thick contiguous axial slices with identical position among the three MRI modalities [1]. DWI used a fat suppressed DW-EPI sequence with 2 b-values (0 and 800s/mm²). For DCE, dynamic 3D gradient-echo images with a temporal resolution of 10s were acquired after a gadolinium bolus injection. Permeability (Ktrans) maps were calculated offline. The findings using the combination T2W, DWI and DCE-MRI, were compared with the histopathological and PSA parameters.

Results: Localised PC was detected in 26 patients showing no disease extension through the prostate capsule using T2W, DWI and DCE-MRI. The remaining 7 patients were re-staged and treatment management was re-assessed as CK was not the appropriate treatment.

Conclusion: CK necessitates accurate PC localization. The challenge of ever more accurately delivering a radiation dose to the prostate, and a higher (boost) dose to dominant intra-prostatic lesion(s), precipitated the need for improved imaging modalities. The combined approach of T2W, DWI and DCE-MRI appears to hold promise as a non- invasive imaging modality in the detection and subsequent exact localization of PC, and in turn define the stage, as well as influence the treatment strategy, which may mean the difference between treatment success and failure.

References: [1] Barentsz JO, Heijmink SWTPJ, Hulsbergen-van der Kaa C, Hoeks C and Futterer JJ: Magnetic resonance imaging of prostate cancer. IDKD 2010 Davos, 125-141, 2010.

P1096

INTERIM RESULTS: OF STEREOTACTIC BODY RADIOTHERAPY FOR LOCALIZED PROSTATE CANCER

Hun-Jung Kim¹ Woo-Chul Kim¹ Jung-Hoon Phak¹

(1) Inha University Hospital, Inha University School of Medicine, Incheon, Korea

Purpose: Recent clinical data suggest that large radiation fraction sizes are radiobiologically favorable in prostate cancer radiotherapy. Technological advanced Cyberknife have allowed precise targeting and delivery of radiation to the moving prostate while sparing normal tissues. This is suitable device for performing hypofractionated stereotactic body radiotherapy. We report our early experience using this technique to patients with localized prostate cancer.

Materials and Methods: This study was based on a retrospective analysis of the 40 patients treated with CyberKnife radiotherapy for localized prostate cancer. Image-guided SBRT was delivered to all patients using the CyberKnife with motion tracking of internal fiducial seeds. Twenty-four patients identified as low and favorable intermediate risk group received irradiation at a dose of 36.25 Gy in 5 fractions of 7.25 Gy per fraction. Sixteen unfavorable intermediate and high risk group patients received 45 Gy at whole pelvis by three dimensional radiation therapy and received a boost by the CyberKnife at dose of 21 Gy in 3 fractions. The acute and late toxicities were recorded using the Radiation Therapy Oncology Group scale and the CTCAE, version 4.0. Prostate-specific antigen response was monitored.

Results: All patients were able to complete the treatment. The median follow-up for patients was 18.3 months (range 6 - 32 months). All 40 patients finished planned radiation therapy without any

severe complication. There were no biochemical failures. Acute Grade 1 and Grade 2 gastrointestinal (GI) toxicities were observed in 50.0% and 5.0% of the patients, respectively. There were no acute Grade 3 or 4 GI toxicities. Late Grade 3 GI toxicity, rectal bleeding, was noted in 1 patient in high risk group (5.0%) but bleeding was stopped with 3 times laser coagulation. Acute Grade 1 and Grade 2 genitourinary (GU) toxicities were seen in 60.0% and 30.0% of the patients, respectively. There was acute Grade 3 urinary frequency in one patients of high risk group. In all patients, PSA decreased continuously, with a mean of 1.47 ng/ml at 6 months, 1.14 ng/ml at 12-months, 0.60 ng/ml at 24-months, and 0.15 ng/ml at 32-months.

Conclusions: The acute and late toxicity profile and PSA response for hypofractionated stereotactic body radiotherapy with CyberKnife for localized prostate cancer are highly encouraging. Additional follow-up is required to confirm durable biochemical control rates and late toxicity profiles.

P1097

TOXICITY OUTCOME AFTER HYPOFRACTIONATED STEREOTACTIC CYBERKNIFE DELIVERED RADIOTHERAPY FOR EARLY STAGE PROSTATE CANCER.

Giampaolo Bolzicco¹ Maria S. Favretto¹ Gianluca D'amato¹ Enrico Scremin² Carmelo Tambone² Andrea Tasca² Rosabianca Guglielmi¹

(1) Division of Radiation Oncology, San Bortolo Hospital , Vicenza, Italy (2) Division of Urology, San Bortolo Hospital , Vicenza, Italy

Purpose: To evaluate acute and late genitourinary (GU) and gastrointestinal (GI) toxicity after hypofractionated stereotactic CyberKnife delivered radiotherapy.

Methods: s and material: Acute and late toxicity was assessed using the Radiation Oncology Group scale in a total of 60 patients (Pts) treated with stereotactic body radiation therapy (SBRT) for low and intermediate prostate cancer from August 2006 to October 2010. The median patient age was 74 years (range 55-81). At diagnosis the mean PSA value was 8.7. There were 27 Low risk cases and 33 Intermediate risk. The clinical stage was: T1b in 1 patient, T1c in 22 Pts, T2a-b in 20 Pts and T2c in 17. Five patients had a Gleason score from 2+2 to 3+2, 48 Pts had 3+3, 7 Pts had 3+4. Patients received 35 Gy in 5 consecutive fractions at the isodose of 80 %, with mean PTV coverage of 97%.

Results: at a median 22-months (3-50 months) follow-up, acute(GU+GI) toxicity occurred in 35 Pts (58.3%). Acute GU toxicity was found in 26 Pts (43.3%): 19 Pts (31.6%) had Grade 1 and no more than 7 Pts had Grade 2 (11.6%). Acute GI toxicity was found in 26 Pts (43.3%): 14 Pts (23.3%) had Grade 1 and 12 Pts had Grade 2 (20%). Seventeen out of 35 Pts had both toxicities (GU and GI). The most common GU events were frequency and nocturia or dysuria, while GI events were rectal discomfort, rectal bleeding and diarrhoea. The symptoms disappeared generally after 2 weeks. Late toxicities (GU+GI) were found in 5 Pts (8.3%), 4 Pts had GU (6.6%) and 2 Pts had GI (3.3%). Only one patient (1.6%) had Grade 3 urinary toxicity, one Pt (1.6%) experienced late grade 2 gastro-intestinal toxicity (1.6%). As for PSA value, it progressively declined in all patients from a mean 5.0 ng/mL baseline to 1.5 ng/mL at 3 months, 0.60 ng/mL at 12 months and 0.39 ng/mL at 24 months.

Conclusions: hypofractionated stereotactic radiotherapy with CyberKnife seems to be well tolerated, as it resulted in no Grade 3-4 acute toxicity, and only 1 Grade 3 late toxicity. Moreover,

biochemical control is good in this treatment of early prostate cancer, thus encouraging further follow-up.

P1098

DOSIMETRIC COMPARISON BETWEEN 3D AND VMAT PLANS FOR LUNG STEREOTACTIC BODY RADIOTHERAPY

Geoffrey Zhang¹ Lichung Ku² Thomas Dilling¹ Craig Stevens¹ Weiqi Li¹ Vladimir Feygelman¹

(1) Moffitt Cancer Center, Tampa, USA (2) Salem Hospital, Salem, USA

Purpose: Conventionally, three-dimensional (3D) conformal beams are used in lung cancer stereotactic body radiotherapy (SBRT). Recently, volumetric modulated arc therapy (VMAT) is introduced as a new lung SBRT treatment modality. This modality usually delivers treatment in a shorter time, reducing the possibility of target misalignment due to patient motion during each treatment, though dose distributions are quite different from standard 3D therapy. This study quantifies those differences.

Methods: Fifteen lung cancer patients previously treated with 3D or VMAT SBRT were randomly selected. For each patient, 3D, and coplanar and a non-coplanar VMAT plans were generated to meet the same objectives with 5000 cGy to cover 95% PTV. Two dynamic arcs were utilized in each VMAT plan. The couch was set at ± 5 degrees to the straight position for the two non-coplanar arcs. Pinnacle version 9.0 (Philips, Fitchburg WI) was used to generate plans. SmartArc was used for the VMAT planning. The conformity index (CI), which is the ratio of the total volume receiving at least the prescription dose to the target volume receiving at least the prescription dose, the conformity number (CN) which is the ratio of the target coverage to CI and the gradient index (GI) which is the ratio of the volume of 50% of the prescription isodose to the volume of the prescription isodose were compared.

Results: The CI for the 3D, coplanar and non-coplanar VMAT plans ranged from 1.20 to 2.45, 1.07 to 1.89 and 1.07 to 1.79 respectively, with an average and one standard deviation of 1.52 ± 0.33 , 1.29 ± 0.21 and 1.28 ± 0.18 respectively. The CN values were 0.65 ± 0.11 , 0.75 ± 0.10 and 0.76 ± 0.09 respectively. The GI values were 8.41 ± 3.78 , 7.42 ± 2.98 and 7.33 ± 3.00 respectively, indicating sharper dose fall-off in normal tissues in VMAT plans. The mean dose to the PTV was 5348 ± 118 , 5294 ± 125 and 5291 ± 117 cGy respectively. An additional 10 cases are being evaluated currently for inclusion in the final presentation.

Conclusion: Besides the advantage of faster delivery times, VMAT plans demonstrated better conformity to target and sharper dose fall-off in normal tissues than the 3D plans for lung SBRT while maintaining mean target dose.

P1099

INVERSE MARGIN (IM) - A NEW CONCEPT OF ITV IN A 4D DOSIMETRIC APPROACH FOR CA LUNG RADIATION THERAPY

V. Y. W. Wong¹ C. R. Baker² T. V. How³ A.s. Lee¹ T. W. Leung⁴ S. Y. Tung¹

(1) Department of Clinical Oncology, Tuen Mun Hospital, Hong Kong, China (2) Physics Department, Clatterbridge Centre for Oncology, Liverpool, UK (3) Department of Eye and Vision Science, Liverpool University,, Liverpool, UK (4) Department of Clinical Oncology, Queen Mary Hospital,, Hong Kong, China

Objectives: Lung cancer remains the leading cause of cancer-related mortality in Hong Kong and other developed countries. Radiotherapy is an alternative choice of treatment from surgery especially for inoperable cases. To account for the often significant tumor motion, geometrical misses of the target are avoided by employing safety margins which extend substantially beyond the GTV to create the planning target volume. This Results in excessive lung tissue irradiation and restricts the ability of dose escalation. To explicitly account for internal variations in tumor position, size and shape, Internal Target Volume(ITV) was suggested with the delineation of GTV on each phase of the four-dimensional computed tomography(4D-CT) image date set. However, the concept of ITV accounts for the tumor motion only from the geometrical aspect but does not take into consideration the temporal movement of the tumor which generates excessive irradiation on the neighboring healthy tissue. An effective ITV should be governed by the optimal dose coverage, namely dynamic dose coverage of the tumor and minimized irradiation on healthy tissue. It would be therefore more appropriate to define the ITV on the 4D dosimetric basis, accounting for both the geometrical and temporal translation of tumor motion.

Methods: In this study, a DICOM-RT based toolbox was developed to automate 4D dose calculation using deformable image registration(DIR), which explicitly accounts for the relative non-rigid anatomical changes in shape, volume, position and density during normal respiration. The deformable image registration tracks the displacement of each voxel of the 4D-CT image during a respiratory cycle. The sum of the dose along the trajectory of each voxel generates the realistic 4D dose. Based on the Results of 4D dose calculation, a new concept(IM) to inversely define the ITV from GTV via the resultant 4D dose distribution was introduced. The ITV was defined with the volume enclosed by D100 (the dose value encloses 100% target volume). The prescription dose was then re-adjusted such that the complete ITV/PTV was covered by the desired dosage according to the 4D dose distribution

Results and Conclusions: The concept of IM aims to provide a planning volume more representative of the geometrical and temporal excursion of the GTV during respiration, in order to eliminate the excessive volume which was included with the conventional ITV. Retrospective studies were applied on five clinical cases, significant reduction on the ITV volume defined with IM was found as compared with conventional ITV in most of the cases.

P1100

DOSE PRESCRIPTION STRATEGIES FOR LIVER TUMOR SBRT

Anna Simeonova¹ James Tanyi² Jayashree Kalpathy-cramer² Charles Mccracken² Martin Fuss²

(1) University Medical Center Mannheim, Mannheim, Germany (2) Oregon Health & Science University, Portland, Oregon, USA

Objectives: Highly heterogeneous dose prescription and steep dose gradients between target and surrounding normal tissues are hallmarks of SRS dose distributions. In contrast, SBRT, while conceptually derived from SRS, is most often delivered using relatively homogeneous dose distributions. We aimed to assess the advantages and tradeoffs of heterogeneous vs. homogeneous dose distributions in SBRT planning.

Methods: Electronic data from 30 patients with HCC previously treated by SBRT to 50 Gy in 5 fractions formed the basis for this dose planning study. Three different dose prescription strategies were tested: HET: highly heterogeneous dose distribution with plan maximum of 150% of the prescribed dose; HOM: homogeneous dose prescription with plan maximum of 125%; ExHOM: extremely homogeneous planning with plan maximum of 115%. PTV and normal liver (liver minus ITV) DVHs were obtained. For PTVs, we computed the generalised equivalent uniform dose (gEUD(n)), Dmean, and the tumor control probability (TCP). For the normal liver Dmean, gEUD(n) Veff (effective volume), and normal tissue complications probability (NTCP) were compared.

Results: The average PTV Dmean was highest for the HET planning, followed by HOM and ExHOM, respectively (mean 60, 57, and 55 Gy; $p < 0.001$). The gEUD(n) values for HET planning, calculated with a n value of -5, showed the highest mean doses, followed by HOM and ExHOM plans, respectively ($p < 0.001$; 58.1 vs. 56.5 vs. 55 Gy). TCP calculated for the clinically used HET plans with D50 of 45 Gy matched clinical outcomes best, whereas higher D50 values predicted unreasonably low local control rates (87.5% vs. 72.1%, 45.3%, and 24.3% using a D50 of 45, 50, 55, and 60 Gy respectively; $p < 0.001$). HET planning resulted in significant lower normal liver Dmean and gEUD(n) compared to HOM ($p = 0.003$) and ExHOM ($p < 0.001$). For all patients, the calculated NTCP values were $0.00\% \pm 0.00\%$. For Veff a favorable trend was observed for HET planning, reaching statistical significance only in comparison to the ExHOM planning ($p = 0.008$).

Conclusion: SBRT using heterogeneous dose planning (HET) with a target dose maximum of 150% of the prescribed dose was resulted in increased target radiation doses, and was associated with lowered liver radiation exposure. This planning strategy allows for ablative SBRT dose delivery and superior liver sparing when compared with more homogeneous dose planning.

P1101

VALIDATION OF INTERNAL TARGET VOLUME (ITV) CONSISTENCY, USING 4DCT FOR LUNG SBRT TREATMENTS

Bill J. Salter¹ Brian Wang¹ Scott Ruhnau¹ Jacob Hinkle¹ Sarang Joshi¹ Vikren Sarkar¹ Molly Sadinski¹ Ying J. Hitchcock¹ Kristine E. Kokeny¹ Dennis C. Shrieve¹

(1) University of Utah, Salt Lake City, USA

Objectives: SBRT is being increasingly utilized in lung tumor treatment and recent studies have reported promising Results. 4DCT has proven valuable in characterizing patient specific tumor motion for these high dose treatments. Typical approaches use a 4DCT data set to define an ITV (i.e. motion envelope). A critical assumption of such approaches is that the ITV motion envelope remains unchanged during the subsequent 3-5 delivery fractions. Here we test this assumption using 4DCT data scans obtained from lung SBRT tumors treated in our clinic.

Materials/Methods: The treatment planning and image guidance process for our lung SBRT program entails acquisition of a 4DCT data set at simulation (for ITV definition) and prior to each treatment fraction (for image guidance purposes). This affords us the opportunity to compare the individual ITV's from simulation, to ITV's acquired prior to each delivery fraction. A total of 116 simulation and image guidance 4DCT data sets, for 28 SBRT patients, treated 3-5 fractions each, were retrospectively analyzed. One operator segmented all ITV's using a semi-automated approach with a well-known 3D segmentation tool: ITK-SNAP program. The mean ITV across all patients for the simulation image set was 21.1cc (range 0.6-142.7cc). Multiple metrics were used to compare ITV's acquired at simulation, to those acquired prior to each treatment session. Reproducibility and consistency of the semi-automated segmentation Methods was also confirmed.

Results: The volume ratio of treatment ITV to simulation ITV, across all patients, had a mean \pm SD of 1.043 ± 0.214 (range 0.60-1.60; 1 = Ideal). After aligning the centroids of the treatment ITV and simulation ITV, the ratio of the 'intersecting' volume to the combined volume (i.e. Boolean AND \div Boolean OR) was 0.821 ± 0.105 (range 0.596-0.944; 1 = Ideal). This shows that the volume/shape of the ITV does not change significantly for most patients, but that it can change dramatically for some cases. Use of a 3mm symmetric PTV margin lead to dose coverage of 95% of RX, or greater, for 80 of 88 treatment fractions, and less than 95% for 8 of 88 treatment fractions (mean volumetric coverage = $98.1\% \pm 2.9\%$; Range = 86.6% - 100.0%), demonstrating adequate dose coverage for most patients but unacceptable coverage for some cases.

Conclusions: We confirm that for most lung SBRT patients, ITV volume/shape does not vary much between simulation and subsequent treatment fractions. But we also demonstrate that for a limited number of cases it can change significantly, thus emphasizing the value of confirming ITV consistency prior to each treatment fraction.

P1102

AN INTEGRATED IMAGES-GUIDED 4-D TREATMENT VERIFICATION TECHNIQUE FOR STEREOTACTIC BODY RADIATION THERAPY (SBRT) OF LUNG CANCERS

Fang-Fang Yin¹ Jing Hu¹ Christopher Kelsey¹ Zhiheng Wang¹ Jing Cai¹

(1) Duke University Medical Center, Durham, USA

Objective: Minimizing margin required to compensate for target motion is an important goal in lung SBRT procedure. Proper management of target motion in lung cancer treatment requires accurate quantification of target motion, effective technique of motion management, and treatment verification prior to and during the treatment. The purpose of this study is to develop an integrated images-guided 4-D treatment verification strategy and assess its effectiveness of motion management for lung SBRT.

Materials and Methods: 4DCT imaging with a respiratory motion monitoring device was used for quantification of target motion and checked by fluoroscopic imaging. Patient condition, breathing patterns, and target volume/location during the treatment planning were analyzed and used as the basis for selecting motion management techniques either breathe hold or free breathing or respiratory gated. Treatment verification was done by both kV fluoroscopic imaging prior to treatment and MV cine imaging during treatment. The effectiveness of integrated motion management was retrospectively analyzed for ten lung cancer patients treated with 3D conformal SBRT. Both internal target volume (ITV) and planning target volume (ITV+5 mm) were created. During the treatment, cine MV images were acquired for each beam and analyzed with a MATLAB program to calculate average motion range (AMRMV) and max motion range (MMRMV) of the tumor. The means of AMR and MMR (mAMRMV and mMMRMV) over all beams and all fractions were calculated for each patient, and compared to tumor motion range determined from 4DCT (TMR4DCT). Statistical significance was evaluated using Wilcoxon signed rank test with a significance level of 0.05.

Results: A total of 396 beams were imaged with cine MV throughout the treatments for all 10 patients. Tumor diameter ranged from 1.7cm to 3.9cm (mean: 2.7cm). Tumor motion in cranial-caudal direction was tractable in 244 beams (61.6 %). There was a good agreement between mAMRMV and TMR4DCT (mean difference=-0.1±1.4 mm, p-value=0.84). mMMRMV was significantly greater than TMR4DCT (mean difference=1.2±1.6 mm , p-value=0.04).

Conclusion: Optimal motion management should be integrated from simulation to verification during the treatment. Cine MV images can be used to verify tumor motion during SBRT treatment of lung cancers. Tumor motion range measured in 4DCT is equivalent to the average mean motion range, but less than the average max motion range of the tumor.

P1103

INTRA-FRACTIONAL TARGET DISPLACEMENT IN STEREOTACTIC BODY RADIATION THERAPY OF LUNG TUMORS IN A STEREOTACTIC BODY FRAME

Marius Røthe Arnesen¹ Christina Ramberg¹ Odd Terje Brustugun² Einar Waldeland¹

(1) Department of Medical Physics, The Norwegian Radium Hospital, Oslo University Hospital, Oslo, Norway

(2) Department of Clinical Oncology, The Norwegian Radium Hospital, Oslo University Hospital, Oslo, Norway

Background: Annually, approximately 40 patients receive stereotactic body radiation (SBRT) of tumors in the lung at our hospital. The treatment planning is based on a conventional CT scan and information about tumor movement from a four dimensional CT scan (4DCT). The patients are immobilized in a stereotactic body frame (SBF) during treatment, and pre-treatment positioning using a kilovoltage (kV) cone beam CT (CBCT) is performed for all patients. Additionally, a second kV CBCT scan of the patients is acquired immediately after treatment. Currently the Planning Target Volume (PTV) is created by a 5 mm isotropic expansion from the Internal Target Volume (ITV) to account for setup errors due to positioning and intra-fractional motion. The purpose of this study was to determine the intra-fractional displacement of the ITV during SBRT for patients immobilized in a SBF.

Materials and Methods: CBCT scans taken after treatment were matched to the planning CT using an automatic gray value Methods in the commercial software of the treatment unit (Elekta XVI system). The automatic result was manually corrected by matching the ITV to the visible tumor in the kV CBCT scan. The post-treatment positional deviation of the ITV relative to the planning position, defined the intra-fractional target displacement.

Results: Preliminary Results show average ITV deviation of 0, 0 and -1 mm in L/R, C/C and A/P directions, respectively. The median intra-fractional target displacement was 2.1 mm with a standard deviation of 1.4 mm, while 90% of all treatment sessions showed target displacement below 4 mm.

Conclusions: The Results indicate that patient comfort using the SBF is acceptable, without causing substantial patient movements during treatment. Online positioning using kV CBCT provides satisfying geometrical precision during SBRT of lung tumors, although patient movements during treatment are observed. The Results also indicate that the 5 mm margin currently applied from ITV to PTV may be slightly reduced, as the online positioning procedure marginalizes setup errors due to positioning.

P1104

EVALUATION OF A NOVEL COMBINED-MODE PLANNING AND DELIVERY METHODS FOR CHALLENGING STEREOTACTIC RADIOSURGERY CASES

Brian Wang¹ Vikren Sarkar¹ Prema Rassiah-szegedi¹ Hui Zhao¹ Yjessica Huang¹ Martin Szegedi¹ Dennis Shrieve¹ Bill Salter¹

(1) University of Utah, Salt Lake City, USA

Objectives: Fully modulated, multi-field (e.g. 9-13 fields), static gantry IMRT (SG-IMRT) can produce extremely conformal dose distributions but can also take long delivery times. Single-pass Intensity

Modulated Arc (IMA) treatments, on the other hand, can yield extremely efficient delivery times but may lack sufficient modulation from specific beam angles to achieve plan goals, especially for very challenging stereotactic treatment geometries. Here we present and evaluate a novel Combined-Mode (CM) delivery approach combining an intensity-modulated-arc (IMA) with a static-gantry-IMRT (SG-IMRT) delivery approach.

Materials/Methods: To quantify the potential for dosimetric improvement we used a prototype version of the Prowess treatment planning system (TPS) capable of simultaneously optimizing isodose distributions for both components of the CM delivery approach. Very challenging treatment geometries [four spine and two cavernous sinus stereotactic radiosurgery (SRS) cases] were evaluated using plans employing 'multi-field' SG-IMRT alone, single-pass IMA alone and CM (2-4 SG-IMRT ports combined with one single-pass IMA).

To quantify delivery accuracy we delivered 25 treatment plans on a prototype version of a Siemens Artiste LINAC, using flattening-filter-free 2000 MU/min mode. Dosimetric accuracy was validated by film/ion chamber and 3D diode-array systems (Delta4 and ArcCHECK). Gamma analysis and absolute dose comparisons were performed. Delivery times were recorded to quantify efficiency of each delivery modality.

Results: Dosimetric accuracy was seen to be excellent with mean ion chamber agreement of $-0.8\% \pm 1.7\%$, and mean gamma analysis (3% / 3 mm) agreement of $93.0\% \pm 2.2\%$. Multi-field SG-IMRT generated high quality plans, but had low delivery efficiency. The IMA plans were delivered fastest, but could not meet plan requirements for 5 out of 6 of these very challenging cases. By adding only 2-4 SG-IMRT ports onto the single-pass IMA plans, all the CM plans met the prescription with only slightly longer delivery time than the single-pass IMA plans. CM plans had an average decrease of 28.6% and 53.5% in delivery time compared to the SG-IMRT plan for the spine and cavernous sinus cases, respectively, and were on average only 5% - 10% longer to deliver than IMA alone.

Conclusions: A novel CM treatment planning and delivery approach was evaluated and was seen to be capable of meeting plan quality requirements for very challenging stereotactic radiosurgery cases, and to be capable of very accurate delivery, while allowing for significant reductions in delivery time.

P1105

INTRA-FRACTION AND INTER-FRACTION PATIENT POSITIONING UNCERTAINTY USING THE GAMMA KNIFE EXTEND SYSTEM

David Schlesinger¹ Zhiyuan Xu¹ Chun-Po Yen¹ Jason Sheehan¹

(1) University of Virginia, Charlottesville, USA

Purpose: Gamma Knife radiosurgery is traditionally a single-fraction modality. Recently a non-invasive, relocatable frame system (Extend TM, Elekta AB) was developed to enable Gamma Knife multi-fraction stereotactic radiotherapy. In order to determine the patient position within the frame, the Extend system makes use of a repositioning check tool (RCT): a four-sided plastic measuring tool that securely attaches to the Extend frame; and associated digital measuring gauges. The purpose of this study is to evaluate the inter- and intra-fraction patient positioning uncertainty using the RCT for the first five patients treated with the Extend System at the University of Virginia Gamma Knife Center.

Methods: For each patient, the RCT was used to acquire a set of reference measurements of the patient position within the Extend Frame at the time of CT simulation. Repositioning measurements were then acquired for each patient before and after each treatment fraction. Patient position was adjusted until the system-calculated radial difference between the pre-fraction repositioning measurements and the reference position measurements were less than 1mm.

Residual patient setup uncertainty was analyzed by decomposing the total repositioning difference between reference and pre-fraction measurements on each plate of the RCT into systematic and random uncertainty components. Intra-fraction uncertainty was evaluated by comparing the pre- and post-fraction repositioning measurements within and across patients.

Results: The interpatient group mean residual radial setup deviation after patient repositioning was 0.56mm, standard deviation (SD)=0.17mm. The spread (1 SD) of the distribution of systematic setup uncertainty for each measurement plate was 0.24(anterior), 0.21(superior), 0.30(left), and 0.22(right)mm respectively. The spread of the random setup uncertainty on each plate was 0.26(A), 0.27(S), 0.30 (L), and 0.28(R)mm.

The group mean radial intra-fraction positioning uncertainty was 0.54mm, SD=0.21mm. The mean SDs of the intra-fractional deviation on each plate was 0.22(A), 0.17(S), 0.18(L), and 0.21(R) mm. The spread (1 SD) of these SDs was 0.06(A), 0.07(S), 0.09(L), and 0.14(R) and are a measure of the inter-patient variation in the extent of intrafraction positioning deviation.

Conclusions: Under the assumption that the head is a rigid body with negligible organ motion, the Extend system appears to immobilize the patient comparably to rigid, frame-based systems. With appropriate patient selection, the Extend system appears to provide adequate setup and immobilization for hypofractionated SRT techniques with the Gamma Knife.

P1106

PERIPHERAL DOSES FROM IMRT AND STEREOTACTIC TREATMENTS IN PAEDIATRIC PATIENTS

Stephen Bosi^{1, 2} Paul White¹ Robert Smeeth^{1, 3}

(1) Prince of Wales Hospital, Randwick Sydney, Australia (2) University of Sydney, Sydney, Australia (3) University of New South Wales, Sydney, Australia

Motivation: Radiotherapy is given for a small percentage of paediatric patients (PPs), rarely for very young patients. Most of our PPs receive Intensity Modulated Radiation Therapy (IMRT) or Stereotactic Radiotherapy within the brain. While dose to the region of interest is calculated accurately by the treatment planning system (TPS), this isn't so for dose to peripheral organs (eg. thyroid, breasts, ovaries and testes). Normally, these organs are not deemed critical as they are not close to the treatment field, particularly in adults. In PPs these organs are much closer and more radiosensitive. Due to TPS model limitations, doses to these organs are inaccurate or unknown and not typically recorded. This project aims to produce a phantom-based estimate of paediatric peripheral doses for several IMRT and stereotactic plans.

Methods: Our paediatric phantom («Jelly Baby») consisted of stacked elastomeric bolus sheets, cut to follow the outer contour of coronal CT slices of a previously treated 3.9yo patient. The Jelly Baby was planned for one stereotactic plan and four IMRT plans, using combinations of coplanar and noncoplanar beams. Contours for the tumour in the original patient were copied into the phantom treatment plan, located near the middle of the brain. One «upper-limit» IMRT plan employed a

vertex field beam passing close to the thyroid. Doses were then measured during «treatment» on the phantom using TLDs at equivalent positions of the thyroid, breast, ovaries and testes. For comparison, a geometric phantom, «Block Baby», was created using stock blocks of solid water, Perspex and bolus. It was designed with similar linear dimensions, treated using the same beam arrangements, and TLDs used to measure doses at equivalent organ positions.

Results: For each plan, measured doses were expressed as percentage of isocenter dose. Two of the more conventional IMRT plans, one with all coplanar beams and another including one noncoplanar beam, yielded peripheral doses very similar to the stereotactic plan. The average organ doses for these three plans were: Thyroid 1.9%, Breast 0.57%, Ovaries 0.16% and Testes 0.10%. Two more unconventional plans with non-coplanar beams yielded roughly tenfold larger doses, the means being: Thyroid 20%, Breast 1.2%, Ovaries 2.0% and Testes 1.2%.

Conclusions: These higher doses to the thyroid were for plans involving beams passing quite near to the organ, and because the thyroid was a distance of only 10cm from isocentre.

P1107

COMPARISON BETWEEN CALCULATED DOSE FOR GAMMA KNIFE TREATMENTS BASED ON A HEAD CONTOUR DETERMINED BY MANUAL MEASUREMENTS AND CT SCAN

Françoise De Smedt¹, ² Daniel Devriendt¹, ² Nicolas Massager¹ Stéphane Simon¹, ²

(1) Gamma Knife Center, Erasme Hospital, Brussels, Belgium (2) Bordet Institut, Brussels, Belgium

Purpose: For Gamma Knife treatments, since Leksell GammaPlan 9.0 treatment planning, it is possible to use a head contour for dose calculation performed from a CT scan. The head contour usually used is based on interpolation from measurements. The contour performed from CT scan is more accurate compare to measured contour, it is thus interesting to analyse the influence of change in head contour on dose calculation.

Materiel and Methods: 34 Gamma Knife 4C and 31 Gamma Knife Perfexion treatment plans were used for comparison. For each treatment plan, we compare calculated treatment time from head contour based on measurements and head contour based on CT scan. The 50% isodose volume was also compared. The influence of lesion localization (peripheral or central), pathology, maximum dose and the number of shots were also analysed.

Preliminary Results: The mean difference (in absolute value) in treatment time for the 31 Perfexion treatment plans is 0,73% with a maximum of 1,96% and a minimum of 0%. For the 34 Gamma Knife 4C treatment plans the mean difference is 0,69% with a maximum of 2,43% and a minimum of 0%. The mean difference in treatment time for lesion located less than 2 cm from the edge of the head is 0,73% (max 1,84%, min 0%) for Perfexion treatment plans and 0,73% (max 1,96%, min 0%) for lesions located more than 2 cm from the edge of the head. For 4C treatment plans the mean differences are respectively 0,64% (max 1,67%, min 0,03%) and 0,76% (max 2,43%, min 0%).

If we analyse the mean differences in treatment time in function of pathologies, we have for Perfexion plans 0,49% for meningioma; 0,7% for metastasis; 1,09% for AVM and 0,99% for schwannoma. In case of 4C plans, the Results are 0,6% for metastasis; 0,72% for meningioma; 0,62% for trigeminal neuralgia; 0,73% for schwannoma and 1,24% for AVM.

The measurement of 50% isodose volume is more accurate for volume less than 1 cm³. The mean difference for Perfexion plans is 0,08% and 0,07% for 4C plans for volume in the order of a mm³.

The number of shots and the maximum prescribed dose have no influence on the mean differences in treatment time. The DVH will be also compare.

Conclusion: The mean differences in dose calculation are less than 1%. It seems that the use of a head contour based on CT in place of measurements will not affect so much the treatment time and the dose delivered to the patient.

P1108

POSITIONING ACCURACY AND INTRA-FRACTION STABILITY FOR 100 PATIENTS TREATED WITH NON-INVASIVE IMAGE-GUIDED SRS

Fred Hacker^{1, 2, 4} Scott Friesen^{1, 2} Paul Kelly^{1, 2, 4} Edward Mannarino^{1, 2} Karen Marcus^{3, 2, 4} Stephanie Weiss^{1, 2, 4}

(1) Brigham and Women's Hospital, Boston, USA (2) Dana-Farber Cancer Institute, Boston, USA (3) Children's Hospital Boston, Boston, USA (4) Harvard Medical School, Boston, USA

Purpose/Objective(s): Intra-cranial stereotactic radiosurgery (SRS) traditionally uses an invasive frame for patient localization and immobilization. In January 2009 we began treating SRS patients using a system which eliminates the invasive frame by using image guidance (IG) for localization and a thermo-plastic mask for immobilization. Compared with the invasive frame this system provides many advantages in terms of patient comfort and department workflow. Here we report on the observed positioning accuracy and intra-fraction stability for 100 patients treated with this system. These Results are compared to our previously reported Results for the BRW invasive frame.

Materials/Methods: A stereoscopic kilovoltage x-ray system combined with infra-red (IR) position tracking (ExacTrac by Brainlab) is used for patient localization. Automatic bony anatomy fusion is used for positioning. Patient immobilization is achieved using a relocatable stereotactic frame with aquaplast mask (Brainlab Mask System). Positioning accuracy was evaluated for 100 patients (165 isocenters) receiving single fraction cranial radiosurgery with this system. Initial imaging was acquired after patient positioning with the Brainlab Laser Localizer. The shifts indicated by the imaging system were performed and verification imaging was acquired to determine residual setup error. Post-treatment imaging was used to provide an estimate of intra-fraction motion for the mask system. The residual setup error and intra-fraction motion Results were then compared to those for 52 patients (102 isocenters) who received radiosurgery with an invasive BRW frame and were passively monitored with the imaging system.

Results: The mean initial setup error magnitude for patients immobilized with the Brainlab Mask and positioned with the laser localizer was 2.3 mm (SD=1.1 mm). The mean residual setup error magnitude after imaging based corrections were made was 0.5 mm (SD=0.2 mm). The mean intra-fraction shift magnitude was 0.6 mm (SD=0.4 mm). For comparison, patients conventionally setup with BRW frame based stereotactic localization and no imaging based correction were found to have a mean residual setup error magnitude of 1.0 mm (SD=0.5 mm). The mean intra-fraction shift magnitude for patients immobilized with the BRW frame was 0.4 mm (SD=0.3 mm).

Conclusions: The direct anatomical targeting provided with the IG system was found to improve patient positioning over conventional frame based stereotactic positioning. There was a minimal increase in intra-fraction motion for the mask system compared to the invasive BRW frame. We have now adopted the mask system with image guidance as our standard for intra-cranial radiosurgery.

P1109

DOSIMETRIC COMPARISON OF FOUR AVAILABLE TREATMENT MODALITIES FOR STEREOTACTIC RADIOSURGERY

Thierry Gevaert¹ Dirk Verellen¹ Thomas Lacornerie² Benedikt Engels¹ Nick Reynaert² Tom Depuydt¹ Koen Tournel¹ Michael Duchateau¹ Truus Reynders¹ Eric Lartigau² Marc Levivier³ Mark De Ridder¹

(1) Universitair Ziekenhuis Brussel, Brussels, Belgium (2) Centre Oscar Lambret, Lille, France (3) Centre Hospitalier Universitaire Vaudois, Lausanne, Switzerland

Background and Purpose: The aim of this study was to compare the dosimetric Results of stereotactic radiosurgery (SRS) using four available treatment modalities: Gamma Knife, Novalis, Cyberknife and Tomotherapy. As all these systems are already accepted technologies, our goal is not to show superiority of one technology over the other but to give an idea of the effect of beam collimation on the dose distribution with the use of 201 collimators of 4 different sizes with multiple isocenters (the Gamma Knife system), a mMLC collimator using one isocenter and multiple arcs (the Novalis system), multiple focal entries with different collimator sizes (the cyberknife system) and a binary MLC producing a fan beam with a helical treatment (the Tomotherapy system),

Material and Methods: Patients with arteriovenous malformation (n=10) or acoustic neurinomas (n=5) previously treated with SRS using the Novalis system were replanned with the Gamma Knife, the Cyberknife and the Tomotherapy systems. The conformity index (CI) and dose heterogeneity (DH) for the planning target volume (PTV) and gradient index (GI) for the dose fall-off outside the PTV were used as dosimetric indices to compare the different treatment systems.

Results: The Gamma Knife system can achieve a high degree of conformity ($CI=1.63 \pm 0.15$) with limited low doses ($GI=2.84 \pm 0.05$) surrounding the inhomogeneous dose distribution ($DH=0.81 \pm 0.05$). The Novalis system improved this inhomogeneity ($DH=0.28 \pm 0.06$) ($p < 0,01$) at the cost of conformity ($CI=1.93 \pm 0.31$) ($p < 0,01$) and the Tomotherapy system improves the inhomogeneity ($DH=0.12 \pm 0.05$) ($p < 0,01$) at the cost of the low doses surrounding the target ($GI=9.09 \pm 4.08$) ($p < 0,01$). The Cyberknife system has the best degree of conformity ($CI=1.30 \pm 0.09$) ($p < 0,01$) with limited doses ($GI=3,48 \pm 0.47$) surrounding the homogeneous ($DH=0.21 \pm 0.02$) dose distribution.

Conclusion: This study demonstrates the dosimetric non-equivalency between three stereotactic radiosurgery systems and a dedicated IMRT system, with a small advantage for the Cyberknife system for target coverage as well as for dose fall-off outside the target.

P1110

SETUP AND IMMOBILIZATION PRECISION OF A MODIFIED GTC FRAME: A RETROSPECTIVE ANALYSIS OF 45 PATIENTS

Brian Winey¹, ² Juliane Daartz¹, ³ Marc Bussiere¹, ²

(1) Massachusetts General Hospital, Boston, USA (2) Harvard Medical School, Boston, USA (3) German Cancer Research Center (DKFZ), Heidelberg, Germany

Purpose: To determine the interfractional and intrafractional immobilization accuracy and precision

of an mGTC frame.

Approach: Images obtained from 45 patients in an mGTC frame treated with proton stereotactic radiotherapy were anonymized and retrospectively analyzed for interfractional and intrafractional setup accuracy and precision. The modified frame employs a radiotransparent carbon cup and low density cushion to enable posterior beam directions for cranial lesions. Orthogonal kV setup images for 1002 fractions were analyzed. The kV setup images were acquired with a room mounted set of kV sources and Varian aSi panels. Patients were aligned with three 1/16 inch surgical stainless steel microsphere, implanted into the outer shelf of the skull, and aligned in full 3D space using an inhouse error minimization algorithm. The positions of the three fiducials are established relative to the isocenter coordinates in the treatment planning system and the positions are exported to the inhouse developed alignment software. On each day of treatment, the patients are aligned first with an orthogonal pair of kV images to establish the interfractional setup position and the baseline for the specific fraction. Prior to all subsequent treatment fields, orthogonal pairs of images are reacquired to verify shifts of the patients and record intrafractional patient motions. The patient alignment Results were recorded in a log file and were analyzed for interfractional and intrafractional shifts.

Results: 957 pairs of interfraction image sets and 974 intrafraction image sets were analyzed. 3D translations and rotations were recorded as the difference between the patient baseline position for interfractional and the fractional baseline for intrafractional shifts. The interfraction setup reproducibility was $0.13\text{mm} \pm 1.80\text{mm}$ for translations and $0.12^\circ \pm 1.33^\circ$ for rotations. The intrafraction immobilization efficacy was $0.19\text{mm} \pm 0.66\text{mm}$ for translations and $0.18^\circ \pm 0.59^\circ$ for rotations. The system error of the fiducial based alignment was 0.10mm.

Conclusions: The mGTC frame provides reproducible setup with a precision of 1.80mm and effective intrafraction immobilization with a precision of 0.66mm while allowing for a greater range of posterior treatment angles compared to the original GTC frame. The intrafractional precision is on the same order or better than published data for other cranial immobilization devices. The retrospective analysis has allowed us to reduce our reliance upon invasive fixation and reduce the need for intrafractional patient imaging on a patient specific basis.

P1111

A COMPARISON OF RAPIDARC TO CIRCULAR COLLIMATOR TECHNIQUES FOR INTRACRANIAL RADIOSURGERY

Jason Pukala¹ Frank Bova¹ William Friedman¹

(1) University of Florida, Gainesville, USA

Objective: To evaluate the merits of RapidArc® vs. circular collimator-based Methods for intracranial stereotactic radiosurgery. Plan metrics were compared for single target scenarios. Multiple metastatic targets were also considered and evaluated. Additionally, total treatment times were compared for both Methods.

Methods: Treatment plans were created for vestibular schwannoma, meningioma, metastases, and arteriovenous malformation diagnoses with each category consisting of 12 patients. Each disease category was further classified into simple, intermediate, and complex targets. Clinically delivered cone plans were compared to single-arc, three-arc, and five-arc RapidArc® configurations for each

patient. Conformity, gradient, 12-Gy volume, mean dose, maximum dose, total MU, and treatment time data were compared for each plan.

Results: The RapidArc® plans resulted in a mean prescription isodose to target volume (PITV) ratio of 1.17 (range: 0.98-2.78) vs. 1.43 (range: 0.98-2.93) for the cone-based plans. However, the improved conformity of the RapidArc® configurations may have been caused by an inherent study bias. The cone plans typically showed better gradient measures (mean: 0.40cm, range: 0.26cm-0.69cm) compared to the RapidArc® plans (mean: 0.52cm, range: 0.34cm-0.86cm) except for the most complex cases. Among the RapidArc® plans, the mean gradient improved from 0.57cm (range: 0.37cm-0.86cm) for a single arc, to 0.51cm (range: 0.36cm-0.81cm) for three arcs, to 0.47cm (range: 0.34cm-0.71cm) for five arcs. 12-Gy volumes and mean doses were comparable across all plans. Multiple isocenter cone plans required more total MU for treatment delivery because each isocenter must be treated individually. This did not necessarily equate to longer patient heading times because plan optimization and calculation add a substantial amount of time to the overall RapidArc® treatment time. Complete RapidArc® treatments were estimated to take 1:42:05 for a single arc, 2:01:52 for three arcs, and 2:40:51 for five arcs. A cone-based procedure was estimated to take 1:38:21 for three-isocenter treatment with the total time increasing or decreasing with the number of isocenters.

Conclusions: Dosimetric Results show that RapidArc® could be an alternative to cone-based radiosurgery but the conformity/gradient trade-off must be considered. RapidArc® treatments would lead to increases in patient heading times unless the cone-based treatments were sufficiently complex.

P1112

ICRU TREATED VOLUME ADJUSTED IRRADIATION CONFORMITY INDEX

Cheng-Ying Shiau^{1, 4, 5} Wen-Yuh Chung^{2, 4, 5} Hsiu-Mei Wu^{3, 4, 5} Eric Swei^{1, 4} Kang-Du Liu^{2, 4, 5} Wan-Yuo Guo^{3, 4, 5} Ling-Wei Wang^{1, 4, 5} David Hung-Chi Pan^{2, 4, 5}

(1) Department of Radiation Oncology, Cancer Center, Taipei, Taiwan (2) Department of Neurosurgery, Taipei, Taiwan (3) Department of Radiology, Taipei, Taiwan (4) Taipei Veterans General Hospital, Taipei, Taiwan (5) National Yang-Ming University, Taipei, Taiwan

Background: Report 62 of International Commission on Radiation Units and Measurements (ICRU) specifies conformity index (CI-ICRU) as the quotient of the «Treated Volume» and «Planning Target Volume». The value of CI-ICRU is generally larger than 2 as the Treated Volume is defined by the volume of minimal dose to target. In radiosurgery for benign lesions, the prescribed isodose (PID) usually covers around 95% of target volume (TV). To adjust for the under-coverage, modified CIs, such as Paddick's formula, were proposed. Optimization of radiosurgery plan solely based on number crunching of Paddick's CI to unity may result in selecting a PID with inadequate TV coverage.

Materials and Methods: Two new irradiation conformity indexes (IRCI) and inverse Paddick's CI (IPCI) are studied:

$$\text{Eq. (1) } \text{IRCI} = (\text{RV} + \text{TV} - \text{«TV in RV»}) * \text{TV} / (\text{«TV in RV»})^{\wedge} 2$$

$$\text{Eq. (2) } \text{ICRU-Adjusted IRCI} = (\text{RV} + (\text{TV} - \text{«TV in RV»}) * \text{CI-ICRU}) * \text{TV} / (\text{«TV in RV»})^{\wedge} 2$$

$$\text{Eq. (3) } \text{IPCI} = \text{RV} * \text{TV} / (\text{«TV in RV»})^{\wedge} 2$$

where RV is the «Radiation Volume» enclosed by PID, and «TV in RV» is the partial TV receiving PID or more. The dose volume histograms and CIs of consecutive 49 patients with solitary meningioma treated by Gamma Knife radiosurgery at Taipei Veterans General Hospital in 2005 were retrospectively analyzed.

Results: The mean TV is 3.94ml (0.2-18.84, median 2.82). The median PID is 58% (with maximum dose normalized to 100%). TV coverage («TV in RV»/TV) ranged from 94% to 100% (median 97%). The median values for IPCI, IRCI, ICRU-adjusted IRCI, and CI-ICRU are 1.35 (1.19-2.87), 1.40 (1.21-2.91), 1.45 (1.23-3.26), and 2.60 (1.71-9.30), respectively.

The values of these 3 CIs were recalculated for each and every isodose levels of all DVHs. The smallest median value of IPCI could be reduced to 1.28 (1.16-1.98) by increasing the PID to a median 64% (59%-85%), but at the expense of decreasing TV coverage to a median 89.8% (70.6%-94.5%). The median TV coverage of PID optimized by IRCI and by ICRU-adjusted IRCI was 94.9% (79.4%-97.4%) and 97.1% (94.5%-98.5%), respectively.

Conclusions: The conventional CI overestimates the quality of a RS plan with inadequate target coverage. As a result, the conventional CI should only be used to compare RS plans with same target coverage by PID. The new IRCIs, mandating adequate target coverage of 95% to 97%, are recommended to replace the conventional CI for planning, documenting and reporting of radiosurgery.

P1113

ACCURACY AND PRECISION OF THE ISOCENTER IN LINAC RADIOSURGERY - LONG TERM RESULTS:

Harald Treuer¹ Moritz Hoevels¹ Klaus Luyken¹ Stefan Hunsche¹ Wolfgang Baus²

(1) Dept. of Stereotaxy, U. of Cologne, Cologne, Germany (2) Dept. of Radiotherapy, U. of Cologne, Cologne, Germany

Stereotactic radiosurgery (SRS) requires high spatial accuracy in dose application [1]. Accuracy may be limited e.g. by deviations in positioning the target point to the isocenter or by misalignments of the beam axis. Thus, key items in physical quality control in linac based SRS are (i) the distance of the isocenter indicated by the lasers to the beam isocenter, (ii) the radius of the isocenter sphere and (iii) the minimal distance between gantry and table rotation axes. This items determine the isocentric accuracy and precision in linac SRS [2].

In many institutions, isocentric accuracy and precision is determined using the so called Winston Lutz test or the Heidelberg test [3]. Alternatively, star shot measurements can be used. An advantage of star shots is that they also give detailed information on how to readjust a misaligned system [4]. We used star shot measurements routinely since 7/2000. Each measurement was performed in two planes, one perpendicular to the table rotation axis and one perpendicular to the gantry rotation axis. Films were digitized and evaluated using special software [4]. Results were displayed and evaluated using control charts [5].

From 7/2000 to 10/2010 we performed 256 star shot measurements at an Elekta SL25. The mean deviation (+/- 1 standard deviation) of the isocenter from the position indicated by the lasers was -0.06 mm +/- 0.25 mm, -0.07 mm +/- 0.30 mm und -0.05 mm +/- 0.41 mm in x, y and z-direction respectively. The resulting mean spatial deviation was 0.52 mm +/- 0.24 mm. In 3 cases the

deviation was larger than 1.3 mm. The mean radius of the isocenter sphere was 0.52 mm \pm 0.19 mm (maximum: 1.25 mm), including the distance between gantry and table rotation axes (mean: 0.23 mm \pm 0.25 mm, range: -0.48 mm to 1.03 mm). Control charts with exponentially weighted moving averages could help uncovering problems due to abrasion of gantry tread.

In summary, star shot measurements and control charts proved to be useful for control of the isocentric accuracy and precision in linac based SRS.

[1] Treuer, H. et al. Impact of target point deviations on control and complication probabilities in stereotactic radiosurgery of AVMs and metastases. *Radiother. Oncol.* 81 (2006) 25-32.

[2] DIN 6875-1 (2004) Perkutane stereotaktische Bestrahlung.

[3] Hartmann, GH. et al. Quality assurance program on stereotactic radiosurgery. Berlin: Springer; 1995.

[4] Treuer, H. et al. On isocentre adjustment and quality control in linear accelerator based radiosurgery with circular collimators and room lasers. *Phys. Med. Biol.* 45 (2000) 2331-42.

[5] NIST/SEMATECH e-Handbook of Statistical Methods, <http://www.itl.nist.gov/div898/handbook/>, Nov-2010

P1114

ASSESSMENT OF VARIATION IN ELEKTA SOLID WATER CALIBRATION PHANTOM AND ITS IMPACT ON THE LEKSELL GAMMA KNIFE CALIBRATION

Josef Novotny Jr.¹ Jagdish Bhatnagar¹ Jonas Johansson² Kenneth Vanek³ Daniel Bourland⁴ Gennady Neyman⁵ Hyun-Tai Chung⁶ Jeong-Hoon Park⁷ Saiful Huq¹

(1) Department of Radiation Oncology, University of Pittsburgh Cancer Institute, Pittsburgh, USA (2) Elekta Instrument AB, Stockholm, Sweden (3) Department of Radiation Oncology, Medical University of South Carolina, Charleston, USA (4) Department of Radiation Oncology, Wake Forest University School of Medicine, Winston-salem, USA (5) Department of Radiation Oncology, Cleveland Clinic, Cleveland, USA (6) Department of Neurosurgery, Seoul National University College of Medicine, Seoul, Korea (7) Department of Neurosurgery, Seoul National University Bundang Hospital, Seoul, Korea

Purpose: Elekta Dosimetry Phantom is made of Certified Therapy Grade Solid Water (Gammex, Middleton, WI, USA) and can be used for both absolute calibration and relative dosimetry directly on the Leksell Gamma Knife (LGK) Perfexion and the LGK C. The purpose of this study was to evaluate variation in Elekta Dosimetry Phantom and its impact on the LGK calibration.

Methods and Materials: Altogether 7 Elekta Dosimetry Phantoms were collected from 5 different centers. To assess variation in phantoms, the diameter, and mass densities (calculated from weight and volume of each phantom) were measured. Diameter of all 7 phantoms was measured at five different points by MITUTOYO dial height gage MIT 509-314 (Mitutoyo, Japan). Weight of each phantom was measured using a precision weighing scale Mettler PM6 (Mettler Instrument Corp., Hightstown, NJ, USA). To assess the impact on the LGK calibration, the outputs of two LGK units (LGK Perfexion and LGK 4C) were subsequently measured for all 7 different phantoms with Exradin A16 ion chamber and Standard Imaging electrometer, Max 4000 (Standard Imaging, Middleton, Wisconsin, USA). Air pressure and temperature correction was applied for all readings.

Results: A very small deviation in phantom diameter between mean measured value and expected 160 mm was observed. Mean measured deviation in diameter for 7 tested phantoms was 0.15 mm (range 0.11- 0.22 mm). Mean weight of all 7 phantoms (just solid water part without phantom

holder) was 2388.9 ± 2.4 g (range 2384.0 - 2391.1 g). Very high consistency was observed for all phantoms for corrected reading measured on both LGK Perfexion and LGK 4C units. The mean of individual phantom reading deviation from mean of all 7 phantoms reading was 0.14% and 0.12% for LGK Perfexion and LGK 4C, respectively. Deviation in extremes (minimum and maximum values) of corrected readings for 7 tested phantoms was 0.45% and 0.47% measured on LGK Perfexion and LGK 4C, respectively.

Conclusions: This study demonstrated very high consistency in Elekta Dosimetry Phantom. Minimal deviations in geometrical phantom dimensions as well as its material composition were observed for tested sample of phantoms. Small observed variations had very small impact (less than 0.5%) on the LGK calibration. In comparison with the Elekta ABS plastic spherical calibration phantom (data published by Novotny Jr. et al in Med. Phys. 37, 2010) the Elekta Dosimetry Phantom provides higher consistency and less variation between phantoms.

P1115

PERTURBATION OF LOCALIZATION TECHNIQUE IN DOSIMETRIC EVALUATION FOR SMALL TARGET IN LINAC BASED STEREOTACTIC RADIOSURGERY(SRS)

Kaile Li¹ Dan Cornell² Arnold Able¹

(1) Associates in Medical Physics, Lanham, USA (2) John R. Marsh Cancer Center, Hagerstown, USA

Introduction: Advanced Imaging techniques can distinguish smaller targets in patients, and SRS requires high conformity and precise dose delivery to ever smaller target. The small target radiosurgery dosimetric accuracy is affected by different factors such as calculation grid size, image voxel size, imaging fidelity related to the lesion, and external geometric localization technique, etc. The risk of the dose delivery due to any geometric localization error will always affect the dosimetric conformity level. In this study, perturbation localization Methods is introduced to generate a set of dosimetric conformity index data, which provide quantitative distribution guideline for a risk managed decision Methodology for Linac based SRS when treating small target.

Methods and Materials: An anthropomorphic phantom was treated as a patient model. An Eclipse treatment planning system and 3D Brush function was used to generate the isolated spherical target, whose size is equivalent to 0.03cc in volume. The treatment plan is single 360 degree ARC with 2mm margin and the isocenter placed at the center of the spherical target. The translational patient alignment errors were simulated by setting the translational displacement in x, y, z directions with magnitude of 0mm, 1mm, 2mm, 3mm, and 5mm. The prescription is set to the mean value of the target. The DVH curves were used to get the volume and dose information from target volume (TV), prescription isodose volume (PIV) and TVPIV, which is the intersection of TV and PIV. Then, the undertreatment ratio (TVPIV/TV), overtreatment ratio (TVPIV/PIV) and the integrated conformity index (ICI), which is the product of the undertreatment ratio and overtreatment ratio, were calculated.

Results: In this study, by assuming different displacements during SRS setups, the calculation from the simulation shows that ICI for x displacement are 0.43, 0.32, 0.14, 0.07 and 0.05, the ICI for y displacement is 0.43, 0.22, 0.20, 0.14 and 0.03, the ICI for z displacement are 0.43, 0.33, 0.08, 0.03 and 0.01, when displacement are changed from 0mm, 1mm, 2mm, 3mm and 5mm. This study shows over 20% of conformity index difference due to the misalignment of localization of 1mm,

which is the limiting setup accuracy for SRS.

Conclusion: The perturbation study can provide clinical decision guideline by generating a conformity Index probability distribution for risk management in LINAC SRS for small targets when sequential localization Methods are used.

P1116

COMPARISON OF CONVENTIONAL VS. SOFTWARE-BASED METHODS FOR RAPID-ARC BASED SRS QA

Amirali Etemadnia¹ Henry Yampolsky² Azita Gilardi⁴ Bryan Martyn⁴, ³ Frances Moser⁴, ³

(1) Saint John's Hospital, Santa Monica, USA (2) Valley Radiotherapy Associates, Beverly Hills, USA (3) Center for Radiation Therapy, Beverly Hills, USA (4) Vantage Oncology Physics, Beverly Hills, USA

Purpose: Rapid Arc is a volumetric modulated arc therapy delivery system which delivers dose through upto 360 degree rotation using 177 control points per arc with five degrees of freedom. These are modulations of dose rate, gantry angles, field sizes, gantry speed & the multi-leaf collimator. As a result, it presents a unique set of challenges when it comes to performing standard quality assurances (QA). This task spans further in the case of stereotactic radiosurgery (SRS) using the rapid arc delivery Methods due to higher dose per fraction, steep dose gradients & smaller field sizes. From QA perspective, this translates into Methods & equipment that could ensure adequate QA which is critical to patient safety. In this study, we have evaluated Methods of RapidArc SRS QA performing Absolute Dosimetry and Relative Dosimetry.

Methods: We have performed absolute measurements using Standard Imaging's Exradin A16 thimble chamber with a collective volume of 0.007 cc. The relative dosimetry has been performed using Kodak EDR2 film in conjunction with the RIT software. These Results have been compared to a portal dosimetry based collection Methods using the Dosimetry Check (DC) software. QA was performed on 18 treatment plans using chamber & film. The same plans were delivered & analyzed using the DC software. Dose & gamma index (3mm/3%) deviation from the expected values were evaluated for each Methods.

Results: The absolute dosimetry Methods using the chamber resulted in an average difference of 1.2% with a SD of 2.1% vs. the absolute dosimetry Methods using the DC with an average of -0.2% difference with a SD of 2.8% from the predicted values. The relative dosimetry Methods using the film resulted in an average of -0.8% difference with a SD of 1.8% vs. the relative dosimetry Methods using the DC with an average of 0.9% difference & a SD of 1.0% from the predicted values.

Conclusions: DC successfully performs QA demonstrating comparable Results when compared to conventional Methodss of QA. The advantage mainly lies in logistic factors such as single exposure absolute & relative Results as well as systematic advantages such as detector dimensions (averaging effects) & their spread (detectors/mm), film saturation, processing complexities, cable noises & performing manual shifts on multiple targets with single isocentre treatments which would not be of concern using DC. In addition, DC reconstructs dose on original CTs as well as a DVH comparison of organs contoured using the same measured data.

P1117

VERIFICATION OF DOSE DISTRIBUTION IN GAMMA KNIFE USING PAGAT POLYMER GEL DOSIMETER AND MC SIMULATION

Mahmoud Allahverdi^{1, 3} Tayyeb Allahverdi Pourfallah^{2, 3} Mohammad-ali Bitaraf³ Maziyar Azar³ Farid Kazemi³ E Alikhani³

(1) Tehran University of Medical Sciences, Tehran, Iran (2) Mazandaran University of Medical Sciences, Sari, Iran (3) Iran Gamma-Knife Center, Tehran, Iran

Purpose: Polymer gel dosimetry is still the only dosimetry Methods for directly measuring three-dimensional dose distributions. MRI-polymer gel dosimeters are tissue equivalent and can act as a phantom material. Polymer gel dosimeters offer a practical solution to 3D dose verification for conventional radiotherapy as well as intensity-modulated and stereotactic radiotherapy. In this study, EGSnrc calculated and measured PAGAT polymer gel dosimeter dose volume histograms (DVHs) for single-shot irradiations of Gamma Knife (GK) unit were used to investigate the effects of presence of inhomogeneities on 3D dose distribution.

Methods and Materials: A custom-built 16 cm diameter spherical Plexiglas head phantom was used in this study. The PAGAT polymer gel dosimeter was fabricated according to composition proposed by Venning et al (1) and the Methods proposed by De Deene et al (2). After irradiation the polymer gel dosimeters were imaged using a Siemens 1.5 T clinical MRI scanner in a transmitter/receiver head coil. A multi-echo sequence with 32 echoes was used for the evaluation of irradiated polymer gel dosimeters. The EGSnrc-based MC user code BEAMnrc (3) was used to simulate the geometry of the GK source channel, and outputs phase-space data (phase-space files). Another general-purpose MC EGSnrcs user code DOSXYZnrc (4) which considers the phantom divided in a large number of small volume elements, or voxels, was employed to obtain the 3D dose distributions in the phantom.

Results: The Results of simulation for homogeneous and heterogeneous phantoms showed 23.24% difference in DVH within 90-100% relative isodose level. They also revealed that a significant part of the target (28.56%) received relative doses higher than maximum dose, which exceeds the acceptance criterion (5%).

Conclusion: It concluded that MRI-polymer gel dosimeter is an accurate 3D verifying tool in GK radiosurgery. Moreover, the findings of Monte Carlo calculation revealed that the applied simulation code (i.e. EGSnrc) is a proper tool for evaluation of 3D dose distribution in GK unit.

P1118

EVALUATION OF PATIENT SETUP ACCURACY DURING IMAGE-GUIDED STEREOTACTIC BODY RADIATION THERAPY

Hisato Nakazawa^{1, 2} Yoshimasa Mori¹ Yukio Uchiyama¹ Chisa Hashizume¹ Tatsuya Kobayashi¹ Takahiko Tsugawa¹ Masahiro Hagiwara¹ Yasunori Obata² Masataka Komori² Masami Yamada¹

(1) Nagoya Radiosurgery Center ,Nagoya Kyoritsu Hospital , Nagoya, Japan (2) Nagoya University Graduate School of Medical Science, Nagoya, Japan

We do Novalis stereotactic body radiation therapy (SBRT) for whole body tumors including lung

and liver cancers. Novalis is equipped with image-guided positioning system, ExacTrac consisting of infrared and X-ray systems. The initial patient setup is guided by infrared camera and then the target localization is accomplished by X-ray imaging. Spinal bony structures are main landmark for X-ray. We don't use 6-dimension couch movement (both translations and rotations) but only 3-dimension movement (only translations) to correct dislocation of the target from the isocenter after X-ray evaluation, because we mind change of radiation absorption by the rotated couch itself. If each rotational gap is more than 2 degrees, we do patient re-positioning. As for peripheral type lung tumors and liver tumors, the targets are often located laterally distant from the spine at the midline. In such cases, it is difficult to make sure the patient set-up, especially if there are rotational gaps (yaw, pitch, and roll) of patient positioning (, though they are less than 2 degrees). We evaluated patient set-up errors by our original Methods during the positioning of 15 patients with lung tumors or liver tumors.

We established virtual isocenter at the midline other than true isocenter. First, X-ray auto-fusion at the virtual isocenter at the midline is evaluated. After the correction of the couch position in 3D, we calculate the difference (theoretical values in 3D distances between the true isocenter and the set-up isocenter) between simple lateral movement by the distance from the virtual isocenter to the true isocenter and the complex lateral movement including the tangent gaps (the other 3D) calculated with rotation degrees. Second, after simple lateral movement of the couch by the distance from the virtual isocenter to the true isocenter for target, we do manual -fusion by macro inspection of the spinal bony structures on the X-ray images and get the errors in 3D (practical values in 3D distances between the true isocenter and the set-up isocenter). Finally, we compare the theoretical values and the practical values in each patient. The maximum difference between the theoretical values and the practical values was 2.2 mm and it was less than 1 mm in most patients.

In conclusion, though we use only 3D correction of couch position, we can estimate that the set-up errors are minimal by our Methods.

P1119

SMALL FIELDS NUMERICAL DOSIMETRY USING MONTE CARLO

Luiz Flávio Telles¹ Ademir Silva² Alan Cardec¹

(1) Liga Norte riograndense Contra o Câncer, Natal, Brazil (2) COPPE - UFRJ, Rio De Janeiro, Brazil

The stereotactic radiosurgery for treatment of brain lesions with beams photons of high energy emitted by Linear Accelerators is a complex treatment modality already well established. However, measurements of Tissue maximum ratios (TMR), Total Scatter Factor (TSF) and beam profiles at 5 cm depth of very small diameters beam (5-10 mm) still present a significant challenge¹. The objective this paper is to show a Methods using Monte carlo (MC) to simulate a dosimetry of small fields and to compare with the result of measurement of two ionization chambers. The Methods presented in this work can be useful in the dosimetry of treatment fields used in Stereotactic radiosurgery for functional disorders. In recent work, Gerhard² mentions treatments with fields of 4 mm in diameter. Two virtual photons source were defined in the MC. A focal source of photons has been defined, located with source surface distance (SSD) = 100.0 cm from water. The secondary collimators and the cones were defined as cells of zero importance for the transport of photons and electrons. Seven cones were simulated, from 0.75 cm to 3 cm. The energy spectrum emitted was obtained in

Bagueri et al. The extra-focal source was located at 12.4 cm below of the target and was divided into two parts. The electron flux was obtained in the spherical cells (diameter 0.2 cm), which was located inside the water phantom, it was multiplied by stopping power mass then added up after the execution of all source parts.

A constant, which multiplies the Results of the extra-focal source, was adjusted so that the simulated TSF for cones 1 and 3 cm of diameter equal the measured ones. The TMR, TSF and profiles were measured with two ionization chambers Exradin A12 (0.007 cc) and PTW TN31015 (0.03cc). The uncertainty of this dosimetry was around $\pm 1\%$ and the uncertainty of the MC result was of the 2%. The value found for the constant was 0.8.

The differences were less than 2%, when compared TMR, TSF and profile simulated and measured with Exradin chamber, for all cones. The differences found between measurements, with PTW chamber, and simulation were bigger than 10% for the profiles and 8% for TSF of the cone of 0.75 cm diameter.

The simulation Methods presented has shown that it can to be used for numerical dosimetry of small fields. The Results obtained with PTW chamber were very divergent when compared with the Results of MC and chamber Exradin. This ionization chamber is not suitable for dosimetry of fields less than 1 cm of diameter.

P1120

QUANTIFICATION OF THE VALUE OF A ROBOTIC 6-DEGREE OF FREEDOM TREATMENT COUCH FOR FRAMELESS RADIOSURGERY

Thierry Gevaert¹ Dirk Verellen¹ Benedikt Engels¹ Tom Depuydt¹ Karina Heuninckx¹ Koen Tournel¹ Michael Duchateau¹ Truus Reynders¹ Mark De Ridder¹

(1) Universitair Ziekenhuis Brussel, Brussels, Belgium

Purpose: To evaluate the added value of 6 degree of freedom (DOF) (3 translations and 3 rotations) patient positioning with robotic couch compared to 4DOF (3 translations and vertical rotation) positioning for intracranial lesions and to estimate the immobilization characteristics of the Brainlab frameless mask, more specifically the setup errors and the intrafraction motion.

Material and Methods: Forty patients with 66 brain metastases treated with frameless stereotactic radiosurgery and 6DOF robotic couch were enrolled. Patient positioning was optimized with the Brainlab ExacTrac stereoscopic x-ray system. Positioning Results were collected before and after treatment to assess patient setup error and intrafraction motion. Existing treatment plannings were loaded and the patients were simulated for 4DOF positioning and compared to the actual 6DOF positioning. The clinical relevance was analyzed by means of the Paddick conformity index (CI) and the ratio of prescribed isodose volume covered with 4DOF positioning to that obtained with the 6DOF positioning.

Results: The mean 3D setup error before 6DOF correction was 0.63 mm (SD2.21 mm). The rotational errors were larger in the longitudinal (0.23° SD0.82°) direction compared to the lateral (-0.09° SD0.72°) and vertical (-0.10° SD1.03°) ones ($p < 0.05$). The mean 3D intrafraction shift was 0.11 mm (SD0.89 mm). The residual rotational errors were comparable, 0.01° (SD0.35°), 0.03° (SD0.31°), -0.03° (SD0.33°), for the vertical, longitudinal and lateral, respectively. The mean CI decreased from 0.68 (SD 0.08) (6DOF patient positioning) to 0.59 (SD 0.12) (4DOF patient positioning) ($p < 0.05$). A

loss of prescribed isodose coverage of 5% (SD0.08) was found with the 4DOF patient positioning ($p < 0.05$). A threshold to lose coverage was 0.5 degrees for longitudinal and lateral rotations.

Conclusions: With a mask immobilization, patient setup error and patient intrafraction motions need to be evaluated and corrected for. The 6DOF patient positioning with 6DOF robotic couches to correct translational and rotational setup errors improves the target positioning with respect to treatment isocenter, which is in direct relation with the clinical outcome, compared to 4DOF patient positioning.

P1121

USE OF THE SRS PROFILER FOR CYBERKNIFE PATIENT SPECIFIC QUALITY ASSURANCE (PSQA)

Elizabeth Henderson¹, ² Janos Szanto¹, ²

(1) The Ottawa Hospital Cancer Center, Ottawa, Canada (2) University of Ottawa, Ottawa, Canada

Introduction: CyberKnife radiosurgery treatments are complex, involving multiple degrees of freedom, and frequently very small field sizes. It is therefore very difficult to independently assess the accuracy of dose calculation and delivery on a patient-by-patient basis. We have developed a simple Methods for performing PSQA of CyberKnife treatments using the SRS Profiler (Sun Nuclear), a diode array with diodes spaced every 4mm in a star pattern.

Methods: Two 2 cm thick acrylic buildup blocks were constructed with the same area as the SRS profiler, with 2 gold seed fiducials implanted with a 3.5cm spacing on the posterior surface of each block. In order to evaluate dosimetric accuracy of the SRS Profiler, a series of total scatter factor (TSF) measurements were acquired for CyberKnife fixed collimators from 5 to 60mm in size and Results compared to total scatter factor measurements made using a stereotactic EDGE diode and an Exradin A16 chamber. A CT scan of the SRS profiler and buildup blocks was acquired, and the plans for 8 patient treatments were re-calculated on the phantom using the Accuray Multiplan software, with the plan centered on the center diode. The patients plans were delivered to the phantom using the fiducial tracking algorithm on a Cyberknife G4 system, and the measurements were compared to calculated dose.

Results: TSF measurements made using the SRS profiler agreed within 0.7% with those made using the A16 chamber corrected for detector effects (1) for all collimator sizes. For the central diode, we obtained good agreement between SRS Profiler PSQA and the Multiplan calculation: five Results were within 1.5%, and three ranged from 6.5-8.5%. The larger discrepancies were due to steep dose gradients in the plan calculated on the phantom geometry, complicated by operator inability to precisely identify the location of the active detector element on the CT scans, and uncertainties in the dose calculation and phantom positioning.

Conclusions: The SRS Profiler has potential as a convenient, reliable and accurate tool for CyberKnife PSQA.

1. Francescon, P, et al. Medical Physics 35(2), p. 504-513 (2008).

P1122

DOSIMETRIC VERIFICATION OF TRATMENT PLANS AS QA TOOL FOR CYBERKNIFE COMMISSIONING

Gennady Gorlachev¹ Natalia Antipina¹ Alexandra Dalechina^{1, 2}

(1) Burdenko Neurosurgery Institute, Moscow, Russian Federation (2) Moscow Physical Engineering Institute, Moscow, Russian Federation

Objective: Cyberknife dosimetry commissioning is based on measurement of output factors and dose profiles of such small fields as 5 mm, where electron equilibrium does not exist and measurements interpretation still not fully understood. CyberKnife irradiation technique is most sensitive to the accuracy of small field measurements because of superposition of multiple beams in each point when each of those points locate in shadow area of beams essential part of time. We decided that the only way to be sure in final accuracy absolute dose to relatively large target should be measured by relatively large ionization chamber.

Materials and Methods: During commissioning time PTW TM-31006 0.01 cc micro ionization chamber was used for all relative measurements. Than two type tests were performed. First was dedicated to the system commissioning check. Cylindrical solid water phantom was scanned and cylindrical target 3 cm diameter and length around ionization chamber hole was defined. Three plans were designed with 5, 7.5, and 10 mm diameter collimators and dose at the target center was measured. Second set of tests is similar to IMRT verification technique. Absolute dose was measured by PTW TM-31010 0.125 cc ionization chamber, which is big enough to smooth dose distribution heterogeneity. Dose distribution at the reference plane was measured by Kodak EDR-2 film. Dose distribution comparison was performed by PTW-VeriSoft 2.11 software.

Results: Commissioning verification test showed deviation calculated dose from measured for collimators 5, 7.5, and 10 mm respectively -1.2, -1.6, and -1.%. Verification of three selected patient plans with complex shape targets of volumes 57, 35, and 250 cc had errors 3.2, -0.6 and 0.4% respectively. Standard gamma-index criteria 3% / 3 mm were achieved on 70-90% of points only. Taking into account complexity of manual matching calculated and measured distribution we believe that more intelligent software is necessary for comparison.

Conclusion: CyberKnife commissioning measurements with micro ionization chamber leads to correct dose calculations by treatment planning system.

P1123

IMPROVEMENT OF CONFORMITY FOR SMALL TARGET LINAC BASED STEREOTACTIC RADIOSURGERY(SRS) BY EMBEDDING MACHINE GEOMETRIC PERTURBATION

Kaile Li¹ Arnold Able¹

(1) Associates in Medical Physics, Lanham, USA

Objective: With advance of imaging technology, more visible small tumors could be treated by SRS. Usually, ARC delivery technique is used for the benefit of low peripheral dose. However, for small target there is still a relative large conformity index deviation due to 1mm targeting accuracy in LINAC based SRS. And this deviation is generated by the perturbation from rotation of gantry,

collimator and cone mounting mechanism, etc. In this study, the Methods to improve treatment conformity was investigated by embedding the gantry geometric perturbation into treatment delivery.

Methods: An anthropomorphic phantom was treated as a patient model. An Eclipse treatment planning system and 3D Brush function was used to generate the isolated spherical target, whose size is equivalent to 0.03cc in volume. The treatment plan is single 360 degree ARC with 2mm margin and the isocenter placed at the center of the spherical target, whose coordinate is (Xiso, Yiso, Ziso). A Winston Lutz test is attained before the LINAC SRS treatment and this test result will give the translational displacement of different gantry angles in X, Y and Z direction is dX, dY and dZ. With this profile, one 360 degree ARC is separated into 4 ARCs, which have angle range at 90 degrees, and the new isocenter will be at (Xiso-dX), (Yiso-dY) and (Ziso-dZ). Then the integrated Conformity index ((TVPIV)/PIVxTV)) was used to evaluate the resulted plans.

Result: The Winston-Lutz test of a Varian TrilogY LINAC was attained and analysis by PIPSPRO software was shows that, at gantry angle 45, 135, 225, and 315 degree, the vector dU and dV were (0.6, -0.4), (-0.1, -0.5), (-0.0, -0.5), (0.6, -0.2) and the offset between mechanical and radiation isocenter (dX, dY, dZ) is (0.2mm, 0.0mm, 0.3mm). When this isocenter displacement was input into the 4ARC treatment plan, the integrated conformity index (ICI) index of the plan is changed from 0.43 to 0.17. Then, the isocenters of each arc in the plan were adjusted based on the angle range, and the conformity index shows an improvement from 0.17 to 0.34. This result was also verified by experiment.

Conclusion: The gantry geometric perturbation, which Results from the discrepancy of the mechanic and radiation isocenter, can be delicately adapted to improve the treatment conformity in LINAC based SRS for small target.

P1124

A NEW, AUTOMATED DATA ACQUISITION SYSTEM FOR STEREOTACTIC RADIOSURGERY

Dalong Pang¹ Abdul Rashid¹ Guowei Zhang¹

(1) Georgetown University Hospital, Washington, Dc, USA

Objectives: To evaluate the accuracy and efficiency of a new data acquisition system specifically designed for stereotactic radiosurgery. We show that use of such a system not only increases the accuracy of clinical beam data, such as the TPR, TMR, beam profiles, but also drastically reduces the time required for beam scanning by orders of magnitude.

Materials and Methods: We used two data-acquisition systems to collect beam data for treatment planning system (TPS) commissioning for the two Cyberknife systems operational at our institution. One system is a conventional Scanditronix Wellhoffer 3-D blue phantom system that has been in use at our department for several years, and the other is a newly acquired M3000 RS system specifically designed for SRS data acquisition by Advanced Radiation Measurements (ARM), Inc. Specifically, tissue-phantom-ratio (TPR), off-axis-ratio (OAR), and output factors (OF) were measured for each fixed and the variable IRIS cones. The accuracy of the collected beam data was compared with a compiled reference data set from a collection of many previous measurements. The time required to complete each set of measurements was compared for the two systems.

Results: With the conventional wellhoffer system, data acquisition for TPR is manual and point-by-

point for a minimum of 15 depths. It requires manual measurement of percent dose at each depth. Change of measurement depth requires manual reposition of the Cyberknife robot to maintain a constant SAD. For each fixed cone, or IRIS cone size, it takes 25-29 minutes to collect the TPR data. The TPR curves are reconstructed by interpolation of the 15 data points. Whereas with the M3000RS system, the TPR data scanning is automatic and takes only 45 seconds for each cone. Furthermore, manual measurement of TPR data can result in large errors, due to the position inaccuracy introduced in the process and reconstruction of TPR curve from a finite set of 15 data points.

Conclusions: Manual, point by point data acquisition for TPR is a highly time-consuming and inaccurate Methods, requiring extensive labor-intensive intervention to achieve acceptable data. For accurate and efficient data acquisition for SRS treatment planning system commissioning, a data acquisition system that permits direct and automated measurement of the TPR and OAR data, such as the M3000RS, should be used.

P1125

STEREOTACTIC RADIOSURGERY OF INTRACRANIAL TUMORS: A COMPARISON OF INTENSITY-MODULATED RADIOSURGERY AND DYNAMIC CONFORMATIONAL ARC

Marcos Dellaretti^{1, 2, 4} J lio Leonardo Barbosa Pereira^{1, 2, 4} Eduardo K Tagawa^{3, 4} Baltazar Le o Reis^{1, 2, 4} Mariana Pedrini^{3, 4}

(1) Department of Neurosurgery, Santa Casa de Belo Horizonte, Belo Horizonte, Brazil (2) Department of Neurosurgery, Hospital Lifercenter, Belo Horizonte, Brazil (3) Department of Radiotherapy, Hospital Lifercenter, Belo Horizonte, Brazil (4) Centro de Radio-Oncologia de Minas Gerais, Belo Horizonte, Brazil

Purpose: Intensity-modulated radiosurgery (IMRT) and dynamic conformational arc (DCA) are two techniques for linac-stereotactic radiosurgery using the micromultileaf collimator. The objective of this study is to examine advantages and disadvantages of these techniques in the treatment of treatment of intracranial tumors.

Materials and Methods: SRS treatment plans were made for 13 patients with meningioma, pituitary adenomas and vestibular schwannoma. For all patients, we made an IMRT and a DCA plan using BrainLab Iplan 4.1. Plans were evaluated using: target coverage conformity index (CI), homogeneity index (HI) and doses in critical structures (optic pathways, cochlea and brainstem).

Results: In the overall comparison of both techniques: HI was better in IMRT group (1,12 vs 1,20) with difference statistically significative ($p=0,008$). The comparison of the mean of CI and dose in critical structures of the techniques, the difference was not statistically significative. The DCA plan was acceptable in 7 patients and IMRT in 10 patients. IMRT was preferred in 10 of 13 patients due to better CI and lower dose in critical structures with adequate target coverage.

Conclusions: IMRT is preferred stereotactic radiosurgery technique for most intracranial benign tumors closely critical structures.

P1126

APPLICATION OF GAMMA EVALUATION METHODS IN GAMMA KNIFE RADIOSURGERY

Jeong-Hoon Park^{1, 3} Hyun-Tai Chung² Jung Ho Han¹ Chang Wan Oh¹ Dong Gyu Kim² Tae-Suk Suh³

(1) Seoul National University Bundang Hospital, Seongnam, Korea (2) Seoul National University Hospital, Seoul, Korea (3) Catholic University of Korea, Seoul, Korea

Purpose: Radiosurgery is a minimally invasive surgical technique for the treatment of intracranial tumors by irradiating high dose in a single fraction. It requires sub-millimeter accuracy higher than typical IMRT treatment to minimize neurologic deficits. In this paper, the delivery accuracy of Gamma Knife (GK) radiosurgery was assessed for planning dose distribution and film measurement data using gamma evaluation Methods.

Materials and Methods: With Gamma Knife (GK) Perfexion (PFX) treatment planning system (TPS), single 4mm, 8mm, 16mm and composite shot plans were generated as test cases and their planning dose distributions were exported as DICOM RT files. For film dosimetry, ten GafChromic EBT2 films were irradiated for 0~12Gy range with 16mm collimator using spherical solid water phantom and the calibration curve was determined by 4th order polynomial fitting. The four test plans were delivered to the phantom in axial and coronal plane with prescription dose of 5Gy at 50% isodose line and the exposed films were converted to absolute dose value by calibration curve. The film measurement Results and planning dose distributions were aligned in same Leksell coordinate for further analysis using in-house software. And the gamma evaluation Methods was applied for two dose distributions with various spatial tolerance 0.5~1.0mm and dosimetric tolerance 0.3~1.0% to verify the accuracy of GK radiosurgery inversely.

Results: First, 20, 50, 80% isodose lines calculated in TPS were qualitatively compared with film measurement by aligning them in same coordinate. They showed good agreement for all dose levels within 0.5mm and the comparison of line profiles across major axis gave similar Results. The gamma evaluation Methods resulted in high passing rates within 50% isodose line more than 95% for 0.5mm/0.5% tolerance criteria in both axial and coronal planes for 8mm, 16mm, composite shot plans.

Conclusion: It was possible to apply gamma evaluation Methods to GK radiosurgery and the Results showed GK radiosurgery meets at least 0.5mm/0.5% tolerance criteria that are higher than CRT or IMRT requirement.

P1127

AN ERROR ANALYSIS COMPARISON OF NONINVASIVE AND INVASIVE FRAME CRANIAL SRS/SRT PROTOCOLS

Brian Winey^{1, 2} Marc Bussiere^{1, 2} Helen Shih^{1, 2}

(1) Massachusetts General Hospital, Boston, USA (2) Harvard Medical School, Boston, USA

Purpose: To define and quantify the errors within the noninvasive and invasive frame protocols utilized for photon SRS and SRT cranial treatment at the Massachusetts General Hospital.

Approach: Errors associated with invasive and noninvasive frame SRS/SRT processes were analyzed

and quantified. Errors that are common to both immobilization Methods, i.e. dosimetry, fusion, and contouring, were not included. Specifically, for invasive fixation, we analyzed the isocentric agreement of lasers and radiation and treatment planning system (XKnife) isocenter accuracy and used published intrafractional frame immobilization(1) accuracies. For noninvasive fixation, we analyzed the image guidance system mechanical accuracy, image system and radiation isocenter agreement, treatment planning system isocenter accuracy (XiO), and intrafractional frame immobilization. The invasive and noninvasive intrafractional immobilization error estimates were obtained from retrospective patient analyses. In addition to the above analysis, an end-to-end hidden target test with a custom made cranial phantom was passed through both systems to compare the summation of individually assessed errors. A gold ball positioned at the known mechanical isocenter enabled us to calculate the system accuracy and precision.

Results: The sum of the errors for the invasive frame protocol was 0.99 mm with all sources of error contributing nearly equally in the range of 0.50 mm. The sum of errors for the noninvasive fixation was 1.06 mm, with the primary difference coming from the imaging/radiation isocenter discrepancy of 0.63 mm versus 0.50 mm for the laser/radiation isocenter uncertainty of the invasive setup. Comparing these summations to the end-to-end hidden target cranial phantom test, the Results were comparable at 0.86 mm for the invasive frame and 1.02 mm for the noninvasive procedure. While the phantom was not subject to the extent of real patient uncertainties, it did incorporate point isocenter measurements that were subject to uncertainties, particularly in the axial slice dimension.

Conclusions: The errors of the invasive and noninvasive protocols at the Massachusetts General Hospital are at an acceptable level according to national guidelines. A hidden target end-to-end test with a custom made phantom confirmed the summation of errors from individual experiments of specific portions of both invasive and noninvasive protocols.

(1)Ramakrishna, et.al. Radiotherapy and Oncology, 95(2010) 109-115.

P1128

END TO END TEST FOR IMAGE GUIDED SBRT ON TRUEBEAM SYSTEM

Lei Wang¹ Kaylar Kiehl¹ Edward Mok¹ Annie Hsu¹ Sonja Dieterich¹ Lei Xing¹

(1) Stanford University Medical Center, Palo Alto, USA

Objectives: The Varian TrueBeam STXTM linear accelerator is equipped with flattening filter free (FFF) mode (6MV and 10MV), HDMLC (2.5mm leave width), as well as kV imaging and CBCT making this machine ideal for SBRT. The purpose of this work is to design an end-to-end test to determine the dosimetric and targeting accuracy achievable with the TrueBeam system.

Methods: A head phantom with Ball Cube II insert has been used to determine the accuracy of sub-millimeter targeting of the Cyberknife system for years. This phantom along with analysis software (FilmQA), were used to evaluate the accuracy of dose delivery for the TrueBeam SBRT delivery. Laser cut EBT2 films with 0.15mm accuracy are used.

The head phantom and Ballcube II with previously irradiated films inserted was first scanned with our GE scanner, and imported to the planning system. Plans were created and optimized to have a steep dose fall off surrounding the target. Four RapidArc plans (6MV and 10 MV FFF) and five IMRT

plans (6MV and 10MV FFF; 6MV, 10MV and 15MV with Flattening Filter) were studied. All the plans were created with target diameter of 3cm except the RapidArc plan with 6MV FFF (Planned with target diameter of 3cm, 2cm and 1cm).

Plans were then delivered on TrueBeam with kV imaging and CBCT as the guidance in locating the isocenter. Films were analyzed with software, FilmQA (3cognition). The film dose was compared with calculated dose, and analyzed using a Gamma criterion of 3%/1mm and 3%/2mm. The shifts required to align the film and calculated dose after the auto registration were estimated to be the targeting errors.

Results: Targeting accuracy was found to be within 1 mm in all three orthogonal directions for all the 9 plans studied. Gamma (3%, 2mm) for all the plans were found to be above 97%. Gamma (3%, 1mm) for all the plans were found to be above 90% except the plans with smaller target (87% and 84% for the plans with target size of 2cm and 1cm respectively) and the plan at 15MV (81%).

Conclusions: The head phantom with Ballcube II and FilmQA software combine to be an excellent tool in determining the targeting accuracy of the overall delivery of the TrueBeam system. Excellent relative dose agreement and sub-millimeter targeting accuracy was achieved. Increased deviations in spatial and dosimetric accuracy were found for 15MV measurement and lesions less than 2 cm.

P1129

SPECIFIC QUALITY CONTROL TESTS, THEIR FREQUENCY AND TOLERANCE LIMITS FOR THE LEKSELL GAMMA KNIFE® PERFEXION

Jagdish Bhatnagar¹ Josef Novotny Jr.¹ Saiful Huq¹ Dade Lunsford²

(1) Department of Radiation Oncology, University of Pittsburgh Cancer Institute, Pittsburgh, USA (2) Department of Neurological Surgery, University of Pittsburgh Medical Center, Pittsburgh, USA

Objective: Based on our experience of more than three years with the operation of the latest model of Leksell Gamma Knife® PerfexionTM (LGK PFX), we suggest Quality Control (QC) tests, which are specific to LGK PFX along with the frequency of tests and their tolerance limits. There are a few other tests, which are common with the older models of LGK, which still need to be performed periodically but are not mentioned in this study.

Methods: (I) Dosimetric Tests

(1) The 'flash-radiation' dose with 16 mm collimator is suggested to be measured monthly using '1 shot-n shot' technique. Based on our measurements, this dose should not exceed 1.2% of the calibration dose rate for that month.

(2) The 'focus-precision' test is suggested to be carried out daily using the Elekta diode-test tool. The test will fail if deviations for x, y, and z coordinates exceed certain limits specified by Elekta. From our experience we have noticed that the mean deviations of x, y, and z coordinates from ideal coordinates are 0.1, 0.0 and 0.0 with occasional maximum deviation of 0.2 mm of either coordinates.

(3) The 'sector-dose uniformity' is suggested for annual testing and at the time of installation of LGK PFX. The sector-dose uniformity should be within 1% of the average dose output of all 8 sectors. If using Elekta ABS phantom for these measurements, caution is advised of the unintended attenuation by phantom holder of beams coming from sectors 3, and 7 (Bhatnagar et al. Medical Physics 36, 1208 - 1211, 2009).

(II) Mechanical and Functionality Tests

(1) The correct attachment of 'G-frame adapter' to the coordinate frame is suggested for daily checking including the testing of secure docking of G-frame adapter to the patient-positioning-system (PPS).

(2) All 8 sectors with their 4, 8, and 16 mm collimators are suggested for daily checking for their 'positioning' as planned.

(3) The 'Collision clearance test tool' is suggested for checking on a monthly basis.

(III) Safety Related Test

The 'collimator-cap-collision' test is suggested every 6 months when cap is removed for leak testing of ^{60}Co sources.

Conclusions: Only the test procedures specific to LGK PFX are suggested here along with their frequency, and tolerance limits. We believe the tests suggested here are simple to carry out and, which assure the preparedness and proper and safe functioning of the LGK PFX.

P1130

SETUP ACCURACY OF THE NOVALIS EXACTRAC 6DOF SYSTEM FOR FRAMELESS RADIOSURGERY

Thierry Gevaert¹ Dirk Verellen¹ Nadine Linthout¹ Samuel Bral¹ Benedikt Engels¹ Christine Collen¹ Tom Depuydt¹ Michael Duchateau¹ Truus Reynders¹ Guy Storme¹ Mark De Ridder¹

(1) Universitair Ziekenhuis Brussel, Brussels, Belgium

Purpose: Stereotactic radiosurgery using framebased positioning is a well-established technique for the treatment of benign and malignant lesions. In contrast, a new trend towards frameless systems using image guided positioning techniques is gaining mainstream acceptance. This study was designed to measure the detection and positioning accuracy of the ExacTrac/Novalis Body (ET/NB) for rotations and to compare the accuracy of the frameless with the frame-based radiosurgery technique.

Materials and Methods: A program was developed in-house to rotate reference CT images. The angles measured by the system were compared to the known rotations. The accuracy of ET/NB was evaluated with a head phantom with seven lead beads inserted mounted on a robotic tilt module equipped treatment couch and was measured with a digital waterlevel and portal films. Multiple hidden target tests (HTT) were performed to measure the overall accuracy of the different positioning techniques for radiosurgery (i.e. frameless and frame-based with relocatable mask or invasive ring respectively).

Results: The ET/NB system can detect the rotational set-up errors with an averaged accuracy of 0.09° (SD 0.06°), 0.02° (SD 0.07°) and 0.06° (SD 0.14°), for longitudinal, lateral and vertical rotations, respectively. The average positioning accuracy was 0.06° (SD 0.04°), 0.08° (SD 0.06°) and 0.08° (SD 0.07°), for longitudinal, lateral and vertical rotations, respectively.

The Results of the HTT showed an overall three dimensional accuracy of 0.76 mm (SD 0.46 mm) for the frameless technique, 0.87 mm (SD 0.44 mm) for the relocatable mask and 1.19 mm (SD 0.45 mm) for the frame-based technique.

Conclusions: The study showed high detection accuracy and a sub-degree positioning accuracy. Based on phantom studies, the frameless technique showed comparable accuracy to the frame-based approach (golden standard).

P1131

COMMISSIONING AND CLINICAL IMPLEMENTATION OF COMMERCIAL SOFTWARE FOR INDEPENDENT VALIDATION OF THE LEKSELL GAMMAPLAN TREATMENT PLAN

Josef Novotny Jr.¹ Jagdish Bhatnagar¹ Saiful Huq¹ John Flickinger¹ Douglas Kondziolka² Dade Lunsford²

(1) Department of Radiation Oncology, University of Pittsburgh Cancer Institute, Pittsburgh, USA (2) Department of Neurological Surgery, University of Pittsburgh Medical Center, Pittsburgh, USA

Background and Purpose: Gamma Knife Check (GKC) Version 8.00.1A (Oncology Data Systems, Inc.) is an independent dose validation software to check calculations performed by the Leksell GammaPlan (LGP) treatment planning software for gamma knife radiosurgery on Leksell Gamma Knife models B, C and 4C. The purpose of this study was to perform commissioning of this software and determine whether this software can be implemented into clinical practice.

Methods and Materials: An irradiation geometry consisting of single 4, 8, 14 and 18 mm shots positioned at the center ($X=Y=Z=100$) of the ELEKTA spherical (160 mm diameter) calibration phantom were simulated for the commissioning of the GKC. A dose of 100 Gy to 100% point was used for this simulation. Altogether 55 control points were selected for each of the four collimators to compare absolute and relative deviations between LGP and GKC calculations for these irradiation geometries. These points were placed on main X, Y, Z axes going through the isocenter (100, 100, 100) and covering isodose levels between 10-100 % in 10% steps. GKC was also used for ten clinical gamma knife cases with following diagnoses: AVM, acoustic neuroma, meningioma, pituitary adenoma, trigeminal neuralgia, glioma, single metastasis and multiple metastases. Five control points were selected for each of these ten clinical cases at the following locations: inside the target, close to periphery of the target and at critical structures located in a close vicinity of the target. Total time including all necessary steps to perform the validation of the treatment plan by GKC was monitored for each case.

Results: Good agreement between LGP and GKC was observed for selected points between 30-100% isodose levels in commissioning geometry. In this case mean observed deviations between LGP and GKC were 1.7 %, 1.3 %, 2.2 % and 1.9 % for 4, 8, 14 and 18 mm collimators, respectively. However, points between 10-20 % isodose levels experienced much higher deviations in the typical range of 5-15 %. Although lower isodose lines are typically not of great clinical interest the reason for these discrepancies is currently being investigated. Very good agreement between LGP and GKC calculations was observed for all ten clinical cases with mean deviation 0.9% (range 0.4-1.8%). Mean total time needed for validation of the individual patient plan was 2.3 min (range 1.8-3.2 min) including final protocol printout.

Conclusions: Commissioning and clinical implementation of the presented software was very easy with minimal demand on time. Very short time is needed to perform individual patient LGP treatment plan validation. Implementation of this software into clinical practice can increase safety and reduce potential errors related to the treatment planning.

P1132

MODELING V10GY AND V12GY FOR DIFFERENT LINAC BASED INTRACRANIAL STEREOTACTIC RADIOSURGERY TECHNIQUES

Jian-Yue Jin¹ Lei Ren¹ Samir Patel¹ Benjamin Movsas¹ Indrin Chetty¹ Samuel Ryu¹

(1) Henry Ford Health System, Detroit, USA

Purpose: Brain radionecrosis is the major potential complication in intracranial stereotactic radiosurgery (SRS). It has been reported that V10Gy (V10) and V12Gy (V12) (the volume receiving 10 or 12 Gy single fraction dose) correlates with the radiation necrosis. The purpose of this study is to compare V10 and V12 among various techniques of linac based SRS, and develop a model to estimate them from the target volume and prescription dose for potential prediction of radionecrosis.

Methods: A total of 20 cranial lesions were retrospectively analyzed. The volume ranged from 0.16 to 64 CC. Three SRS techniques, including 9-field coplanar IMRT, 9-field non-coplanar IMRT, and 5 dynamic conformal arcs (DCA), were compared. The prescription dose was 18 Gy to 90% isodose line. The target coverage was kept similar for all plans (98.5-99.4%). The total volume that received the 50% and 60% of the isocenter dose, corresponding to V10 and V12, were calculated.

Results: We found that Vx, the volume receiving x (=10, and 12) Gy can be estimated using the following model: when target volume is less than 10 cc, $V_x = a * V^{0.7}$, and when the target volume is larger than 10cc, $V_x = b * V$, where V is the target volume. For x=10 Gy, a = 6.9, 6.4 and 5.5 for coplanar IMRT, non-coplanar IMRT, and DCA techniques, respectively; and b=3.5, 3.0 and 2.7, for the corresponding three techniques respectively. For x=12 Gy, a =4.9, 4.6 and 4.1; b = 2.4, 2.2, and 2.0 respectively. The DCA plan had the smallest V10 and V12 among three techniques, and the 9-field non-coplanar IMRT had smaller V10 and V12 than the 9-field coplanar IMRT.

Conclusion: The DCA technique is better than the IMRT techniques in terms of V10 and V12. A mathematical model has been developed to predict V10 and V12, which may associate with the probability of radionecrosis. Clinical correlation is necessary for decision of dose and volume.

P1133

DOSIMETRIC CHARACTERISTICS OF LEKSELL GAMMA KNIFE® 4C

Sethuraman Tkr¹ Aftab Khan² Hassan Khajah² Narayanan Subramanian¹ Hadi Abed Khawla³ Abbas Ramadan² Kazem Mirza¹

(1) Department of Radiation Physics, Kuwait Cancer Control Center, Kuwait, Kuwait (2) Kuwait Gamma Knife Center, Ibn Sina Hospital, Kuwait, Kuwait (3) Elekta AB, Stockholm, Sweden

Objects: To evaluate the measurement of dosimetric parameters for Leksell Gamma Knife® 4C (LGK 4C) with the calculations performed using Leksell Gamma Plan.

Materials and Methods: At our center, we used spherical polystyrene phantom of 160 mm diameter for all measurements and calculations. The irradiation geometry consisted of the placement of a single shot at the center of this phantom (i.e.) X = Y = Z = 100 for all collimators of 4, 8, 14 and 18 mm. GaF chromic EBT type films were used to perform the measurements and Leksell Gamma

Plan (LGP) version 5.34 was used to perform the calculations. The obtained parameters were then compared. The investigated dosimetric parameters were dose profiles for all collimators in all 3 axes (X, Y, and Z) including the full width at half maximum (FWHM) and the penumbra for each profile and also the relative output factors for all collimators.

Results: The exposed films were scanned by means of a flatbed scanner (EPSON Expression 1680 Pro) with the selected geometrical resolution of 0.05 mm. Measured Dose Profiles on 3 axes for all collimators agreed very well with the Leksell Gamma Plan calculated profiles within the specifications (less than or equal to 1 mm at 50 % isodose level). There was very good agreement between the experimental and calculated parameters of FWHM & penumbra for all collimators. Also, the measured relative output ratio of 14, 8 and 4 mm collimators was 0.988, 0.967, and 0.879 against the default values (0.984, 0.956, and 0.87) entered by vendor in the planning system.

Conclusions: Our experimental Results are very well matches with LGP calculated parameters and hence no changes are required in the LGP.

References:

1. Arndt J: Gamma Knife dosimetry & treatment planning. AAPM: 1999.
2. Bhatnagar JP, Novotny J, Niranjana A, Kondziolka D, Flickinger J, Lunsford LD, Huq MS: First year experience with newly developed Leksell Gamma Knife® Perfexion TM. Journal of Medical Physics 34: 141-148, 2009.
3. Novotny J, Bhatnagar JP, Niranjana A, Quader MA, Huq MS, Bednarz G, Flickinger JC, Kondziolka D, Lunsford LD: Dosimetric comparison of the Leksell Gamma Knife Perfexion and 4C. Journal of Neurosurgery 109: 2008.

P1134

ABSOLUTE DOSIMETRY OF INTRACRANIAL SRS WITH RADIOCHROMIC FILM

Nicholas Hardcastle¹, ² Amar Basavatia¹ Adam Baylis¹ Wolfgang Tome^{1, 2, 3}

(1) Department of Human Oncology, University of Wisconsin-Madison, Madison, USA (2) Centre for Medical Radiation Physics, University of Wollongong, Wollongong, Australia (3) Department of Medical Physics, University of Wisconsin-Madison, Madison, USA

Objectives: High resolution, absolute dosimetry measurements of large doses such as those seen in SRS are inherently difficult due to a lack of electronic equilibrium, detector size and high sensitivity to setup errors. Film provides an attractive option for absolute dosimetry of SRS delivery. The aim of this work was to verify the delivery of linac cone-based intra-cranial stereotactic radiosurgery (SRS) using radiochromic film.

Methods: Planning KVCTs of the Lucy phantom were taken. Two targets were delineated at the centre of the phantom: 4mm and 12mm diameter spheres. Treatment plans were created to deliver 21Gy to 80% of the maximum dose in each target. For both targets, plans were created for the phantom with Gafchromic EBT2 film in the film cassette. A third plan was created for the 12mm target with the ionization chamber cassette inserted. The three plans were delivered using a linac cone-based SRS technique. The dose was measured with the film (both targets) and the ionization chamber (12mm only). All measurements were performed three times. A calibration curve for the film was obtained by irradiating separate film pieces from 0-32Gy. Films were scanned with an Epson Perfection V700 flatbed scanner as 150dpi 48bit colour tiff images. The sensitivity of the green channel was greater than that for the red channel for doses over 6Gy therefore the green

channel was used for analysis. The films were converted to absolute dose and 2D dose maps were compared to the planned doses.

Results: For the 4mm target the measured peak dose was $25.75 \pm 0.99\text{Gy}$ and the planned was 26.24Gy . The 21Gy prescription isodose line was planned to cover $3.34 \pm 0.5\text{mm}$ (left-right) and $3.06 \pm 0.5\text{mm}$ (ant-post) over the target. The measured 21Gy isodose was $3.33 \pm 0.02\text{mm}$ (LR) and $3.04 \pm 0.27\text{mm}$ (AP). For the 12mm target the measured peak dose was $26.44 \pm 0.77\text{Gy}$ and the planned was 26.25Gy . The 21Gy prescription isodose line was planned to cover $12.51 \pm 0.5\text{mm}$ (LR) and $10.99 \pm 0.5\text{mm}$ (AP) over the target. The measured 21Gy isodose line width was $12.45 \pm 0.46\text{mm}$ (LR) and $11.14 \pm 0.49\text{mm}$ (AP) across the target. The 95% CI on the film measurements within the target was 5.3% and 6.3% for the 4mm and 12mm targets respectively. The ionization chamber measured dose at the center of the 12mm target was $25.46 \pm 0.34\text{Gy}$ with the planned dose to the chamber volume being 25.94Gy .

Conclusions: Gafchromic EBT2 film was found to be a useful tool for absolute dosimetry of intra-cranial SRS delivery provided the relatively large confidence intervals are taken into account.

P1135

RETROSPECTIVE STUDY OF 3 YEARS OF TREATMENTS WITH THE LEKSELL GAMMA KNIFE PERFEXION AND THE TREATMENT PLANNING SYSTEM GAMMA PLAN AT THE GAMMA KNIFE CENTER IN LISBON.

Luis Madureira¹ Sofia Iklbal¹ Angela Fernandes¹ Ana Rato¹ Ana Luisa¹ Ana Soares¹ Maria João Rosa¹ Katia Jacob¹ Begoña Cattoni¹ Julieta Silva¹

(1) Centro Gamma Knife, Lisbon, Portugal

The Gamma Knife Center in the Hospital Cuf Infante Santo Lisbon is the only hospital in Portugal that has the Gamma Knife Perfexion from Elekta. The system comes complete with Leksell GammaPlan® PFX, the dedicated treatment planning system. Since 2007 more than 250 patients received the Gamma Knife treatment at the hospital, which means that more than 400 brain lesions were treated. The most common pathologies treated include Metastasis, AVM, Acoustic Schwannomas, Meningiomas and Adenomas. One of the main purposes of this study is to obtain reference values, by pathologies, for some parameters such as the dose prescribed in each treatment planning, conformity index, dose gradient index, treatment time and dose obtained in the organs at risk. Other purposes is to establish analysis criteria for the treatment planning, so we can relate the number of shots, the size of the shots, the treatment time and the dose prescribed with the target volume. In this study an analysis was performed in all the treatments done in the Leksell GammaPlan 8.3.1. and they are all divided by the different pathologies. The parameters analyzed are the prescribed dose, isodose, number of shots, conformity index, dose gradient index, volume of the lesions, dose to organs at risk and treatment time. Only volumes exceeding 0.5 cc were considered to calculate the dose gradient index and the conformity index. For the AVM pathology the mean values are: prescribed dose is 20 Gy (range 14-25 Gy), isodose value is 51% (range 45-64%), treatment time is 102 min. (range 16-236 min.), conformity index is 0.71 and the dose gradient index is 3.1. For volumes above 0.5 cc were used shots of 8 mm and for volumes above 1.7 cc were used shots of 16mm. In AVM are used on average 5 shots per cc. In the Metastasis pathology, the mean values are: the prescribed dose is 19 Gy (range 12.5-22 Gy), isodose value

is 64% (range 45-96%), treatment time is 30 m (range 7-150 m). In this pathology, for volumes above 0.1 cc were used shots of 8 and 16 mm. In Metastasis are used on average three shots per cc. The mean conformity index is approximately 0.8 and the mean dose gradient index is 3. For the other pathologies the majority of the Results are between those two mentioned. Through this work we conclude that the restrictions in terms of conformity index and dose gradient must be defined in terms of pathology and not in a general base. It's difficult to estimate the time of treatment for pathologies with irregular shape.

P1136

A COMPARISON OF TWO STEREOTACTIC TREATMENT PLANNING SYSTEMS

Paul White¹ Joel Poder¹ Stephen Bosi^{1, 2}

(1) Prince of Wales Hospital, Randwick Sydney, Australia (2) University of Sydney, Sydney, Australia

Prince of Wales Hospital treats approximately 180 Stereotactic Radiosurgery (SRS) patients per year. Patients are planned using the Radionics XKnife Treatment Planning System (TPS), with a fixed head ring attached to the linac couch. This system has been in operation at our centre for about 20 years. Recently CMS, Inc., offered an option on their XiO Treatment Planning System for planning stereotactic treatments, (in addition to their conformal and IMRT planning modules). The aim of this project is to compare the models offered by both planning systems.

This presentation will present the Results of an investigation of matters related to implementing a new stereotactic model in the clinic:

- Measured data required for modelling;
- Suitable measurement devices and the pitfalls of measuring very small fields;
- Modelling Results;
- Standard plan checks;
- Comparison of XiO model with XKnife;
- Comparison of plans given using both models;
- Advantages and disadvantages of both planning systems.

P1137

THE EFFECT OF METALLIC IMPLANTS FOR THE RADIOSURGERY IN THE SPINAL TUMOR PATIENTS WITH METALLIC SPINAL IMPLANTS

Seok Hyun Son¹ Young Nam Kang¹ Mi Ryeong Ryu¹ Byung Ock Choi¹ Hong Seok Jang¹ Ih Bohng Choi¹

(1) the Catholic University of Korea, Seoul, Korea

Purpose: To evaluate the effect of metallic implants on the dose calculation for radiosurgery in patients with metallic implants and to find a way to reduce the error of dose calculation.

Methods and materials: In our study, we made a phantom in which titanium implants were inserted into positions similar to the implant positions in spinal posterior/posterolateral fusion. We compared the calculated dose of the treatment planning systems with the measured dose in the

treatment equipment. We used three kinds of CT (kilovoltage CT, extended-scaled kilovoltage CT and megavoltage CT) and three kinds of treatment equipment (ARTISTE, TomoTherapy Hi-Art and Cyberknife). For measurement of doses, we used an ionization chamber and Gafchromic EBT film.

Results: The absolute doses that were measured using an ionization chamber at the isocenter in the titanium phantom were on average 1.9% lower than those in the reference phantom ($p = 0.002$). There was no statistically significant difference according to the kinds of the CT images, the treatment equipment and the size of the targets. As the distance from the surface of the titanium implants became closer, the measured doses tended to decrease ($p < 0.001$), and this showed a statistically significant difference among the kinds of the CT images: The effect of metallic implants was less in the megavoltage CT than in the kilovoltage CT or the extended-scaled kilovoltage CT.

Conclusions: The error caused by the titanium implants was beyond a clinically acceptable range. To reduce the error of dose calculation, we suggest that the megavoltage CT should be used for planning. In addition, it is necessary to consider the distance between the titanium implants and the targets or the organ at risk to prescribe the dose for the target and the dose constraint for the organ at risk.

P1138

THE DOSIMETRIC VERIFICATION OF 5MM COLLIMATOR CONE OF THE ZMED STEREOTACTIC RADIOSURGERY SYSTEM

Joel YC Cheung¹ WK Monica Kan¹ MF Bonnie Lau¹ KH Nelson Lam¹ HT Lucillus Leung¹ CC Yau¹

(1) Princess Margaret Hospital, Hong Kong, China

Objectives: The experimental determination of output factor (OPF) and off-axis ratio (OAR) for the smallest 5mm collimator cone are difficult. This is due to the extremely narrow beam for which the dose is determined. The experiment will be most difficult for beams from the narrowest collimator, so the OPF for the 5-mm collimator cone is subject to the greatest degree of uncertainty. The lack of charged particle equilibrium condition for narrow beams was presumed to be the cause of difficulty in obtaining accurate measurements in obtaining the output factor.

To determine the OAR of 5mm collimator cone, the OARTOOL of FASTPLAN Planning System accepts the measured OAR data of any three bigger collimator cones and applied a curve fit algorithm using the modified Cunningham model to extrapolate the result. The accuracy of this extrapolated result is therefore a doubt. In this paper, we present how we obtain the OPF and the OAR of the smallest 5mm collimator cone.

Methods: Dose measurements to better define the output factors were performed. The detectors employed included PTW pinpoint chamber, micro-TLDs, Wellhofer SFD stereotactic diode and the Monte Carlo technique. Gafchromic EBT2 dosimetry films were used for the OAR measurements. Averaged Results of eight measurements were taken to minimize the uncertainty.

Results: The average value of the OPF for the 5-mm collimator cone thus obtained was 0.682 ± 0.03 . The Gafchromic EBT2 dosimetry films show small discrepancy between the measured and the extrapolated OAR. The FASTPLAN underestimates doses close to the beam axis (maximum 12% $\pm 1\%$ at 2mm radial distance) and overestimates doses outside the radiation field (maximum 6% $\pm 1\%$ at 3mm radial distance).

Conclusions: The OAR curve fit, using the modified Cunningham model, by OARTOOL showed small discrepancy with the measured OAR using Gafchromic EBT2 dosimetry films. The OPF and OAR Results of the 5mm collimator cone are important in serving a dosimetric reference for the accurate treatment of Trigeminal Neuralgia.

P1139

EVALUATION OF IMAGE DOSE DURING RESPIRATORY TRACKING METHODS OF CYBERKNIFE ROBOTIC TREATMENT DELIVERY

Kumutinee Pairat¹ Pornpan Yongvithisatid¹ Patchareporn Dechsupa¹ Tunyarat Wucharapruk¹ Kanjana Boonpitak¹

(1) Ramathibodi hospital, Bangkok, Thailand

Introduction: The Synchrony® Respiratory tracking system is a real time tracking for tumors that move with respiration. The Synchrony technique refers to a special function of the Cyberknife system that tracks thoracic and abdominal treatment sites due to breathing. During the treatment, images can be taken before every treatment beam. The robot or the couch will correct for patient motions. The total exposure for each target position determination is contributed from two orthogonal X-ray images.

Purpose: To determine the image dose during respiratory tracking Methods at the treatment region. **Methods:** The image dose was measured in air with calibrated diagnostic dose measurement equipment. A 6 cm³ ionization chamber was placed perpendicularly to the beam at a fixed distance from the focal spot and approximately 23 cm above the table top. The dose was measured by varying the imaging technique of 100, 150, and 200 mA, for the exposure time of 75 and 100 ms and kV between 100 and 125. Free in air exposure values (mR) at the center of the x-ray images were obtained and changed to KERMA (mGy) using the value of 0.00876. Estimation of the number of exposures for the synchrony technique is 350-438 times for the pairs of x-ray images.

Result: For an image pair at the center of X-ray image, the dose range is 0.21-0.76 mGy (S.D.=0.16). Using the estimated number of image pairs, the approximately total dose per course of the treatment is ranged between 8.41 and 30 cGy (S.D.=6.17).

Conclusion: The dose at the center of the X-ray images in Cyberknife Robotic treatment delivery was reported. To convert the dose to the patient's skin distance needs to use an inverse square and back scatter factors. Above all, to lower the patient dose while maintaining the quality of the images is an important issue, it will be accomplished in further study.

P1140

USE OF A FLATTENING FILTER FREE LINAC FOR STEREOTACTIC RADIOSURGERY

Jerome Krayenbuehl¹ Jan Hrbacek¹ Stephanie Lang¹ Claudia Linsenmeier¹ Stephan Kloeck¹

(1) Radiation and Oncology, Zurich, Switzerland

Introduction: The treatment for intracranial stereotactic radiosurgery patients is time-consuming. In the past years, the use of volumetric intensity modulated radiotherapy (RapidArc) allowed a

reduction of the treatment time [1]. Since beginning of 2010, the use of a flattening filter free (FFF) beam is available for a Varian Linac. The use of FFF allows to increase the dose rate and therefore decreases the beam-on time.

The goal of the present study was to evaluate the feasibility to use FFF for vestibular schwannoma patients.

Material and Methods: Ten vestibular schwannoma patients were planned with RapidArc, using a 6 MV beam with flattening filter (FF) (600 MU/min), and with FFF (1400 MU/min). Those patients were planned on a TrueBeam Linac (Varian Medical System) with a high definition multileaf collimator (2.5 mm width). Plans were generated in Eclipse planning system (V8.9, Varian Medical System) with a single fraction of 12 Gy using one or two arcs. All plans have been normalized to 95 % of the prescribed dose enclosing 100 % of the planning target volume (PTV). The PTV size ranged from 4.4 cm³ to 23.6 cm³. Treatment plan comparison between the different modalities were carried out using the number of monitor units (MU), dose-volume histogram parameters, homogeneity index (HI) and conformity/gradient index (CGIc and CGIg) [2].

Results: Dose distributions between FF and FFF plans showed similar Results with respect to the CGIc, CGIg, total body dose, HI and mean brain dose ($p > 0.05$). A lower maximum dose in 10 % of the brainstem (D10) was observed with FF ($p = 0.04$). Indeed, D10 for the brainstem was 73 % for FF and 75 % for FFF. With FFF, the MU increased by a factor of 1.05 and the beam-on time was reduced by a factor of 2.2 due to the high dose rate available only for FFF ($p = 0.03$).

Discussion: The FFF performed as good as the FF regarding the dose distribution, except for the brainstem where a small dose increase was observed. The high dose rate which is only available for FFF allows to do stereotactic radiosurgery within 15 minutes.

[1] H. A. Wolff et al. Radiation Oncology 2010, 5:77

[2] T. H. Wagner et al., IJRB, Vol. 57, No. 4, pp. 1141-1149, 2003

P1141

MEASUREMENT OF THE CLINICAL ACCURACY OF ELEKTA AXESSE IMAGE-GUIDED STEREOTACTIC RADIOTHERAPY SYSTEM

Pantelis Karaikos¹, ² Efi Koutsouveli² Argiris Moutsatsos¹ Loukas Petrokokkinos¹ Kyveli Zourari¹ Panagiotis Papagiannis¹ Ioannis Seimenis³ Chris Constantinou⁴ Panagiotis Sandilos² Evangelos Georgiou¹

(1) Medical Physics Lab., Medical School, University of Athens, Athens, Greece (2) Medical Physics Dept., Hygeia Hospital, Athens, Greece (3) Medical Diagnostic Center "Ayios Therissos", Nicosia, Cyprus (4) Bank of Cyprus Oncology Center, Nicosia, Cyprus

The aim of this study was to determine the overall clinical accuracy of Axesse (Elekta) linear accelerator utilized in stereotactic radiotherapy. For this purpose a special phantom with a cylindrical air area (10 mm in diameter and 5 mm long) close to its center, along with EBT films, were used to accurately reproduce every link in the treatment chain; from CT imaging and planning to positioning and dose delivery using CBCT and a 6D robotic system (HEXAPOD-Elekta) with sub-millimeter positioning accuracy. An EBT film was placed in contact with the cylindrical air area and the phantom was CT scanned to obtain slices of 1 mm thickness. A spherical target contour 4

mm in diameter was defined at the center of the film, while the cylindrical air area was contoured and defined as a critical organ. A VMAT plan was created for target irradiation. Before phantom irradiation, the procedure followed for patient positioning correction was applied; a CBCT was performed and positioning corrections based on automatic co-registration between the planning CT and the CBCT were calculated. The co-registration accuracy was verified using the cylindrical air area which was clearly visible on both planning CT and CBCT. Positioning corrections were applied using the HEXAPOD 6D robotic system and 7 Gy were delivered to the target using the VMAT plan. The whole procedure was repeated 6 times over a period of one month using films placed perpendicular (axial plane), as well as parallel (sagittal plane) to the Gantry-Target (GT) direction. EBT film scanning was performed 24 hours after irradiation to preclude post-irradiation coloration effects, using a Microtek ScanWizard Pro flatbed optical scanner in transmission mode with a resolution of 150 dpi (pixel size = 0.169 mm). The films were analyzed using IMRT-PRO (IBA) software and the center of the irradiated area of the film was compared with the center of the film (which coincided with the target center) to determine the overall accuracy of the simulated treated. This was found equal to 0.19 ± 0.10 mm in the x direction, 0.25 ± 0.11 mm in the y direction and 0.18 ± 0.09 mm in the z direction. These Results are well within the 1 mm accuracy required for radiosurgery applications and comparable to corresponding Results measured for a Gamma Knife system using the same phantom.

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P1142

END-TO-END TARGETING AND DOSIMETRIC ACCURACY ASSESSMENT OF A FRAMELESS TRIGEMINAL NEURALGIA RADIOSURGERY SYSTEM USING AN IGRS PHANTOM WITH SIMULATED INTRA-FRACTION MOTION

Brett Poffenbarger¹ Chantal Audet¹

(1) PAMF, Palo Alto, USA

Objectives: The high radiation dose, small target size and the close target proximity to critical structures that characterize the radiosurgery treatments for trigeminal neuralgias place extra stringent requirements on the targeting and dosimetric accuracy of the treatments. It is therefore very important to characterize the typical treatment delivery accuracy and assess its affect on the surrounding critical structures. In this work we use a simple image guided radiosurgery phantom and calibrated film dosimetry (Kodak EDR2) to assess these accuracies for the frameless radiosurgery system and process we use to treat our trigeminal neuralgia patients. The result of our end-to-end test quantifies the combined uncertainties introduced by CT scanning, treatment planning (BrainLab iPlan 4.1.1), image-guidance and robotic couch positioning (Exactrac BrainLab), simulated intra-fraction motion, and the NovalisTx HD120 linac (Varian).

Methods: A simple IGRS phantom was created by affixing several artifact-free, '+' shaped markers (CT-SPOTS, Beekley) to two surfaces of an acrylic slab phantom (BrainLab). The markers provide the contrast detail necessary for image matching. The phantom was scanned using the same CT parameters that are used for our radiosurgery patients. A treatment plan was designed to deliver 250 cGy to the isocenter using four arcs and a 4 mm cone (0.590 cone factor). The phantom was

loaded with film and then placed on the end of the BrainLab cranial couch-extension and roughly aligned with the isocenter. Infrared markers, used by the Exactrac imaging system to precisely move the couch in 6-dimensions (6D) of motion, were affixed to the phantom surface. A stereoscopic set of x-ray images was then acquired and an automatic image analysis was subsequently used to rotate and translate the 6D couch until the phantom was in the planned position. At each new couch angle the phantom was manually nudged and rotated a few degrees to simulate intra-fraction patient motion and then the phantom was repositioned using image-guidance before delivering an arc.

Results: After correcting the measurements for the image-guidance dose, the film dosimetry Results indicate that the targeting, i.e., 50% dose profile center, was within 0.3 ± 0.1 mm of the planned position and the absolute dose to the isocenter was within $5.2 \pm 1.5\%$ of the planned value.

Conclusions: Our end-to-end tests indicate that the aforementioned system provides accurate dose delivery and sub-millimeter targeting accuracy for the frameless treatment of trigeminal neuralgias.

P1143

THREE-DIMENSIONAL VERIFICATION OF TARGET POINT DEVIATION USING GEL DOSIMETRY FOR CONVENTIONAL AND FRACTIONATED STEREOTACTIC RADIOSURGERY

Dong-Joon Lee¹ Kyung-Nam Lee² Chan-Young Choi¹ Tae-Suk Suh²

(1) Inje University, Goyang, Korea (2) The Catholic University, Seoul, Korea

Objectives: Stereotactic radiosurgery necessarily require stringent overall target point accuracy and precision. We determine three-dimensional intracranial target point deviations (TPDs) in a whole treatment procedure using magnetic resonance image (MRI)-based polymer-gel dosimetry, and suggest a technique for overall system tests.

Methods and Materials: Overall TPDs were evaluated using a custom-made anthropomorphic head phantom and polymer-gel dosimeter to simulate various brain regions simultaneously. Computerized tomography (CT) scan data was transferred to the treatment planning system. Planning included creating virtual organs-at-risk (OARs). T2-weighted MR scan was performed following irradiation within 30 hours. We calculated TPDs using BrainSCANTM (Version 5.31, BrainLAB, Germany). TPDs were compared using mid bi-plane and three-dimensional volume Methods for spherical and elliptical targets.

Results: This study investigates three-dimensional TPD during treatment by MRI-based gel dosimetry, and proposes an analytical Methods as a global system accuracy test. We simulated treatment based on a treatment plan using a phantom to simulate small brain lesions. Average and maximum additive errors for ellipses were 0.62 and 0.69 mm, respectively. Total displacements were 0.92 ± 0.25 mm and 0.77 ± 0.15 mm for virtual stereotactic radiosurgery and fractionated stereotactic radiosurgery respectively. Average TPD_{total} at peripheral regions was greater than that at central regions for both.

Conclusions: Gel dosimetry based target point verification allows real three-dimensional quantification of overall TPDs for both spheres and ellipses. Our technique could be used as an overall system accuracy test that easily considers the real radiation field shape. Average total TPD is within previously reported error ranges.

P1144

THE EFFECT ON SECONDARY PARTICLES OF PROTON BEAMS BY INHOMOGENEITY

So-Hyun Park¹ Tae-Suk Suh¹ Won-Gyun Jung¹

(1) The Catholic University of Korea, Seoul, Korea

In proton therapy, the analysis of secondary particles is important due to delivered dose outside the target volume and thus increased potential risk for the development of secondary cancer. The purpose of this study is to analyze the influence on fluence and energy deposition of secondary particles from proton beams by using Geant4 simulation toolkit, when inhomogeneous material is placed in the traveling path of proton beams.

The inhomogeneity was modeled with the condition that the adipose tissue, bone and lung equivalent slab with thickness of 2 cm were inserted at 30% (Plateau region) and 80% (Bragg peak region) dose points of maximum dose in Bragg curve. The energy of proton was varied with 100, 130, 160 and 190 MeV for energy dependency. The re-sults were presented about the fluence and energy distribution of secondary particles in inhomogeneous condition.

Fluence of secondary particles shows within 0.2 % differences according to the den-sity of inhomogeneous materials. Deposited energy of secondary particles has difference patterns by position placed inhomogeneous materials. It is caused by the characteristic of Bragg-peak Curve of proton beams. Energy deposition also has within 30 % differ-ences by the density of inhomogeneous materials and initial energy of proton beams. The Results are affected by Multiple Coulomb Scattering (MCS) that causes different energy-loss relationships between proton and material.

Our Results are helpful for the prediction concerned with the distribution of second-ary particles within complex heterogeneity.

P1145

IMPACT OF COLLIMATOR LEAF WIDTH, IMRT AND VOLUMETRIC INTENSITY MODULATED ARC RADIOTHERAPY FOR VESTIBULAR SCHWANNOMA TREATMENT

Jerome Krayenbuehl¹ Stephanie Lang¹ Claudia Linsenmeier¹ Stephan Kloeck¹

(1) Radiation and Oncology, Zurich, Switzerland

Introduction: This study evaluated the dosimetric impact of intensity modulated radiotherapy (IMRT) and volumetric intensity modulated arc therapy (RapidArc) as well as the multi-leaf collimator width (MLC) for the treatment of vestibular schwannoma patients. These lesions present challenges in maximizing the target dose while keeping the dose below critical tolerance dose for the organ at risk surrounding the target.

Material and Methods: Seven vestibular schwannoma patients were planned with IMRT and RapidArc, with two MLC widths (5mm and 2.5mm). A total of 28 treatment plans were created with Eclipse (V8.9, Varian Medical System). All plans have been normalized to 95 % of the prescribed dose enclosing 100 % of the planning target volume (PTV). The PTV size ranged from 4.4 cm³ to 16.3 cm³. Treatment plan comparison between the different modalities were carried out using dose-volume histogram parameters, homogeneity index (HI) and conformity/gradient index (CGI)

and CGI_g) [1].

Results: In the overall comparison of IMRT and RapidArc, we found acceptable organ sparing and PTV coverage. IMRT and RapidArc achieved the same Results regarding the HI. A better CGI_c, CGI_g, brain mean dose, maximum dose in 10% of the brainstem (D10) was observed with RapidArc ($p < 0.05$). The 5 mm MLC width showed better Results than the 2.5 mm MLC width regarding CGI_c and D10 to the brainstem for IMRT ($p < 0.05$). For RapidArc, the small MLC performed better than the large MLC regarding mean dose to the brain and D10 to the brainstem ($p < 0.05$).

Discussion: The 2.5 mm MLC width combined with the RapidArc technique provided the best dose distribution for the treatment of vestibular schwannoma patients. The 2.5 mm MLC provided better organ sparing when used with RapidArc technique. When used with IMRT, the finer MLC resulted in worse dose conformity and brainstem sparing. This result is contradicting Results published by Wu et al. [2] and the reason for this behavior is under investigation.

[1] T. H. Wagner et al., International Journal of Radiation Oncology Biology Physics, Vol. 57, No. 4, pp. 1141-1149, 2003

[2] Q. J. Wu et al., Radiation Oncology, 4:3, 2009

P1146

MEASUREMENT THE SCATTER DOSE WITH CYBERKNIFE RADIOTHERAPY

Pornpan Yongvithasit¹ Kumutinee Pairat¹ Patchareporn Dechsupa¹ Nattiya Yodtongde¹ Juthamat Khaophong¹

(1) Radiosurgery center, Ramathibodi hospital, Bangkok, Thailand

Current knowledge of radiation therapy have been developed in every aspect. In terms of detecting disease early and in the radiation therapy target with high accuracy by one of the most cyberknife. It is a Methods of treatment with radiation system that can solves the problem of radiation in a relatively small organs such as brain, liver and moving all the time was pretty good. And usage monitoring organ motion during radiation. With this feature, it can abilitive dose to the patient. It is predicted that The survival rate increases. However, these patients have the risk of secondary primary malignancy in the long term.

The purpose of this study is to evaluate the dose outside the treatment field received by various regions with cyberknife. Cyberknife treatment plans were developed from patient informations expect actual usage in an anthropomorphic phantom, in brain, thyroid, bladder, ovary and testis, and measurement were made with LIF thermoluminescent dosimeters (TLD- 100) placed within the phantom at various depths and distances from irradiated volume.

The Results showed that the scatter dose (in cGy) ranged from 0.14 to 1.7 % (+ 0.019 %) of the delivered number of monitor units (MU). In conclusion, the cyberknife peripheral dose is directly related to the number of MU delivered and beam oriented entering or exiting through the body. Anyway, benefits of treatment should be judged clearly outweigh the risk.

P1147

SET-UP ACCURACY WITH FRAMELESS RADIOSURGERY OF INTRACRANIAL LESIONS USING EXAC TRAC 6-D ROBOTIC COUCH ON NOVALIS TX LINEAR ACCELERATOR

Revathy Kesvan² Karthikeyan Srinivasan² Niteen More¹ Vijay Anand Reddy¹ Vinitha Reddy¹ Padma Ganesan² Tamilselvan Kasirajan² Muthulingam Shunmugavel²

(1) Dept of Radiation Oncology, Apollo Health City, Hyderabad, India (2) Dept of Medical Physics, Apollo Health City, Hyderabad, India

Objective: To determine set-up accuracy in patients undergoing frameless radiosurgery of intracranial lesions using Exac Trac 6 degree- of-freedom robotic couch on Novalis Tx linear accelerator.

Methods: Ten patients with intracranial lesions planned for single or fractionated (3 to 5 fractions) frameless radiosurgery on Novalis Tx linear accelerator were the study population. Planning CT images were transferred to the Brain Lab Exac Trac X-ray verification system and digitally radiographs (DRRs) were generated for all the treatment couch positions. All patients were planned for stereotactic radiosurgery using 6 to 9 beams. Isocentre and X-ray calibration of Exac Trac system using X-ray calibration phantom with infrared markers was performed along with Winston Lutz test for Novalis Tx machine. Patients were positioned using infrared localizer attached to the couch and infrared cameras mounted in the room. A pair of oblique X-rays was obtained and fused with the DRRs on Exac Trac system. The shifting parameters (transverse and rotational) for the couch were noted and position was corrected using Exac Trac 6 degree-of-freedom robotic couch. Subsequently couch was rotated in different positions according to treatment parameters and a pair of verification X-rays was obtained for residual error. Snap verification was performed after correction of couch position and randomly during treatment. An analysis of the interfraction set-up variation and intrafraction variation in different couch positions is performed.

Results: The mean variations in the lateral, longitudinal and vertical directions were 0.47 +/- 0.39mm, 0.76 +/-0.52mm and 0.53 +/-0.34 mm, respectively. The mean angular variations of roll, yaw and pitch were 0.6 +/-0.3, 0.7 +/- 0.3 and 0.6 +/- 0.4 degrees of rotation, respectively.

Conclusions: Exac Trac X ray verification with 6 degree-of-freedom robotic couch is a robust system to perform frameless radiosurgery of intracranial lesions with high accuracy. This is more applicable for fractionated radiosurgery patients to reduce the daily set-up time.

P1148

THE STUDY OF OFF-AXIS RATIO (OAR) IN THE FASTPLAN SRS PLANNING SYSTEM

Joel YC Cheung¹

(1) Princess Margaret Hospital, Hong Kong, China

Objectives: Off-Axis Ratio (OAR) is defined as the ratio of absorbed dose at any point to the absorbed dose on the beam axis at the same depth when a photon beam irradiates in a water phantom. The OARTOOL of FASTPLAN Planning System accepts the measured OAR data and applied a curve fit algorithm using the modified Cunningham model. However, the curve fitted Results are not ideal. Small discrepancy was observed between the curve fitted OAR and the measured OAR.

The FASTPLAN overestimates doses close to the beam axis and underestimates doses outside the radiation field. Such discrepancy may affect the overall planning accuracy. Two different collimator cone sizes were studied, 14 mm and 26 mm.

Methods: The planning accuracy was determined based on the comparison of dose volume histograms (DVH) with the curve fitted OAR and the measured OAR. The measured OAR data were obtained using a Wellhofer SFD stereotactic diode and then confirmed by Gafchromic EBT2 dosimetry films. The OAR data were inputted into our home made software to calculate the DVHs of a single beam irradiated on a water phantom. Both static field and arc field were studied.

Results: For both static and arc field, there were no significant differences in DVH of the bigger collimator cone (26 mm) with the curve fitted OAR and the measured OAR. For the smaller collimator cone (14 mm), significant difference was observed at the low dose region of DVH for both static and arc field.

Conclusions: The small discrepancy of OAR was observed between the curve fitted OAR and the measured OAR. The FASTPLAN overestimates doses close to the beam axis and underestimates doses outside the radiation field. This discrepancy makes the FASTPLAN overestimates doses at the low dose region of DVH when using small collimator cone. However, this small discrepancy of OAR may be small to give a clinical significance.

P1149

QA OF IMAGE REGISTRATION IN RADIOSURGERY WITH HELICAL TOMOTHERAPY

Ji-Young Jung¹ Young-Nam Kang² Hun-Joo Shin¹ Jae-Hyuk Seo¹ Chul-Seung Key¹ Myung Ho Kim¹ Hyoung Wook Park³ Gi Woong Lee³

(1) The Incheon ST. Mary's hospital , Incheon, Korea(2) The Catholic university of Korea, Seoun, Korea(3) The Kyonggi University, Suwon, Korea

This study is MVCT image QA in stereotatic radiosurgery with helical tomothera QA of image registration in radiosurgery with helical tomotherapy in brain tumor and spine tumor. Megavoltage computed tomography (MVCT) of a tomotherapy is implemented imaging technique using image-guided radiotherapy (IGRT) to correct patient setup immediately before tomotherapy treatment. So we can reduce the PTV margin and exposure high dose to target. Tomotherapy system has auto registration function using planning kilovoltage CT(KVCT) and MVCT. In the helical tomotherapy system, the operator can choose 3 registration modes. Those are bone, bone and tissue, and full image technique. And operator can choose MVCT image thickness(fine, normal course). The fine MVCT image is 2 mm, normal is 4 mm, and course image is 6 mm, respectively. MVCT thickness was important in stereotatic radiosurgery in tomotherapy, because the PTV was very small. The thick slice was not appropriate for the auto registration in radiosurgery. We acquired CT image brain phantom and spine phantom for planning. The CT image thickness were 2, 4, 6 mm and contouring target in 7 slices, planning 3 cases using these images, respectively. First, The kVCT images(2, 4, 6 mm) were transferred to the tomotherapy planning station, and a plan was generated to enable the scan and auto registration using MVCT images(2, 4, 6mm) processes at the operator station. Second, we used 3 mode auto registration in brain and spine planning. The same slice thickness planning and MVCT image were more fit than different thickness. And, the Bone and tissue image registration image technique is most useful when brain image auto registration. The

Bone registration image technique is most useful when spine image auto registration. We should acquired an appropriate thickness planning CT image and MVCT image for image guided radiation therapy(IGRT) in tomotherapy. And we choose appropriate registration mode for quick and correct auto registration.

P1150

COMPARISON OF HELICAL TOMOTHERAPY AND CYBERKNIFE IN SPINE RADIOSURGERY

Young-Nam Kang¹ Ji-Young Jung² Hun-Joo Shin² Jae-Hyuk Seo² Ihl-Bohng Choi² Byong-Ock Choi¹ Hong Seok Jang¹ Myung Ho Kim² Hyoung Wook Park³ Gi Woong Lee³ Chul-Seung Key²
(1) The Catholic university of Korea, Seoul, Korea(2) The Incheon ST. Mary's hospital , Incheon, Korea(3) The Kyonggi University, Suwon, Korea

The purpose of this study is planning comparison of helical tomotherapy and Cyber knife in spine radiosurgery. Spine radiosurgery is an alternative to invasive spine surgery. The tomotherapy is megavoltage CT(MVCT) based image guided helical IMRT delivery system. The cyberknife using robotic arm and image guided based fiducial marker kilovoltage X-ray image. In the helical tomotherapy planning(HTP) system, the operator must choose 3 parameters. Those are field width(1, 2.5, 5 cm), pitch, and modulation factor(MF). The field width is defined as the slice thickness of the radiation field. The pitch is defined as the couch movement relative to the field width during one gantry rotation. The modulation factor is defined as the ratio of the maximum number of opening leaves and the average number of opening leaves in active gantry rotations. We choose 1 cm field width, 2.15 pitch and 3 MF in this study. In the cyber knife planning(CKP) system, the operator must choose 2 parameters. Those are cone size, beam path. We choose 7.5 mm cone size and full beam path. We acquired 2 mm thickness CT image and fusion MRI image to decided target. The PTV (vertebra body,T-spine) encompassed the gross tumor volume (GTV) with an additional localization uncertainty margin of 1.0 mm in 3 dimensions. We prescribed dose 15 Gy in both plan. The Spinal cord maximum dose was 11.9 Gy and 10 Gy received volume is 2.334 % in HTP. The CKP was able to reduce Spinal cord dose 8Gy. Because, it was machine mechanical limit in helical tomotherapy. The helical tomotherapy is modulated by a 64-multileaf collimator that has paired, pneumatically driven, 6.25-mm-wide leaves calculated to open or close at approximately every 7° of LINAC rotation, or 51 times per gantry rotation. But cyber knife use 100 or more than beam path. Although, cord maximum dose in CKP is lower than HTP, target homogeneity in HTP is better than CKP. Target coverage is 85% in CKP, 92% in HTP. It was benefit of helical radiation therapy. Tomotherapy and cyberknife are useful equipment to spine radiosurgery.

P1151

STUDY ON ACCURACY MANAGEMENT OF GAMMA KNIFE USING IMAGING PLATE WITH ORIGINAL FIXTURE

Yoshiyuki Konishi¹ Masao Usukura¹ Motohiro Hayashi¹
(1) Tokyo women's medical University, Tokyo, Japan

Purpose: The Gamma Knife is a stereotactic radiation surgery machine which focuses about 200 cobalt-60 gamma-ray beams on a therapeutic target. Its accuracy control and management of irradiation are at present performed using X-ray films. This Methods is, however, insufficient to provide sufficient accuracies in space distributions of the beams as well as dose distributions. Furthermore, computed radiography systems widely used in modern clinical settings add to the difficulty in evaluating accuracy management of radiation therapy machines. In order to solve these problems, we investigated whether using imaging plate (IP) is a practical approach to accuracy management of the Gamma Knife.

Methods: We positioned an IP parallel to the front face of its collimator helmet and irradiated it by gamma-ray beams from about 200 cobalt-60 sources for 0.1 minute. We could observe each beam clearly on the IP. We repeated the procedure at different axial positions (3mm → 15mm) of IP from the front face of the collimator. Images obtained by this Methods enabled us to evaluate beam profiles from the cobalt sources from the Gamma Knife.

Results and Conclusions: This indicated a possibility of evaluating 50% isodose region at the center of the irradiation field. From these measurements we demonstrated the feasibility of an accurate evaluation of isodose distribution at the center of the irradiation field. In conclusion, this study showed that we could establish a simple, convenient and practical Methods to check the center of irradiation field as well as a useful Methods for the accuracy management of the Gamma Knife by using the imaging plate.

P1152

DOSIMETRIC IMPACT OF INTENSITY-MODULATED ARC THERAPY FOR CRANIAL RADIOSURGERY

Lichung Ku¹, ² Carol Marquez² Wolfram Laub² Samuel Wang² Tasha Mcdonald¹ Martin Fuss²

(1) Salem Cancer Institute, Salem, USA (2) Oregon Health & Science University, Portland, USA

Purpose: To evaluate the potential dosimetric benefit of Intensity-modulated Arc Therapy (IMAT) for cranial radiosurgery. The secondary objective is to develop effective planning strategies.

Methods: Ten patients with intracranial lesions of various sizes (1.0 - 6.0 cc) treated with dynamic conformal arcs (DCA) were retrospectively reviewed. In each case, the lesions were replanned with IMAT (RapidArc, Varian Medical, Palo Alto, CA) without modifying geometric parameters (5 non-coplanar arcs and 1-2 mm expansion of the GTV for the PTV). The DCA and IMAT plans were compared using the following criteria: 1) Conformity index: using $CI = 1 + V_n / V_t$, where V_n and V_t are the volumes of the normal tissue and the target receiving the prescription dose, respectively. 2) Dose gradient: measuring the distance between the prescribed isodose line and the 50% line 3) Peripheral dose: evaluating the volumes encompassed by the 30% isodose line (V30). Two ring structures were created to control the dose gradient and conformity.

Results: All plans achieved 100% coverage of the gross target volume (GTV) and were normalized to 97% coverage of the PTV. Dosimetric conformity was substantially improved by IMAT--- average CI of 1.04 (range 1.0 - 1.1) for IMAT vs. 1.41 (range 1.3 - 1.6) for DCA. The dose gradient was steeper in the IMAT plans with the 50% isodose lines within 4 mm outside the PTV, averaging 1mm closer than the DCA plans. The V30 in DCA and IMAT plans were comparable. However, IMAT planning lowered the dose to organ-at-risk (OAR) by shaping peripheral dose distribution. The average monitor units (MUs) in IMAT plans were 1.6 to 2.5 times higher in DCA plans. Computation

time for the IMAT plans were twice as long as the DCA ones. Ring avoidance structures were found to be effective to optimize dose distribution.

Conclusions: IMAT significantly improves the quality of the DCA plans. IMAT plans produce higher conformity, steeper gradient and lower dose to OARs, while having increased MUs and computation time. IMAT may be a superior alternative to DCA for cranial radiosurgery.

P1153

A COMPARISON OF TWO MODALITIES FOR MULTI-TARGET CASES: PROTONS AND DYNAMIC ARCS

Marc Bussiere^{1, 2} Brian Winey^{1, 2} Helen Shih^{1, 2} Paul Chapman^{1, 2} Jay Loeffler^{1, 2}

(1) Massachusetts General Hospital, Boston, USA (2) Harvard Medical School, Boston, USA

Purpose: To compare two radiosurgery modalities available at our hospital and quantify the benefits for multi-isocenter cases.

Methods: Over 300 radiosurgery cases are treated annually at the Massachusetts General Hospital. A non-negligible number of these cases involve simultaneous treatment of multiple lesions. Patients with multiple lesions most commonly present with metastatic disease or atypical meningiomas. The stereotactic options available at our hospital include passively scattered protons and Linac based cone or dynamic arc radiosurgery. Proton treatments can be delivered using a gantry based delivery system with a flat robotic couch as well as a dedicated stereotactic fixed horizontal beamline with a specialized patient positioner, STAR, that can rotate the patient to achieve the same beam directions as the gantries. Linac treatments are done on a Varian IX 6 MV unit using dynamic conformal or cone based arcs. The same fixation Methods, imaging protocols and similar fiducial based alignment techniques are utilized for both modalities; therefore we focus on the dosimetric differences in this study. A variety of cases with three or more lesions that were treated with protons were planned using identical prescription and coverage criteria using photon based options. The plans were compared and evaluated for target conformity, normal anatomical structure avoidance and integral dose.

Results: Although both proton and photon modalities can be used to implement clinically appropriate plans, passively scattered protons have an advantage in limiting integral dose. In all cases with three or more lesions, protons reduced the integral dose to healthy tissue. When lesions were located in regions where critical structures were present or in close proximity to another lesion, conformity decreased for Linac based plans compared to protons. Dose to critical structures was reduced using protons for lesions close to the structure while maintaining similar target coverage. Comparable plans were achievable for multiple lesion patients if the lesions were far apart and far from critical structures.

Conclusion: A triage system which incorporates dosimetric considerations is important for patients requiring treatment to multiple lesions. Protons generally allow for greater target conformity and lower integral dose to patients with multiple isocenters which might reduce radiation related toxicity and allow for more future treatment options if patients develop recurrences. The higher conformity advantage becomes more prominent when the isocenters are in close proximity to each other or to critical structures, allowing for reduced dose to critical structures without compromise to target coverage.

P1154

PLAN QUALITY AND TREATMENT DELIVERY EFFICIENCY OF A HIGH OUTPUT LINEAR ACCELERATOR (TRUEBEAM)

John Fiveash¹ Evan Thomas¹ James Markert¹ Barton Guthrie¹ Sharon Spencer¹ Michael Dobelbower¹ Richard Popple¹

(1) University of Alabama at Birmingham, Birmingham, USA

Objectives: To describe the radiosurgery and SBRT plan quality and efficiency of a high output flattening filter free (FFF) linear accelerator in a clinical setting.

Methods: A new radiosurgery platform (TrueBeam, Varian) includes a very high output 10 MV FFF beam that provides variable output up to 2400 MU/minute as well as conventional flattened beams (6 MV @ 600 MU/min). This linear accelerator is also equipped with a new generation multileaf collimator (HD-MLC) with 2.5 mm leaf resolution in the middle and a lower leaf leakage than previous models. Since commissioning in July 7 2010, 80 total plans including 25 FFF plans have been administered through October 22 2010. The beam time and treatment times were measured for SBRT and RS cases. Treatment time was measured from the start of beam on to the end of final beam off and included time to enter room for couch adjustments or for intrafraction image guidance if done.

Results: Dose per fraction prescriptions have varied from 1.8-20 Gy at a variety of sites including brain, spine, lung, prostate, head/neck, and pancreas. Treatment delivery modes included dMLC intensity modulation radiation therapy and VMAT in single or multiple arcs at up to 2400 MU/min. In radiosurgery cases where the predominant treatment-planning goal was three dimensional conformity rather than organ avoidance, the conformity indices varied from 1.1 to 1.3. All treatments except for respiratory-gated SBRT cases have been administered in 10-15 minute time slots including hypofractionated and single fraction CNS plans. Typical treatment times for CNS radiosurgery with single or multiple arcs was less than five minutes including room entry if needed for couch angle adjustment for multiple non-coplanar arcs. The least efficient case was 20 Gy x 3 fraction 13-field respiratory gated dMLC plan with a treatment time of 22.5 minutes (including room entry and intrafraction cone beam CT image guidance). For VMAT plans, the maximum speed of gantry rotation rather than dose output often determined the treatment time. Therefore, we observe very little difference in treatment time of hypofractionated plans (e.g. 6 Gy) compared to higher dose per fraction plans (e.g. 12 Gy or higher).

Conclusions: The high output FFF mode produces high quality radiosurgery plans that generally can be administered in a conventional time slot. This treatment delivery efficiency will not only provide better resource utilization (machine and physician) but will contribute to better patient comfort leading to reduced intrafraction motion.

P1155

CONFORMITY INDEX TO DOSIMETRIC OPTIMIZATION. RADIOSURGERY AND STEREOTAXY CLINICAL CASES EVALUTATION

Patrizia Pelosi², ¹ Enrico Zollo¹ Giuseppina Iorio³, ¹ Carmine Franco Muccio⁴ Teresa Peronti¹ Giuseppe Catapano³

(1) Hospital G.Rummo Oncology Radiotherapy Department, Benevento, Italy (2) Hospital G.Rummo Medical Physic Department, Benevento, Italy (3) Hospital G.Rummo Neurosurgery Neurodiagnostic Department, Benevento, Italy (4) Hospital G.Rummo Neurodiagnostic Department, Benevento, Italy

Stereotaxy is a Methods that rigidly localizes anatomical structures in a space defined by stereotactic coordinates system, so that a high accuracy of delivery radiation dose is mandatory.

The technique is only possible because of high conformity of the dose, because its goal is to encompass target-volume with therapeutic isodose by means of a steep dose gradient, up to 2mm, in order to spare the surrounding normal tissue.

Analysis of radiosurgery and stereotactic ipofractionated clinical cases shows that the quality evaluations of isodose distribution based on visual dosimetric analysis in axial, sagittal and coronal CT-projections and quantity evaluations by statistical tool of cumulative dose distributions (DVH) is unsatisfactory.

We demonstrate that the conformity index gives better performances as complementary dosimetric tool of evaluation

Critical analysis of literature works get us to implement Paddick Conformity Index algorithm, CI, in our dosimetric software system, Ergo ELEKTA, to increase optimization of dosimetric conformity configuration. $CI_{Paddick} = \frac{TIV(D)}{TV} \times \frac{TV}{PIV(D)}$ -where TIV(D):Target Isodose Volume, TV:target volume, PIV(D):Percentage Isodose Volume- is an objective measurement of how well the distribution of radiation conforms to the shape and the size of radiosurgical target. CI ratio is volume-independent and gives a score of unity only for a perfectly conformal plan.

We use a protocol of research with hydrogen-spettroRMN to have metabolic information as for healthy as pathologic nervous tissues. Conventional sequences of RM give insufficient informations about the extension of some neoplastic lesions in surrounding nervous tissues, such as gliomas. Spectroscopic analysis of follow-up studies gives a complete definition of neoplastic margins by to differential diagnosis between recidives and radionecrosis.

This work presents 40 clinical cases from year 2008 to 2010 of radiosurgery and stereotaxy. We elaborated three treatment plans for every patient, with different geometric and weighing configurations ensuring optimized tumor volume coverage and sparing of critical structures. For each of them we analyzed the 3D distribution isodose curves and the maximum, minimum, mean, and modal dose values delivered to each volume of interest represented in the form of dose-volume histograms. No decisive Results has been obtained by means of this dosimetric tools. Finally evident differences between CI calculated for each plan of every case achieve the best solution to objective assessment of treatment plans conformity. Studies of clinical advantages are waiting from our follow-up spettroRMN data.

P1156

DOSIMETRIC ANALYSIS OF MODULATED ARCS IN STEREOTACTIC RADIOSURGERY

Geoffrey Zhang¹ Lichung Ku² Michael Yu¹ Siriporn Sarangkasiri¹ Weiqi Li¹ Vladimir Feygelman¹

(1) Moffitt Cancer Center, Tampa, USA (2) Salem Hospital, Salem, USA

Purpose: Conformal (called dynamic in BrainLab) arcs are conventionally used in cranial stereotactic radiosurgery (SRS). This study compares dosimetric parameters of volumetric modulated arc therapy (VMAT) and VMAT-conformal hybrid plans with conformal arc plans. In the hybrid plans, various numbers of conformal arcs in a conformal plan are replaced with VMAT arcs.

Methods: Ten brain cancer patients previously treated with frameless cranial stereotactic radiosurgery using conformal arcs were retrospectively studied with various numbers of VMAT arcs replacing the conformal arcs. Pure VMAT plans of different numbers of arcs were also generated using the same angle and arc length setup of all or part of the conformal arcs and compared with the original and hybrid plans. Pinnacle version 9.0 (Philips, Fitchburg WI) was used for the plan generation. SmartArc was used for the VMAT planning for a Novalis accelerator (Varian Medical Systems, Palo Alto, CA). The conformity index (CI), defined as the ratio of the isodose volume to the isodose covered target volume, gradient index (GI), defined as the ratio of the 30% isodose volume (V30) to the 100% isodose volume, mean dose in target were studied.

Results: With one of the conformal arcs replaced with a VMAT arc of the same weighting and geometric setup, the average CI with one standard deviation was improved from 1.21 ± 0.05 of the conformal plans to 1.17 ± 0.03 while the average GI degraded from 5.37 ± 0.51 to 7.36 ± 1.55 . The CI and GI values changed little with the number of arcs being replaced. Pure VMAT plans usually demonstrated better CI values than the hybrid plans when the number of arcs was greater than 2. For VMAT plans of 3 arcs, the CI and GI values were 1.05 ± 0.13 and 8.02 ± 1.04 respectively. The GI value was improved with increasing number of arcs in VMAT plans, but it was not better than that in the plans of conformal arcs. The degraded GI in plans with VMAT arcs is because of the absence of beam margin limit in SmartArc planning. For larger target volumes, all conformal, hybrid and VMAT plans were better in CI and GI. The mean dose in target volumes in VMAT plans was about the same as it in the conformal plans.

Conclusion: VMAT and conformal-VMAT hybrid plans usually offer better target conformity but compromise the dose fall-off in normal tissues due to the lack of beam margin limit in SmartArc planning. The number of arcs in VMAT plans is recommended to be greater than 2 for better CI and comparable GI values.

P1157

DOSIMETRIC CHARACTERIZATION OF BRAINLAB NOVALIS CONE-BASED STEREOTACTIC RADIOSURGERY

Daniel Zucca Aparicio¹ Juan María Pérez Moreno¹ Pedro Fernández Letón¹ Juan García Ruiz-zorrilla¹ Ángel Miñambres Moro¹

(1) Hospital Universitario Madrid Sanchinarro / Grupo Hospital de Madrid, Madrid, Spain

Objectives: Functional Radiosurgery is a treatment modality performed with Cone-Based

Stereotactic Radiosurgery (SRS) so small field sizes (down to 4.0 mm in diameter) are commonly used. The present abstract summarizes the Results obtained during the Commissioning of a SRS Treatment Planning System (TPS) previous to the clinical implementation of this type of treatments for patients treated with SRS.

Methods: Cone-Based SRS Commissioning for BrainLAB iPlan RT Dose 4.1.2. (Feldkirschen, Germany) TPS requires the measurement of Nominal LINAC Output, Relative Scatter Factors, Tissue Maximum Ratio (TMR) and the Off-Axis Ratio (OAR) for each cone collimator (diameters of 4.0, 6.0, 7.5 mm) following the measurement setup parameters (SSD and depth) based on the BrainLAB Physics Reference Guide. PTW MP3 water tank with Mephysto mc2 1.7.1. were used for the dose profiles and TMR measurements scanned with PTW 60012 diode detector (SSD 92.5 cm and depth of 7.5 cm for the OAR) Nominal LINAC Output was measured for the 100 mm x 100 mm square field size with a calibrated ionization chamber PTW 30013 (SSD 98.5 cm and depth of 1.5 cm) as well as the Relative Scatter Factors with PTW 60012 diode detector and normalized to the calibration geometry. Relative Scatter Factors measurements were performed aligning the diode detector with the radiation field for each cone collimator shifting along its CAX deviation. Jaw positions were selected to define a square shape of 14 mm x 14 mm while the mMLC was parked outside the radiation field as BrainLAB recommended.

Results: Relative Scatter Factors for the 4.0, 6.0, 7.5 mm cone collimators were 0.646, 0.765, 0.812, while Nominal LINAC Output was 1.012 cGy / MU. TMR scans were obtained to a depth of 210 mm with a scan resolution of 0.1 mm and OAR scans (both inplane and crossplane profiles) were obtained for the range from -60 mm to 60 mm with a scan resolution of 1.0 mm. For TPS input data reasons, OAR scans were processed with PTW DataAnalyze shifting all profiles along their CAX deviation, symmetrizing them and averaging inplane with crossplane profiles for each cone collimator.

Conclusions: Clarkson Dose Calculation Algorithm is a measurement based algorithm which is used for Conical Collimator Dose Calculation with iPlan RT Dose 4.1.2. so the good agreement between TPS dose calculations and LINAC dose measurements relies on a good performance of the data obtained for the beam modelling in TPS for each cone collimator.

P1158

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P1159

DOSIMETRIC CONSIDERATIONS FOR SPINAL SINGLE FRACTION INTENSITY MODULATED STEREOTACTIC RADIOSURGERY WITH BRAINLAB NOVALIS

Daniel Zucca Aparicio¹ Juan María Pérez Moreno¹ Pedro Fernández Letón¹ Juan García Ruiz-zorrilla¹ Ángel Miñambres Moro¹ Ángel Miñambres Moro¹

(1) Hospital Universitario Madrid Sanchinarro / Grupo Hospital de Madrid, Madrid, Spain

Objectives: Spinal Radiosurgery is often performed with Intensity Modulated Stereotactic Radiosurgery (IMRS) so availability of a class solution should be useful for routine planning of this

kind of treatments.

Methods: BrainLAB iPlan RT Dose 4.1.2. (Feldkirchen, Germany) TPS has been used for implementation of a class solution for spinal metastasis treatments based on 9 equal spaced coplanar IMRS beams (dynamic leaf sequencing) and considering IMRT optimization parameters such as 3 mm beamlet size max with adaptive dose grid size for small objects and tongue&groove optimization of segments. For ensuring dose fall-off outside PTV, Normal Tissue Restriction have been taken into account by considering a maximum dose around 5 mm from PTV of 16 Gy (dose prescription to PTV are such as 18 Gy covers 100% of volume) RTOG 0631 guidelines have been followed for the evaluation of the dose coverage for the PTV and HDV constraints for involved OAR. IMRT verifications with radiochromic film have been performed for each complete treatment by gamma analysis for axial plane measures by rescaling dose prescribed to be inside the optimal dose range from the calibration curve. Also bidimensional calibrated ion chambers array (PTW 2D array seven29) placed inside IMRT Phantom (PTW Octavius) measures have been analyzed for coronal plane gamma comparison and absolute dose distribution evaluation.

Results: From November 2008 to April 2010 we have treated 9 patients with vertebral metastasis, medium age 56 years [46-72], all the patients received single fraction of 18 Gy to the entire body of the vertebra and the affected transverse and spinous processes. The location of the vertebral metastasis was: cervical spine 2, thoracic spine 5, lumbar spine 2; none of the patients have had prior radiotherapy on the treatment site. The mean PTV volume was 51 cm³ [30-95]. Dose coverage was evaluated to ensure at least 90% of target volume was covered by 16 Gy and 95% of prescription dose covered 95% of PTV. All the cases analyzed accomplished the most important dose constraint of 10 Gy to the 10% of the partial spinal cord volume defined as 6 mm above and below the target. Gamma analysis (3% difference dose - 3 mm DTA) for Gafchromic EBT and Gafchromic EBT2 evaluated over a wide ROI around PTV cross section presents an agreement over 97.4% [mean 99.3%] for all the comparisons and for the complete film analysis over 92.1% [mean 95.7%]

Conclusions: A class solution has been provided to formalize Spinal Radiosurgery IMRT optimization and accomplish the recommendations included in RTOG 0631. In addition, IMRT quality assurance verification are needed due to the high doses involved in target volume very close to critical structures or embedded inside PTV.

P1160

IMAGE GUIDED STEREOTACTIC RT OF INOPERABLE LUNG TUMORS: TUMOR DOSE COVERAGE USING AN SBF AND CONVENTIONAL MARGINS

Christina Ramberg¹ Marius Røthe Arnesen¹ Åslaug Helland² Eirik Malinen^{1, 3} Einar Waldeland¹
(1) Department of Medical Physics, The Norwegian Radium Hospital, Oslo University Hospital, Oslo, Norway (2) Department of Clinical Oncology, The Norwegian Radium Hospital, Oslo University Hospital, Oslo, Norway (3) Department of Physics, University of Oslo, Oslo, Norway

Background: In our centre, some patients with inoperable lung tumors are treated with Stereotactic Body Radiation Therapy (SBRT), using immobilization in a Stereotactic Body Frame (SBF) and image-guided positioning. In the treatment planning, internal motion is accounted for using 4D-CT images for target contouring, facilitating direct delineation of the Internal Target Volume (ITV). Furthermore,

an isotropic 5 mm margin between the ITV and the Planning Target Volume (PTV) is applied.

The aim of this retrospective study was to investigate the impact of kV cone beam CT (CBCT) guided positioning on the dose delivered to lung cancer patients, and to discuss the need for set-up margins in SBRT.

Materials and Methods: So far twenty patients are included in this study, all treated at an Elekta Synergy linear accelerator equipped with a CBCT system. Using the lung tumor as positioning reference, the set-up corrections resulting from the CBCT guidance were extracted. Individual dose plans were recalculated by shifting the isocenter in the opposite direction of the set-up correction, thus mimicking a treatment where no set-up correction is performed. Resulting doses to the ITV and to organs at risk (OAR) were obtained.

Results: Preliminary Results indicate that 80% of the patients received full dose coverage to the ITV using the initial setup, without applying cone beam CT for positioning. The recalculation of the dose plans did not seem to affect the dose to the OARs systematically.

Conclusions: The majority of our patients will receive an appropriate treatment in the SBF, even without CBCT guidance. Thus, one may consider to increase the action limit for repositioning, or conversely to reduce the margin between ITV and PTV. For the latter, however, intrafraction motion should also be taken into account.

P1161

A CBCT-BASED METHODS FOR ESTIMATION OF TARGET DOSIMETRIC COVERAGE DURING LUNG STEREOTACTIC BODY RADIOTHERAPY (SBRT)

Juan Francisco Calvo Ortega¹ Joan Casals Farran¹ Enrique Puertas Calvo¹ Sol San José Maderuelo¹ Sandra Moragues Femenía¹

(1) Hospital Quirón, Barcelona, Spain

Purpose: A CBCT-based dose reconstruction procedure is presented in order to study the potential dosimetric impact on target coverage due to setup errors during lung SBRT treatments.

Materials/Methods: Lung SBRT treatments are planned in our department by using Eclipse TPS and delivered with a Varian Clinac 2100 CD equipped with the On Board Imager (OBI) system. Patients are immobilized on a vacuum bag and treatments are planned using the internal target volume (ITV) concept. ITV is delineated from five rapid planning CT scans covering different breathing phases (three free breathing, one deep end-inspiration and one end-expiration breath holding) and PET scan. No internal markers are used for target localization and not respiratory gating procedure is used during treatment delivery. Patient setup is performed on each treatment session by acquiring a CBCT scan which is on-line registered to the corresponding planning CT (pCT). Radiation oncologist performs the CBCT/pCT match so that the GTV visualized on CBCT scan is encompassed by the ITV structure. OBI system allows a 4 freedom degree registration, where three translations and one rotation (swivel) of linac couch can be remotely applied to patient. In order to check the dosimetric accuracy of this setup strategy, the following off-line dose reconstruction is done: i) each CBCT is imported into Eclipse TPS where treatment isocenter is localised; ii) treatment isocenter is mapped from CBCT to pCT via CBCT/pCT registration (6 degrees of freedom) and iii) original plan is re-calculated on pCT for the treatment isocenter to give the «delivered» plan. Three lung SBRT treatments were analysed to illustrate this procedure. Planned («intended») and re-

calculated («delivered») dose distributions were compared to assess the target volume dosimetric coverage during the SBRT course.

Results: On the analysed SBRT plans, a mean reduction of 4% on marginal dose to ITV was appreciated between intended and delivered plan. Differences within $\pm 3\%$ were noted on the mean and maximal doses on both plans.

Conclusions: CBCT technique allows to study the target coverage on each session and compare it with the intended one. Hence, it's possible to apply corrective strategies in case of large disagreements observed. The described Methodology permits to assess setup errors in terms of target dosage and provides a platform for lung SBRT adaptive therapy.

P1162

DOSIMETRY COMPARISON OF GATING V.S. ITV APPROACH FOR MOVING TARGETS IN SBRT, DYNAMIC TREATMENTS

Dror Alezra¹ Maoz Ben Ayun¹ Sergey Dubinsky¹ Zvi Symon¹ Roberto Spigelman² Uzi Nisim² Raphael Pfeffer¹

(1) Sheba medical center, Oncology Dept., Tel Hashomer, Israel (2) Sheba medical center, Neurosurgery Dept., Tel Hashomer, Israel

Introduction: To measure and determined the accuracy of delivered dynamic dose IMRT or RapidArc (RA) in cases of moving targets using gating vs. internal target volumes (ITV) approach for SBRT of lung or any other moving target.

Methods: A Varian breathing RPM phantom was attached to a toy wagon for simulating horizontal movements. A 2 slice Perspex phantom was placed on the wagon with option to use mini ion chamber and films for dose measurements. We investigated different setup combinations with different target moving distances, target sizes and shapes. All setup combinations underwent 4DCT. ITV and gated targets were delineated with ECLIPSE TPS contouring tools for all 4DCT phases.

Dynamic SBRT plans were created (RA, IMRT) with different dose rates to be delivered in different number of breathing cycles, and different MLC leaves direction, parallel and perpendicular to target moving direction. Point dose and 2D dose distribution were measured and compared to the calculated dose using DVH and Gamma test.

Results: The combination of dynamic SBRT and ITV approach may lead in some setup combinations to dosimetric errors of $>5\%$ in dose and $>5\text{mm}$ in isodose distance. In general Gated SBRT is more accurate from the dosimetry point of view.

Conclusions: ITV approach in SBRT dynamic treatments should be used with great caution and every dynamic SBRT protocol should take into account the dosimetry inaccuracy as a result of combination of: target moving distances; target size and shape; dose rate; number of breathing cycles; MLC leaves direction.

P1163

A CARBON FIBER MARKER CARRIER COUPLED TO A VACUUM BITE BLOCK FOR USE IN PROTON BEAM STEREOTACTIC PROTON TREATMENT

Melina Loubser¹ Julyan Symons¹ Chris Trauernicht² Jeanette Parkes² Sandra Sinske³ Fred Vernimmen³

(1) iThemba LABS, Cape Town, South Africa (2) Groote Schuur Hospital, Cape Town, South Africa (3) Tygerberg Hospital, Cape Town, South Africa

Objective: At iThemba LABS, a Stereo-Photogrammetric Patient Positioning System is used for proton stereotactic radiotherapy and radiosurgery of intracranial lesions. A bite block system was developed to decouple the localization system and the immobilization. The localisation device consists of a carbon fiber marker carrier embedded with 0.8 mm steel balls and mounted on a vacuum-assisted bite block. A study was done to evaluate the reseating reproducibility of the bite block.

Methods: Anterior-posterior and lateral films were taken during simulation and used as reference and at least two sets of treatment films. Open source software was used to measure the coordinates of the steel balls and specific bony landmarks. A program was used to do a registration between the related anatomical points on the treatment and simulation films. The transformation obtained from the registration was applied to transform the coordinates of the radio-opaque markers from the treatment film to the markers on the reference film. The differences between the transformed marker coordinates and the measured marker coordinates from the reference film describes the displacement of the carrier during the treatment session relative to its position during simulation.

Discussion: The placing of the anatomical landmark markers could have been influenced by subjective identification of corresponding bony landmarks and in some cases a limited dataset are factors that could have influenced the standard deviations.

Results: The average standard deviations in mm for AP, lat and axial respectively are 0.219, 0.374 and 0.324.

Conclusion: The vacuum-assisted bite block coupled to the carbon fiber marker carrier allows excellent repositioning reproducibility

Highly accurate positioning of the target is reached, when using the SPG system to position the carbon fiber marker carrier attached to the patient with the vacuum-assisted bite block

P1164

A COMPARISON OF DIFFERENT STEREOTACTIC RADIOSURGERY TREATMENT TECHNIQUES FOR EXTRACRANIAL LESIONS

Mahmoud Hegazy¹

(1) ROV, Melbourne, Australia

The purpose of this study is to compare circular collimators arc-based and mini-multileaf collimator (mMLC)-based radiosurgery treatment plans using isodose distributions and dose-volume histograms. A total of 12 patients were treated by conventional arc-based radiosurgery for extracranial malignancies, seven patients with one isocenter, four patients with two isocenters and one

patient with three isocenters. The same cases were re-planned using a test version of mMLC-based radiosurgery software for multiple static non-coplanar fields. For non-spherical targets, treatment planning is relatively intuitive with mMLC-based radiosurgery. It reduces the time required for planning. Moreover, a lower dose of radiation is delivered to normal tissue with mMLC-based radiosurgery than with arc-based radiosurgery, which may lead to the reduction of complications.

Keywords: Stereotactic radiosurgery; Mini-multileaf collimator; Isodose distributions; Dose-volume histograms

P1165

QUALITY MANAGEMENT PROGRAM (QMP) DESIGN FOR RADIATION THERAPY WITH AN EMPHASIS ON RADIOSURGERY AND SBRT

Nzhde Agazaryan¹

(1) UCLA School of Medicine, Los Angeles, USA

Objective: Radiosurgery and Stereotactic Body Radiotherapy have great potential but must be executed with care, caution and in a coordinated teamwork environment. Decisions are made in a complex environment that often involves sophisticated equipment, multidisciplinary team, evolving and ambiguous situations and performance pressure. The objective of this work is to design and then subsequently implement Radiation Therapy Quality Management Program (QMP) with an emphasis on Radiosurgery and Stereotactic Body Radiotherapy (SBRT) Programs.

Models and Methods: The underlying principle of the QMP design is a system of management activities that involves four cyclic quality action components: Define, Adapt, Improve and Sustain. In this model, quality metrics are primarily based on the assessment of incidents, resources, program structures and processes. Associated with that, the proposed Incident Decision Tree is based on James Reason's culpability model. The Decision Tree ensures a balance between systemic and individual responsibilities or collective and personal responsibilities.

Results: Resulting main components of the QMP are Quality Planning and Design, Quality Assurance, Quality Improvement, Incident Reporting and Response System. Quality Planning activity ensures that appropriate QC procedures are implemented and appropriate metrics are being recorded. Quality Assurance activity ensures proper execution of designed QC procedures and audits against expected metrics. Quality Improvement activity is a cyclical process that re-evaluates all aspects of the QMP for continuous improvement. Incident Reporting and Response System is a systematic Methods of reporting, prioritizing and responding to incidents. The QMP is ultimately overseen by the Quality Oversight Committee (QOC) who makes final recommendation to responsible administrative authorities of the institution.

Summary and Conclusions: Radiation therapy process has become highly complex with implementation of wide range of technologies that require wide range of expertise. The purpose of this work is to look at ways of reducing errors which are caused by systemic and individual human errors. The design and implementation phases of the QMP are strongly linked because almost undoubtedly implementation of initial designs will require far more resources than institutions can provide; hence, the design of the QMP itself must be continuously evaluated in view of available resources and effectiveness.

P1166

FIRST INDIAN EXPERIENCE WITH SHAPED BEAM RADIOSURGERY OF CRANIAL AND SPINAL LESIONS ON NOVALIX TX LINEAR ACCELERATOR WITH EXAC TRAC 6D ROBOTIC COUCH

Vijay Anand Reddy¹ Niteen More¹ Alok Ranjan² Rahul Lath² Kausik Bhattacharya¹ Vinitha Reddy¹ Gnana Ratnam Boola² Sajal Kakkar¹ Amitav Ray² Sajal Kakkar¹

(1) Dept of Radiation Oncology, Apollo Health City, Hyderabad, India (2) Dept of Neurosurgery, Apollo Health City, Hyderabad, India (3) Dept of Medical Physics, Apollo Health City, Hyderabad, India

Objective: To present the initial experience of stereotactic radiosurgery treatment of cranial and spinal lesions with Novalis Tx at Apollo Cancer Hospital, Hyderabad, India.

Methods: From May to October 2010, thirty three patients (8 arteriovenous malformations, 10 vestibular schwannomas, 2 trigeminal schwannomas, 3 meningiomas, 2 pituitary adenomas, 4 brain metastases and 4 spine metastases) were treated with stereotactic radiosurgery. 3D volumetric MR imaging was performed for every patient and was fused with high resolution (0.75mm thickness) stereotactic CT images on Brain Lab, iPlan planning system. Twenty two patients were considered for Frameless radiosurgery using BrainLab thermoplastic mask and ExacTrac 6 degree-of-freedom (6-D) robotic couch. Plans were generated using intensity modulated beams in 28 patients. Circular, small volume targets in 5 patients were treated with dynamic conformal arcs. Isocentre and X-ray calibration of Exac Trac system using X-ray calibration phantom with infrared markers was performed along with Winston Lutz test for Novalis Tx machine. For frame-based radiosurgery, beam's eye view projections were verified on treatment localizer box in eleven patients. For frameless radiosurgery, target position was verified using a pair of oblique X-rays fused with digitally reconstructed radiographs generated on Exac Trac system. The corrections in the couch positions were applied using 6-D robotic couch.

Results: Mean volumes of the targets were 4.39cc (range 0.29-18cc) in vestibular and trigeminal schwannomas; 14.95cc (range 4.4-31cc) in AVMs; 4.8cc (range 2.8-7.4cc) in meningiomas; 1.62cc (range 0.39-2.85cc) in pituitary adenomas; 0.56cc (range 0.2-1.5cc) in brain metastases and 42cc (range 14.5-83cc) in spine metastases. Mean volume of target in single fraction radiosurgery group was 3.93 cc (range 0.22-13.4cc). Mean dose for single fraction radiosurgery was 12Gy (range 12-13Gy for vestibular and trigeminal schwannomas; 18Gy (range 15-20Gy) for AVMs; 20Gy (range 18-23Gy) for brain metastases; 17.5Gy for pituitary adenomas, 14Gy for meningiomas. Large volume AVMs were treated with 28-35Gy divided in 4 or 5 daily fractions of 7Gy each. Vestibular schwannomas and meningiomas close to brainstem or optic chiasm were treated with 25 Gy divided in 5 fractions. Spine metastases were treated with 30Gy divided in 5 fractions.

Conclusions: Novalis Tx radiosurgery system can be used effectively for different cranial and spinal lesions. Fractionated radiosurgery treatment is feasible using Exac Trac 6-D robotic couch without compromising the target positioning accuracy.

P1167

COMPATIBILITY OF THE NEXSTIM NAVIGATED BRAIN STIMULATION SYSTEM WITH LEKSELL GAMMAPLAN AS AN AID FOR TREATMENT PLANNING.

Katharine Hunt¹ Alan Waterworth¹ Lee Walton¹ Andras Kemeny¹

(1) National Centre for Stereotactic Radiosurgery, Sheffield, UK

Introduction: The Nexstim Navigated Brain Stimulation (NBS) system utilises image-guided transcranial magnetic stimulation (TMS) to carry out cortical mapping.

Motor evoked potentials (MEP) triggered by TMS pulses are recorded with Electromyography EMG. The stimulus points, which produce maximal MEP responses, are mapped onto a co-registered Magnetic Resonance image (MRI) in order to create a mapping of critical areas within the motor cortex. The aim of this preliminary investigation was to test whether the NBS system output could be integrated with the Gamma Knife treatment planning system to give extra information about the location of eloquent areas such as the motor cortex to aid planning of Radiosurgery treatments close to these areas.

Methods: A volunteer underwent a T1 weighted MRI and non-invasive mapping of the primary motor cortex with the Nexstim NBS system using the MRI for image guidance. The MRI was aligned with the volunteer's head using 3D rendering and optical tracking.

The mapping process involved determination of the motor threshold before systematic mapping was performed with the aid of the NBS software grid displayed on the NBS screen.

Following analysis of the Results the stimulation points, representing the maximal MEP responses, were exported in DICOM format. This data set was combined with the MR scan using in house software developed in Sheffield. The combined MRI and stimulation point image set was then imported into GammaPlan. A second MRI was acquired with the volunteer's head positioned within the Elekta frame and MRI Fiducial box. This MRI was imported into GammaPlan and defined into stereotactic space using the Fiducials. The combined MRI and stimulation point image set was then co-registered with the stereotactic images using the GammaPlan co-registration software.

Results: Combining the NBS output and the MRI was successful with auditory canal and nose bridge landmarks on the stimulus output aligning correctly on the MRI. Co-registration of this combined image set with the stereotactic MRI using GammaPlan was also successful therefore this work has demonstrated that the NBS output can be imported into GammaPlan.

Conclusions: Through knowledge of the position of the maximal response stimulation points, it should be possible to create a treatment plan which delivers high dose to a lesion close to eloquent motor areas whilst minimising the dose to these eloquent areas using the beam blocking facilities provided by the Gamma Knife.

P1168

INVESTIGATION OF THE UNCERTAINTY OF THE DOSE MEASUREMENT OF A LUNG TISSUE USING A GLASS DOSIMETER IN LUNG SRT

Shimpei Hashimoto^{1, 2} Katsuyuki Karasawa¹ Yukio Fujita² Atsushi Myojoyama² Toru Kawachi³ Hidetoshi Saitoh²

(1) Tokyo Metropolitan Cancer and Infectious diseases Center Komagome Hospital, Tokyo, Japan (2) Tokyo Metropolitan University, Tokyo, Japan (3) Chiba Cancer Center, Chiba, Japan

Purpose: Stereotactic radiotherapy (SRT) is to reduce the dose of normal tissue, maintaining the homogeneity of the dose to a tumor by irradiating from many gantry angles and small radiation field. In the lung SRT, exposed dose evaluation of a lung tissue is an important factor for predicting generating of side effects, and accurate dose evaluation is needed. The dose calculation in lung tissue is more complicated than homogeneous materials, such as water, and it is necessary to understand the dose calculation accuracy. Measurement Methods of using a glass dosimeter into a lung tissue equivalent phantom is used for a verification of the dose calculation accuracy of a lung. Generally, the calibration for determining an absorbed dose from a glass dosimeter is performed in the water or a water equivalent phantom. However, the energy spectrum in the lung tissue equivalent phantom may differ from in the water. Therefore, when a glass dosimeter is calibrated in the water, the dose evaluation in a lung may not be performed correctly.

In this study, the measurement accuracy in a lung was examined by using a Monte Carlo simulation.

Material and Methods: The calculation of absorbed dose of glass dosimeter and water when a water phantom and a lung tissue equivalent phantom are irradiated with 6 MV X-rays (10 cm x10 cm field) was performed using the EGSnrc Monte Carlo code, respectively. Furthermore, the analysis of the electron which contributes to the absorbed dose of a glass dosimeter was performed.

Results: In the water, the ratio of the absorbed dose of water and a glass dosimeter was 1.153. On the other hand, in the lung tissue equivalent phantom condition, it was 1.163. Both difference was 1% and was a small difference. Moreover, in the absorbed dose of a glass dosimeter, the contributions by the electron generated from the glass dosimeter are 37% and 39% in a lung and underwater, respectively, and the large difference was not shown.

Conclusion: The present study examined the measurement accuracy of the dose evaluation of the lung tissue using the glass dosimeter. As a result, when it performed the dose evaluation of the lung tissue using the glass dosimeter calibrated in the water, it was shown that a high accuracy measurement is possible. The detailed spectrum analysis on actual irradiation conditions, such as a small radiation field, is due to be carried out in the future.

POSTER SESSION 2

P2001

DOSE TO MEDIUM VERSUS DOSE TO WATER AS AN ESTIMATOR OF DOSE TO POST EMBOLIZATION AVM RADIOSURGERY

Luiz Flávio Telles¹ Ademir Silva² Bruno Silva¹

(1) Liga Norte riograndense Contra o Câncer, Natal, Brazil (2) COPPE - UFRJ, Rio De Janeiro, Brazil

The Embolization is cutting off the blood supply to the AVM with glue introduced by a radiographically guided catheter. Thereby, the target volume (PTV) has tissue inhomogeneity. The purpose of this study is to determine whether dose to medium, Dm, or dose to water, Dw, provides a better estimate of the dose to the AVM radiosurgery. This is addressed in the larger context of the ongoing debate over whether Dm or Dw should be specified in Monte Carlo (MC) calculated radiotherapy treatment plans (Walters et al 2010, Dogan et al 2006).

The emitted radiation by focal source and scattered by head structures of the linear accelerator Clinac 2100 (6 MV) were simulated using two virtual sources in MCNP5 Monte Carlo code (Telles et al 2009). The skull has been simulated using elliptic geometry, both the composition and the stopping power mass of the bone, brain and skin were achieved on the National Institute of Standards and Technology site (NIST). The material used in the simulation of the glue was carbon (density=2,2 g/cm³). The electron flux obtained in the cell and stopping power mass was divided in 79 energy intervals and they were multiplied in each energy interval. The end result was so added in the energy range of 0,05 at the 6 MeV. The TMR and the output (or scattering factor) were simulated in MC to Dw and Dm. These values were compared with the TMR and the output obtained in the treatment plan software (TPS) Brainscan. The dosimetry performed to release the cone system was compared with the simulated dosimetry in the MC, thereby, the Methods used was validated. The bigger difference found in this latter comparison was smaller than 2%. The simulated TMR in the MC (Dw) was 5% bigger than that calculated by the TPS. The calculated output with MCNP (Dw) was 2.1% smaller than that obtained with the TPS. A tangent beam incident on the skull was simulated, what might explain the mentioned differences. A difference of 13% was obtained when compared the simulated TMR in MC (Dm) to the TMR calculated by TPS and of 1% when this comparison was between the simulated output in MC (Dm) and the output calculated by TPS. This difference of 13% might be due to the fact that the isocenter is located in the medium where there is glue. As there is a significant difference we can conclude that it is more advisable to use the Dm rather than the Dw.

P2002

ANALYSIS OF RADIOSURGERY-BASED ARTERIOVENOUS MALFORMATION GRADING SCALE AND FACTORS INVOLVED IN OBLITERATION AFTER GAMMAKNIFE RADIOSURGERY FOR ARTERIOVENOUS MALFORMATIONS

Pierre-Yves Borius¹ Michel Lefranc¹ Gustavo Touzet¹ Nicolas Reys¹ Thierry Sarrazin¹ Xavier Leclerc¹ Serge Blond¹

(1) Gamma-Knife Center, Department of Stereotaxy and Functional Neurosurgery Hospital Roger Salengro, Lille Regional University Hospital, Lille, France

We analyze factors involved in obliteration and the predictive value of modified radiosurgery-based arteriovenous malformation (AVM) grading scale (RBAS).

Between January 2004 and June 2006, 330 patients with cerebral AVMs were treated by Leksell Gamma Knife 4C. The mean age was 35 years [7-77]. The discovery mode was bleeding (43.1%), epilepsy (27.9%), headache (13.3%), fortuitous (10.3%) or neurologic deficit (5.4%). Nineteen patients (5.75%) had a partial surgical resection, 137 (41.5%) embolizations and 46 (14%) a LINAC radiosurgery. The average volume was 2.3cm³ [0.09-14.7] with a median of 1.3cm³. The mean peripheral dose prescribed to isodose 50% was 23.6Gy [17-25], median dose of 24Gy was prescribed in 70.3% of cases. RBAS was defined by: $(0.1 \times \text{volume cm}^3) + (0.02 \times \text{age years}) + (0.5 \times \text{location})$. The location values are brainstem, basal ganglia, thalamus = 1, other = 0.

Clinical and radiological follow-up were completed for 237 patients with a mean duration of 3.9 years [2-6.2]. Seven patients (2.9%) died, 3 from hemorrhage, 2 unrelated to the AVM and 2 of undetermined cause. During follow-up, 16 (6.75%) patients had a bleeding episode, including 3 deaths. Nine patients were cured after surgical excision because of the occurrence of hemorrhage (4) or the persistence of a residue (5). The absence of obliteration or partial occlusion was noted in 94 patients including 3 with a staged radiosurgery procedure. A complete obliteration was present in 127 patients. The overall cure rate is 57.4%. New neurological deficits occurred in 6 patients (2.5%) including 3 transients and 3 permanents despite corticosteroid therapy. Of the 31 patients who underwent radiosurgery first 14 are cured. The mean RBAS was 1.01 [0.24-2.35], mean for patients with obliteration was 0.936 and 1,106 without. Complete obliteration was achieved in 70.1, 65.1, 58.1, and 41.5% of patients with respectively AVM scores of <0.8, between 0.8 and <1, between 1 and <1.2, and >or=1.2. Factors leading to a better obliteration rate were smaller nidus, higher marginal dose, K index ($p < 0.0001$), lower RBAS ($p = 0.002$) and no prior embolization ($p = 0.02$), but age, location and prior radiosurgery were not correlated with obliteration.

The RBAS seems to be a predictor of obliteration in patients with AVMs.

P2003

FIVE YEAR EXPERIENCE OF TREATMENT AVM IN MOSCOW GAMMA-KNIFE CENTER, RUSSIA

S Maryashev¹ A Golanov¹ S Il'yalov¹ S Yakovlev¹ I Pronin¹ V Kostjuchenko¹ M Zotova¹

(1) NN Burdenko Neurosurgical Institute, Moscow, Russian Federation

Stereotactic radiosurgery was proved as useful treatment of small arteriovenous malformations (AVMs) of the brain. The first line of treatment of patients with AVM is embolisation and surgical resection. In cases when it is impossible radiosurgery can be use. To avoid the reduction of AVM-volume pre-radiosurgical embolisation used. Though the efficiency of treatment after embolisation is slightly less. Recanalisation of embolized AVM components may require often retreatment for portions of the AVM previously thought to be occluded by successful embolization. Surgical removal is an important option for patients with resectable AVMs, although incomplete surgical removal require eventual radiosurgery

Methods: Between October may 2005 and September 2010, 1411 patients with different intracranial pathology was treated in Moscow gamma knife center. 128 patients were with AVMs.

Preradiosurgical embolization was used in 25 cases, in 5 patients grosse-volume hematoma was evacuated. The volume of the nidus ranged from 0.09 to 16.8 cm³ (median 2.9 cm³). It is known, that the authentic result of obliteration can be received only after two years of supervision of radiosurgery, so only in 88 patients we have follow-up angio control investigation.

Results: in 88 patients for whom we received control angio-investigation from 2005 till 2008 AVM obliteration was achieved in 67% after radiosurgery. Final angiography verified complete obliteration by 12 to 96 months (median, 25 months) after initial radiosurgery. Smaller volume AVMs and the application of a higher radiation dose resulted in a higher chance of obliteration. The risk of rebleeding after radiosurgery was 2% until full obliteration, and the overall mortality from rebleeding was 0%.

We analyse factors which can influence on Results of obliteration after GN radiosurgery: - age, previous embolisation, previous hemorrhage, AVM volume, dose etc..

Asignificantly higher incidence of AVM nidus obliteration was observed in male patients, in patients with previous hemorrhage, in patients with an AVM volume less than 10.0 cm³, in patients in whom the dose to maximum in the avm nidus was higher than 35 gy.

Conclusion: gamma knife radiosurgery can offer a high cure rate for patients treated for AVMs with a low risk of morbidity and mortality from rebleeding during the latent period. The Methods can be use as a single option in treatment of patients with AVM and also as a part of combined treatment with surgery and embolisation.

P2004

EXTENSIVE RADIONECROSIS MASS AND CYSTS COMPLICATIONS AFTER STEREOTACTIC RADIOSURGERY FOR AVM: ILLUSTRATIONS, RISKS FACTORS AND MANAGEMENT

Michel Lefranc¹ Nicolas Reyns¹ Gustavo Touzet¹ Xavier Leclerc¹ Thierry Sarrazin¹ Eric Lartigau¹ Serge Blond¹

(1) Gamma-Knife Center, Department of Stereotaxy and Functional Neurosurgery, Hospital Roger Salengro, Centre Hospitalier Regional Universitaire 59037 Lille-Cedex France, Lille, France

Purpose: Stereotactic Radiosurgery (SRS) as primary or secondary treatment in brain arteriovenous malformation (AVM) is now a well-accepted, proven and effective way of reducing the risk of hemorrhage from AVM. SRS allows, with a very low morbidity and mortality rate, the treatment of AVM by endothelium obliteration. Radionecrotic mass and cysts are ones of the main side effects of SRS.

Material and Methods: We present 4 cases of extensive mass radionecrosis secondary to AVM SRS associated or not with extensive cysts. We illustrate the management of these 4 cases pointing on their common characteristics' and our management.

Results: There were 3 supra tentorial AVM and 1 in regard of the brainstem. All AVM were symptomatic revealed by hemorrhage in 3 cases and by epilepsy in 1 case. The mean irradiation dose was 21 Gy at 70% isodose margin (first stage / LINAC SRS). In 2 cases there were 2 SRS procedures in front of persistence of nidus after a mean delay of 5 years.

In 2 cases, AVM were angiographically occulted and appeared occulted on MRI in 1 case. In 1 case there was still an active nidus. In 3 cases, edema was present before extensive radionecrosis after a mean delay of 7,3 years. Extensive mass radionecrosis appeared after a mean delay of 11,5

years. In one case steroid therapy was sufficient to solve symptoms. The patient is steroid therapy free today. There is still a radionecrosis mass but without mass effect. 3 cases were resistant and dependent to steroid therapy. There was one death (brainstem AVM). In one case we placed a catheter into the cyst relied to Omayya's reservoir and allow a regression of the major part of the symptoms but the patient is still dependent of steroid. In the last case, the patient is still symptomatic; surgical resection is discussed.

Conclusion: Even if extensive mass radionecrosis are very rare complications, they must be known by radiosurgeons. Steroid therapy must be the first step of the management. Then therapies, even surgical resection, must be discussed case-by-case depending on the clinical status of the patient. The long time occurring after SRS procedure points out the importance of an extra long clinical and radiological follow up even after the obliteration of the AVM.

P2005

ARTERIOVENOUS MALFORMATIONS NON INVASIVE STEREOTACTIC RADIOSURGERY

Ruth Rodríguez Romero¹ Pablo Castro Tejero¹ Patricia Sánchez Rubio¹ Luis Núñez Martín¹ Juan Carlos Medrano¹

(1) Servicio de Radiofísica. Hospital Puerta de Hierro Majadahonda, Madrid, Spain

Objective: Stereotactic Radiosurgery has historically been associated with invasive systems that would ensure sub-millimeter accuracy to deliver high radiation doses to small volumes. Stereotactic frames are not necessary for radiosurgery treatment since non invasive system were developed improving patient comfort without compromising accuracy. BrainLAB cranial frameless treatments are not unusual except in AVM cases whose angiography localizer compatibility has recently been available. This study analyzes the preliminary Results of frameless AVM patients accuracy positioning.

Methods: Fiducial markers on thermoplastic mask have been used to check the agreement between angiography and CT images both for an anthropomorphic head phantom and a patient.

Patients are pre-positioned using infrared system and stereoscopic xray images are acquired to be registered with DRR to achieve shift corrections to be applied with 0° couch angle. According to our IGRT protocol for radiosurgery treatments, another set of xray images are obtained at initial position to ensure the accuracy of the corrections performed. For significant couch angle rotation treatment (>45°) more verification images are acquired and registered.

Nine patients displacement have been analyzed to quantify residual error, possible systematic errors and intrafraction movement.

Results: Checks performed with fiducial markers show deviations below 1.0 mm, except 1.5 mm longitudinal axis probably due to CT spatial resolution (usual slice thickness is 2 mm).

From IGRT data a residual error was estimated for translations +0.3mm and rotations +0.3°. Systematic and intrafraction movements obtained are <1mm <1° in any direction.

Conclusions: Reliability of angiography and CT images correlation has been proven. Therefore spatial discordances between both image sets would be caused by incorrect mask fit and/or low patient movement inside the mask, as could happen during the treatment date, so it should be comparable as IGRT errors obtained. Anyway disagreement between angiography and CT images can be easily detected, quantified and solved without discomfort head frame patient. In

addition, BrainLAB radiosurgery frameless allows patient positioning control at any moment while unexpected head frames shifts can occur and there is no way to easily detect and correct them. With non-invasive system more complex irradiation techniques as IMRT are allowed since it can be designed and verified previously.

References: Breneman et al. International Journal of Radiation Oncology Biology Physics. 2008 74(3)702-706.

Takakura et al. Phys Med Biol 2010 55:1-10.

P2006

GAMMA KNIFE RADIOSURGERY FOR CEREBRAL ARTERIOVENOUS MALFORMATIONS: RESULTS: OF TREATMENT OF 69 CONSECUTIVE PATIENTS AT A SINGLE CENTRE.

Frederick Zeiler¹ Anthony Kaufmann¹ Derek Fewer¹ Garry Schroeder² Patrick Mcdonald¹ Michael West¹

(1) University of Manitoba, Dept of Neurosurgery, Winnipeg, Canada (2) University of Manitoba, Dept of Radiation Oncology, Winnipeg, Canada

Background: Treatment of cerebral arteriovenous malformations (AVM) includes surgical resection, endovascular embolization, and recently stereotactic radiosurgery. This study reports the institutional Results of a consecutive series of patients treated with Gamma Knife (GK) radiosurgery for cerebral AVMs.

Methods: We retrospectively reviewed 69 patients treated with GK for cerebral AVM between November 2003 and August 2010. Clinical data, treatment parameters, and AVM obliteration rates were evaluated.

Results: There were 69 patients. Ten patients were lost to follow-up. Presentations included: seizure (24), hemorrhage (18), persistent headache (12), progressing neurological signs (10), and asymptomatic (9). In 24 patients (34.8%) treatment planning consisted of digital subtraction angiography (DSA), MRI, and CT angiography. We relied on CT angiography and/or MRI scanning only, in 45 patients (65.2%).

Forty-one patients have been followed for a minimum of 3 years, with an average age of 40.9 years and 58.5% being male. AVM locations included: 9 frontal, 9 temporal, 6 parietal, 9 occipital, 4 cerebellar, 2 brainstem, 6 basal ganglia, and 1 midline. Six AVMs overlapped two cortical regions. Average dose at the 50% isodose line was 20.3 Gy, with doses ranging 16 to 26.4 Gy. Obliteration was observed in 87.8% of this group by MRI, CT, or DSA. Not all obliteration was confirmed by DSA. Average time until radiographic change in AVM size was 12.6 months, with one patient failing to demonstrate any AVM response. There were patients 37 patients with 3 years of follow up and single stage therapy, 34 of 37 (91.9%) demonstrated AVM obliteration.

Complications occurred in 12 of 59 (20.3%) patients, and in 11 of 41 (26.8%) with 3 year follow-up. Temporary complications for the 59 included symptomatic cerebral edema (7), seizure (2), and hemorrhage (1). Permanent complications occurred in one patient suffering a cranial nerve V deafferentation, and in 2 patients suffering a hemorrhage, one of which was lost to follow-up.

Conclusion: GK of cerebral AVM's offers an effective and safe Methods of treatment, with low permanent complication rate.

P2007

INFLUENCE OF THE INTRODUCTION OF GAMMA KNIFE RADIOSURGERY ON THE NEUROSURGICAL MANAGEMENT OF CEREBRAL ARTERIOVENOUS MALFORMATIONS. THE MOROCCAN EXPERIENCE.

Adyl Melhaoui^{1, 2} Yasser Arkha^{1, 2} Justin Onen² Achille Komlan² Abdessamad El Ouahabi² Mohamed Jiddane¹ Moulay Rachid El Hassani¹ Abdeslam El Khamlichi^{1, 2}

(1) Radiosurgical Unit, Gamma knife perfexion, National Centre of Rehabilitation and Neurosciences, Rabat, Morocco (2) Department of Neurosurgery ,Hopital des Specialites, O.N.O, Rabat, Morocco

Introduction: Arteriovenous malformations are common condition in our areas and represent the most treated pathology in our Gamma Knife Center. Radiosurgery by Gamma Knife is an effective treatment strategy that permits a progressive obliteration of the malformation with time. Through our recent experience with the first 93 cases radiosurgically treated cases, we propose to assess the influence of introduction of such technique on our practice when compared to historical series in our department.

Material and Methods: A review of the prospective database at the radiosurgery Gamma Knife Unit was carried out, with Results obtained of 93 patients treated between June 2008 and June 2010. All patients are treated according to one standardised radiosurgical Methods based on a planning according to MRI CT scan and angiography imaging. Yearly follow-ups with MRIs are instituted and the Results are then quantified. The Results of this series are compared to a historical series of 73 cases treated between 1990 and 2008.

Results: The radiosurgical series comprises 66 males and 27 females, the mean age was 31.75 years (8-63), The most common presentation was cerebral haemorrhage 39 cases and epilepsy 13 cases, the average volume was 3 cc, the average prescribed marginal dose was 24Grays. 33 patients had MRI done at 1 year follow-up and the rate of observed significative modification in terms of reduction of intranidal flow well exceeds 60%. Perilesional oedema was observed in two cases and one case presented a new hemorrhagic episode. In the historical series 20 cases were treated by surgery with good Results especially in Spetzler Grades I and II while only 15% of patients treated by endovascular technics, the embolisation could achieve total occlusion, 3 cases had to be transferred abroad for radiosurgical treatment.

Comments: The follow-up at one year in our recent radiosurgical experience clearly demonstrates a reduction in intranidal flow of the malformations in more than half the cases which illustrates an early effect of radiosurgery on the AVMs while the complication rate remains very low. When compared to our historical series the introduction of radiosurgery seems to provide benefits to a large number of patients with deep seated AVMs not treatable by endovascular techniques.

P2008

NIDUS OBLITERATION AFTER GAMMA KNIFE RADIOSURGERY FOR ARTERIOVENOUS MALFORMATIONS OF BRAIN. A STUDY OF 102 CASES.

Abid Saleem¹ Azher Rashid¹ M Hashim A Sattar¹

(1) Pakistan GammaKnife and Stereotactic Radiosurgery center.NMI, Karachi, Pakistan

Objective: Gamma knife radiosurgery is in its infancy in Pakistan. The first and only Gamma

unit was stabilised at NMI Karachi in May 2008. We have treated more than 800 patients so far with various indications. The present paper is an interim retrospective study of 102 cases of arteriovenous malformations and will overview the radiosurgical technique utilised, demographic data, clinical outcome and the Results.

Material and Methods: In an initial two years experience using 201 source cobalt 60 Gamma knife at Pakistan Gamma Knife center Karachi 835 patients were treated which include 102 cases with arteriovenous malformations. There were 31 females and 70 males whose ages ranged between 6 and 60 years (median age 25.7 yrs.). Symptoms at presentation included prior hemorrhage in 76 pts (74%), seizures in 19 patients (18%) and neurological deficits were present in 43 pts (42%). Prior subtotal surgical resection was performed in three cases and embolisation was attempted in two cases. The lesions were classified according to the S.M. grading system. There were 11 patients in Grade I, 23 pts. in Grade II, 33 patients in Grade III, 19 pts. in Grade IV and 3 pts. in Grade VI. Total coverage was possible in 96% cases. The median margin dose was 19.5 Gy (range 16-24 Gy). Two cases underwent prospective volume based staged radiosurgery.

Results: The patients were followed up with 6 monthly MRI or CT angiography for two years and then annually. Successful complete nidus obliteration is achieved as early as one year. Substantial obliteration is noticed in 6 month follow up even in larger AVMs. Out of 14 patients who have completed 2 years after gamma knife radiosurgery, radiological images are available for review for 12 patients. Complete obliteration is noted in 8 patients (67%). Partial obliteration upto 80 % is noted in rest of the 4 patients. Out of 66 patients who have completed one year follow up 40 patients with radiological follow up are available for review. Total obliteration is noted in 17 Pts. (42.2%). Partial Obliteration is noted in 23 Pts. (57.5%).

Young age, hemispheric location, low flow and few draining veins were associated with successful outcome. Four patients had re bleed while in the latency period. Increase T2 signals were noted around the obliterating AVM in 5% cases without new neurological deficits at 6-8 month interval which resolved completely in later images.

Conclusion: GammaKnife radiosurgery is a safe and effective Methods for obliteration of AVMs even those previously considered inoperable. It also improves symptoms, controls seizures and preserves existing neurological functions.

P2009

TREATMENT OF AVM USING LINEAR ACCELERATOR BASED RADIO-SURGERY: INSTITUTIONAL EXPERIENCE AND PRELIMINARY RESULTS

Vikram Maiya Manoor¹ Ashok Bhanage¹ Sathyanarayanan Kumaraswamy¹ Sumeet Basu¹

(1) Ruby Hall Cancer center, Pune, India

Objective: There is an inadequacy of data in private hospitals for the treatments of arterio venous malformations (AVM) using linear accelerator based stereo tactic radio-surgery (SRS) in the Indian scenario. We present the data on our experience for the treatment of AVMs.

Methods: Between April 2006 to September 2010, 27 patients were treated with SRS according to location, size, initial presentation, neurological condition and prior intervention for the AVM. All patients underwent either digital subtracted angiography (DSA) before the procedure. 2 patients underwent magnetic resonance angiography (MRA) as they had undergone embolization with

Onyx so as to prevent the artifacts. Brainlab invasive frame was used and CT scan was done using a localizing box. After localization, fusion and planning on Brainlab software, the final dose prescription was done and treatment delivered using either arcs or fixed beams. Patients were followed up with either a DSA or CT angiography.

Results: The male to female ratio of the patients were 1.7. The mean age of the patients was 33 (range 9 to 64). The mean volume of PTV was 15.92 cc (range 0.63 to 60 cc). The mean dose prescribed was 19.79 Gy (range 15 to 24 Gy). The mean conformity index was 1.73 (range 1.3 to 2.1). The maximum dose to the brain stem and optic chiasm were 5.2 Gy and 2.9 Gy respectively. 2 of the patients had immediate post procedural seizures and were managed accordingly. At a median follow up of 24 months (range 1 to 36 months), of the 15 patients who presented with seizures, 13 of them had no further episodes of seizures. Of the 10 patients who underwent CT angiography or DSA at 1.5 to 2 yrs, 8 of them showed complete obliteration of the AVM and 2 of them showed partial obliteration.

Conclusion: Proper selection of cases provides optimum obliteration rates in AVM.

P2010

THE DIFFERENCE BETWEEN THE TARGET DELINEATED BY CROSS-SECTIONAL IMAGES AND ANGIOGRAPHY FOR STEREOTACTIC RADIOSURGERY TO INTRACRANIAL VASCULAR LESION

Yu-jie Huang^{1, 3}, Yeh-lin Kuo¹, Pei-ju Chao¹, Ya-yu Huang¹

(1) Radiation Oncology, Chang Gung Memorial Hospital – Kaohsiung Medical Center, Chang Gung University College of Medicine, Kaohsiung, Taiwan (2) Radiology, Chang Gung Memorial Hospital – Kaohsiung Medical Center, Chang Gung University College of Medicine, Kaohsiung, Taiwan (3) Bio-Image and Electronics Laboratory, Institute of Biomedical Engineering, National Cheng Kung University, Tainan, Taiwan

Purpose: To evaluate the difference of the target delineated by computer tomography (CT), Magnetic resonance imaging (MRI) and angiography for stereotactic radiosurgery to intracranial vascular lesions.

Materials and Methods: The patient who underwent stereotactic radiosurgery to intracranial vascular lesions had MRI study before head ring fixation. The angiography with localizer and the CT study for radiosurgery treatment planning were performed. The image registration was handled by BrainLab iPlan RT Image. The lesion was delineated according to angiography, CT, MRI and CT-MRI fusion by radiologist respectively. The target volume by CT, MRI, CT-MRI fusion was compared with the volume defined by angiography.

Results: 18 intravascular targets for stereotactic radiosurgery were checked. The target volume defined by CT, MRI, CT-MRI fusion and angiography were 0.48-61.42cm³, 0.45-43.09cm³, 0.07-54.87cm³ and 0.10-65.83cm³. The pair t-test of the target volume defined by different image modality demonstrates a statistical significant ($p < 0.001$). The percentage for the intersection volume delineated by CT, MRI and CT-MRI fusion with angiography was 48.2%, 54.4% and 66.7%, respectively.

Conclusion: There are clear disagreement between the targets defined by different image modality for intracranial vascular lesion. The targeting of intravascular lesions should be manipulated carefully and comprehensively.

P2011

OUTCOME OF LINAC-BASED SRS FOR ARTERIOVENOUS MALFORMATION: THE ST LUKE'S MEDICAL CENTER EXPERIENCE

Miriam Joy Calaguas¹ Frances Lily Lantin¹ Emmanuel Enrique Magalona¹ Peter Rivera¹

(¹) St Luke's Medical Center, Quezon City, Philippines

The study aims to present the experience of St Luke's Medical Center Department of Radiation Oncology on Linac-Based Stereotactic Radiosurgery (SRS) in patients with Arteriovenous Malformation (AVM). In this retrospective analysis, the dosimetric and clinical outcomes of patients treated with Stereotactic Radiosurgery for Arteriovenous Malformation (AVM) will be described.

The specific objectives are as follows:

1. Determine the obliteration rate of AVMs after LINAC-based stereotactic radiosurgery at St Luke's Medical Center
2. Present the demographic and dosimetric profiles of patients with AVM who underwent linac-based SRS at St Luke's Medical Center from 2003-2009
3. Document the incidence of morbidity or complications post-SRS for AVM

Materials and Methods: A descriptive, retrospective analysis will be done on patients with angiography-proven arteriovenous malformation (AVM) who underwent stereotactic radiosurgery at St Luke's Medical Center from 2003-2009

Inclusion Criteria: Patients with AVMs who underwent SRS at St Luke's Medical Center from 2003-2009.

Exclusion Criteria: Patients without follow-up imaging studies (DSA or MRI/MRA) post-SRS will be excluded.

Results: The mean nidus volume, mean prescribed maximum dose and the marginal dose will be presented. Mean dose to brain stem, optic chiasm and other organs at risk will be defined as well. Obliteration rate of AVMs treated with SRS will be determined. Patients will be followed-up for incidence of morbidity post-SRS or episodes of hemorrhage

Conclusion: Careful selection of cases suitable for SRS provides optimum obliteration rates with low toxicity. It is hoped that through presenting our local experience on LINAC-based SRS for obliteration of AVM, we will be able to identify factors that will allow us to select which patients will benefit most from this treatment.

References: 1. Flickinger JC, Kondziolka D, Maitza AH, Lunsford LD. An analysis of the dose-response for arteriovenous malformation radiosurgery and other factors affecting obliteration. *Radiother Oncol* 2002;63:347-54

2. Saunders WM, Winston KR, Siddon RL, Svensson GH, Kijewski PK, Rice RK, et al. Radiosurgery for arteriovenous malformation of the brain using a standard linear accelerator: rationale and technique. *Int J Rad Oncol Biol Phys*. 1988;15:441-4.

3. Schlienger M, Atlan D, Lefkopoulos D et al. LINAC radiosurgery for cerebral arteriovenous malformations: Results in 169 patients. *Int J Rad Oncol Biol Phys* 2000;46:1135-42

P2012

DYNAMIC AND REVERSIBLE CHANGES ON MAGNETIC RESONANCE IMAGES MIMICKING RADIATION NECROSIS AFTER GAMMA KNIFE RADIOSURGERY FOR ARTERIOVENOUS MALFORMATIONS.

Atsuya Akabane¹ Itaru Kanazawa¹ Toru Machida² Ichiro Shirouzu² Akio Morita³ Chikayuki Ochiai³

(1) Gamma Knife Center, NTT Medical Center Tokyo, Tokyo, Japan (2) Department of Radiology, NTT Medical Center Tokyo, Tokyo, Japan (3) Department of Neurosurgery, NTT Medical Center Tokyo, Tokyo, Japan

Backgrounds/Purposes: Radiation necrosis, which sometimes occurs after gamma knife radiosurgery (GKS), is generally considered an irreversible pathological change. Therefore, the findings on magnetic resonance (MR) images resulted from the radiation necrosis, such as a high-signal intensity area on T2-weighted images (T2HIA) and contrast-enhancement of the surrounding the irradiated nidus, are usually kept for more than several years. However, we found that dynamic and reversible changes on MR images, of which the features are similar to them caused by the radiation necrosis but quite different, occasionally appear after GKS for arteriovenous malformations (AVM). A unique difference was that they were almost completely resolved within several months. The aim of this study is to make clear the characteristics and pathogenesis of these unique, dynamic and reversible changes on MR images after GKS for AVM.

Materials and Methods: This investigation included 44 patients who underwent GKS for AVM from 2003 to 2007 and then routinely underwent neuroimaging follow-up only at our institution. The mean age of the patients was 44 years, the mean nidus volume was 3.6 ml, and the mean peripheral dose was 22 Gy. All patients underwent MR imaging 3 and 6 months after GKS and then every 6 months thereafter or, in the event of abnormal findings, more frequently. The medical record and MR images obtained from the follow-up studies are retrospectively analyzed.

Results: Over a mean follow-up period of 45 (6 to 93) months, 4 patients (9%) presented the dynamic and reversible changes on MR images. In these 4 patients, the T2HIA and contrast-enhancement surrounding the irradiated nidus appeared accompanying a shrinkage of the nidus and narrowing of the draining veins at an average of 9 months after GKS, and rapidly peaked 6 months on average thereafter. These changes on MR images were mostly resolved 10 months thereafter on average. Cerebral angiography revealed complete or near-complete nidus occlusion in all these patients, indicating a good response to GKS. With a mean age of 15 years, these patients were significantly younger than the others, but peripheral dose and nidus volume did not differ significantly from those of the other patients.

Discussions: The fact that the T2HIA and contrast-enhanced regions were completely resolved within several months suggests that these changes are not resulted from radiation necrosis. The concurrent a shrinkage of the nidus and a narrowing of draining veins indicates that rapid hemodynamic change such as occlusive hyperemia may, at least in part, participate in this pathogenesis.

Conclusions: It is concluded that during the process of nidus obliteration after GKS, hemodynamic imbalance may causes a transient but extensive brain edema particularly in young patients.

P2013

INTRACTABLE SEIZURES AFTER RADIOSURGERY OF AVM: EFFECTIVENESS OF MICROSURGICAL RESECTION OF THE OBLITERATED NIDUS

Masahiro Izawa¹ Mikhail Chernov^{1, 2, 3} Motohiro Hayashi^{1, 2} Noriko Tamura¹ Hiroshi Iseki^{1, 2} Yoshikazu Okada¹ Kintomo Takakura^{1, 2}

(1) Department of Neurosurgery, Tokyo Women's Medical University, Tokyo, Japan (2) Faculty of Advanced Techno-Surgery, Tokyo Women's Medical University, Tokyo, Japan (3) Diagnostic and Treatment Center, International Institute of the Biological Systems, Saint-petersburg, Russian Federation

Objective: Evaluation of outcome after microsurgical resection of the obliterated nidus for management of intractable seizures after Gamma Knife radiosurgery (GKR) of cerebral AVM.

Materials and Methods: From 1993 to 2010, 546 patients with intracranial AVM were treated with GKR in Tokyo Women's Medical University. Nine of them underwent subsequent microsurgical resection of the obliterated AVM nidus due to persistent intractable seizures. One case was lost to follow-up, whereas 8 others were analyzed retrospectively.

There were 5 men and 3 women. Their age varied from 21 to 60 years (mean, 40). All AVM were located in the cerebral lobes: frontal (2 cases), parietal (3 cases), and temporal (3 cases). The volume of the nidus varied from 3.8 to 15.3 ml (mean, 9.6 ml). Seizures were initial presentation of the disease in 6 patients, and headache in 2. No one patient underwent embolisation of the nidus. Radiosurgery was done using Leksell Gamma Knife model B in 7 cases, and model C in one. The marginal dose varied from 15 to 22.5 Gy (mean, 19.3), and maximal dose from 25 to 50 Gy (mean, 43.9). The treatment resulted in complete nidus obliteration in 6 cases, and in incomplete obliteration in two. The interval between GKR and surgery varied from 4 to 15 years (mean, 8). The main indication for surgery was intractable seizures (all 8 cases), which were associated with presence of residual nidus (2 cases), persistence or increase of the neurological symptoms (4 cases), or headache (1 case).

Results: In all cases complete resection of the obliterated and residual (if presented) nidus was achieved. Postoperative complications were encountered in 4 patients and included mild hemiparesis (2 cases), mild visual field deficit (2 cases), and cognitive impairment (1 case). Follow-up after surgery varied from 14 to 120 months (mean, 67). All patients achieved freedom from seizures.

Discussion: Intractable seizures represent rare, but troublesome complication after radiosurgical treatment of AVM. Delayed injury and destruction to areas near the radiosurgical target may contribute to its development [1]. As it is shown in the present study microsurgical resection of the nidus provides good outcome in the majority of such patients.

Conclusion: Microsurgical resection of the obliterated nidus should be considered as a reasonable management option for intractable seizures on the long-term follow-up after radiosurgery for cerebral AVM.

Reference:

1. Husain AM, et al: Intractable epilepsy following radiosurgery for arteriovenous malformation. J Neurosurg 95: 888-892, 2001.

P2014

LONG-TERM SEIZURE OUTCOME AFTER RADIOSURGERY FOR CEREBRAL ARTERIOVENOUS MALFORMATIONS

Seung-Yeob Yang¹ Dong Gyu Kim² Hyun-Tai Chung²

(1) DongGuk University Graduate School, Seoul, Korea(2) Seoul National University College of Medicine, Seoul, Korea

Background: Conclusions about seizure outcome after radiosurgery for arteriovenous malformations (AVMs) are difficult to draw because of its inadequate assessment as a secondary target of most studies and lack of consistent seizure outcome assessment. We aimed to determine the effect of radiosurgery on seizure outcome in patients having seizure without a hemorrhage, depending on AVM obliteration.

Methods: Between 1997 and 2006, 86 consecutive patients presented with seizure underwent radiosurgery for unruptured AVM and were retrospectively assessed by their medical records and updated clinical information when necessary with direct patient contact. Assessment of seizure outcome was performed using the Engel seizure frequency scoring system.

Results: Follow-ups ranged from 43.7 to 151.0 months (mean, 89.5 months). The duration of epilepsy before radiosurgery ranged from 1.0 to 421.1 months (mean 38.8 months). Of these 86 patients, 66 (76.7%) achieved seizure-free and 50 (58.1%) were medication-free at last follow-up: 96.7% (58/60) of patients with obliteration vs. 30.8% (8/26) of patients without obliteration (OR, 65.2; 95% CI, 12.7 to 335.4; $P < 0.001$). The proportions who were medication-free were 81.7% (49/60) in patients with obliteration and 3.8% (1/26) in patients without obliteration (OR, 111.4; 95% CI, 13.6 to 912.2; $P < 0.001$). Factors significantly associated with seizure freedom were AVM obliteration (OR, 370.9; 95% CI, 14.6 to 9412.3), preradiosurgical seizure frequency score (OR, 3.6; 95% CI, 1.4 to 9.4), and single seizure only before radiosurgery (OR, 19.9; 95% CI, 1.0 to 384.3).

Conclusions: Radiosurgery may improve seizure outcomes in patients with AVM, especially in patients with AVM obliteration.

P2015

OUTCOME AFTER LINAC-STEREOTACTIC RADIOSURGERY FOR CEREBRAL ARTERIOVENOUS MALFORMATION - DIFFERENCES BETWEEN PRIMARY EMBOLIZED AND NON-EMBOIALIZED LESIONS/ THE EFFICACY OF THIS TREATMENT MODALITY ACCORDING TO POLLOCK-FLICKINGER GRADING SYSTEM.

Martin Malacek¹ Augustin Durkovsky² Yaroslav Parpaley³ Alexander Lysak⁴ Omelyan Trompak¹ Juraj Steno⁴

(1) Department of Stereotactic Radiosurgery, St. Elisabeth's Cancer Institute, Bratislava, Slovakia (2) Department of Radiology, St. Elisabeth's Cancer Institute, Bratislava, Slovakia (3) Department of Neurosurgery, Univesity Medical Center, Bonn, Germany (4) Department of Neurosurgery, Derer's Comenius University Hospital, Bratislava, Slovakia

Introduction: Outcome after LINAC-stereotactic radiosurgery (LSRS) for arteriovenous malformation (AVM) has been analysed/updated using the Pollock-Flickinger grading system (PFGS).

Methods: 146 LSRSs in 141 patients with AVM were performed from 1/2001 to 9/2010. In 41 cases a residual/embolized lesion was irradiated at least once, 100 patients underwent at least one/primary LSRS. Mean margin dose of the initial procedure was 17.71 Gy (range 13-20 Gy). Treated lesions included 58 small (under 3 cc), 55 medium (3-10 cc) and 28 large (over 10 cc) AVMs with 35 diffuse and 106 compact nidus-type. According to PFGS there were patients with PFGS up to 1.2, from 1.21 to 2.2 and more than 2.2. The functional/radiological changes were evaluated, laying stress upon differences between non-embolized/embolized volumetrically comparable lesions/their ranking among three PFGS groups. Patients were followed at least 18 months.

Results: Mean overall follow-up in 102 patients with available follow-up data was 71.9 (range 20 - 144) months. Of 42 small AVMs the nidus was obliterated in 40 = 95.2%, of 38 medium-sized AVMs in 22 = 57.9.5%, of 22 large AVMs in 11 = 50%. Diffuse niduses have been obliterated in 15/29 = 51.7%, compact ones in 55/73 = 75.3 %. A mild monoparesis 11 months after repeated LSRS/achieving an obliteration of AVM was found in one case, severe hemiparesis due to intracerebral hemorrhage after follow-up 9/24 months in two other cases without any obliteration, three deaths due to same reason/one death due to non-radiosurgical cause disrupted follow-up after 10, 11 and 43/two months. A ratio non-embolized/embolized radiosurgically completely obliterated AVM was 93.9/88.9% in small, 67.9/40% in medium, 50/50% in large AVMs, according to PFGS 96.2/60% in the group up to 1.2, 73.7/50% in the group from 1.21 to 2.2, 50/50% in the group more than 2.2.

Conclusions: Higher obliteration rate among non-embolized AVMs was found. Embolization prior radiosurgery obviously deteriorates this favorable outcome. The obliteration-probability expands from large up to small lesions/from diffuse to compact niduses. By our independent study the highest one in PFGS up to 1.2 has been confirmed. LSRS-treatment often fails in large AVMs harboring a diffuse nidus. Repeated radiosurgery helps to cure some of them.

P2016

RADIOSURGERY IN THE TREATMENT OF CEREBRAL HAEMANGIOBLASTOMAS-SINGLE INSTITUTION EXPERIENCE

Rakesh Raman¹ Karen Tipples¹ Aza Azizan¹ Nick Plowman¹

(1) St Bartholomew's Hospital, London, UK

Introduction: Haemangioblastomas are uncommon slow growing tumours, occurring either sporadically or in association with von Hippel Lindau (vHL) syndrome. Small asymptomatic lesions can be managed by watchful surveillance. (1) Surgery is usually offered for solitary lesions and radiotherapy for lesions in surgically inaccessible locations, recurrent or multiple lesions. (2-3) In the absence of randomized trials to support either the timing or the choice of therapeutic interventions, treatment options need careful consideration in individual patients. We studied the outcome for patients treated at our centre between 2000 and 2009.

Methods: This retrospective study is a review of treatment outcome for patients with haemangioblastomas treated with Radiosurgery at St Bartholomews Hospital. 16 patients were identified and a total of 53 lesions treated. 9 patients had vHL syndrome. All patients had at least one annual follow up. Response was evaluated with contrast enhanced MRI scan.

Results: Clinical and Radiological follow up data was available for 11 patients. Information about

response was available for 48 lesions, unavailable for 4 patients (4 lesions) and 1 patient (1 lesion) was awaiting response assessment. The mean age was 38 years. There were 9 men and 7 women. 8 patients had a solitary lesion. Number of lesions ranged from 1-21. The cerebellum was the most common site of lesion in 20%. 12 patients had previous surgery. The median clinical follow up was 24.6 months (range 11.6-71.4 months). The median radiological follow-up period was 24.2 months (range 8.6-71.4 months). The dose of radiation to the periphery of the lesion averaged 15.02 Gy (range 8-20 Gy). The mean tumour volume was 1.19 cm³ (range 0.0047 cm³-5.2 cm³). Radiological regression was seen in 9 tumours (19%), 39 tumours (81%) remained unchanged, 1 patient was awaiting response assessment and 1 patient died within a year of treatment of other cause. There were no reported post treatment complications.

Conclusion: Radiosurgery is a safe and effective treatment option to achieve local tumour control in cerebral haemangioblastomas, especially in v HL patients, who have a propensity to develop multiple lesions.

P2017

OUTCOMES OF RADIOSURGERY FOR BRAIN STEM ARTERIOVENOUS MALFORMATIONS

Shunya Hanakita¹ Tomoyuki Koga¹ Masahiro Shin¹ Nobuhito Saito¹

(1) Department of Neurosurgery, University of Tokyo Hospital, Tokyo, Japan

Objectives: This study was conducted to evaluate treatment outcomes of gamma knife radiosurgery for brain stem arteriovenous malformations (AVM).

Methods: s: Between July 1990 and October 2009, 44 patients with brain stem AVM were treated by gamma knife radiosurgery at our institute. Outcomes that include the rates of obliteration, hemorrhage after treatment, and adverse events were retrospectively analyzed based on the latest follow-up data.

Results: The annual hemorrhage rate before radiosurgery in this cohort was 17.5%. The mean follow-up period after SRS was 71 months (range, 2- 168 months). The rate of obliteration after radiosurgery confirmed by angiography or MRI was 57% at 5 years. Factors associated with higher obliteration rate were previous hemorrhage ($p = 0.038$), and higher margin dose ($p = 0.039$). For 37 patients who were treated with margin dose of 18 Gy or more, obliteration rate was 71% at 5 years. Nidus obliteration without any adverse events or hemorrhage after treatment was achieved in 20 (54%) patients, and there was no significant difference between locations inside the brain stem. Persistent worsening of neurological symptoms was observed in 5 %. The annual hemorrhage rate after SRS was 2.4%. Four patients died of rebleeding, and disease-specific survival rate was 86% at 10 years after treatment.

Conclusions: Sufficient marginal dose was necessary to effectively obliterate brain stem AVM. Even with sufficient doses, radiation-related morbidity was relatively low and radiosurgery was considered to be acceptable as an alternative treatment for small brain stem AVM especially in the location for which surgical approach was difficult.

P2018

THREE-DIMENSIONAL ROTATIONAL ANGIOGRAPHY FOR STEREOTACTIC RADIOTHERAPY PLANNING OF CRANIAL ARTERIOVENOUS MALFORMATIONS

Dominic Davis¹ Michael Dally¹ Anoop Madan² Anna Seeley¹ Brendan Erskine² Ellisa Marshall²

(1) William Buckland Radiotherapy Centre, Melbourne, Australia (2) Alfred Hospital Angiography Department, Melbourne, Australia

Stereotactic Radiotherapy, alongside Surgery and Embolisation, is a major option in the treatment of cranial Arteriovenous Malformations (AVMs). Accurate definition of the AVM nidus in 3-dimensions is critical for nidus obliteration with Stereotactic Radiotherapy, and to reduce the volume of surrounding normal brain tissue irradiated (2). Many commonly used imaging modalities are limited in their ability to accurately define the AVM, and can lead to over or under-estimation of the volume of the AVM to be treated.

Aim: To investigate 3-Dimensional Rotational Angiography (3DRA) and its usefulness for planning of Stereotactic Radiotherapy for AVM's.

Discussion: 3DRA is an angiography technique for visualizing vasculature, with a cone-beam CT acquired over a 200 degree rotation. This data is post-processed to create slice reconstructions that may be useful for planning Stereotactic Radiotherapy. Current imaging modalities for defining the AVM nidus include Magnetic Resonance Imaging, CT-Angiography and 2-D Digital-Subtraction Angiography. These current modalities have inherent flaws that limit the ability of medical professionals to accurately define the AVM nidus in 3-dimensions, or to distinguish the nidus from normal brain vasculature surrounding the AVM (1). For planning at the William Buckland Radiotherapy Centre, axial slice reconstructions from 3DRA were loaded into BrainLab's iPlan software and fused to axial CT-Angiogram and Time-Of Flight MRI data-sets to aid in delineation of the AVM nidus. Stereotactic planning was performed using BrainLab's frameless mask and planning system. This frameless technique eliminates the need for invasive immobilisation of the skull for 3DRA and Stereotactic Radiotherapy procedures, and allows for 3DRA examinations from outside institutions to be used for planning.

Conclusion: 3DRA provides an additional imaging tool to accurately define the AVM nidus in 3-dimensions by providing visualisation of vital blood-flow information from feeding and draining blood-vessels. This increased ability to define the AVM nidus may lead to better outcomes for patients in regard to side-effects as well as increasing the likelihood of achieving complete obliteration of the AVM.

1) F. Bova, C. Cavedon: Three-dimensional rotational angiography adds substantial information to radiosurgery treatment planning of AVM's compared to CT and angio-MR. Medical Physics. 31 (8). 2181-2183 (2004)

2) H. Inoue, A. Akihiko, K. Tagayanagi: Failure of Arteriovenous Malformations and its prevention using True Image Fusion of Rotation CINE Angiograms in Integrated Multiplanar Imaging. Radiosurgery. 7, 100-112 (2010).

P2019

MECHANISM OF ENLARGEMENT OF CYST DEVELOPING AFTER GAMMA KNIFE RADIOSURGERY FOR ARTERIOVENOUS MALFORMATION

Takashi Shuto¹ Shigeo Matsunaga¹

(1) Yokohama Rosai Hospital, Yokohama, Japan

Purpose: To analyze the mechanism of formation and enlargement of cyst developing after gamma knife radiosurgery (GKS) for arteriovenous malformation (AVM).

Materials and Methods: This retrospective study included 10 patients with cyst formation (Group A) and 5 patients with combination of cyst and expanding hematoma (Group B) among 748 patients who underwent GKS for AVM at our hospital.

Results: The 8 male and 7 female patients were aged 17 to 42 years (mean 26.2 years). The mean nidus volume was 10.9 ml (0.1-26.7 ml), and the mean prescription dose at the nidus margin was 20 Gy (18-28 Gy). Complete obliteration of the nidus was obtained in 11 patients, partial obliteration in 3, and no change in 1. Cyst opening in 2 patients and placement of Ommaya reservoir in 2 were necessary in Group A. Craniotomy was performed in 3 of 4 patients in Group B. Another patient in Group B was lost to follow up and the final outcome was unknown. At surgery, the inner surface of the cyst cavity was reddish brown and cyst content was xanthochromic with high protein concentration. Histological examination of the cyst wall revealed fibrosis and deposits of hemosiderin, and no evidence of bleeding within the wall. Histological examination of the associated degenerated nidus demonstrated obliterated nidus and newly developed capillary vessels with fresh and old bleeding.

Conclusions: Cyst formation is not rare as a late complication of GKS for AVM. Some cysts show spontaneous regression and others enlarge gradually and become symptomatic. This study suggested that repeat minor bleeding into the cyst from newly developed capillary vessels in the degenerated nidus is important in enlargement of the cyst. Surgery such as placement of Ommaya reservoir or craniotomy should be considered for symptomatic cases.

P2020

STEREOTACTIC RADIOSURGERY FOR BRAIN AVMS: OUTCOME RELATED TO VOLUME AND LOCATION OF BRAIN RECEIVING HIGH DOSE RADIATION

Ana Escolástico¹, ² António Gonçalves-ferreira¹ Herculano Carvalho¹ Rosário Vicente¹ Álvaro Almeida¹ Justo Ugidos¹

(1) Centro Oncológico Drª Natalia Chaves, Clinica Quadrantes, Carnaxide, Portugal (2) Medical Consult S.A., Lisboa, Portugal

Purpose: Stereotactic Radiosurgery (SRS) has a recognized important role in the treatment of brain AVMs. It promotes the AVM obliteration in most of the cases. The therapeutic effect depends on several factors like lesion volume and location, dose-margin radiation, time elapsed after SRS and other treatments previously done. Moreover, side effects and clinical morbidity rely on mechanisms not yet entirely understood. The main goal of this study was to analyze the outcome of the patients with brain AVMs we treated by stereotactic radiosurgery in what concerns to the relation between

the neurological sequelae and the amount of normal tissue that received high dose radiation (at least 10-12Gy) as well as the localization and volume of the treated AVMs.

Methods: A retrospective review of 57 patients treated between 2004 and 2009 was performed. The patients were from both sexes and their age ranges from 20 to 60 years old. All were treated with a single dose fraction of 14-17Gy using a 6MV photon beam in a Linear Accelerator 2300CD_Triology® (Varian Medical Systems, Inc., Palo Alto, CA), with a HD120 multileaf collimator incorporated, at Centro Oncológico Dr^a Natália Chaves, Clínica Quadrantes, Carnaxide.

To delineate the target volume and the organs at risk, every patients were submitted to Angio-MRI, Angio-CT and a Digital Angiography in stereotactic conditions, the two last exams on the day of the treatment.

Results and conclusions: All 57 patients had a minimum of 2 years (24-96 months) follow-up post-SRS. Clinical evaluation was made at one month post-SRS and then on simultaneously with the imaging follow-up; this included Angio-CT/MRI at 6, 12, 24 months and then every year after the treatment.

The main temporary and permanent neurological sequelae were found to be related with the amount and the location of normal tissue that received a dose equal or greater than 10-12Gy, especially in brain eloquent areas.

P2021

STAGED-VOLUME RADIOSURGERY FOR LARGE ARTERIOVENOUS MALFORMATIONS

Kazuhiro Yamanaka¹

(1) Osaka City General Hospital, Osaka, Japan

The treatment Results of stereotactic radiosurgery for small or medium sized arteriovenous malformations(AVMs) were established. We evaluated the treatment Results of staged-volume gamma knife radiosurgery (GKS) for large AVMs over 20 ml.

We encountered eight patients with large AVMs over 20ml treated by staged-volume GKS between January 1994 and December 2009. Patients included 4 men, 4 women and the mean age was 43 (range 27 - 56). The onset was hemorrhage in 4 patients (50%) and the other 4 patients (50%) received embolization before GKS. Mean nidus volume at the first GKS was 28.3 ml (range 21- 36 ml). In staged-volume GKS, nidus was divided into 2 or 3 volumes radiographically and each was treated on a separate occasion with an interval of more than 6 months. Each GKS was carried out for a mean volume of 13 ml (range 6.5 - 20 ml) with mean marginal dose of 14.6 Gy (range 12 - 18 Gy). Repeated GKS was carried out for residual nidus in two patients. Mean follow-up period was 81 months (range 6 -150 months) after the first GKS.

As 2 patients died because of hemorrhage 6 and 18 months after the first GKS, 6 patients completed the staged-volume GKS. Obliteration of nidus was confirmed in two patients 90 and 150 months after the first GKS. In the other 4 patients, the size of the nidi decreased. Though no apparent symptomatic radiation injury appeared, the formation of a feeder aneurysm was noted and embolization was needed for the aneurysm 100 months after the first GKS.

Staged-volume GKS was effective for some large AVMs over 20 ml that were unsuitable for any other treatments.

P2022

LONG-TERM RESULTS OF STEREOTACTIC RADIOSURGERY OF ARTERIOVENOUS MALFORMATIONS.

Martin Henzel¹ Gerd Strassmann¹ Rita Engenhart-cabillic¹

(1) Department of Radiation Oncology, Philipps University Marburg, Marburg, Germany

Introduction: Stereotactic radiosurgery (SRS) is well established in the treatment for arteriovenous malformations. SRS is delivered as a treatment alternative to operation and embolization and the only treatment option for unresectable locations (Spetzler VI°). This retrospective study aimed to investigate long-term Results, toxicity and bleeding risk.

Methods & Patients: From 1998 till 2008 164 patients (89 male, 75 female) were treated with SRS. Median age was 36 years (range, 7-69 years). 39% of the patients experienced haemorrhage before SRS and 27% suffered from epileptic seizures. Before SRS 73% of the patients were treated with previous embolizations, 8% previous operations and 2% were treated with proton therapy. 51% of the patients were treated with primary SRS.

Patients were immobilized with a stereotactic frame. They underwent CT-, MRI-scans (1-2 mm slice thickness) and angiography for treatment planning. Treatment was delivered by a LINAC with 6 MV photons. Median single dose was 19 Gy (range, 18-20 Gy) prescribed to the nidus surrounding 80% isodose. Nidus obliteration, toxicity (CTC score, LENT SOMA) and symptomatology were evaluated half-yearly by clinical examinations, MRI scans and with a final angiography.

Results: Patients were followed-up for at least 12 months. Median follow-up was 93 months (range, 12-140). Based on angiography overall complete obliteration (CO) was observed in 62% of the patients and further 27% observed a subtotal obliteration (SO, CO in MRI scans, >90% obliteration in angiography). Median obliteration time was 29 months, 3- and 4-year CO rates were 61% and 88%, respectively. Depending on the AVM-score the CO and SO rates for AVM-score <1.00 (I), 1.01-1.50 (II), 1.51-2.00 (III) and >2.00 (IV) were 86%/7%, 63%/29%, 60%/25% and 28%/50%, respectively. Intracranial haemorrhage was seen in 6% of the patients after SRS. Annual bleeding risk was 1.3% after 1 year and 1,3% after 2 years, respectively. 3% of the patients died because of the haemorrhage. Mainly, haemorrhage after SRS occurred in patients belonging to AVM-score II+III. After SRS an improvement of the main symptoms was seen especially for headache, epileptic seizures and paralysis. A worsening was seen only in 9 cases. Toxicity >II° was observed in 9%. They developed severe edema, ataxia and paralysis. These patient belonged to AVM score III+IV.

Conclusion: SRS is an effective treatment option for arteriovenous malformations especially for unresectable lesions. After SRS the toxicity and bleeding risk are very low depending on AVM-score. An improvement of main symptoms is achievable for headache, epileptic seizures and paralysis.

P2023

DOSIMETRIC PARAMETERS OF RADIOSURGERY AS PREDICTORS OF ADVERSE RADIATION EFFECTS FOLLOWING GAMMA KNIFE TREATMENT OF AVM.

Caroline Hayhurst¹ Shelly Lwu¹ Cynthia Menard¹ Michael Schwartz¹ Gelareh Zadeh¹

(1) University Health Network, Toronto, Canada

Purpose: We have previously reported that V12 Gy, target volume and the absence of prior hemorrhage are the most accurate predictor of adverse radiation effects and complications following radiosurgery for Arteriovenous Malformations (AVM). The purpose of this study was to evaluate the significance of specific dosimetric variables such as conformality index (CI) and in specific various target volumes with regards to adverse radiation effects following radiosurgery for treatment of AVMs

Methods: 125 patients with AVMs were treated at our institution between 2005 and 2009. 85 patients have at least 12 months clinical and radiological follow-up. Any new onset headaches, new or worsening seizures or neurological deficit were considered adverse events. Follow-up MR Images were assessed for new onset T2 signal change and the volume calculated. Dosimetric variables, V12, 15, 20, 25 and 30 Gy in addition to CI were analysed using both univariate and multivariate analysis.

Results: There were 19 children and 66 adults in the study cohort, with a mean age of 34 (range 6 -> 74). 23 (27%) patients suffered adverse radiation effects (ARE), 9 patients with persistent neurological deficit (10.6%). Of these, 5 developed fixed visual field deficits. Target volume and 12Gy volume were the most significant predictors of adverse radiation effects on univariate analysis ($p < 0.001$). No other target volume was found to have any significant association with the development of adverse events.

Conclusions: Other than target volume of 12Gy, no other dosimetry parameter was found to be predictive of adverse radiation events.

P2024

FRAMELESS STEREOTACTIC RADIOSURGERY OF ARTERIOVENOUS MALFORMATIONS USING HIGH RESOLUTION 3-DIMENSIONAL ROTATIONAL ANGIOGRAPHY

Javad Rahimian¹ Lei Feng¹ Michael R. Girvigian¹ Joseph C.t. Chen¹ Alonso Arellano¹ Michael J. Miller¹

(1) Southern California Permanente Medical Group, Los Angeles, USA

Purpose: Since 2006 we have effectively treated over 915 patients utilizing a frameless image guided radiosurgery (IGRS) technique with the Novalis ExacTrac IGRS system. Although this technique has been effective for most intracranial lesions, arteriovenous malformations (AVM), requiring cerebral angiography for proper localization, have been excluded. We propose a new imaging technique to localize the AVM lesions using 3-Dimensional Rotational Angiograms (3DRA), which allows us to treat these lesions using the frameless IGRS system. The 3DRA helps to overcome the limitations of 2D angiography by more definitively visualizing the AVM nidus. This study measures in a phantom, the geometric accuracy of the 3DRA for the localization of seven hidden targets and compare this

to the conventional orthogonal angiogram image pair. We also report our initial experience with 15 AVM cases treated with the BrainLab frameless IGRS utilizing 3DRA.

Materials and Methods: An in-house phantom was made with seven hidden 4mm- long metallic markers inserted randomly inside the phantom. A frameless mask was made to immobilize the phantom. CT, as well as 3DRA image data sets were acquired. Orthogonal images of the phantom were acquired with the Brainlab angiographic localizer. The 3DRA, and orthogonal images were fused with the planning CT. The markers were contoured in the planning reference CT. The contours overlapped the markers in the 3DRA as well as the orthogonal data sets. The deviation of the centers of the contours from the center of the markers were measured on both the 3DRA, and orthogonal images, and reported as geometric errors. The 3DRA was acquired for the 13 patients by arterial bolus injection of 20cc radio opaque contrast agent using a Phillips Bi-plane C-arm. Volumetric images were acquired with a 4 seconds image acquisition time. 256 axial images were reconstructed in a 256x256 matrix, with 0.6 mm slice thickness.

Results: A geometric accuracy of 0.39 ± 0.15 mm, and 0.27 ± 0.14 mm were measured for the 7 markers using the digital angiography orthogonal image pairs, and the 3DRA, respectively. 13 patients underwent the AVM SRS treatment with an AVM volume of 4.33 ± 7.51 cc (0.04 cc to 27.31 cc). These lesions were successfully localized with the 3DRA, and matched with the digital angiography orthogonal image pairs.

Conclusions: High precision frameless SRS treatment of AVMs is feasible using high-resolution 3DRA for nidus localization and BrainLab treatment planning software. The 3DRA images are fused with the planning CT based on the patients bony landmarks, and thus the 3DRA is geometrically more precise in localizing the nidus when compared with the orthogonal angiogram image pairs. The technique described allows for pain free treatment and better patient workflow.

P2025

SOFTWARE TOOL FOR AVM VOLUME DEFINITION USING ANGIOGRAPHIC 2D IMAGES FUSION TO CT

Gennady Gorlachev¹

(1) Burdenko Neurosurgery Institute, Moscow, Russian Federation

Objective: Stereotactic treatment planning systems (TPS) use angiographic images in one of two ways. 2D images assume study in localization box, which usually require repeating difficult study. 3D angiography is not as informative as 2D live images. Software tool for reregistration 2D X-ray images with CT study and contouring volumes of interest was created to solve those problems.

Materials and Methods: Considered task solution has a few technical problems. First is reliable coincidence measure function. After testing different known approaches the «pattern intensity» measure (PIM) was selected. X-ray units without flat image receiver may have distortion problem. In the presented tool one parameter radial distortion correction can be used as an option. The other variables are: 3 shifts, 3 rotations and source's detector distance. Global solution search uses simplex Methods. Depending on the target TPS interface the output can be one of two types. First is a pair of 2D images with user adjusted subtraction and localization box marks, produced by the tool. In this case CT study is assumed to be done in localization box, which is identified by this tool. The second output type is a result of volumes contouring over CT, exported in DICOM RTSTRUCT

format. The most compute intensive part is repetitive DRR calculations, which were implemented in GPU.

Results: PIM showed smooth properties in the vicinity of global solution along all coordinates which is a key point of success. In those cases, where tool found wrong solution, deviations were clearly visible. All tested cases showed that proper solution could be easily found after manual adjustment search starting point. Retrospective evaluation of localization box marks coincidence for radiosurgery patients showed, that in almost all cases errors were from one to two millimeters. The patterns of deviations indicate mostly rotation errors. Relatively big error is not clearly understood. Partly up to 1 mm it may be related to localization process, which was observed in the tool. However, due to the lesion much closer location to the center of body the accuracy of translation points of interest from X-ray to the CT is estimated as better than 1 mm. Many AVM patients have small intracranial markers left after surgery. Testing their position both on the X-ray and CT showed excellent agreement, definitely better than 1 mm.

Conclusion: Skull based X-ray image reregistration with CT study can be done in a reliable way and should be implemented in dedicated radiation treatment planning systems for vascular pathologies as a routine tool.

P2026

SEIZURE OUTCOME AFTER GAMMA KNIFE RADIOSURGERY FOR ARTERIOVENOUS MALFORMATIONS

Selcuk Peker¹ Meric Sengoz² Fehim Arman³ Necmettin Pamir¹

(1) Acibadem University Department of Neurosurgery, Istanbul, Turkey (2) Acibadem University Department of Radiation Oncology, Istanbul, Turkey (3) Acibadem University Department of Neurology, Istanbul, Turkey

The aim of this study is to determine the effect of Gamma Knife radiosurgery (GKRS) on seizure outcomes for patients with arteriovenous malformations (AVM).

Between September 2005 and October 2009, 58 patients with a history of single or recurrent seizures underwent AVM radiosurgery, had more than 1 year of follow-up, and sufficient data to record an Engel seizure frequency score. Follow-up ranged from 12 to 61 months (median, 27 months). Seizure frequency was compared before and after GKRS with the Engel Seizure Frequency Scoring System.

Overall, 24 patients (41.3%) were seizure-free and 18 patients (31.2%) were with less frequent seizures after GKRS. Factors associated with seizure-free outcomes include a low seizure frequency score before radiosurgery and longer follow-up after GKRS.

GKRS improves seizure outcomes in the majority of patients. In most of the patients with medically intractable epilepsy excellent seizure outcome after GKRS can be seen.

P2027

RADIOSURGERY FOR TRIGEMINAL NEURALGIA CAUSED BY AN ARTERIOVENOUS MALFORMATION (AVM) INTRINSIC TO THE TRIGEMINAL (V) NERVE

Michael Schwartz^{1, 2} Young-bin Cho^{1, 2} Michael Cusimano^{1, 2} Mustafa Heydarian^{1, 2} Cynthia Menard^{1, 2} May Tsao^{1, 2}

(1) University of Toronto, Toronto, Canada (2) University Health Network, Toronto, Canada

Objective: To present a novel and effective 4C gamma knife treatment plan for an unusual case.

Methods: Our standard Methods s for the radiosurgical treatment of AVMs and trigeminal neuralgia were combined to treat a 45 year old man who presented with left V3 trigeminal neuralgia, found to have an AVM intrinsic to the left trigeminal nerve at the root entry zone. The presenting clinical details and imaging, but not the treatment, have been published (1).

In our center, AVMs <4cc in volume are treated to a marginal dose of 25 Gy. AVMs 4 to 15cc are treated to 20 Gy. Dose to eloquent brain is limited to 15 Gy so that AVMs in contact with structures such as the pons, receive a marginal dose of 15 Gy. Tic is treated with 80 Gy to the mid-cisternal nerve. Accordingly, a 6 shot 4mm helmet gammaplan ® with 23 plugs was devised to deliver 15 Gy to the margin of the AVM at the 19% isodose contour with the shots arranged to deliver 79 Gy to the trigeminal nerve.

Result: At 3 month follow up, the patient reported that he was pain-free off medication 5 weeks after treatment and that he had no facial numbness. At 6 months, MRI scanning showed slight reduction in AVM volume.

Conclusion: Both structural and physiological factors should be considered in radiosurgical planning.

Reference: Singh et al., Can. J. Neurol. Sci. 2010;37: 681-683

P2028

EVALUATION OF RESIDUAL ARTERIOVENOUS MALFORMATIONS FOLLOWING GAMMA KNIFE RADIOSURGERY: COMPARISON OF 3-DIMENTIONAL TIME-OF-FLIGHT MR ANGIOGRAPHY AND DIGITAL SUBTRACTION ANGIOGRAPHY

Jun Kawagishi¹ Hidefumi Jokura¹ Koh Takahashi¹ Kazuyuki Sugai¹ Teiji Tominaga²

(1) Jiro Suzuki Memorial Gamma House, Furukawa Seiryō Hospital, Ohsaki, Japan (2) Department of Neurosurgery, Tohoku University Graduate School of Medicine, Sendai, Japan

Background: Digital subtract angiography (DSA) is an ideal examination for confirming complete obliteration of the nidus after gamma knife radiosurgery (GKRS). However, the status of the nidus sometimes has to be evaluated by only magnetic resonance imaging (MRI), because the agreement of the patient for DSA was not obtained.

Objective: To investigate the potential of the source image of three-dimensional time-of-flight magnetic resonance angiography (3D TOF MRA) for the assessment of cerebral arteriovenous malformations after GKRS.

Methods: In case the source image of 3D TOF MRA demonstrated disappearance of the nidus, DSA

was carried out and the images were assessed. DSA was performed in 147 patients. The mean duration of the follow-up study was 57.4 months (range: 10 - 165 months).

Results: In 131 (89.1%) of 147 patients, complete obliteration of the nidus was confirmed. DSA revealed no complete obliteration in sixteen patients (10.1%). However, in twelve of sixteen patients, only the early filling venous drainage was observed and the residual nidus was not detected. The nidus was almost completely obliterated in the other four patients. After confirming absence of the nidus by the source image of 3D TOF MRA, no hemorrhage was observed in all patients, included the patients who did not undergo DSA.

Conclusion: The use of source images of 3D TOF MRA enables a noninvasive assessment of the status of the nidus. This Methods is helpful to predict complete obliteration after GKRS, even if DSA was not performed.

P2029

STEREOTACTIC RADIOSURGICAL RESULTS: ACCORDING TO THE ANGIOGRAPHIC PATTERNS IN INTRACEREBRAL ARTERIOVENOUS MALFORMATION

In-young Kim¹ Shin Jung¹ Tae-young Jung¹ Woo-youl Jang¹ Sam-suk Kang¹ Seung-jin Park¹

(1) Chonnam National University Hawsun Hospital , Chonnam, Korea

Introduction: On the outcome after STX for cerebral AVM, several prognostic factors have been reported and most important ones are the size of the AVM and prescription dose. Although the volumetric reduction cannot fully represent the control or outcome in STX for AVM, volumetric reduction during follow-up period could be an important sign of control of AVM.

We investigated the angiographic patterns of AVM at the time of STX, and tried to find the relationship of the patterns to volume reduction after STX in intracerebral AVM during relatively short-term periods.

Materials & Methods: From June 2004 to December 2008, total 49 patients underwent gamma knife radiosurgery (GKR) for intracerebral AVM and have been followed up regularly. The mean age was 36.8 year (range, 9 to 77), and the number of male patients was 28. Thirty-one patients (63%) had previous hemorrhage from the AVM before GKR. Six patients underwent surgery and two patients embolization before GKR.

The GKR was performed conventionally using MRI and digital subtraction angiography (DSA). Especially, we got short-time consecutive images (7.5 frame/sec) during DSA. The mean treatment volume was 4.8cc (range 0.3 to 28.3), mean 19.9 Gray (range 10 to 25) radiation dose was prescribed to the margin of the AVM nidus.

According to the last images, we divided the radiological outcome into 4 groups; A (no visualization of AVM in DSA), B (no visualization of AVM in CTA but no DSA performed), C (marked reduction of AVM at least in one of MRI, CTA, DSA), and D (slight reduction in volume or no change).

Results: The mean follow-up period was 28 months (range, 7 to 58). There was no mortality or morbidity except one patient who showed delayed hemorrhage. The favorable radiological outcome (group A, B, and C) showed in 39 patients (79.6%). In our investigation, the angiographic favorable prognostic factors related to the volumetric reduction were 1) persistent filling of nidus longer than normal intracerebral venous drainage ($p= 0.000$) and 2) nidus filling time from feeding artery longer than 0.5 second ($p= 0.001$). However, the time from the visualization of feeding

artery to draining vein was not significant in this study ($p = 0.5$).

Conclusion: Although the follow-up period was not long enough to confirm the control of AVM after GKR in this study, above angiographic parameters at GKR could help physicians expect the treatment effect during the follow-up periods.

P2030

DOSIMETRIC PLANNING ASSISTED BY TIME RESOLVED CONTRAST ENHANCED MR ANGIOGRAPHY FOR THE TREATMENT PLANNING OF ARTERIOVENOUS MALFORMATIONS BY GAMMA KNIFE RADIOSURGERY. PRELIMINARY STUDY

Vianney Le Thuc^{1, 2, 3} Nicolas Reyns^{1, 2, 3} Xavier Leclerc^{1, 3} Serge Blond^{1, 3} Maximilien Vermandel^{1, 2, 3}

(1) Université Lille Nord De France, Lille, France (2) Inserm U703, Loos, France (3) CHU Lille, Lille, France

Purpose: The Gamma Knife offers the possibility to treat cerebral arteriovenous malformations (AVM) in a non invasive way. So as to plan the treatment, MR imaging and conventional angiography (DSA) are carried out under stereotactic conditions. The time resolved contrast enhanced MR angiography (TR-CE-MRA) offers several advantages compared to conventional angiography: a 4D vision of the AVM (3D+time) and the absence of irradiation of the patient. Our objective was to evaluate the contribution of time resolved contrast enhanced MR angiography compared to the conventional angiography and to validate the integration of this non stereotactic imagery to the radiosurgical treatment planning by comparing the planned dosimetries.

Methods: Five patients have been treated by gamma knife radiosurgery. CT, 1.5 T MRI and conventional angiography have therefore been performed in stereotactic conditions for each patient. TR-CE-MRA allowed to obtain 13 volumes of 165 slices every 1.7 second. This sequence was carried out before setting the stereotactic frame, since this subtraction imagery could not be carried out in stereotactic conditions. Therefore, we were not able to use Gamma Plan (Elekta AB softwares) to co-register this sequence. We have thus developed a tool capable of ensuring this integration into the radiosurgery planning on Gamma Plan. This tool was developed on Amira/AmiraDev (Visage Imaging) and IDL (ITT Visual Information Solutions).

Results: The developments carried out allowed us to ensure the radiosurgical planning using the TR-CE-MRA sequence only. The Bland and Altman analysis performed on the two conformity indexes show that the plannings using TR-CE-MRA or DSA were similar. However the TR-CE-MRA sequence remained limited in terms of spatial and time resolution at 1.5 tesla.

Significance: TR-CE-MRA co-registered in Gamma Plan is a new imagery technique. It has to be considered as a convenient and an additional tool for the radiosurgical treatment planning of AVMS since it is up to now the only one to provide axial angiographic views of the nidus without any ionizing radiation. Nevertheless, its spatial and time resolutions at 1.5 Tesla do not allow to use it as a substitute for the DSA.

P2031A

PROSPECTIVE NEUROCOGNITIVE ASSESSMENT OF PATIENTS RECEIVING HYPOFRACTIONATED STEREOTACTIC RADIOTHERAPY FOR AVM

Michael Dally¹ Aimee Jeffreys² Nola Bailey¹ Andrea McInnes²

(1) The Alfred, Melbourne, Australia (2) Melbourne University, Melbourne, Australia

Objective: As part of a phase II study examining the safety and efficacy of hypofractionated stereotactic radiotherapy (FSRT) for large or eloquently located AVM, prospective neurocognitive assessment was undertaken. We postulate that correction of cerebral blood flow anomalies (steal)1 may lead to improvement in cognitive functioning. This study evaluated the neurocognitive testing over time, which will be correlated with cerebral perfusion.

Methods: Attention, processing speed, visuospatial function, naming, memory (learning and delayed recall), semantic and executive function domains were assessed at 0, 6 and 26 weeks post FSRT. All patients received 55Gy in 11 fractions to the isocentre, with 95% covering the periphery of the nidus.

Results: 13 patients were evaluated. The mean AVM volume was 27.38 (SD 17.12) cm³. Pre-treatment, patients were impaired in 3 of 8 cognitive domains. At 6 weeks, impaired performance was noted in learning and semantics. At 26 weeks, these functions were restored to baseline levels.

Conclusion: We found no decline in cognitive functioning at 26 weeks post FSRT for AVM. Previous studies have found no clear relationship between cognitive performance and angiographic location of the AVM2. We postulate that cognitive abilities may actually improve with correction of steal following successful obliteration of an AVM. We intend further evaluation at 2 years and prospective evaluation of a subsequent cohort with CT/MRI perfusion in conjunction with the cognitive evaluation, piloted in this study.

References:

1. Guo WY, Wu YT, Wu HM, Chung WY, Kao YH, Yeh TC, Shiau CY, Pan DH, Chang YC, Hsieh JC. Toward normal perfusion after radiosurgery: perfusion MR Imaging with independent component analysis of brain arteriovenous malformations. *AJNR Am J Neuroradiol.* 2004 Nov-Dec;25(10):1636-44
2. Brown, G.G., Spicer, K.B., Robertson, W.M., Baird, A.D., Malik, G. (1989). Neuropsychological signs of lateralized arteriovenous malformations: comparison with ischemic stroke. *Clinical Neuropsychology*, 3, 340-352.

P2031B

EARLY CYST FORMATION AFTER STEREOTACTIC RADIOSURGERY FOR INTRACEREBRAL ARTERIOVENOUS MALFORMATION: A CASE REPORT

Tomohito Hirao¹, Kensaku Kamada¹, Takayuki Matsuo¹, Kenta Ujifuku¹, Shiro Baba¹, Kazuhiko Suyama¹, Izumi Nagata¹, Nobuyuki Hayashi²

(1) Department of Neurosurgery, Nagasaki University School of Medicine, Nagasaki, Japan (2) Department of Radiology, Nagasaki University School of Medicine, Nagasaki, Japan

Stereotactic radiosurgery is well established and less invasive treatment for cerebral arteriovenous

malformation. Delayed cyst formation is a rare but well-known complication of radiosurgery for arteriovenous malformation. Most cases of cyst formation occur after 5-15 years from radiosurgical treatment. Furthermore, the mechanism and optimal treatment of cysts forming after radiosurgery remains debatable. We present a case of «early» cyst formation after radiosurgery for cerebral arteriovenous malformation that was treated with steroid administration. A 22-year-old woman presented with headache and memory disturbance. Computed tomography (CT) revealed intracerebral hemorrhage in the left fronto-temporal lobe. Digital subtraction angiography revealed arteriovenous malformation at left middle cerebral artery (Spetzler-Martin grade 3). Craniotomy was performed and nidus was removed, but post-operative angiography showed a small residual nidus. After 6 month of surgery, we performed linac-based stereotactic radiosurgery for residual nidus. The 1.25 cm³ nidus was covered with the 80% isodose. The maximum dose was 22.5 Gy and the marginal dose was 18 Gy. Eight months after radiosurgery, routine follow-up MRI revealed cyst formation in the irradiated area with pericystic edema. One more month later, the patient grew worse of her headache, and cyst increased in size. Then we started per oral administration of glucocorticosteroid (Dexamethasone). Thereafter, the cyst began to decrease in size and her symptom alleviated. Three month later, we stopped administration of steroid, but the cyst continued to shrink. In some cases, post-radiosurgical cysts are healed by steroid administration alone, without surgery. It is necessary to follow up those patients carefully with neurological examination and neuroimaging.

P2032

VOLUME STAGED STEREOTACTIC RADIOSURGERY FOR LARGE ARTERIOVENOUS MALFORMATIONS

Hideyuki Kano¹ Douglas Kondziolka^{1, 2} Kyung-jae Park¹ Phillip Parry¹ Huai-che Yang¹ Sait Sirin¹ Ajay Niranjani¹ Josef Novotny Jr.² John Flickinger^{1, 2} L. Dade Lunsford^{1, 2}

(1) Department of Neurological Surgery, University of Pittsburgh, Pittsburgh, USA (2) Department of Radiation Oncology, University of Pittsburgh, Pittsburgh, USA

Introduction: To define the long-term outcomes and risks of staged stereotactic radiosurgery (SRS) for symptomatic large volume arteriovenous malformations (AVMs) unsuitable for surgery.

Methods: In 1992, we prospectively began to stage anatomic components in selected patients so that obliteration rates and safety might be improved for AVMs > 15 cc in volume. In this series of 47 patients, 18 (38%) had one or more prior hemorrhages and 21 patients (45%) underwent prior embolization. The median interval between stages was 4.9 months (range, 3-14 months). The median initial AVM volume was 22.0 cc (range, 10.2-56.9 cc). The median target volume was 11.5 cc (range, 4.0-26 cc) in the first stage SRS and 9.5 cc in the second stage SRS. The median margin dose was 16 Gy (range, 13-18 Gy) for both stage SRS. Seventeen patients with incomplete obliteration underwent additional SRS at 33 to 113 months after the second procedure (median, 61 months).

Results: The 10 year total obliteration rate eventually documented by MRI or angiography was 65% after 2 or more procedures at a median follow-up of 70 months (range, 0.4-209 months). Higher margin doses were associated with higher rates of AVM obliteration. One patient had a hemorrhage between the first and the second SRS. Twelve patients had a hemorrhage during the subsequent latency interval and six patients died after sustaining a brain hemorrhage. The rate

of AVM hemorrhage (until obliteration) was 4.3%, 8.6%, 8.6%, 13.9%, and 29.0% at 1, 2, 3, 5, and 10 years, respectively. The overall annual hemorrhage rate was 4.2%. Prior hemorrhage was associated with higher risk of hemorrhage after staged SRS. Permanent neurological deficits due to adverse radiation effects (AREs) developed in three patients (6.4%) after staged SRS and two patients after repeat SRS. No patient died due to ARE. No patient developed delayed cyst formation after SRS.

Conclusions: Prospective volume staged SRS for large AVMs has potential benefit but often requires 3-4 procedures spread over time. In the future prospective volume staged SRS followed by embolization (to reduce flow, obliterate fistulas, and occlude associated aneurysms) may further reduce the risk of hemorrhage.

P2033

GAMMA-KNIFE RADIOSURGERY OF LUNG CANCER BRAIN METASTASES. A 69- PATIENT SINGLE COHORT STUDY

Nicolas Reyns¹ Y. Ouammou¹ T. Sarrazin¹ F. Dubois¹ E. Lartigau¹ J.-j. Lafitte¹ S. Blond¹

(1) Gamma-knife Center, Department of Stereotaxy and Functional Neurosurgery, Hospital Roger Salengro, Lille, France

Purpose: To evaluate our Results of Leksell gamma knife 4C radiosurgery in the management of lung cancer brain metastases.

Material and Methods: Between January 2004 and December 2008, 69 patients (14 females, 55 males) presenting with lung cancer were treated for brain metastases by gamma knife radiosurgery in our institution. The mean age was 58 years (range 40-77). Following recursive partitioning analysis (RPA) classification, 35% of patients were in RPA class I, 33% in RPA class II and 32 % in RPA class III. 102 metastases (1.4 per patient) were treated with 88 radiosurgical treatment (1.3 per patient). Radiosurgery was performed as the only treatment in 53 procedures and for a new metastasis after radiation therapy in 35 procedures. The mean marginal dose was 23 grays (range 16-25). The mean volume treated was 2606 mm³ (range 92-13000). The mean follow-up was 17 months (range 3-69).

Results: The tumor control rate was 82%. The overall morbidity rate was 5,8% . 4 patients presented with a transient morbidity related to hydrocephalus in 2 cases of posterior fossa metastases, or to motor deficit in 1 case, or to visual disturbance in 1 case.

The progression free survival rate was 68% and the overall survival rate was 81%. 12 out of 13 patients who died were in RPA class III, one patient in RPA class II. Only one death had a neurological origin (carcinomatous meningitis).

Conclusion: The safety and efficacy of gamma knife radiosurgery is again documented in this single cohort study of brain metastases. The patient-TMs prognosis is therefore correlated to the systemic disease.

P2034

GAMMA KNIFE RADIOSURGERY: DOES THE NUMBER OF BRAIN METASTASES DETERMINE THE PATIENT'S OUTCOME?

Bodo Lippitz^{1, 2}

(1) Gamma Knife Centre, Bupa Cromwell Hospital, London, UK (2) Karolinska Gamma Knife Center, Stockholm, Sweden

Background: Gamma knife radiosurgery has shown that physically focused and stereotactically applied radiation can overcome many biological limitations of fractionated radiotherapy (WBRT). There is increasing evidence for the efficacy of radiosurgery even for patients with multiple metastases in terms of local tumor control and maintained functional status. Numerous retrospective analyses demonstrate a high local control even for patients with more than 4 brain metastases but several radiosurgical treatment recommendations still exclude patients with multiple brain metastases.

Objectives: The current retrospective analysis describes prognostic criteria and outcome of a large series of patients with cerebral metastases treated with Gamma Knife radiosurgery. The focus of the current review lies on the relation between the number of brain metastases and prognosis.

Patients and Methods: 301 consecutive clinically unselected patients representing 1217 brain metastases were treated by Gamma Knife radiosurgery in 451 treatments at the Karolinska Gamma Knife Center. Data were analysed retrospectively. The median prescription dose was 22 Gy.

Results: Median survival of the entire group was 7.5 months. Tumor control was achieved in 94.4 % of metastases. Tumor control did not differ significantly between various cancer histologies. The strongest indicator for survival was the clinical condition according to the Karnofsky performance scale (KPS): Patients with a KPS > 70 (n=225) survived a median of 9.6 months (vs. 2.2 mo: n=74; p<0.0001). Patients presenting with a single metastasis at the initial treatment (n= 113) had a significantly better prognosis (median survival: 11.1 months) than patients with multiple metastases (median survival: 5.7 months) (p<0.0001 Log rank). The small group of patients with 7 and more metastases at initial treatment (n=17) showed a significantly worse outcome with a median survival of 2.8 months (p=0.009). There was no significant difference in survival within the group of patients pre-senting with 2-6 cerebral metastases (n=171) at the initial treatment with a median survival of 6 months (p=0.29).

Discussion: The current analysis documents the high local efficacy of Gamma Knife radiosurgery even in patients with multiple metastases. Treatment recommendations in radiosurgery often include specific numbers of metastases. The scientific evidence for this restriction however, seems unclear, since the all prospective randomized studies determine the number metastases in their inclusion criteria. Hence there is no available evidence that radiosurgery is ineffective in higher number of brain metastases. The current series documents that there is no simplistic relation between the number of brain metastases and the patient's prognosis.

P2035

GAMMA KNIFE RADIOSURGERY FOR BRAIN METASTASIS FROM LUNG CANCER

Takuya Kawabe^{1, 2} Masaaki Yamamoto^{1, 3} Bierta E. Barfod¹ Yoichi Urakawa¹

(1) Katsuta Hospital Mito GammaHouse, Hitachi-naka, Japan (2) Kyoto Prefectural University of Medicine, Kyoto, Japan (3) Tokyo Women's Medical University Medical Center East, Tokyo, Japan

Object: We describe herein the clinical efficacy of gamma knife radiosurgery (GKRS) for patients with brain metastases (METs) from lung cancers as well as new, state-of-the art, trends in brain MET treatment.

Methods: We retrospectively analyzed 1283 patients (399 females, 884 males, mean age; 65 [range; 19-96] years) who underwent GKRS for brain METs from lung cancers from July 1998 through June 2008. Median and mean lesion numbers were three and seven, range 1-85. The most common histology was adenocarcinoma (718 patients) followed by small cell carcinoma (185), squamous cell carcinoma (127) and others/undetermined (253). The median volume of the largest tumor was 2.9 (range; 0.01-94.2) cc, and the median peripheral dose was 21.0 (range; 5.8-25.0) Gy.

Results: At the end of March, 2010, excluding three patients (0.2%) lost to follow-up, 60 (4.7%) of the 1283 patients were still alive while the remaining 1220 (95.1%) were confirmed to have died. Causes of death could not be determined in 50 patients, but were confirmed in the remaining 1170; non-brain diseases in 1033 (88.3%) and progression of brain METs in 137 (11.7%). Among the 1283 patients, salvage GKRS was required mostly for lesions which had newly appeared in 407 (31.7%); twice in 285, three times in 79 and four or more times in 43 (maximum; seven). The overall median survival time (MST) after GKRS was 7.7 months. MSTs according to Recursive Partitioning Analysis (RPA) were 23.9 months in Class I (108 patients), 7.4 in Class II (1114) and 2.4 in Class III (58, $p < .0001$ for each pair). Among various clinical factors, both uni- and multi-variate analyses demonstrated female gender, age < 65 , Karnofsky performance status $> 80\%$, single metastasis, tumor volume < 15 cc, well-controlled primary tumors and non-brain METs to be significant factors predicting longer survival (threshold level; $< .01$).

Conclusions: Our present Results suggest that RPA class I and II patients can be regarded as good candidates for aggressive treatment of brain METs from lung cancers using GKRS. However, the treatment decision remains difficult in RPA class III patients because of their generally poorer outcomes.

P2036

STEREOTACTIC RADIOSURGERY FOR THE MANAGEMENT OF BRAIN METASTASES IN THE ADOLESCENT AND YOUNG ADULT POPULATION

Sonia Skamene¹ Paul Sperduto² Ryan Shanley³ David Roberge¹

(1) Department of Radiation Oncology, McGill University Health Centre, Montreal, Canada (2) University of Minnesota, Gamma Knife Center, Minneapolis, USA (3) Division of Biostatistics, University of Minnesota, Minneapolis, USA

Introduction: During recent decades, older adolescents and young adults diagnosed with cancer have emerged as a unique population that has failed to fully benefit from the advances in pediatric and adult oncology. Focused young adult cancer research has been lacking and this group has seen the least progress in cancer survival. Brain metastases are uncommon in this epidemiologically distinct group as is the use of radiosurgery. We sought to describe the use of radiosurgery in management of young patients suffering from brain metastases.

Methods: Patients 35 years of age or younger were identified in a multi-institutional, retrospective database of 5,067 brain metastases patients treated from July 1985 to August 2008. Demographic and outcome data for these patients were collected from 11 North American academic institutions.

Results: 131 patients were identified from 11 institutions. Patients were 18-35 years of age (median 31). The median KPS was 90% (range 50-100). The median GPA score was 2.5 (range 1-4). The most common primary tumors were melanoma (33.6%), breast (28.2%), lung (11.5%), sarcoma (6.1%), and testis (5.3%). This sample reasonably represents the distribution of cancer types found in this population with a propensity towards brain metastasis.

66.4% of patients had stereotactic radiosurgery as part of their treatment, either alone (31.3%), after surgery (7.6%), with whole brain radiotherapy (WBRT) (21.4%), or with surgery and WBRT (6.1%). Patients managed with SRS had a median of 2 lesions (range 1-19) vs. 3 for patients managed without SRS (range 1-innumerable). Compared with older adults, SRS was more commonly utilized in the 18-35 age group ($p < 0.0001$). For patients treated with SRS there was no difference in the rate of utilization of WBRT.

Median overall survival from initial treatment of brain metastases was 11.7 months (vs. 7.2 months for patients > 35 years of age, $p = 0.001$). The median survival was 13.6 months (5-year OS 5%) for patients managed initially with radiosurgery, and 4.0 months for those managed without ($p = 0.02$).

Conclusions: Young adult patients with brain metastases have a unique mix of primary tumors. These young patients are more commonly treated with radiosurgery and tend to have a more favorable prognosis than older patients.

P2037

COMPARISON OF LOCATION OF BRAIN METASTASES AMONG DIFFERENT DIAGNOSES AND CORRELATION WITH BRAIN VOLUME AND BLOOD FLOW

Jami Johnson¹ Yoichi Watanabe¹ Scott Jackson¹ Charles Watts¹ Paul Sperduto¹

(1) University of Minnesota, Gamma Knife Center, Minneapolis, USA

Background: Preliminary research suggests the location of brain metastases (BM) is not necessarily

related to lobar brain volume or blood flow but rather molecular events such as tumor-specific cell surface proteins or receptors which may explain the location of BM. (1) The purpose of this study is to compare the distribution of brain metastases (BM) among different diagnoses and correlate that distribution with brain volume and blood flow.

Methods: A retrospective database of 918 BM was created from Gamma Knife (GK) records at the University of Minnesota. The primary diagnosis and the location of each metastasis was recorded from GK treatment plans and correlated with the lobar brain volume and blood flow estimated from anatomic references. (2,3)

Results: The primary diagnoses and number of BM were non-small cell lung cancer (412), breast cancer (182), melanoma (163), renal cell carcinoma (106) and small cell lung cancer (55). The location of the BM, brain volume (cc) and blood flow (ml/min) were: frontal, 302, 34.8%; cerebellum, 159, 18.3%; parietal, 139, 16.0%; occipital 108, 12.4%; temporal, 96, 11.0%; brainstem, 45, 5.2%; other, 20, 2.3%. The location of brain metastases correlated with brain volume and blood flow for all diagnoses except for breast cancer and small cell lung cancer. Based on brain volume and blood flow estimates, the expected rate of BM in the cerebellum would be 13% of all BM. The observed rate of BM in the cerebellum in breast cancer and small cell lung cancer were 53/182 (29%) and 15/54 (28%), respectively, more than twice the expected rate. The difference between the expected and observed number of BM in the cerebellum was statistically significant for these two diagnoses ($p < 0.01$ for both breast cancer and small cell lung cancer).

Conclusions: The distribution of BM correlate directly with brain volume and blood flow for all diagnoses except for breast cancer and small cell lung cancer which show a predilection for the cerebellum. Further research is needed to confirm and explain these findings.

References:

1. Santarelli JG, Sarkissian V, Hou LC, et al. Molecular events of brain metastasis. *Neurosurg Focus* 2007;22(3):E1.
2. Allen JS, Damasio H, Grabowski TJ. Normal neuroanatomic variation in human brain. *Am J Phys Anthro* 2002;118(4):341-358.
3. Ito H, Inoue K, Goto R et al. Database of normal human cerebral blood flow. *Ann Nuc Med* 2006;20(2):131-138.

P2038

GAMMA KNIFE RADIOSURGERY FOR TREATMENT OF CEREBRAL METASTASES FROM NON-SMALL CELL LUNG CANCER

Micaela Motta¹ Antonella Del Vecchio² Piero Picozzi³ Luca Attuati³ Alberto Franzin³ Angelo Bolognesi¹ Riccardo Calandrino² Pietro Mortini³ Nadia Di Muzio¹

(1) San Raffaele Scientific Institute - Radiotherapy Dept., Milan, Italy (2) San Raffaele Scientific Institute - Medical Physics Dept., Milan, Italy (3) San Raffaele Scientific Institute - Neurosurgery Dept., Milan, Italy

Introduction: Aim of this retrospective study is to evaluate efficacy and safety of Gamma Knife radiosurgery (GKRS) for treatment of brain metastases from Non Small Cell Lung Cancer (NSCLC).

Methods: Between 2001 and 2006, 373 patients (298 men and 75 women, mean age 64.9 years) with brain metastases from NSCLC underwent GKRS. All of them had KPS > 60, number of brain

mets <8, confirmed histopathological diagnosis and recent stadiation (<3 months). 35 patients were in RPA class I, 307 patients were in RPA class II, 7 patients were in RPA class III. Mean tumor volume was 3.6 cm³. Medial marginal dose was 22.5 Gy with isodose at 50% in; median 10-Gy and 12-Gy isodose volumes were 30.8 cm³ and 15.8 cm³ respectively.

Out of 373 patients, 113 were submitted to another treatment before or after GKRS (surgery, WBRT, another GKRS, cystic metastasis drainage).

Follow up with MRI was performed every three months. Overall survival data were collected from internal database, telephonic interviews and identifying registries.

Results: Median follow-up after GKRS was 8.1 months. Mean overall survival was 14.2 months. Of 373 patients, 29 are still alive at present, 104 died from cerebral progression, 176 died from systemic cause. In 64 cases we were not able to assess the cause. Multivariate analysis with COX regression Hazard ratio based on RPA class, surgery, WBRT, age, sex, number of lesions, mean tumor volume, mean peripheral dose, 10-Gy and 12-Gy volumes, identified RPA class and mean total tumor volume as significant in conditioning overall survival. Clinically evident radionecrosis requiring treatment occurred in 8% of patients.

Conclusion: GKRS was effective in local disease control in these patients. RPA class was the most important prognostic factor. These data support the use of GKRS as first line therapy especially for patient in good general condition and controlled systemic disease.

P2039

THE EVALUATION OF IMAGE-GUIDED POSITINING IN INTRACRANIAL NON-INVASIVE STEREOTACTIC RADIOSURGERY

Ferrat Dincoglan¹ Kaan Oysul¹ Sait Sirin² Omer Sager¹ Bora Uysal¹ Selcuk Demiral¹ Hakan Gamsiz¹ Serdar Surenkok¹ Bahar Dirican¹ Murat Beyzadeoglu¹

(1) Gulhane Military Medical School, Dept. of Radiation Oncology, Ankara, Turkey (2) Gulhane Military Medical School, Dept. of Neurological Surgery, Ankara, Turkey

Purpose: The aim of this study is evaluating the feasibility of non-invasive, relocatable head frame in IGRS (Image Guided Radiosurgery) for improving patient comfort and quality of life (QoL) during stereotactic radiosurgery planning and therapy of patients with brain metastases.

Methods and Materials: Total 92 lesions of 42 patients with brain metastasis were included in the study. After immobilization with thermoplastic mask and bite block different from invasive frame-based procedure, planning CT (Computed Tomography) images were acquired and fused with MRI (Magnetic Resonance Imaging) images. After contouring metastatic lesions and critical structures, VMA-RS (Volumetric Modulated Arc-Radiosurgery) planning was done (ERGO++ planning system, CMS, Elekta) and the patients were re-immobilized on treatment couch for the therapy. A set of kV-CBCT (kiloVoltage-Cone Beam Computed Tomography) images were taken to determine set-up errors and achieve on-line correction. The patients then underwent single fraction definitive treatment.

Results: For the 92 lesions treated, mean \pm standard deviation (SD) values of translational set-up corrections in lateral (X), longitudinal (Y), vertical (Z) dimensions were 1 ± 1.5 mm, 0.7 ± 1.3 mm, 0.8 ± 1.2 mm and X, Y, Z rotational set-up corrections were $0.5 \pm 1.1^\circ$, $0.06 \pm 1.1^\circ$, $-0.1 \pm 1.1^\circ$, respectively.

Conclusion: The IGRS technique we used in order to improve patients' comfort and QOL during therapy provided acceptable geometric inaccuracy and corrected by XVI (XRay Volumetric Imaging, Elekta). Non-invasive IGRS for brain metastasis therapy is feasible approach and this treatment technique can be routinely used in clinical practice.

P2040

INITIAL CLINICAL EXPERIENCE WITH VOLUMETRIC MODULATED ARC THERAPY (VMAT) FOR INTRACRANIAL STEREOTACTIC RADIOSURGERY (SRS) FOR BRAIN METASTASES.

Henry Yampolsky^{1, 2}

(1) Valley Radiotherapy Associates, Manhattan Beach, USA (2) Center For Radiation Therapy, Beverly Hills, USA

Objective: To evaluate feasibility and clinical outcomes of VMAT SRS for brain metastases.

Methods: 28 metastatic lesions in 17 patients were treated using Varian RapidArc VMAT. All lesions were treated in a single fraction SRS session, ranging from 1-4 targets per treatment. All patients were immobilized with customized head rest and rigid customized face mask. Optical fiducial array attached to maxillary dentition was used for localization and intra-fraction monitoring. Isocenter position was verified using orthogonal kV-X-ray or cone beam CT in all cases. Local control dosimetric parameters (conformity, heterogeneity, gradient (radius D100-D50)), normal brain dose (V10, V12), and beam-on-time (BOT) were evaluated.

Results: Local control rate was 87% with median follow-up of 4 months (range 0-16). Mean single fraction dose was 2000 cGy (range 1500-2400). Mean target volume was 3.5 cm³ (range 0.4-13.5) with mean equivalent sphere diameter 1.65 cm. No acute SRS related toxicity was noted. No cases of symptomatic or radiographic radionecrosis were noted. Mean BOT was 521 seconds per treatment session. Mean conformity index was 1.3 (range 1.1-1.7), mean gradient was 0.69 cm (range 0.49-0.95), and mean heterogeneity index was 1.14 (range 1.08-1.34). Mean V10 and V12 were 10.1 cm³ (range 4.4-21.5) and 6.6 cm³ (range 2.2-11.9) per lesion respectively.

Conclusion: 1) Dosimetric parameters (conformity, dose gradient, and V12) for VMAT RapidArc SRS plans are comparable to historically reported Results for other SRS techniques.

2) Early Results demonstrate control rates similar to other SRS techniques.

3) Treatment times appear shorter than for other SRS techniques.

4) RapidArc VMAT SRS is feasible and efficient for treatment of single and multiple brain metastases.

P2041

SUBTRACTION-FUSION WITH PRIOR IMAGES HELPS IDENTIFY ADDITIONAL BRAIN METASTASES FOR REPEAT RADIOSURGERY

John Flickinger^{1, 2, 3} Douglas Kondziolka^{2, 1} Josef Novotny^{1, 3} Hideyuki Kano² Ajay Niranjana^{2, 1} L. Dade Lunsford^{2, 1}

(1) University of Pittsburgh School of Medicine, Dept of Radiation Oncology, Pittsburgh, Pa, USA (2) University of Pittsburgh Dept of Neurological Surgery, Pittsburgh, Pa, USA (3) Pittsburgh Cancer Institute, Pittsburgh, Pa, USA

Purpose: Identification of all brain metastases present on planning stereotactic images is necessary

to optimize control of brain metastases and limit the need for additional radiosurgery or radiotherapy to the brain. We hypothesized that subtraction-fusion of new minus old high-resolution stereotactic contrast enhanced magnetic resonance (MR) images of brain metastasis patients for radiosurgery planning would improve detection of small brain metastases.

Methods and Materials: We studied 25 patients with prior brain metastasis radiosurgery undergoing subsequent radiosurgery procedures after June 2010. Prior high-resolution stereotactic contrast-enhanced MR images were co-registered with new images to identify and outline all prior radiosurgery treatment volumes. All new brain metastases were outlined after review by at least one Neurosurgeon, one Radiation Oncologist and one Medical Physicist. Subtraction-fusion (new minus last prior) images were constructed and reviewed to see if additional brain metastases could be identified. Five patients had prior whole-brain and one partial brain fractionated radiotherapy. The number of prior radiosurgery procedures were 1, 2, 3, 4, & 5 in 14, 3, 5, 1 & 2 patients respectively. The median number of brain metastases previously treated by radiosurgery was 4 (range: 1-55). The median interval since the latest prior radiosurgery imaging was 170 days (range: 50-886).

Results: Without the subtraction-fusion imaging 0-16 (median=20) new metastases were identified. One metastasis needed repeat radiosurgery in four patients and two metastases needed retreatment in four other patients. After review of the subtraction-fusion (new-old) MR-images, 8/25 (32 %) of patients had additional brain metastases identified, measuring 3-176 cubic-mm (median, 22). Four patients had one additional metastasis and four patients had two additional metastases identified from subtraction-fusion images. Stepwise linear-regression correlated the number of additional brain metastases identified with the number of new brain metastases identified before subtraction-fusion ($p=0.037$).

Conclusions: Subtraction-fusion of new minus prior contrast-enhanced high-resolution MR images appears to help identify additional brain metastases for radiosurgery planning, particularly with increasing numbers of new brain metastases.

P2042

CONCOMITANT BOOST ON MULTIPLE BRAIN METASTASES AND HIPPOCAMPUS SPARING WITH HELICAL TOMOTHERAPY: A CASE REPORT

Fabrizio Cammarota¹

(1) Fondazione Muto - Onlus, Napoli, Italy

Brain metastases are the most common intracranial tumors in adult patients. In our Institution a substantial part of palliative treatments provides whole brain irradiation. However recent studies have shown that learning aptitudes, especially memory, can be damaged when irradiating the hippocampus while its anatomical location makes impossible to spare it using 3D-conformal radiotherapy. We reported the feasibility and the clinical effectiveness of a whole-brain irradiation approach with a simultaneous multifocal integrated boost to increase local control, sparing the hippocampus, using an Helical Tomotherapy (HT) unit. A 46 years old patient treated in 2006 for breast cancer with 3D-conformal radiotherapy presented, in March 2009 five brain metastases. An HT treatment was so planned with a dose prescription of 30 Gy to the whole brain in 10 fractions with concomitant boost of 40 Gy upon the lesions; optical apparatus, amygdala and hippocampus

were contoured as organs at risk. Magnetic resonance images were fused through a mutual information algorithm with the planning CT to better identify both lesions and brain structures. Helical Tomotherapy has provided a very effective, high conformal dose delivery, especially in the latero-lateral and antero-posterior directions. The hippocampus dose was relatively low, with a maximum of 15 Gy and an average of about 10 Gy. Despite the treatment complexity, the delivery time was quite low (about 11 min). During the treatment the patient did not present acute toxicity. The follow-up performed one year after the end of treatment pointed out that the 5 lesions are slightly reduced in size and today the patient has no neuro-cognitive deficits and he Results well «space and time integrated». In conclusion, for patients affected by brain metastases HT allows very complex treatments to maximize the local disease control while reducing hippocampus dose; also this treatment doesn't result time-consuming with respect to the ordinary HT treatments and so it could be used in the clinical practice. Furthermore this report has been a successful also from the clinical point of view, so we will use it widely in our clinical practice as a «standard of care» in order to have a greater cases number to draw more statistically significant **Conclusions:**

P2043

STEREOTACTIC RADIOSURGERY FOR THE TREATMENT OF MELANOMA BRAIN METASTASES

Rodney Wegner¹ Katharine Reineman² Dwight Heron¹ Arlan Mintz² Steven Burton¹

(1) University of Pittsburgh Cancer Institute, Pittsburgh, USA (2) University of Pittsburgh School of Medicine, Pittsburgh, USA

Objectives: Melanoma is one of the most common malignancies to metastasize to the brain, occurring in up to 40% of patients with stage IV disease. Ultimately, the majority of such patients will succumb to their CNS disease, highlighting the importance of effective local treatment of brain metastases in these patients. The objective of this study was to evaluate the outcomes associated with stereotactic radiosurgery (SRS) in the treatment of melanoma brain metastases.

Methods: We retrospectively reviewed the records of 54 patients with a total of 103 tumors treated with SRS between 2004 and 2010. Twenty patients had surgical resection prior to SRS and 9 patients had undergone prior whole brain radiation therapy (WBRT). Seventy-one percent of patients had active extracranial disease at the time of SRS. The median number of tumors treated per patient was 1 with a median volume of 2.1 cm³ (range: 0.05-59.7 cm³). The median dose delivered to the 80% isodose line was 24 Gy in a single fraction.

Results: The median follow-up from SRS was 5 months for all patients (range:1-30 months). Sixty-five percent of patients had a follow-up MRI available for review. Actuarial local control at 6 months and 12 months was 87% and 68%, respectively. Gender was the only variable which predicted for improved LC (p=0.042). Eighty-one percent of patients developed new distant brain metastases at a median time of 2 months. Twenty-two of these patients were treated with repeat SRS and 4 patients had salvage WBRT. The 6-month and 12-month actuarial overall survival rates were 50% and 25%, respectively. The factors found to be significant predictors of overall survival were patients who had surgical resection and percent tumor coverage by the prescription dose. Post- SRS bleeding was documented in 18% of patients and occurred at a median interval of 1.5 months. There was no other treatment-related toxicity in follow-up.

Conclusions: SRS for brain metastases from melanoma is safe and achieves good local control. In

our series, the patients that derived the greatest benefit were those who had prior surgical removal of the lesion, highlighting the importance of a multi-disciplinary approach to these patients.

P2044

HYPOFRACTIONATED FRAMELESS STEREOTACTIC INTENSITY MODULATED RADIOTHERAPY WITH WHOLE BRAIN RADIOTHERAPY FOR THE TREATMENT OF BRAIN METASTASES.

Piet Ost¹ Bruno De Potter¹ Anne-sophie Beerens¹ Bruno Speleers¹ Gert De Meerleer¹

(1) Ghent University Hospital, Ghent, Belgium

Purpose: The efficacy and toxicity of hypofractionated frameless stereotactic radiotherapy (HSIMRT) with whole brain radiotherapy (WBRT) for the treatment of 1-3 brain metastases, using a non-invasive fixation of the skull, was investigated.

Materials and Methods: Between January 2009 and August 2010, 22 patients with 32 brain metastases were treated at Ghent University Hospital with WBRT (10x3Gy) followed by HSIMRT (5x6Gy). Patients were positioned with thermoplastic masks followed by cone-beam computed tomography as position verification system. Only patients with recursive partitioning analysis (RPA) class 1 (n=6) and 2 (n=16) were eligible for HSIMRT, following our in-house protocol. Acute toxicity was scored using the RTOG toxicity criteria. Response rates were scored at 3 months and 9 months of follow-up (McDonald criteria). Overall survival (OS), brain-specific survival (BSS), local and distant brain control were calculated using the Kaplan-Meier Methods. Patient (age, Karnofsky Performance score, KPS) and tumor characteristics (number of lesions, extracranial metastases, brain tumor volume, RPA class) were tested in univariate and multivariate analysis.

Results: One patient died of an urosepsis before receiving the HSIMRT boost. Twenty-two out of 30 lesions received the prescribed median dose. In the remaining 8 lesions the dose was lowered due to the proximity of organs at risk (mean dose 5x4.4Gy). A complete and partial response was seen in 17% (n=5) and 33% (n=10) of the lesions, respectively. In 30% (n=9) of the lesions, a reduction of <25% was seen. Six lesions in 5 patients were not evaluable because the patients died (n=5) before 3 months of follow-up. The median OS was 9.2 months for the whole group, 13 and 8 months for RPA class 1 and 2 patients (p=0.5), respectively. The 1-year actuarial OS and BSS was 46% and 94%, respectively. The 1-year actuarial local and distant brain control was 90% and 75% respectively. On univariate analysis the number of lesions (1 vs. >1) and KPS (70-80 vs. 90-100) were significant predictors for OS (p<0.05). On multivariate analysis, only KPS remained significant (p<0.05). Acute grade 2 toxicity was seen in 23% of the patients. Three patients (14%) had transient grade 3 toxicity, resolving under corticosteroid treatment.

Conclusion: WBRT plus HSIMRT offers an excellent brain-specific survival with good local and distant brain control rates. Karnofsky performance score at referral was an independent prognostic factor for overall survival.

P2045

ANALYSIS OF FACTORS WHICH INFLUENCE LOCAL CONTROL FOLLOWING SRS FOR BRAIN METASTASES

Amol Ghia¹ Randy Jensen¹ Annabelle Shrieve¹ Dennis Shrieve¹

(1) University of Utah, Salt Lake City, USA

Objective: To analyze factors correlating with local control (LC) of intracranial metastatic disease following stereotactic radiosurgery (SRS).

Methods: Patients with intracranial metastases were treated between March 1999 and April 2010. Serial post-contrast T1-weighted MRI scans were analyzed. Failure was defined as re-treatment of a given lesion or a sustained increase in the diameter sum of 20% following SRS treatment.

Results: Two hundred thirty-three patients with 647 metastases were analyzed. Median age was 57.9 years (range 21.5-89.0). The most common histology was melanoma (45.1%). Most were RPA class 2 (73.4%) and had a single brain metastasis at initial SRS treatment (49.8%). Most underwent a single course of SRS (75.1%) while 47.2% did not have any whole brain radiotherapy (WBRT). The median SRS prescription isodose was 2000 cGy and most metastases were less than 2 cm (73.6%). Median LC follow-up was 5.0 months.

The median actuarial overall survival (OS) was 10.2 months and the crude LC rate was 79.0%. Those with melanoma had worse OS (HR 1.54; $p=0.0028$) and LC (HR 2.04; $p<0.0001$) while renal cell carcinoma had better LC (HR 0.17; $p=0.0006$). SRS alone had worse LC than WBRT followed by SRS (HR 2.77; $p<0.0001$) but equivalent OS (HR 0.89). Pre-treatment hemorrhage correlated with worse LC (HR 2.13; $p=0.0048$) but not OS ($p=0.68$). Recurrent lesions had worse LC than previously unirradiated lesions (HR 3.12; $p<0.0001$). There was no difference in LC between frame-based and frameless techniques (HR 0.68; $p=0.26$) nor between those receiving 20 Gy vs. >20 Gy (HR 1.56; $p=0.12$).

Sixteen patients (6.9%) with 23 metastases survived 2 years with LC. Long-term survivors had more breast, RCC and unknown primaries ($p<0.0001$). All 23 metastases were between 2 and 3 cm versus the entire cohort in which 19.6% were between 2 and 3 cm ($p<0.0001$).

Conclusions: Histology, pre-treatment hemorrhage, previous irradiation and concurrent WBRT were associated with LC rates following SRS treatment. Frameless technique had equivalent LC compared with frame-based technique. Melanoma brain metastases were correlated with worse OS. 6.9% of study patients were alive at 2 years with LC.

P2046

HELICAL TOMOTHERAPY FOR MULTIPLE BRAIN METASTASES

Ruth Rodríguez Romero¹ Patricia Sánchez Rubio¹

(1) Servicio de Radiofísica. Hospital Universitario Puerta de Hierro, Madrid, Spain

Objective: Despite there is available a specific stereotactic linear accelerator with frameless system in our hospital, multiple brain metastases patients are treated with Helical Tomotherapy due its simplicity to localize and treat various target volumes. This study evaluates the feasibility of these treatments by analyzing dose distribution plans, quality assurance Results and positioning

displacements.

Methods: Five patients with 2-5 brain metastases have been treated with helical tomotherapy. Patients were immobilised using radiosurgery thermoplastic mask and planning target volumes (PTV) were obtained as 3mm geometric expansion of gross tumour volumes (GTV), except in one case. The prescribed dose to PTV was 20-25 Gy in 5 daily fractions (95%dose to 95%volume). Dose distribution plans were reported following ICRU83 recommendations (near minimum dose D98%, near maximum dose as D2%). Routinely IMRT experimental verifications were done using ion chambers and gafchromic films. Daily MVCT were performed before every fraction and displacements were applied and registered.

Results: Treatment beam-on time obtained were 6.4 - 10.2 minutes. Dose homogeneity was evaluated: standard deviation <1Gy; <4% of prescribed dose and subdosage were <10% and overdosage were <3%. To analyze OAR doses from all the treatment plans, 20 Gy dose plan was reescalated to 25 Gy. Optic nerves mean dose was <4 Gy with <6%, chiasm mean dose Mean dose and near maximum dose was less than: 4 and 6 Gy for optic nerves, 6 and 8 Gy for chiasm, 19 and 8 Gy for brainstem, 4 and 2 Gy for eyes respectively. Quality assurance verifications were agree to treatment planning system; discrepancy of ion chamber measurements <3%, 95% points follow gamma(3%,3mm) criteria. Systematic and expected errors were found: <3mm longitudinal due to CT slices resolution, <4mm vertical because of table sag. Since shift corrections were performed every session which are really important are random errors: <1mm for translation and <0.8° for rotation.

Conclusions: Since location and irradiation of multiples targets can be performed simultaneously with Tomotherapy, patient time at treatment room is certainly reduced (30 minutes per lesion vs 30 minutes total). Beside this clear advantage, Tomotherapy achieves dose distributions with high homogeneity of dose at PTV and great OAR sparing that are realizable as it provides enough dosimetric and setup accuracy.

References: Shaghera et al. Br J Radiol.2010 -Feb;83(986):98-100. Soisson et al. Medical Dosimetry.2010-Feb.

Tomita et al. Technol Cancer Res Treat. 2008 Dec 7(6):417-24.

P2047

RETROSPECTIVE ANALYSIS OF STEREOTACTIC RADIOTHERAPY FOR THE TREATMENT OF BRAIN METASTASIS

Valentina Pinzi¹ Sara Gomellini¹ Stefano Arcangeli¹ Katia Pasciuti² Valeria Landoni²

(1) Dept. Radiotherapy Regina Elena National Cancer Institute IFO, Rome, Italy (2) Dept. Physics Regina Elena National Cancer Institute IFO, Rome, Italy

Purpose: The aim of this study was to analyze the Results from a two years experience of stereotactic radiotherapy in single or multi fraction (SRS or FSRT) for the treatment of brain metastasis.

Methods and materials: 137 lesions have been treated either with dynamic arc therapy or intensity modulated radiation stereotactic radiotherapy, with a 6 MV linear accelerator equipped with multileaf collimator (120 leaves). All patients were immobilized with a thermoplastic or fixed stereotactic head mask, an intravenous contrast material was used during the acquisition phase

of computed tomography (CT) scan and images were acquired with 1 mm spacing in the tumor region and 3 mm spacing outside the lesion. The target volumes were delineated by a radio-oncologist on CT images previously registered with magnetic resonance (MR) images. Plans were generated by a BrainSCAN v.5.3 (BrainLAB AG, Germany). One month after radiotherapy, patients were monitored by clinical observation. Subsequently, patients were examined every three months by MR imaging during the first year. The treatment outcome was established according to the RTOG criteria; complete tumor regression, if a complete disappearance of the lesion was observed on the MR scan; partial regression, if a 50% or more reduction was seen; stable disease, if an unchanged lesion in volume was observed, and progression disease, if there was at least a 25% increase of the lesion in volume.

Results: Median overall and cause-specific survival times were 12 and 35 months respectively. The log-rank test was used to compare survival distributions estimated by the Kaplan-Meier Methods and a statistically significant difference between overall and cancer specific survival was found ($p=0.0003$). The effect of primitive tumor, Karnofsky Performance Status (KPS), RTOG recursive partitioning analysis (RPA), stereotactic dose and whole brain radiotherapy as risk factors on survival were analyzed by the Cox proportional-hazards regression; an higher KPS (≤ 70) was correlated with a longer overall and with cancer specific survival ($p=0.0002$ and $p=0.02$ respectively), while a longer overall survival was observed in patients who were administered whole brain radiotherapy ($p=0.03$). No significant correlation was observed with the others prognostic factors analyzed.

Conclusions: The significant difference observed between actuarial overall and cancer specific survival shows that a good local disease control prolongs survival time.

Moreover, our Results, in agreement with previously published data on stereotactic radiotherapy for brain metastasis, indicate an higher value of KPS index as a good prognostic factor for overall and cause specific survival.

P2048

REVIEW ON RADIOSURGERY OF BRAIN METASTASES FROM 1990 TO 2009. DIFFERENCES IN PRACTICE BETWEEN NEUROSURGEONS AND RADIATION ONCOLOGISTS.

Ruud Wigenraad¹ Antoinette Verbeek- De Kanter¹ Henk Struikmans¹

(1) Radiotherapy Centre West, The Hague, The Netherlands

Background: Historically, radiation oncologists (RO) more often use a linear accelerator (lineac) whereas neurosurgeons (NS) use more often use a gamma knife (GK) in stereotactic radiosurgery (SRS) of brain metastases. A discussion is ongoing about the maximum number of brain metastases that can be treated with radiosurgery. We performed a systematic search for literature on radiosurgery of brain metastasis. The purpose of this paper is to study differences in practice during this period.

Methods and materials: A literature search was performed in Pubmed and Embase for all single center patient series, published between 1990 and 2009, describing Results of SRS of brain metastases. From all papers we extracted the following data: medical specialty of the first author (RO, NS, or others), treatment machine (GK, lineac), number of patients treated and number of metastases treated

Results: We identified 260 papers describing 28049 patients treated with SRS for brain metastases with or without whole brain irradiation. The first author was a NS in 124 papers and a RO in 90 papers. The remaining papers were either multicenter studies or had a first author of another medical specialty. There were 127 GK papers (77% of which written by NS) and 87 lineac papers (68% of which written by RO). Over the four five-year periods the percentage of GK papers written by NS and RO rose from 55% to 74% and from 0% to 52% respectively. Over the four five-year periods the mean number of treated metastases per patient rose from 1.5 to 3.1 in the NS papers, from 1.4 to 2.3 in the RO papers, from 1.5 to 3.4 in the GK papers and from 1.4 to 1.8 in the lineac papers.

Conclusion: In the literature of the last twenty years we noticed a trend that patients with a higher mean number of brain metastases were treated with SRS. Neurosurgeons, especially those using the GK, treat patients with a mean number of more than three metastases with SRS. Neurosurgeons and Radiation Oncologists seem to use different criteria for the maximum number of brain metastases that are treated with SRS.

P2049

BRAIN METASTASES FROM BREAST CANCER TREATED WITH LINAC- RADIOSURGERY: PREDICTING FACTORS FOR DISTANT RELAPSE

Christos Boskos¹, ³ Moomina Lekehal¹ Michel Duyme⁴ Gilbert Boissier² Philippe Cornu¹ Jean-jacques Mazon² Charles A Valery¹

(1) Neurosurgery department, Hôpital de la Salpêtrière, APHP, Paris, France (2) Radiotherapy department, Hôpital de la Salpêtrière, APHP, Paris, France (3) Radiotherapy department, Iatriko medical center, Athens, Greece (4) Biostatistics, epidemiology and clinical research, EA 2415, Montpellier, France

Introduction For years, neurological control including distal control of brain metastases (BM) has been achieved by whole brain radiation therapy (WBRT). Iterative radiosurgery (RS) is now increasingly proposed in order to reach this goal while minimizing toxicity. Prolonged survival of patients with breast cancer is favorable for further observation of parameters affecting intracranial distal control.

Material and Methods: Hundred and twelve patients were treated 3.5 years after the primary was discovered. Mean age was 54 yo (26-82). Mean Karnofsky index was 90 (60-100). Primary was controlled in 87.5% of the cases. There were extra-CNS lesions in 78% of the cases. Patients were 14% RPA group I, 84% RPA group II and 2% group III. Patients were SIR 8-10 in 35% of the cases, SIR 4-7 in 65% of the cases. They had previous surgery in 12% of the cases, WBRT in 50% of the cases. Mean number of metastases was 189, median lesion volume was 1.5 cc (0.008-44). Irradiation was performed with a 6 MV Varian Clinac 2100 C and a BrainLAB® M3 micromultileaf collimator. Delivered doses were 16 Gy at the reference isodose (6.6-17) and 20 Gy at the isocenter (18-24).

Results: Median survival time was 536 days. Median interval before distal relapse was 518 days. In a monovariate analysis, age ($p=0.016$), interval primary-BM ($p=0.05$) and number of lesions ($p=0.004$) were significant. Presence of WBRT was not significant ($p=0.9$). In a multivariate Cox regression analysis using a backward elimination approach, the best model ($\chi^2 = 23.2$) predicting distal relapse included 5 parameters: age, primary control, previous surgery, interval

between primary and brain metastasis, and number of metastases, the latest being significant ($p=0.007$). A ROC analysis looking for a potential cut-off showed that two lesions was the number above which probability of displaying new lesions was increasing significantly (sensitivity (95% CI) = 0,91/specificity (95% CI) = 0,25).

Conclusion Initial number of lesions is the only significant predictive parameter of distal relapse, patients with more than two lesions having a significantly shorter interval before relapse than those with one or two lesions. Interestingly, WBRT does not seem to influence interval before relapse.

P2050

BILATERAL MALIGNANT MELANOMA METASTASES TO THE INTERNAL AUDITORY CANAL: RADIOSURGICAL MANAGEMENT.

Marcos Dellaretti^{1, 2, 4} Júlio Leonardo Barbosa Pereira^{1, 2, 4} Eduardo K Tagawa^{3, 4} Baltazar Leão Reis^{1, 2, 4} Mariana Pedrini^{3, 4} Atos Alves Sousa^{1, 2}

(1) Department of Neurosurgery, Santa Casa de Belo Horizonte, Belo Horizonte, Brazil (2) Department of Neurosurgery, Hospital Lifecenter, Belo Horizonte, Brazil (3) Department of Radiotherapy, Hospital Lifecenter, Belo Horizonte, Brazil (4) Centro de Radio-Oncologia de Minas Gerais, Belo Horizonte, Brazil

Malignant melanomas constitute 1-8% of all malignant tumors and are the third most common tumor to metastasize to the central nervous system, However, metastases to the cerebellopontine angle (CPA) are rare, accounting for only 0.2 to 0.7% of the lesions identified in this location

Case Report

A 62-year-old man with a history of melanoma of the back were completely excised, and the patient was reportedly tumor-free for 6 years. He presented metastatic CPA melanoma bilateral.

The patients underwent intensity-modulated stereotactic radiosurgery, using BrainLab Iplan 4.1 for both IAC lesions, dose was 18Gy prescribed to the 80% isodose line delivered by 11 fields. The patient had no post-radiosurgery neurological complications.

Conclusion: Patients with lesions in the CPA, the diagnosis of melanoma should be remembered. Especially in cases with rapid progression of symptoms. Radiosurgery in selected patients with melanoma should be considered as first-line treatment.

P2051

TREATMENT OF BRAIN METASTASES WITH LINAC RADIOSURGERY IN CHILE: TUMOR CONTROL, SURVIVAL AND QUALITY OF LIFE

José Lorenzoni¹ Adrián Zárate¹ Roberto Farías¹ Juan Delgado¹ André Vieira¹ Patricio Tagle¹ Pelayo Besa¹

(1) Pontificia Universidad Católica de Chile, Santiago, Chile

Objective: To analyze the experience of radiosurgery for treatment of brain metastases at the Pontificia Universidad Católica de Chile with emphasis in tumor control, survival and quality of life.

Methods: between March 2006 and July 2010 23 patients harboring 42 brain metastases were treated with radiosurgery. The treatment was carried out with a Linear accelerator Varian Clinac 21 EX, equipped with Varian-ZMed system. 20 patients were treated in a single fraction with a

mean marginal dose of 20 Gy (18 to 24) and 3 patients were treated in five fractions of 5 Gy in consecutive days.

Results: Thirteen men and 10 women with a mean age of 58.8 years were treated. The primary tumor was lung in 9 patients, melanoma in 4, breast in 2, kidney in 2 and others in 6. Tumor control was achieved in 36 of 42 lesions (86%). In patients treated with single fraction, the tumor control was in 35 of 39 lesions (90%). In patients treated with hypofractionated scheme the control was in 1 of 3 lesions (33%). At the clousure of this study 15 patients have died and 8 are alive. The overall median survival after the treatment was 12 months. The median survival with a Karnofsky performance status 70 or more was 8 months.

Conclusions: These Results are comparable with Results published in the literature and shows that most of survival is in an acceptable Karnofsky status.

P2052

RESULTS OF THREE-SESSION GAMMA KNIFE TREATMENT FOR LARGE METASTATIC BRAIN TUMOR.

Osamu Nagano¹ Yoshinori Higuchi² Toru Serizawa³ Shinji Matsuda¹ Makoto Sato¹ Kyoko Aoyagi⁴ Koichi Okiyama⁴ Junichi Ono⁴ Naokatsu Saeki²

(1) Gamma Knife House, Chiba Cardiovascular Center, Ichihara, Japan (2) Department of Neurological Surgery, Chiba University, Chiba, Japan (3) Tokyo Gamma Unit Center, Tsukiji Neurological Clinic, Tokyo, Japan (4) Department of Neurosurgery, Chiba Cardiovascular Center, Ichihara, Japan

Purpose: We have reported three-session gamma knife (GK) treatment for large brain metastases (>10cc in volume) in Int. J. Radiation Oncology Bio Physic (2009). In this study the long-term Results for more patients were evaluated according to the same irradiation protocol.

Patients and Methods: The subjects were 80 patients (47 men and 33 women) who had large brain tumors according to the same protocol with total 30Gy / 3 fractions / 2 week-intervals. Eighty-four large brain metastases (TV>10cc) were analyzed in this study. Tumor progression-free, overall, neurological death-free and functional independence-free survivals were evaluated.

Results: Age ranged from 25 to 84. Primary organs were lung in 33 patients, gastro-intestine in 20, breast in 16 and others in 11. The mean tumor volume prior to treatment was 19.4 cc (range 10.2 to 48.4). The tumor volumes were significantly decreased to 15.8 cc (22.7% volume reduction) at 2nd session and 10.8cc (43.7%) at the 3rd session. The cumulative tumor progression-free survival rates were 91.8% and 67.8 % at 6 and 12 months, respectively. There were 17 control-failure (>20% increase in diameter on enhanced MRI) tumors (tumor recurrence in 11, radiation injury in 5 and tumor bleeding in 1). The mean overall survival period was 8.9 months. Neurological death-free and functional independence-free survival rates at 12 months were 88.8% and 86.4%, respectively.

Conclusions: Our Results suggested that three-session GK treatment could be an alternative to surgical removal or WBRT in treating large brain metastases.

P2053

2-STAGED GAMMA KNIFE SURGERY FOR LARGE METASTATIC BRAIN TUMORS

Shoji Yomo^{1, 2} Motohiro Hayashi^{1, 2} Teruhisa Watayo^{1, 2}

(1) Saitama Gamma Knife Center, Saitama, Japan (2) Tokyo Women's Medical University, Tokyo, Japan

Objective: Standard treatment for large metastatic brain tumors is surgical resection if feasible. Fractionated stereotactic radiotherapy without WBRT is recently reported as an alternative for treating large brain metastasis. A prospective clinical trial was conducted as to evaluate the efficacy and the limitation of 2-staged Gamma Knife surgery (GKS) for large metastatic brain tumors.

Methods: Inclusion criteria were as follows; i) metastatic brain tumors not amenable to surgical resection, ii) tumor volume > 15mL in the supratentorial region or > 10mL in the infratentorial region. Consecutive 21 lesions in 20 patients (13 men and 7 women) were included in this study and their age ranged from 32 to 88 y/o (median, 63.5). Radiosurgical protocols were as follows; 20-30Gy / 2 fractions / 2-4 weeks. The local tumor control rate and the overall survival were calculated using the Kaplan-Meier Methods.

Results: Median tumor volumes were 16.1mL at 1st GKS and 7.6mL at 2nd GKS, respectively (53% volume reduction). Median KPS improved from 60 (1st GKS) to 85 (2nd GKS). Median follow-up time was 5.9 months. The local control rate was 78% and 52% at 6 and 12 months. The overall survival rate after GKS was 69% and 46% at 6 and 12 months. Subsequent interventions were needed surgical removal in two patients and repeat GKS for local recurrence in one patient and for distant tumor relapse in 6 patients. 7 patients died and the causes of death were 2 local progression, one meningeal carcinomatosis and 4 progression of the primary lesion. Symptomatic adverse radiation effects were seen in 2 patients and needed hyperbaric oxygen therapy and steroid administration, which alleviated their symptoms.

Conclusion: Although long-term efficacy and toxicity is still unknown, 2-staged Gamma Knife surgery could provide acceptable local control of large metastatic brain tumors and neurological palliation coupled with significant tumor volume reduction in short-term F/U. Best regimen for dose and fraction schedule, however, should be established.

P2054

HYPOFRACTIONATED STEREOTACTIC RADIOTHERAPY (HSFRT) FOR LARGE BRAIN METASTASIS (BM) OR BM NEAR CRITICAL AREAS: SINGLE SPANISH INSTITUTION EXPERIENCE.

Karina Quispe¹ Ana Lucas¹ Miquel Macia¹ Claudio Flores¹ Karinthia Ballon¹ Ivan Garcia¹ Ferran Guedea¹ Ferran Guedea¹ Ivan Garcia¹ Ferran Guedea¹ Claudio Flores¹ Ferran Ferrer¹ Ferran Guedea¹

(1) Catalan Institute of Oncology, Barcelone, Spain

Purpose Local control of large BM treated with single fraction radiosurgery (SRS) is poor because the prescription dose must be reduced to limit the risk of toxicity. Likewise, the use of SRS in patients with BM near critical areas would cause higher toxicity. We hypothesized that HSFRT might be advantageous in these two groups of patients, although the ideal fractionation scheme is not known. Our aim was to analyze efficacy and toxicity of HSFRT to treat these groups of patients.

Patients and Methods: Between June 2006 and June 2010, 31 patients (pts) with 44 BM were treated with HSRT (BrainLAB) at the Catalan Institute of Oncology. Eligibility criteria included BM larger than 30 mm or located near critical areas. We used 3 different dose schemes: 3 x 6 Gy (28 BM), 4 x 5 Gy (11 BM), and 5 x 5 Gy (5 BM) given daily (20 BM) or on alternate days (24 BM). A 3 mm margin from the CTV to the PTV was used. Lesions were treated after whole brain radiotherapy (WBRT) as a boost (17 pts), upfront (8 pts) or salvage treatment (6 pts). Toxicity was graded according the RTOG scale. Local control (LC), overall survival (OS) and local progression-free survival (LPFS) rates were obtained using the Kaplan-Meier Methods. Cox regression analysis was performed to identify potential prognostic factors.

Results: Median follow-up was 6.7 months (range, 1.5-46). Response was as follows: complete remission, 20.5%; partial remission, 47.7%; stable disease, 22.7%; and progressive disease, 9.1%. LC rates at 6 months and 1 year were 85% and 62.5%, respectively. Median OS was 15.6 months (95% CI: 9.2-22.1). LPFS (without considering new BM) at 6 and 12 months were 88% and 68%, respectively. Eight pts (26%) developed a new BM and the median time to brain progression was 6.5 months. Most patients died of extracranial progression (77%). Median PTV was 5.78 cc for metastases located near critical areas and 27.9 cc for large metastases. On multivariate analysis, predictors of LPFS were tumor size ($p=0.035$) and GPA score ($p=0.012$). LPFS at one year was 58.8% for tumors <20 mm and 37% for tumors ≥ 20 mm ($p=0.017$). Eighteen patients (41%) experienced RTOG grade 2 side-effects while only 3 pts (9.7%) had RTOG grade 3. There were no cases of radionecrosis.

Conclusion: HSRT with these fractionation schemes is a feasible treatment when single fraction SRS is not possible but local control remains poor. Given the minimal toxicity observed we are encouraged to escalate doses to improve local control rates.

P2055

HYPOFRACTIONATED STEREOTACTIC RADIOTHERAPY FOR BRAIN METASTASES LARGER THAN 3 CENTIMETERS

Jianping Xiao¹ Xuesong Jiang¹ Ye Zhang¹ Guozhen Xu¹ Junlin Yi¹ Li Gao¹

(1) Cancer institute and hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, Beijing, China

Purpose: To evaluate efficacy and outcomes of hypofractionated stereotactic radiotherapy (HSRT) for brain metastases larger than 3 centimeters.

Patients and Methods: From March 2003 to October 2009, 40 patients with brain metastases larger than 3 centimeters were treated by HSRT. HSRT was applied in 30 patients for primary treatment and in 10 patients for rescue. Single brain metastasis was detected in 21 patients. Whole brain radiotherapy was incorporated to HSRT in 11 patients for primary treatment. Two course of HSRT boost was applied in 21 patients. The largest diameter of brain metastases were from 3.1 cm to 5.5 cm (median 4.1cm). The median prescribed dose (not including HSRT boost) was 40 grays (range, 20-53 grays) with a median of 10 fractions (range, 4-15 fractions) to a 90% isodose line. The median dose of HSRT boost was 20 Gy (range, 15-35 Gy) in 5-7 fractions within 5-9 days.

Result: The median overall survival time was 12 months, and 11 patients died of neurological cause. Median survival was 16 months. The overall survival and local control rate at 12 months

was 58.5% and 85.3%, respectively. One patients developed radiation necrosis with brain edema. **Conclusion:** HSRT is effective and safe for selected patients with brain metastases larger than 3 cm. High dose provides a high level of tumor control with minimal toxicity

P2056

SURVIVAL OF PATIENTS WITH 5 OR MORE BRAIN METASTASES TREATED WITH GAMMA KNIFE STEREOTACTIC RADIOSURGERY

Ann C Raldow¹ Veronica L Chiang² Jonathan P Knisely³ James B Yu³

(1) Yale University School of Medicine, New Haven, USA (2) Department of Neurosurgery, Yale University School of Medicine, New Haven, USA (3) Department of Therapeutic Radiology, Yale University School of Medicine, New Haven, USA

Purpose: Phase III trials have prospectively evaluated the role of stereotactic radiosurgery (SRS) in the treatment of 1-4 brain metastases, but only limited data is available to help inform decisions about SRS for patients with 5+ brain metastases. We performed a retrospective analysis of patients treated for 5+ brain metastases; outcomes of interest were overall survival (OS) and intracranial recurrence free survival (IRFS).

Methods: The Yale-New Haven Hospital Gamma Knife database was queried for patients who underwent treatment for 5+ brain metastases from October 2005-September 2010. More than one SRS session could have been used, and time of survival was calculated from the date of first treatment of 5+ metastases. Whether patients underwent whole brain radiotherapy (WBRT) or had a history of intracranial surgery was recorded. Intracranial disease progression was defined when post-treatment MRI showed evidence for disease progression. Cox proportional hazards regression was performed for OS and IRFS. Univariate analysis was performed for the following variables: gender, age, Karnofsky Performance Status (KPS), histology, prior radiation, number of metastases treated, and time from first GK treatment to first GK treatment for 5+ metastases. Age, number of metastases, and time from first GK treatment to first GK treatment for 5+ metastases were the variables used in the multivariate analysis.

Results: Our study sample consisted of 103 patients and the median survival was 8.3 months. Median survival was 7.6 months and 8.3 months, for patients with 5-9 and 10+ metastases, respectively. KPS was the only significant variable affecting OS ($p < 0.01$). IRFS for the 27 patients who had prior GK treatment was significantly worse, if the time from the first GK treatment to the first GK treatment for 5+ metastases was < 6 months (vs. > 6 months) (HR 10.98 [95% CI 2.11-57.23], $p < .01$). Median time to intracranial failure was 3.0 months if the time from first GK treatment to > 5 lesion GK treatment was < 6 months, vs. 10.05 months if the time between treatments was > 6 months.

Conclusion: OS for carefully selected patients with 5+ brain metastases treated with SRS alone is reasonable and compares well with historical controls. KPS is the most important factor predicting OS. Patients with < 6 months between initial GK treatment to a GK treatment of 5+ metastases are more likely to experience rapid intracranial failure and should therefore be considered for WBRT.

P2057

STEREOTACTIC RADIOSURGERY FOR BRAIN METASTASES IN OLDER PATIENTS

Giuseppe Minniti¹, ³ Enrico Clarke¹ Guido Trasimeni¹ Alessandro Bozzao¹ Riccardo Maurizi Enrici¹

(1) Departments of Radiotherapy, S Andrea Hospital, University "La Sapienza", Rome, Italy (2) Departments of Neuroradiology, S Andrea Hospital, University "La Sapienza", Rome, Italy (3) Department of Neurological Sciences, Neuromed Institute, Pozzilli, Isernia, Italy

Background: This study was designed to evaluate the therapeutic effect of stereotactic radiosurgery (SRS) in patients aged ≥ 70 years who presented with brain metastasis.

Methods: data from 74 consecutive patients treated with SRS for ≥ 1 brain metastasis have been reported. The median age at the time of treatment for brain metastases was 74 years (range, 70 years-86 years), and the median Karnofsky performance status was 70 (range, 50-100). At the time of SRS, 45 patients were treated for a single metastasis, and the remaining 29 patients were treated for ≥ 2 lesions ($n = 70$ lesions). The median tumor volume was 2.6 cm³. The median doses were 18 Grays (Gy) (range, 16 Gy-20 Gy).

Results: Median survival and brain disease-free survival were 12.5 and 12 months, respectively, from the time of diagnosis of brain metastasis. Overall survival rates at 12 and 24 months were 55% and 10%, respectively. Brain disease-free survival rates at 12 and 24 months were 50% and 35%, respectively. Local control rates were 90% and 78% at 12 and 24 months. Neurological improvement was achieved in 30%, stabilization in 62%, and worsening in 8% of patients. Four cases of symptomatic radionecrosis occurred. According to univariate analysis extra-cranial disease status and RPA (Recursive Partitioning Analysis for aged patients) were significantly related to survival ($p < 0.01$). According to multifactorial analysis only RPA was an independent prognostic factor of overall survival ($p = 0.03$).

Conclusions: SRS for patients aged ≥ 70 years with brain metastases is an effective and safe treatment modality that appears to improve survival, with outcomes that compare favourably with those reported for younger patients.

P2058

BRAIN METASTASES OF LUNG CANCER: SURGERY VERSUS ROTATING GAMMA SYSTEM TREATMENT? THE DEBRECEN EXPERIENCE.

László Bognár¹, ² József Dobai¹, ² Géza Mezey¹ Bernadett Szűcs³ Imre Fedorcsák¹, ² Imre Fedorcsák¹, ²

(1) University Debrecen, Dept. of Neurosurgery, Debrecen, Hungary (2) University Debrecen, Gamma Radiosurgery Center, Debrecen, Hungary (3) University Debrecen, PET-CT Medical Ltd, Debrecen, Hungary

Purpose: Radiosurgery is widely accepted in the management of brain metastases. Different systems are used, but our knowledge of usefulness of rotating gamma system (RGS) is poor. The aim of the study was to retrospectively investigate and report our experience with RGS radiosurgery in the treatment of patients with brain metastases of lung cancer and compare our Results to conventional surgical treatment.

Methods: Between 2007 and 2009, 274 brain metastases of 138 patients with primary lung cancer were treated with GammaART 6000NT Rotating Gamma System (American Radiosurgery, San Diego, CA). Synchronous metastases were detected in 6 patients, the rest 132 had metachronous. Supratentorial were 231(84%) and 43(16%) were infratentorial. The mean marginal dose was 19Gy (14-21Gy). The mean age was 57yrs (39-78). The median Karnofsky performance scale (KPS) was 80. In the surgery treated group 89 metastases of 74 patients were resected. Sixty metastases were supratentorial and 29 infratentorial in location. In 37 cases synchronous, in 37 cases metachronous tumors were removed. The mean age was 57yrs (37-78) also. The median KPS was 70 before surgery. Data was collected retrospectively. All patients were stratified into one of three RTOG RPA (recursive partitioning analysis) classes and survival evaluated using Kaplan-Meier estimates. Survival curves were analysed with the log-rank test.

Results: The median survival for all patients was 9 months. There was no significant difference between the surgical and RGS group. In RGS group the median survivals for RPA classes I, II, III were 14, 8, 2.5 months. In surgery treated patients we calculated 12.5, 7 and 6 months. The 1-year local tumor control rate was 82% in RGS group and 76% in the surgery group. In the surgically treated group, large part of patients required urgent decompression, so the KPS improved significantly within one week after neurosurgical procedure. In RGS group there was no significant changes after procedure. Side effects were observed in 5% of RGS group, 2 patients were underwent a tumor resection later. After surgical resection, a little higher transient or permanent neurological deficit was detectable in 9% of cases.

Conclusion: Our result suggests that there is a little difference between RGS and surgical treatment in the brain metastases of patients with primary lung cancer. RGS is a good option in management of cases where no rapid debulking is necessary. Compared to others(1) we conclude that RGS is as effective as other radiosurgical systems.

Reference: (1) Müller-Riemenschneider F. et al: Stereotactic radiosurgery for the treatment of brain metastases. *Radiother Oncol.*, 2009; 91(1):67-74.

P2059

POSTOPERATIVE STEREOTACTIC RADIOTHERAPY WITHOUT WHOLE BRAIN IRRADIATION FOR BRAIN METASTASES

Stéphanie Gabriel¹ Cécile Ninane² Thierry Gustin³, ⁴ Guus Koerts⁵ Micheline Mouchamps⁶ Jean-francois Daisne¹

(1) Clinique Ste-Elisabeth, Radiation Oncology & Radiosurgery, Namur, Belgium (2) Clinique Ste-Elisabeth, Statistics & Data Management, Namur, Belgium (3) Clinique Ste-Elisabeth, Neurosurgery, Namur, Belgium (4) Cliniques Universitaires, Neurosurgery, Mont-godinne, Belgium (5) CHRN, Neurosurgery, Namur, Belgium (6) CHR Citadelle, Neurosurgery, Liège, Belgium

Objectives: Stereotactic irradiation of brain metastases without upfront whole brain radiotherapy (WBRT) is a currently accepted treatment strategy for selected. For operated patients, standard treatment remains WBRT. Anyway, for patients who, in unoperated situation, would have benefited of stereotactic irradiation alone may be overtreated by WBRT. Since 2008, all patients operated for brain metastase(s) and referred to our radiotherapy facility are prospectively offered

postoperative stereotactic irradiation instead of WBRT. We aim to report Results for overall survival (OS), local control (LC), distant brain control (DBC), salvage treatments and toxicities.

Patients and methods: On a time period of 24 months, patients with maximum three brain metastases (among which one operated), KPS at least 70, controlled extracranial disease and referred for postoperative radiotherapy were treated stereotactically.

Stereotactic irradiation was administered with either an adapted LINAC or a Novalis TX. Stereotactic radiosurgery (SRS) was offered for supra-tentorial surgical cavities with greatest diameter less than three centimeters, hypofractionated stereotactic radiotherapy (hSRT) was prescribed in the other situations. SRS dose was 15 Gy prescribed on 70% isodose, hSRT dose was 23.1 Gy in three fractions prescribed on the same isodose.

Postoperative surgical cavity was delineated on the pre-irradiation MRI. A 2 mm margin was added for microscopic involvement [1]. For hSRT treatments with a thermoplastic mask, an additional margin of 1 mm was added to take account of uncertainty in positioning correction.

Results: 32 patients were prospectively registered. 22% received SRS, 78% hSRT. Median OS was 12 months; 1 year LC and DBC were 85 and 55%, respectively. Salvage WBRT was used in 19 % of the patients. Acute and late toxicities were observed in less than 5% of the patients, related to the concomitant treatment of other unoperated metastases.

Conclusions: Early Results show postoperative stereotactic irradiation of brain metastases is a viable option in selected patients. Updated Results of this rapidly growing population will be presented, together with a dosimetric analysis of the relapsing lesions.

Reference: [1] Soltys SG. Stereotactic radiosurgery of the post-operative resection cavity for brain metastases. *Int J Radiat Oncol Biol Phys* 2008;70:187-93.

P2060

PRIMARY RADIOSURGERY FOR MELANOMA BRAIN METASTASES IN THE IPILIMUMAB ERA

Jonathan Knisely¹ Harriet Kluger¹ Jaclyn Flanigan¹ Mario Sznol¹ James Yu¹ Veronica Chiang¹

(1) Yale University School of Medicine and Yale Cancer Center, New Haven, USA

Objectives: To evaluate survival in a cohort of patients with melanoma brain metastases using stereotactic radiosurgery alone as definitive first line treatment.

Methods: 84 patients with melanoma brain metastases treated with definitive radiosurgery at the Yale-New Haven Gamma Knife Center and who did not receive whole brain radiation therapy (WBRT) as part of the initial management were identified through an IRB-approved retrospective medical record review. Patient accrual spanned November, 2002 to November, 2010. All visualized metastases in each patient were treated with individually customized radiosurgery plans. Survival from the date of the first radiosurgical treatment was assessed in relation to age, gender, craniotomy status, the eventual use of WBRT, ECOG performance status, and the use of ipilimumab.

Results: Univariate and multivariate Cox analysis showed that ECOG performance status (multivariate $p = <0.001$, HR=4.19 (95% CI=2.30-7.64)) and the use of ipilimumab (multivariate $p = 0.021$, HR=0.45 (95% CI=0.23-0.89)) were significantly associated with overall survival. Based on Kaplan Meier analyses median survival for the entire cohort was 8.8 months (95% CI 4.93-19.8). For patients receiving ipilimumab, median survival was 25.2 months (95% CI 15.7-

32.3) compared with 4.9 months (95% CI 3.3-8.8) in those not receiving ipilimumab. Age, gender, and the use of craniotomy and/or post-Gamma Knife WBRT did not impact survival.

Conclusions: This study shows that survival of patients with melanoma brain metastases managed with radiosurgery alone without initial WBRT can exceed the expected 4-6 months.(1,2) An improvement in overall survival is associated with the use of ipilimumab in patients with brain metastases, and this association remains significant even when adjusting for performance status. Further study of ipilimumab in brain metastases patients is warranted.

1. DiLuna M et al. Prognostic factors for survival after stereotactic radiosurgery vary with the number of cerebral metastases. *Cancer* 109:135-45;2007
2. Liew DN, Kano H et al. Outcome predictors of Gamma Knife surgery for melanoma brain metastases. *JNS* 2010 Jun 4; Epub ahead of print. DOI: 10.3171/2010.5.JNS1014

P2061

RADIOSURGERY FOR BRAIN METASTASES FOLLOWED BY PLANNED OBSERVATION: INFLUENCE OF METASTATIC VOLUME ON LOCAL CONTROL AND SURVIVAL.

Hiska Van Der Weide¹, ¹ Suzanne De Kunder¹ Ruud Houben¹ Geert Bosmans¹ Philippe Lambin^{1, 2, 3} Brigitta Baumert^{1, 2, 3}

(1) Department of radiation oncology, MAASTRO Clinic, Maastricht, The Netherlands (2) School for Oncology & Developmental Biology (GROW), Maastricht, The Netherlands (3) Maastricht University Medical Centre (MUMC), Maastricht, The Netherlands

Objective: To evaluate the efficacy and clinical and radiological follow-up (r-FU) of patients with brain metastases (BM) treated with radiosurgery at a single institute.

Material and Methods: Between Jan 2003 and July 2009 patients treated with radiosurgery (single-fraction (SRS) or hypofractionated radiosurgery (SRT)) for BM were selected. Patients were followed prospectively with 3-monthly imaging. All FU imaging was fused to the baseline scan to obtain 3-dimensional information on treatment response. Endpoints were overall survival (OS) and local control (LC, defined as no enlargement (more than 25%) of the metastasis). BM were categorized according to the contrast enhancing pattern (rim, heterogeneous or homogeneous). All data were analyzed using univariate survival and (backward) Cox regression analyses.

Results: A total of 264 BM were irradiated, 62% solitary, 62% lung. 65% of treated BM were evaluated (for 22% of BM no r-FU was available due to early death). The median OS and LC was 7.0 months (range: 3 days - 46 months) and 6.0 months, respectively. As expected, there was a significant difference in OS between RPA classes ($p < 0.001$), and a survival benefit in the first 12 months for breast cancer patients (12 months OS: 60% for breast vs. 26% and 20% for lung and other primaries). The LC of evaluable metastases was 70% until death. The volume of a BM was a significant prognostic factor for LC in univariate analysis ($p = 0.03$) ($HR = 1.26/5cc$ increase in metastasis volume (95% CI 1.02-1.55)). In multivariate analyses, corrected for patient, tumor and treatment characteristics, a trend towards significance was observed ($p = 0.053$) ($HR = 1.23/5cc$ increase (95% CI 0.99-1.53)). The sum of all BM volumes was a significant prognostic factor for OS in univariate analysis ($p = 0.003$) ($HR = 1.17/5cc$ increase in total metastases volume (95% CI 1.06-1.30)) and in multivariate analyses ($p = 0.005$) ($HR = 1.19/5cc$ increase (95% CI 1.05-1.33)).

Patients with a short survival (< 3 months) were more likely to have heterogeneous-enhancing BM and less likely to have rim-enhancing BM ($p=0.03$), suggesting worse prognosis for heterogeneous BM. Toxicity grade 3 or higher was observed in 15 patients.

Conclusions: Increasing volume of metastatic disease was found to be a prognostic factor for survival in this study. A volumetric measurement of brain metastases may provide extra prognostic information for patients eligible for radiosurgery. The pattern of contrast enhancement of the metastases might be an additional prognostic factor for survival.

P2062

WHOLE-BRAIN RADIOTHERAPY VERSUS STEREOTACTIC RADIOSURGERY IN CEREBRAL LUNG CANCER METASTASES

Camilla Sagerup¹ Einar Waldeland² Åslaug Helland¹ Odd Terje Brustugun¹

(1) Oslo University Hospital - Radiumhospitalet, Dept of oncology, Oslo, Norway (2) Oslo University Hospital - Radiumhospitalet, Dept of medical physics, Oslo, Norway

Background and Purpose: Lung cancer is the most common cause of brain metastases. Stereotactic radiosurgery (SRS) may be offered to patients with 3 or less brain metastases. Here we present survival data in lung cancer patients treated with SRS and/or whole brain radiation therapy (WBRT).

Material and Methods: We performed a retrospective survival analysis of patients with 1-3 MRI-verified brain metastases from lung cancer treated with SRS (+/- WBRT) in the period 2007-2009 ($n=33$) or WBRT alone in the period 2004-2006 ($n=52$).

Results: In the SRS group, 23 patients (70%) had 1 brain metastasis and 10 patients (30%) had 2-3 metastases. 16 patients (47%) received SRS as their only radiation treatment. 17 patients received WBRT previous to ($n=6$), or in combination with ($n=11$) SRS. In the WBRT group, 17 patients (33%) had 1 brain metastasis and 35 (67%) had 2-3 metastases. A significant median survival benefit was seen when SRS was used as a boost in addition to WBRT vs. WBRT alone (10 months vs. 3 months, $p=0.0489$). Compared to WBRT alone, a survival benefit was present in patients with 1 metastasis who received SRS for a new or recurrent lesion previously treated with WBRT ($p=0.0398$).

Conclusion: A survival benefit in patients that receive SRS in addition to WBRT versus WBRT alone is suggested, including patients with 2-3 intracerebral metastases.

P2063

LOCALIZED THERAPY FOR LIMITED METASTATIC DISEASE TO THE BRAIN: A PHASE II STUDY OF SURGERY, STEREOTACTIC RADIOSURGERY AND STEREOTACTIC RADIOTHERAPY IN FAVORABLE PATIENTS

Lucien A Nedzi¹ John W Walsh² Roy S Weiner² Ellen Zakris⁴ Robert Sanford² Timothy P Pearman² Raja Mudad³ Robert Timmerman¹ Bruce Mickey¹ Ramzi Abdulrahman¹ Christopher Madden¹ La Whitworth¹ Jessica Crockett¹

(1) UT Southwestern Medical Center, Dallas, USA (2) Tulane University Medical Center, New Orleans, USA (3) Memorial Cancer Institute, Miami, USA (4) Touro Hospital, New Orleans, USA

Purpose: Surgery (S), stereotactic radiosurgery (SRS) and stereotactic radiotherapy (SRT) are local therapies for selected patients with a limited number of brain metastases. The purpose of this study is to determine the feasibility and efficacy of S, SRS and SRT without whole brain radiotherapy (WBRT) in favorable patients with four or fewer brain metastases.

Materials and Methods: We enrolled 58 patients with Karnofsky performance status (KPS) $\geq 70\%$ and with four or fewer brain metastases on an institutional review board approved prospective non-inferiority clinical trial. The trial began enrollment in 2001 and completed enrollment in 2010. Tumor size determined local treatment. We treated tumors $\leq 2\text{cm}$ with SRS and tumors $> 2\text{cm}$ with S+SRT(25Gy/5) or SRS+SRT(25Gy/5), depending on patient and physician preference. We obtained MRI scans every three months and treated additional brain metastases on study if KPS $\geq 70\%$ and there were four or fewer metastases. The primary endpoint was survival.

Results: Forty-seven out of 58 patients were evaluable; eleven patients were ineligible. 52% had a lung primary; 26% had a breast primary, and 22% had other (unknown, kidney, melanoma, ovary, bladder) histologies. Median KPS was 80% (70-100%). 43% had a solitary metastasis, 35% had two, 21% had three or four metastases. 50% had no extracranial disease

We treated 102 metastases in 47 eligible patients: 88 SRS alone; 6 S+SRT, 5 SRS+SRT; 3 SRT alone. Median SRS tumor volume was 1.0cc (0.02-14.7). Median SRS dose was 21.6Gy (12.5-24) prescribed to the 52% (35-80) isodose. For targets $> 1\text{cc}$, the median conformity index was 1.4(1.1-2.5). The median SRT target volume, dose and isodose were 27.8cc (8.7-59.6), 25Gy and 85% (57-99), respectively. The median SRT conformity index was 1.4 (1.0-1.7).

With a median follow-up of 6.0 months (0.6-61), median survival is 6.0 months (0.6-61). Thirty-eight patients have died: 37 with progressive disease, one from a steroid-related GI bleed. 19 patients failed intracranially: five local failures and 14 elsewhere failures. Only ten patients ever received WBRT, four additional SRS, three additional surgery and two declined additional brain treatment.

Conclusions: S, SRS and SRT are prospectively feasible in patients with KPS $\geq 70\%$ and four or fewer metastases. The majority of such patients can be managed without ever receiving whole brain radiotherapy. There is no evidence survival is inferior to historical controls.

P2064

DOSIMETRIC PARAMETERS IN LOCAL RECURRENCE IN PATIENTS WITH SINGLE BRAIN METASTASES TREATED WITH LINAC-BASED STEREOTACTIC RADIOSURGERY (LB-SRS).

Kita Sallbanda¹ Ignacio Sisamón¹ Ricardo Cendales¹ Juan Carlos Bustos¹ Ja Gutierrez¹ Hugo Marsiglia¹ Jose Samblas¹

(1) Radosurgery Unit. Sanatorio San Francisco de Asis, Madrid, Spain

Background: Our series of single brain metastases patients treated with LB-SRS showed an association between minimum dose and overall survival. We aim to explore the impact of dosimetric parameters in local control.

Material and Methods: All patients with newly-diagnosed, single-brain metastases treated with collimator-framed, LB-SRS 200 Florida between January 2005 and September 2009 were included. GTV was defined based on CT/MRI fusion without margins. Planning was performed using BrainScan 5.32 c2008. Clinical and MRI follow-up was performed every three months. Local recurrence was

established when increase of treated lesion occurred, or when persistent PET-CT positive lesions. Local intracranial relapse free survival (LI-RFS) was analyzed. Dosimetric parameters were explored as predictors of local control.

Results: 62 patients (38 males, 24 females) were eligible. Median age 58 years (30-85). 13% of patients had neurosurgery previously to LB-SRS. WBRT was used as primary treatment in 29 patients (46.8%), 23 patients before, and 6 patients after LB-SRS. SIR classes were 1-3(30%), 4-7(68.4%), 8-10(1.6%). Median tumor volume was 4.1cc (0.4-26.3). Median tumor size was 23mm (6-40). Median prescribed dose was 14.5Gy (10-18) to 90% isodose-line. Median minimum dose(Dmin) was 11.9Gy (5.5-15.7). Median maximal dose was 16.6Gy (11.2-26.3). Median minimal dose administered to the 2% of the GTV (D2) was 14Gy, median D4 14.3Gy, median D6 14.5Gy, median D8 14.8Gy. Median maximum dose administered to 0.01cc of GTV (D0.1cc) was 14.62Gy, median D0.5cc 15.28Gy, median D1cc 15.4Gy. Median coverage index was 0.82, median homogeneity index 1.13, median tumoral conformity index 0.96.

Twenty-seven patients had intracranial relapse: 15 patients had a recurrence on irradiated area. The 9,12,18-month LI-RFS probability was 94.3%, 84.2%, and 61.7% respectively. Median LI-RFS was 38.4 months. Significant factors associated with LI-RFS were RPA, neurosurgery previous to LB-SRS, and tumor size <30mm. D2, D4, D6, D8, D0.1cc, D0.5cc, D1cc and Dmin, were explored as potential prognostic factors for LI-RFS, but none of them were found to be relevant. Multivariate analyses did not evidence any relevant prognostic factors.

Conclusion: We did not find any dosimetric factors associated to local control. However, coverage, homogeneity, and tumoral conformity index were acceptable, which limits the possibility of finding significant associations. It seems that on LB-SRS there is no place for analyzing the quality of the dose distribution within GTV area, and it seems this is not essential factor with few isocenters treatments.

P2065

LINAC-BASED STEREOTACTIC RADIOSURGERY IN SINGLE BRAIN METASTASES TREATED WITH A LOW PRESCRIPTION DOSE: A SINGLE CENTER EXPERIENCE

Ignacio Sisamón¹ Ricardo Cendales¹ Ja Gutierrez¹ Jc Bustos¹ Hugo Marsiglia¹ Kita Sallabanda¹ Jose Samblas¹

(1) Radiosurgery Unit, Sanatorio San Francisco de Asis, Madrid, Spain

Background: The minimum radiosurgical dose required to control brain metastases is still unknown. The aim of this study is to describe clinical outcomes in patients with single brain metastases treated with low doses.

Material and Methods: Patients with newly-diagnosed, single-brain metastases treated with framed-collimator-Linac-based stereotactic radiosurgery (LB-SRS) between January 2005 and September 2009 were included. GTV was defined using CT/MRI fusion without margins. OS, local intracranial relapse free survival (LI-RFS), distant intracranial RFS (DI-RFS), and prognostic factors were analyzed.

Results: 62 patients (38 males, 24 females) were eligible. Median age was 58 years (30-85); 58.1% of patients had KPS of 80-90; 74.2% had metachronic metastasis. Primary tumor was breast 24.2%, colorectal 6.4%, NSCLC 48.4%, kidney 3.2% and melanoma 8%. 13% of patients had

neurosurgical procedure previous to LB-SRS. WBRT was used as primary treatment whether before or after LB-SRS in 46.8%. SIR index was 1-3 (30%), 4-7 (68.4%), 8-10 (1.6%). Median tumor biggest size was 23 mm (6-40). Median prescribed dose was 14.5 Gy (10-18) to 90% isodose.

47 patients (75.8%) died. Median follow-up was 21.6 months. 12, 18-month OS probability was 56.7% and 35.8% respectively. Median survival time was 13.5 months. Significant prognostic factors associated with OS in Kaplan-Meyer analyses were RPA, SIR, WBRT, minimum dose superior to 12 Gy, and tumor volume <15cc. Multivariate analyses reported an HR of 0.52 (CI95% 0.27-0.99) for patients receiving WBRT, an HR of 2.38 (CI95% 1.12-5.08) for SIR 4-7, and an HR of 12.5 (1.4-109.9) for SIR 8-10 compared to SIR 1-3 respectively.

27 (43.5%) patients had intracranial relapse: 9 (14.5%) had local relapse (LR), 12 (19.3%) had distant intracranial relapse (DIR), and 6 (9.7%) had both. Rescue treatment was performed with WBRT (4 patients), new course of LB-SRS (10 patients), or neurosurgery (1 patient). The 9,12,18-month LI-RFS probability was 94.3%, 84.2%, and 61.7% respectively. Median LI-RFS time was 38.4 months. Significant factors associated with LI-RFS were RPA, neurosurgical procedure previous to LB-SRS, and tumor size <30mm. The only significant factor associated with DI-RFS was the SIR index. Multivariate analyses did not evidence any relevant prognostic factors.

Conclusion: Results showed satisfactory data for OS and LI-RFS, and turned out comparable with those published. These prescribed doses appear to be effective in single brain metastases.

P2066

RADIOSURGERY VERSUS FRACTIONATED STEREOTACTIC RADIATION THERAPY IN BRAIN OLIGOMETASTASES: A MONO-ISTITUTIONAL ANALYSES

Rosa Autorino¹ Barbara Diletto¹ Silvia Chiesa¹ Giuseppe Roberto D'agostino¹ Stefania Manfrida¹ Laura De Filippo¹ Francesco Micciché¹ Giancarlo Mattiucci¹ Carmelo Anile² Mario Balducci¹

(1) Department of Radiotherapy, Rome, Italy (2) Departement of Neurosurgery, Rome, Italy

Objective: To analyze the outcome of patients with brain oligometastases treated by single dose Radiosurgery (SRS) or fractionated stereotactic radiotherapy (FSRT) after Whole Brain Radiotherapy (WBRT).

Methods: Overall survival and Local control were retrospectively evaluated in patients with 1-2 brain metastases, treated between January 1997 and May 2008, in our Institution, with Radiosurgery (Group A) or FSRT (Group B) plus WBRT.

The two treatment groups were matched for the following potential prognostic factors: WBRT schedule, age, gender, performance status, tumor type, number of brain metastases, extracerebral metastases, recursive partitioning analysis class (RPA).

Results: A Total of 47 patients were selected (25 M; 22 F) who were submitted to WBRT followed by Radiosurgery (Group A, n: 17 pts) or WBRT + FSRT (Group B, n: 30 pts). The median number of brain metastases was 1 (range 1-2) and median age of the patients was 57 (range 40-77 ys). No statistical difference was found in the two groups in terms of age, histology, number of brain metastasis, and RPA class.

With a median follow-up of 102 months (range: 17-151), the median survival was 18,5 months for all patients, with a median of 22 months for the SRS group and 16 months for the SRT group.

One-year and 5-year survival was 56% and 16%, respectively, in Group A, and 62,1% and 3%, respectively, in Group B. Neither treatment proved to significant impact on OS ($p = 0,4$). The 1-year local control rates were 80% and 61,1% respectively in two groups. No difference was observed in terms of brain control between two groups ($p = 0.15$). Toxicity was acceptable in both groups, only one patient (Group A) presented radionecrosis, radiologically demonstrated.

Conclusion: Our data suggest that Radiosurgery or Fractionated Stereotactic Radiation Therapy after WBRT could offer the same outcomes in patients with brain oligometastases. Further investigation is warranted to confirm these data and define the optimal dose/fractionation.

P2067

REPEATED STEREOTACTIC RADIOSURGERY FOR RECURRENT METASTATIC BRAIN TUMORS AFTER PREVIOUS STEREOTACTIC RADIOSURGERY

In-young Kim¹ Shin Jung¹ Tae-young Jung¹ Woo-youl Jang¹ Sam-suk Kang¹ Seung-jin Park¹

(1) Chonnam National University Hwasun Hospital, Chonnam, Korea

Objective: The local control of stereotactic radiosurgery (STR) for metastatic brain tumors is known to be generally favorable. However, there could be local recurrences despite of previous STR, and the incidence seem to increase considering the increasing frequency of STR treatment and patients'™ longer survival. We investigated the outcome of repeated STR for the recurrent metastatic brain tumors despite previous STR.

Methods: Between November 2004 and September 2010, total 33 patients underwent Gamma Knife radiosurgery (GKR) for locally recurrent metastatic brain tumors despite previous GKR. The mean age was 62.7 years (range, 35 to 81). The number of male patients was 20 and female 13. The total number of tumors was 39. The lung cancer was predominant in primary cancer type ($n=25$). We regarded the tumor progression more than 120% than the tumor in the latest image as a recurrent tumor. And, among them, we identified the tumor recurrences using MR spectroscopy, perfusion MRI, and methionin-PET before the second GKR.

Results: At the second STR, the mean tumor volume was 4.5cc (range, 0.04 to 29.9) and mean prescription dose was 18.8 Gy (range, 12 to 24) to the tumor margin. Only 18 patients underwent MRI during the follow-up period. Seventeen out of 24 tumors (71%) were controlled, and the median progression-free survival was 7.1 months (range, 2 to 38). The overall median survival after the repeated STR was 7.2 months (range, 1 to 39). Twenty-six patients (79%) died during the follow-up period. The main cause of death was pulmonary problem (58%), and the brain-related death (including suspected cases) rate was 19% (5 out of 26).

Conclusions: Repeated STR could be one of the management options for the recurrent metastatic brain tumors despite previous STR. Moreover, considering the acceptable control rate and low brain-related death rates, repeated STR could be a good palliation in selected patients.

P2068

GAMMA KNIFE STEREOTACTIC RADIOSURGERY IN BRAIN METASTASES

Azhar Rashid¹ Muhammad Abid Saleem¹ A Sattar M Hashim¹

(1) Pakistan Gamma Knife & Stereotactic Radiosurgery Center, Karachi, Pakistan

Objectives: To evaluate the safety and efficacy of stereotactic radiosurgery (SRS) in brain metastases.

Methods: SRS is the delivery of an ablative dose of radiation to the tumor in a single fraction, targeted by stereotactic localization, with a rapid dose falloff and minimizing radiation dose to surrounding normal structures. From May 2008 to August 2010, fifty patients of brain metastases have been treated with Leksell Gamma Knife Model-4C at our center. Males were 23 (46 %) and females were 27 (54 %), median age was 52.4 years (range: 23-79 years) .45 (90%) patients were having WHO performance score of 0, 1 & 2, while 5(10%) were of III & IV. Recursive Partitioning Analysis (RPA) and Score Index for Radiosurgery (SIR) were determined. Distribution of primaries was as follows: 20 (40 %) of carcinoma breast, 10 (20 %) from bronchogenic carcinoma, 4(8 %) from renal cell carcinoma, 1(2 %) leukemia and 13 (26 %) were from unknown primary. Number of lesions was categorized: 30(60%) with single lesion, 8(12 %) with two lesions, 6(12 %) with three lesions and 6(12 %) have more than 3 lesions. Median peripheral dose was 18Gy (8-32 Gy), median maximum dose was 36.2 Gy (14-49.9 Gy), and the median target volume was 12.6cm3(1.10-36.70 cm3). Review of literature was carried out through web search.

Results: We observed that SRS for a single as well as multiple brain metastases has a high degree of efficacy and safety. Significant shrinkage in tumor size and perilesional edema along with symptomatic improvement provides good local controls. Review of literature supports that it Results in the improvement of the quality of life. Long term follow up will reveal the durability of response in our patients.

Conclusion: SRS is an effective and well tolerated noninvasive treatment option for single to multiple brain metastases. We encourage the use of SRS to achieve good local controls and improved quality of life.

P2069

FRACTIONATED STEREOTACTIC RADIOTHERAPY (FSRT) OF CENTRAL NERVOUS SYSTEM. EXPERIENCE IN OUR CENTRE.

Rosario Del Moral-avila¹ Isabel Tovar-martín¹ Nieves Rodríguez-ibarría¹ Rosa Guerrero-tejada¹ Mercedes Zurita-herrera¹ Pilar Vargas-arrabal¹

(1) Hospital Virgen de la Nieves, Granada, Spain

Background: The principles used for radiosurgery (high precision stereotaxis, highly collimated small field beams and multiple noncoplanar or dynamic beam delivery) were applied to fractionated radiotherapy and using a relocatable immobilization system patients with benign central nervous system tumors can be treated with optimal accuracy. The advantage of this technique is allowing the treatment of larger tumors situated closely to critical normal structures that can not be treated with radiosurgery because of the inferior tolerance of normal structures with high dose single fraction.

Purpose: The aim of this retrospective study is to report the Results obtained with this technique at our institution in terms of local control, toxicity and clinical situation at the end of the study.

Methods: Since April 2005 to February 2010 238 patients with benign intracranial tumors have been treated. The mean age was 48 years, 156 women and 82 men. The most frequent pathologies in the series were meningioma (37%) and pituitary adenoma (41%). The reason of the treatment was postoperative residual tumors (40%), closeness of the optical nerves (21%) or closeness of the optic chiasm. The mean dose of radiation was 50 Gy in 25 fractions of 2 Gy per day, given five days per week over 5 weeks. Most cases were treated using a LINAC accelerator with 1 isocenter and 9 arcs of treatment (98%).

Results: At the end of the study 64% of the patients presented disease stabilization, 26% decrease of the tumor size and 4% complete response. Only 4% of the patients had disease progression and 2% experienced tumor relapse. Related to clinical situation 50% of the patients related the same symptom as before the treatment, 28% had no symptom and 8% had improvement of their quality of live. Only 5% of the patients had worsening of their symptoms. A five per cent of the patients died of their tumor and 2% died of other cause. No acute toxicity was reported in 60% of the patients. The most frequent one was headache (13%). In the 93% not late toxicity was reported.

Conclusion: Fractionated Stereotactic Radiotherapy is a modality of treatment good tolerated and with excellent local control. It is useful for intracranial tumors with higher size and situated close to critical normal structures like optic nerves or chiasm which can have worse tolerance with single fraction radiosurgery.

P2070

HYPOFRACTIONATED STEREOTACTIC RADIO THERAPY FOR BRAIN METASTASIS

Koichi Mitsuya¹ Yoko Nakasu¹ Hideyuki Harada¹ Hirofumi Asakura¹ Tetsuo Nishimura¹

(1) Shizuoka Cancer Center, Shizuoka, Japan

Objective: To evaluate the efficacy and toxicity of hypofractionated stereotactic radiotherapy (hfSRT) for brain metastases, with large size, recurrence after irradiation, location of brain stem/ basal ganglia.

Methods: Between October 2004 and April 2010, 101 patients with 161 metastatic brain tumors underwent hfSRT at our institute. A dose of 30-35 Gy in 5 fractions was prescribed in 95% of the planning target volume for first-line therapy, and a dose of 25 Gy in 5 fractions for tumors of recurrence after irradiation or in the brain stem/ basal ganglia. Thirty-two of 101 patients had lesion a larger than 3 cm of maximal diameter, and 43 had recurrence tumor after irradiation.

Results: The local tumor control rate was 89%. The median survival time was 6 months: 25 months for patients with RPA class 1, 12 months for 41 patients with RPA class 2, and 4 months for 49 patients with RPA class3. Local tumor recurrence rate was 4%. Treatment-related complications (symptomatic radiation necrosis and brain edema) were observed in 7 patients (6.9%): one of 7 underwent surgical resection, and 6 were treated conservatively.

Conclusion: hfSRT achieved effective tumor control with minor toxicity on the selected patients with difficult tumors to control with common SRS.

P2071

THE COMPARATIVE RESULTS OF NEOADJUVANT RADIOSURGERY, ADJUVANT RADIOSURGERY, AND ADJUVANT WBRT FOR TREATMENT OF LARGE METASTATIC BRAIN TUMORS

Jong Hee Chang¹ Won Seok Chang¹ Jae Ho Cho¹ Chang Ok Seo¹ Yong Gou Park¹

(1) Yonsei University Health System, Seoul, Korea

Purpose: It is well known that the surgery plus whole brain radiation therapy (WBRT) is superior to surgery only for metastatic brain tumors. However, we should defer WBRT as long as possible because we have only one chance of performing WBRT, which is only treatment option for miliary brain metastases or leptomeningeal carcinomatosis. Moreover, we should consider WBRT-related delayed neurotoxicity. We evaluated the treatment Results of perioperative radiosurgery for large brain metastatic tumors.

Materials & Methods: We treated 55 patients with Gamma knife radiosurgery before (n=20; Group 1) and after (n=35; Group 2) surgical resection. During same period, 57 patients with large brain metastases were treated by surgical resection followed by WBRT (Group 3). The mean patient age was 63 (35-70) years. The most common primary cancers were lung, colon, and breast. In Group 1, we did surgical resection within 1 week after radiosurgery, and in Group 2, we radiated the operative cavity using radiosurgery within 1 week after operation. The mean treatment volume was 17.3 (13.5-65.2) mL, and the mean marginal dose was 17(15-20) Gy for Group 1 and 2.

Results: Overall, local control rate was 81% of patients. However, new intracranial metastases developed in 41 patients, and leptomeningeal carcinomatosis occurred in 13 patients. The median survival time was 18.1 months. We compared local control rate, new metastasis rate, cerebrospinal fluid (CSF) seeding rate, overall survival, and complication rate in theses 3 groups, and evaluated significant factors affecting the Results.

Conclusions: Perioperative radiosurgery is effective in treating large metastatic brain tumors that needed surgical resection to avoid postoperative recurrence and to defer WBRT. However, there was higher incidence of CSF seeding in adjuvant GKS group. We should be cautious to decrease the CSF dissemination during surgical resection and include enough target volume during dose planning of radiosurgery.

P2072

HYPOFRACTIONATED RADIOSURGERY IN THE TREATMENT OF CEREBRAL METASTASIS - A SINGLE INSTITUTIONAL EXPERIENCE

Che-Chuan Wang¹ Pascal O. Zinn² Peter Warnke³ Ekkehard Kasper⁴ Anand Mahadevan⁵ Scott Folyd⁵ Chin-Hong Chang¹ Chung-Ching Chio¹ Clark C Chen^{2, 4}

(1) Department of Neurosurgery, Chi Mei Medical Center, Tainan, Taiwan (2) Department of Radiation Oncology, Dana-Farber Cancer Institute, Boston, USA (3) Division of Neurosurgery, University of Chicago Medical Center, Chicago, USA (4) Division of Neurosurgery, Beth Israel Deaconess Medical Center, Boston, USA (5) Department of Radiation Oncology, Beth Israel Deaconess Medical Center, Boston, USA

Introduction: Recent development of hypofractionated radiosurgery has expanded the size of lesion that can be safely treated by focused radiation. However, clinical data with regards to the

efficacy of this modality remains scarce.

Methods: We retrospectively identified and analyzed 44 patients with 49 cerebral metastases that were treated with hypofractionated CyberKnife[®] radiosurgeries at the Beth Israel Deaconess Medical Center between 2005 and 2010.

Results: Tumors included: lung (n=15), melanoma (n=16), breast (n=10), kidney (n=5), and colon (n=3). Thirty-seven hypofractionated radiosurgeries were delivered to resection cavities; 12 were delivered to un-resected lesions. Thirty-one of lesions treated were >3 cm; 18 lesions were treated for proximity of critical neuro-anatomic structures. Radiation regimens were selected based on proximity to critical structures and prior history of radiation. Fractionation regimens ranged 400 cGy x 5 to 1000 cGy x 3, with 800 cGy x 3 being the most common scheme. Of the 44 patients, 1-year follow-up data was available for 35 patients (82% data retention). Overall, there were 7 local recurrences (20%). Six of these occurred after resection cavity radiosurgery (6/31, 19%); one occurred after radiosurgery of unresected lesions (1/4, 25%). Tumor recurrence did not correlate with prior WBRT, tumor histology, prior surgical resection, or radiation regimen. Morbidities associated with hypofractionated radiosurgery included: radiation necrosis (n=1, 2.9%), prolonged steroid use (n=1, 2.9%), and new-onset seizures (n=2, 5.7%).

Conclusion: Our experience suggests that the efficacy of hypofractionated radiosurgery compares favorably to historical data derived from WBRT and radiosurgery in selected patients with cerebral metastasis.

P2073

USEFULNESS FOR RTOG RPA CLASSIFICATION IN SELECTING PATIENTS WITH BRAIN METASTASES FROM PRIMARY LUNG CANCER FOR STEREOTACTIC RADIOSURGERY.

Dorota Jezierska¹ Krystyna Adamska¹ Włodzimierz Liebert²

(1) Greatpoland Cancer Centre, Poznan, Poland (2) Medical University, Poznan, Poland

Introduction: Selection of patients who are likely to benefit most from radiosurgery should be based on prognostic factors. RPA classification is based on the presence of four prognostic factors: performance status, control of primary disease, presence of extracranial metastases and age. The aim of our work was to evaluate the Results of treatment in different RPA classes and to assess prognostic factors which RPA classes are based on.

Material and Methods: In our study a retrospective review of 83 patients with brain metastases from primary lung cancer who underwent radiosurgery was performed.

Mean age was 61 years. Patients distribution according to the RTOG RPA classes was: class I - 18%, class II - 57%, class III - 25%. Distribution according to Karnofsky performance status was: KPS 90 - 6%, KPS 80 - 10%, KPS 70 - 59%, KPS 60 - 23%, KPS 50 - 2%.

Survival was evaluated from start of radiosurgery using Kaplan-Meier Methods. Prognostic factors were tested in univariate and multivariate analysis. Factors influencing survival at a significance level $p < 0.05$ in log-rank test were included in multivariate analysis with backward stepwise selection Cox's regression Methods.

Results: Median overall survival in the whole group was 7.8 months.

Median survival time were different in different RPA classes. In RPA I class it was 13.2 months, in RPA II 8.2 months and in RPA III 2.2 months.

In univariate analysis factors associated with improved survival were: class RPA 1 comparing with RPA 2 and 3 ($p < 0.0001$), Karnofsky performance status ≥ 70 ($p = 0.001$), control of the primary disease ($p = 0.001$), absence of extracranial metastases ($p = 0.04$). The age was the only variable taken into account in the RTOG RPA classification without prognostic significance in our analysis. Multivariate analysis confirmed significantly important influence on survival following factors: class RPA 1 comparing with RPA 3 ($p < 0.0001$), Karnofsky performance status ≥ 70 ($p < 0.0001$), absence of extracranial metastases ($p = 0.02$).

Conclusion: Selection of patients who are likely to benefit from radiosurgery may be based on RPA classification.

In RPA III group (patients with KPS < 70) survival time was only 2.2 months. It is similar to that achieved after symptomatic medical management. Patients in bad condition are not good candidate for radiosurgery.

Age alone should not be a criterion of denying radiosurgery because it proved effective and safe in older patients (> 65 years old).

P2074

PRELIMINARY RESULTS OF APPLICATION FRAMELESS ARRAY STEREOTACTIC RADIOSURGERY IN TREATMENT INTRACRANIAL TUMORS WITH USE MODIFIED LINEAR ACCELERATOR

Aleksandr Pankratov¹ Yuriy Ulianov¹ Lyudmila Devyatkina¹

(1) Samara Regional Clinical Oncological Centre, Samara, Russian Federation

The purposes: to estimate efficiency of frameless array SRS in comparison to frame array SRS and to develop indications to application of the given technique.

Materials and Methods: During the period from March 2009 to September 2010 we treated 16 persons by FLA technique. Modified linear accelerator «Clinac 2300 C/D» was used. Age range was 9 - 67 years (a median 41), male - 5 (31.25 %) female 11 (68.75 %). Brain metastases - 8 (50 %), relapse of a primary brain tumor - 6 cases (37.5 %), an acoustic neuroma - 2 cases (12.5 %). The preference was given to the given technique in the following cases: anaesthetic intolerance (2), KPS < 50 (3), presence of serious defects of a skull (3), children's age (1), number of the targets - 5 and more (4), an epilepsy (2). Number of targets from 1 to 7 (a median 2.8). On each isocenter the dose from 12.5 to 26 Gr was brought. Duration of supervision was from 2 to 19 months. During the period from October 2006 to September 2010 we treated 81 patients by technique frame array age range was 14 - 81 years (a median of 49 years). Male - 34 (42 %), female - 47 (58 %). Number of the isocenters from 1 to 7 (a median 2). Metastases at 47 (58 %), a primary tumor at 26 (32 %).

Results: At application of technique frameless array reduction of the target of defeat in the sizes or stabilization in growth was exposed in 8 cases (50 %), a disease progression - 5 (31.25 %), absence information - 2 (12.5 %). On applying technique frame array tumor reduction or stabilization in growth was at 25 (30.9 %), a full reduction of tumor at 14 (17.3 %) and the disease progression was exposed at 33 patients (40.7 %).

Conclusion: Thus technique frameless array doesn't concede by the efficiency to technique frame array and can be successfully used.

P2075

FEASIBILITY OF SINGLE ISOCENTER VOLUMETRIC IMRT (RAPIDARC) FOR TREATMENT OF MULTIPLE BRAIN METASTASES

Sonja Angelmann¹ Daniela Botz¹ Roland Bigler¹ Alessia Pica¹

(1) Department of Radiation Oncology, Inselspital, University of Bern, Bern, Switzerland

Purpose: Arc-based intensity-modulated radiation therapy (IMRT) has emerged as a promising progression from fixed-field techniques. Rapid Arc (RA) technology delivers an entire IMRT treatment in a single gantry rotation around the patient. RA has been evaluated for hypofractionated radiotherapy but not for single fraction radiosurgery. We present our initial experience in one patient with 2 brain metastases treated with RA for intracranial radiosurgery with Novalis Tx.

Materials and Methods: Patient was immobilized in a 3-point-fixed-mask (Sinmed). Treatment plan was created in the Eclipse (version 8.6) treatment planning system with 3 arcs (non coplanar/single isocenter). The lesions were located in different axial planes and the distance between the tumors was 5 cm. The plan was normalized to deliver 100% of the 20 Gy prescription dose to both lesions. The PTV volume was 4.3 cm³. The plan was evaluated by calculation of conformity index (volume enclosed by the prescription isodose surface divided by the target volume) homogeneity index (according to the ICRU 83) and gradient measure (difference between the equivalent sphere radius of the prescription divided by the target volume).

Results: Conformity index, homogeneity index and gradient measure values were 0.59, 1.74 and 0.03, respectively. The Dmean of the healthy brain tissue was 0.5 Gy. The number of monitor units (MU) was 6425.

Conclusion: Our initial experience suggests that single isocenter RA plans can be used as a new alternative for single-fraction radiosurgery for treatment of multiple brain metastases requiring less time than multiple isocenter techniques.

P2076

TREATMENT OF MULTIPLE BRAIN METASTASES USING AXESSE IMAGE-GUIDED STEREOTACTIC RADIOTHERAPY SYSTEM: EARLY EXPERIENCE

Efi Koutsouveli¹ Pantelis Karaiskos¹ Christos Skarleas² Constantinos Dardoufas² Panagiotis Sandilos¹

(1) Medical Physics Dept., Hygeia Hospital, Athens, Greece (2) Radiotherapy Dept., Hygeia Hospital, Athens, Greece

Up to 50% of all patients with malignancies will develop multiple brain metastases. These patients are associated with a considerable drop in life expectancy and quality of life, although several treatment options including surgery, chemotherapy and whole-brain radiotherapy are available for them. Stereotactic radiosurgery has shown to improve both local control as well as quality of life for these patients. This study demonstrates the feasibility of the treatment of multiple metastases using Axesse image-guided stereotactic radiotherapy system. Fifteen patients with multiple metastases (4-15) were treated during an one year period. Five patients had received at least whole brain radiotherapy in the past and presented new or recurrent metastases (4 to 15

multiple metastases with a total volume of 6 to 35 cc) while the rest ten patients with multiple metastases (3 to 5 with a total volume of 5 to 30 cc) had not previously received radiation in the brain. Patients that previously treated for brain metastases received 22 to 27 Gy per metastasis in one to three fractions. Patients without previous irradiation, received whole brain radiotherapy (30 fractions of 3 Gy) followed by 5 to 8 fractions of 3 Gy. For each metastasis, planning target volume (PTV) was defined from the gross tumors volume (GTV) shown in T1-IV images plus 8 mm margins. Independent on the number of metastases, one isocenter was utilized and multiple arcs (one arc for every target) were used. A CBCT was performed before treatment and positioning corrections based on co-registration between the planning CT and the CBCT were calculated and applied using the HEXAPOD 6D robotic system. At least one more CBCT was used to verify the accurate repositioning of the patient during and/or at the end of the treatment. The accuracy of the procedure was verified using a special phantom to simulate the whole treatment and was found well within 1 mm. The total treatment time per fraction, including patient positioning, CBCTs and irradiation was less than one hour. Six patients with at least 6 months follow-up have demonstrated considerable reduction or no progression of the tumor volume while no patients have experienced complications as a result of the procedure. Our first experience demonstrates the feasibility and effectiveness of Axesse image-guided stereotactic radiotherapy system for the treatment of multiple brain metastases.

P2077

METASTATIC BRAIN TUMOR GROWTH RATES IN PATIENTS TREATED PRIMARILY WITH STEREOTACTIC RADIOSURGERY ALONE

Grace Dixon^{1, 2}, James Yu^{1, 2}, Veronica Chiang^{1, 2}, James Bond^{1, 2}, Jonathan Knisely^{1, 2},

(1) Yale University School of Medicine, New Haven, USA (2) Yale Cancer Center, New Haven, USA

Objective: Growth kinetics estimation has been validated for clinical use including the evaluation of serial imaging of pulmonary nodules and response to therapy of brain metastases. Little has been published regarding the use of metastatic brain tumor growth kinetics for guiding treatment and surveillance timing. The goal of this study was to evaluate the growth rates of brain metastases in patients being managed primarily with stereotactic radiosurgery (SRS) alone.

Methods: 77 patients with radiographically documented brain metastases who underwent at least two Gamma Knife SRS treatments between January 2007 and November 2010 were considered for this IRB-approved retrospective analysis. We hypothesized that micro-metastases radiographically inapparent at the time of the previous SRS treatment started growing the next day. Tumor volumes were determined using GammaPlan volumetric software based on 2.0 mm thickness axial MPAGE T1 double-dose gadolinium enhanced treatment MR images. Linear growth kinetics were assumed. Neither previous whole brain radiotherapy, nor previous and current chemotherapy, nor craniotomy precluded selection. 1/77 patients had incomplete data, so 97 treatment intervals from 76 patients were analyzed. Growth rates were estimated and compared between tumor histologies by Poisson analysis.

Results: 37% of the treatment intervals were for melanoma, 31% lung, 12% breast, 12% renal, 3% rectal, 2% prostate and 1% for each of colon, esophagus, unknown primary, and Wilm's tumor histologies. The overall median growth rate for the total metastatic tumor volume was 12.9 mm³/

day (interquartile range [IQR] 5.1-35.7 mm³/day, standard deviation [SD] 112.5) with 80% being less than 41.6 mm³/day. The overall median growth rate for the average metastatic tumor volume was 3.8 mm³/day/met (IQR 1.5-13.5 mm³/day/met, SD 84.7) with 80% being less than 16.4 mm³/day/met. The median growth rates for average tumor volume were 1.3, 2.4, 8.4, and 16.5 mm³/day/met for breast, lung, melanoma, and renal histologies, respectively. Using robust Poisson regression, melanoma and renal histologies predicted higher growth rates when compared to breast ($p=0.029$ and 0.014 , respectively).

Conclusions: This is the first analysis of metastatic brain tumor growth rates in patients being managed with SRS. These findings suggest a difference between primary tumor histologies, which could be clinically useful with patient specific recommendations for surveillance scan intervals and treatment timing. Further research is certainly indicated.

P2078

IMPACT OF MRI DISTORTION OF HEMORRHAGIC BRAIN METASTASES ON RADIOSURGERY TARGETING

Caroline Chung¹ Teo Stanescu¹ Cynthia Menard¹

(1) Princess Margaret Hospital, Toronto, Canada

Objectives: Spatial accuracies of the CT and MRI images used to delineate target volumes are critical for stereotactic radiosurgery. It is assumed that co-registration of the MR and CT ensures accurate target delineation by exploiting the spatial accuracy of CT and the superior contrast resolution of MR images. This study aims to demonstrate the local distortion of hemorrhagic brain metastases that can result in spatial inaccuracies despite good co-registration of MR and CT image sets and to measure and correct for the associated local distortion field.

Methods: Patients treated with radiosurgery for brain metastases with well-delineated hyperintense target lesions on CT were selected. Using Leksall GammaPlan software, gadolinium-enhanced T1-weighted MR (T1-gad) images acquired on a 3.0T MRI and CT images were co-registered using local mutual information, limited to the whole brain. Target lesions were delineated on the T1-gad and CT images. The system-related distortions (gradient non-linearities) were measured via a phantom and applied to patient data. The susceptibility-induced distortions were modelled by using a numerical simulation technique based on solving the Maxwell equation for a static magnetic field.

Results: After good co-registration of the normal brain structures on MRI and CT images using local mutual information was achieved, there was residual discrepancies of $>1\text{mm}$ at the edges of enhancing target volumes on T1-gad and hyperintense target volumes on CT. Applying only the system-related distortions were insufficient for determining an accurate representation of the anatomical topography. This was due to the significant magnetic properties (i.e. susceptibility) of hemorrhagic metastases and the surrounding normal tissue, which introduced additional local distortions. When modelling and correction of the susceptibility-induced distortions were applied, the spatial accuracy was within 1mm.

Conclusions: This study demonstrates that despite good image co-registration to ensure high spatial accuracy, substantial local geometric distortions of hemorrhagic brain metastases can result in spatial inaccuracies of the target lesions due to susceptibility variations. The resulting local

field distortions can be measured and correction Methods have been successfully developed and validated. Utilizing these corrections would help minimize spatial inaccuracies of radiosurgery targeting of hemorrhagic brain metastatic lesions.

P2079

VALUE OF 11C-METHIONIN-PET/MR FUSION IN FOLLOW-UP OF RADIOSURGERY TREATED BRAIN METASTASES: PRELIMINARY RESULTS

Bernadett Szűcs¹ Zsolt Hascsi¹ József Dobai², ³ László Bognár², ³ Ildiko Garai¹

(1) PET CT Medical Ltd, Debrecen, Hungary (2) Dept of Neurosurgery, Debrecen, Hungary (3) Gamma Radiosurg. Center, Debrecen, Hungary

Purpose: The current clinical gold standard to follow-up radiosurgically treated brain metastasis is MRI, which provides superior structural detail but poor specificity in identifying viable tumor tissue(1). Aminoacid PET-tracers such as 11C-methionin (11C-Met) are more sensitive and potentially effective in differentiating recurrent or residual tumors and treatment-induced changes(2). The aim of this study was to examine the clinical efficacy of 11C-Met-PET examination and PET/MR fusion in patients with stereotactic radiosurgery treated brain metastasis and to determine whether the 11C-Met-PET can be useful for follow-up and further clinical management.

Methods: Brain metastasis of fourteen patients who had primary lung cancer were treated with GammaART 6000NT Rotating Gamma System (American Radiosurgery, San Diego, CA). Brain metastases were examined with axial T1 weighted 3D contrast enhanced MRI and 11C-Met-PET before the treatment and 2 and 6 months following the radiosurgical procedure. PET/MRI fusions were also conducted. PET-images (were obtained as a static scan of 20 minutes' duration performed 10 minutes after the injection of 11C-Met. In the PET-scans we measured the size of the lesions in three dimensions and the tumor activity (any area with a level of uptake higher than that in the adjacent normal brain tissue). Data was compared to the MRI findings.

Results: All the fourteen patients displayed good regression, decreased lesion size and tracer uptake decrease. In one case, we did not find any metabolic activity in the treated metastases. In one patient the 11C-Met-PET detected a new metabolic active focus which can not be seen on MRI scans. So it seems to be that Met-PET can provide additional information when used in combination with MRI.

Conclusion: Our preliminary observations suggest that 11C-Met-PET may be useful in follow-up and further clinical management of radiosurgically treated brain metastasis but additional clinical study is warranted with larger patient groups and a longer follow-up period.

Reference:

- 1., Goodman KA. et al.: Relationship between pattern of enhancement and local control of brain metastases after radiosurgery. Int J Radiat Oncol Biol Phys., 2001;50(1):139-46.
- 2., Tang BN. et al.: Three-dimensional Gaussian model to define brain metastasis limits on 11C-methionine PET. Radiother Oncol., 2008, 89(3):270-7.

P2080

STEREOTACTIC RADIOSURGERY FOR THE TREATMENT OF MELANOMA AND RENAL CELL CARCINOMA BRAIN METASTASES

Shelly Lwu¹ Pablo Goetz¹ Mandana Aryae¹ Norm Laperriere² Cynthia Menard² Mark Bernstein¹ Zadeh Gelareh¹

(1) University of Toronto, Division of Neurosurgery, Toronto, Canada (2) University of Toronto, Department of Radiation Oncology, Toronto, Canada

Objective: Renal cell carcinoma (RCC) and melanoma brain metastases have traditionally been considered to be radioresistant, however, stereotactic radiosurgery (SRS) is becoming more accepted as a treatment option for these subtypes of brain metastases. The aims of this study were to evaluate the role of SRS for local control of RCC and melanoma brain metastases, both with and without prior whole brain radiotherapy (WBRT), and to identify predictors of response to SRS for RCC and melanoma metastases.

Methods: From a prospectively collected database, we retrospectively reviewed all RCC and melanoma patients (56; 20 RCC, 36 melanoma) treated with Gamma Knife SRS between July 2006 and September 2010. Research Ethics Board approval was obtained. Dosimetry parameters along with imaging features, specifically extent of edema, hemosiderin ring around the tumor, and mass effect causing normal anatomical distortion were variables that were examined as predictors of response to SRS.

Results: The patient population consisted of 42.9% females and 58.1% males with a median age of 52 years. 61.9% patients had multiple metastases. 63.9% metastases had been treated previously with WBRT with the remaining having received SRS alone upfront. Median prescription dose was 24 Gy (range, 15 to 24). Median target minimum dose was 20.66 Gy (range, 12.61 to 31.85). Median and mean tumor volumes were 0.46 cm³ and 1.42 cm³, respectively (range, 0.01 to 13.36 cm³). Median follow-up was 5 months (range, 1 to 41 months). Median RTOG conformity index was 1.95 (range, 1.13 to 9.4). Local control rates were 83.7%, 91.7%, 92%, 95.5%, and 92.3% at 3, 6, 9, 12, and 18 months respectively. Two (2.8%) of the treated brain metastases required local salvage therapy in the form of surgical resection. Nineteen (26.4%) of the metastases were treated with WBRT 2 to 21 months after SRS for distant brain failure.

Conclusions: Stereotactic radiosurgery is a valuable option for local control of RCC and melanoma brain metastases and based on our institutional data, delay of WBRT is safe without significant difference in local control rates. We also report on the factors that are predictive of response to SRS for RCC and melanoma metastases.

P2081

STEREOTACTIC RADIOSURGERY/RADIOTHERAPY FOR CRANIAL AND EXTRACRANIAL MELANOMA METASTASES

Claudia Menichelli¹ Stefano Masciullo¹ Franco Casamassima¹ Rafaela Doro¹ Laura Masi¹ Ivano Bonucci¹

(1) U.O. Radiobiologia Clinica - University of Florence - Casa di Cura S. Chiara, Florence, Italy

Purpose: Advanced melanoma continue to have a poor prognosis. However, contrary to currently available chemotherapy agents, substantially ineffective, new systemic therapies like immune-based and targeted therapies appear to have some efficacy. If it is possible to influence the systemic spread, local control becomes important beyond the pure palliation. Aim of this work is to evaluate the effectiveness of image-guided stereotactic radiosurgery/radiotherapy for treatment of melanoma metastases.

Materials and Methods: A total of 19 cases of malignant melanoma were reviewed. The age of patients ranged from 40 to 76 years (median 52). The median Karnofsky PS was 80 (60-100). A number of 34 metastases were treated (brain 11, lungs 5, adrenal glands 6, lymph nodes 5, liver 3, bone 1). All patients underwent surgery for cutaneous melanoma (80% nodular type). Median time to metastases appearance was 34 months (7-94). Nine patients were oligometastatic (≤ 3 lesions) at time of SRS/SRT and were treated with «curative» intent (all detectable lesions irradiated); the others, having > 5 lesions, were treated with palliative intent. Fourteen Pts received currently available systemic therapies (fotoemustine, dacarbazine, IFN) before or after the SRS/SRT (within six months). Thirteen lesions were treated with single fraction SRS (brain 10, lung 2, adrenal 1) with dose ranged from 22 to 27 Gy x 1 (PTV 0.8-22 cc), the others were treated with three fractions SRT (9-12.5 Gy x 3, PTV 8-125 cc). One patients also received WBI with SRS. A Cone-Beam CT was acquired before the treatment for setup corrections and target localization. A 6-MV Elekta Synergy equipped with dynamic mMLC was employed. CTCAE v.4 and modified RECIST criteria was used for toxicity and response evaluation.

Results: With a median follow-up of 9.5 months (3-26), only 6 patients are alive (all belonging to the oligometastatic group). The local control was achieved in all cases (4 CR, 18 PR, 9 SD, 3 not evaluable). The 1-year Kaplan Meier overall survival and progression free survival were 54% and 26%. Only three patients have not shown new metastases and median time to progression was 3.5 months. 85% of symptomatic patients have had improvement after radiotherapy. No acute or late toxicity grade > 2 was observed.

Conclusions: In our experience image-guided stereotactic radiotherapy for melanoma metastases is safe and locally effective, but the systemic control of disease remains problematic. However, the possibilities of a high local control offered by stereotactic radiotherapy, despite the relative radioresistance of melanoma, could lead to a revision of radiotherapy role in this setting if the encouraging Results of emerging systemic therapies will be confirmed.

P2082

HELICAL TOMOTHERAPY FOR MULTIPLE BRAIN METASTASES.

Ruth Rodríguez Romero¹ Patricia Sánchez Rubio¹

(1) Servicio de Radiofísica. Hospital Universitario Puerta de Hierro Majadahonda., Madrid, Spain

Objective: Despite there is available a specific stereotactic linear accelerator with frameless system in our hospital, multiple brain metastases patients are treated with Helical Tomotherapy due its simplicity to localize and treat various target volumes. This study evaluates the feasibility of these treatments by analyzing dose distribution plans, quality assurance Results and positioning displacements.

Methods: Five patients with 2-5 brain metastases have been treated with helical tomotherapy. Patients were immobilised using radiosurgery thermoplastic mask and planning target volumes (PTV) were obtained as 3mm geometric expansion of gross tumour volumes (GTV), except in one case. The prescribed dose to PTV was 20-25 Gy in 5 daily fractions (95%dose to 95%volume).

Dose distribution plans were reported following ICRU83 recommendations (near minimum dose D98%, near maximum dose as D2%). Routinely IMRT experimental verifications were done using ion chambers and gafchromic films. Daily MVCT were performed before every fraction and displacements were applied and registered.

Results: Treatment beam-on time obtained were 6.4 -» 10.2 minutes.

Dose homogeneity was evaluated: standard deviation <1Gy; <4% of prescribed dose and subdosage were <10% and overdosage were <3%.

To analyze OAR doses from all the treatment plans, 20 Gy dose plan was reescalated to 25 Gy. Optic nerves mean dose was <4 Gy with <6%, chiasm mean dose

Mean dose and near maximum dose was less than: 4 and 6 Gy for optic nerves, 6 and 8 Gy for chiasm, 19 and 8 Gy for brainstem, 4 and 2 Gy for eyes respectively.

Quality assurance verifications were agree to treatment planning system; discrepancy of ion chamber measurements <3%, 95% points follow gamma(3%,3mm) criteria.

Systematic and expected errors were found: <3mm longitudinal due to CT slices resolution, <4mm vertical because of table sag. Since shift corrections were performed every session which are really important are random errors: <1mm for translation and <0.8° for rotation.

Conclusions: Since location and irradiation of multiples targets can be performed simultaneously with Tomotherapy, patient time at treatment room is certainly reduced (30 minutes per lesion vs 30 minutes total). Beside this clear advantage, Tomotherapy achieves dose distributions with high homogeneity of dose at PTV and great OAR sparing that are realizable as it provides enough dosimetric and setup accuracy.

References:

Shaghera et al. Br J Radiol.2010 -Feb;83(986):98-100.

Soisson et al. Medical Dosimetry.2010-Feb.

Tomita et al. Technol Cancer Res

P2083

NEURAL STEM CELL SPARING IN PATIENTS TREATED WITH WHOLE BRAIN RADIOTHERAPY: A DOSIMETRIC FEASIBILITY STUDY USING VOLUMETRIC INTENSITY MODULATED ARC THERAPY

Javad Rahimian¹ Joseph C.t. Chen¹ Daniel Friedlich¹ Aaron Petersen¹ Michael R. Girvigian¹ Michael J. Miller¹

(1) Southern California Permanente Medical Group, Los Angeles, USA

Introduction: Brain metastases occur in up to 40% of all patients with systemic cancer. Many of these patients can benefit from prophylactic or palliative whole brain radiotherapy (WBRT). It has been shown that children with medulloblastoma treated with radiation demonstrate post-treatment neurocognitive deficits in a number of areas, including memory performance. Further, a transient dose-dependent decline in memory after stereotactic radiosurgery is noted. This dosimetric feasibility study is aimed to assess whether volumetric intensity modulated radiotherapy (VMAT) delivery can effectively spare the hippocampus, fornix, and Neural Stem Cell (NSC) Compartment of the brain, thus lowering the possibility of damage to neurocognitive function .

Methods and Materials: A group of two patients treated with routine opposed lateral WBRT with eye blocks were replanned using Philips Medical System's Pinnacle SmartArc® treatment planning system. The patients MRI was fused with the planning CT and the brain was contoured on MRI as Planning Target Volume (PTV) excluding the hippocampus, fornix, and the NSC. The hippocampus region, including subgranular zone and subventricular zone, with 3mm margin was contoured as organ at risk (OAR). A radiation dose of 30Gy in 12 fractions to the PTV and 11Gy to the OAR were set in the objective function of the SmartArc® optimization module. Two volumetric intensity modulated arcs were used for optimizations using adaptive convolution algorithm for dose calculations. The mean dose, and the standard deviation for each region were calculated.

Results: The mean dose received by the PTV, hippocampus, and subventricular zone were $30.0 \pm 8.5\text{Gy}$, $11.0 \pm 1.7\text{Gy}$, and $11.6 \pm 1.9\text{Gy}$, respectively. Dosimetric analysis showed 63% sparing of these regions known to be responsible for neurocognitive functions when compared to WBRT .

Conclusions: Selective dosimetric avoidance of the brain's NSC which may lower the possibility of damage to neurocognitive function induced by cranial irradiation is feasible using SmartArc® planning software. The study warrants further investigation of the dose delivery and neurocognitive function tests before, and after the cranial VMAT irradiation.

P2084

METASTATIC MALIGNANT MELANOMA WITH UNKNOWN PRIMARY: A CASE REPORT

Seema Gupta¹ Mohan Chand Pant¹ Nuzhat Husain¹ Sham Sudar¹ N Singh¹

(1) C.S.M.Medical University , Lucknow , India

Introduction: Malignant melanoma is next only to lung cancer, as the most frequent cause of brain metastasis and generally develops late in the course of the disease. Only about 7% of malignant melanoma patients present with brain metastases at the time of diagnosis. These patients have a short overall survival time despite optimal local and systemic treatment approaches.

Therefore patient presenting with primary symptoms of brain metastasis with no evidence of

primary site is extremely rare. Here we report an unusual case of a 45 year male where the first symptom of the disease was due to brain metastasis, but presumed primary lesion was not found.

Material and Methods: A 45-year old male with no previous or family history of cancer came to us in April 2010, he presented with head ache, vomiting and paresthesia of left half of the body, followed by left sided hemiparesis and seizure resulting in hospitalization.

On Examination patient was conscious and had abnormal behavior. Patient was disoriented, dyslexic, with loss of speech and signs suggestive of raised intra cranial pressure were positive. Ear, nose, throat, abdominal and rectal examinations were normal. No discrete lesions on the skin were noticed. CT scan of the brain showed large attenuating regular space occupying mass lesion in right fronto-parietal region. It was associated with moderate degree of perifocal edema, presumably representing a glioma (fig1). Examination of the eyes, head and neck mucosa, skin, bone scintigraphy and computed tomography (CT) scans of paranasal sinuses, thorax and pelvis were normal. Upper gastrointestinal endoscopy, proctosigmoidoscopy and colonoscopy were also normal.

In June 2010 a partial resection of tumor was performed. The symptoms improved and the patient was put on anticonvulsant therapy. Histology demonstrated a metastatic tumor with pigmented cells and positive immunohistochemistry for S100, HMB-45 suggestive of malignant melanoma (fig 2)

Patient received sequential radiotherapy after surgery. Patient received total dose of 56Gy in 28 fractions in 51/2 weeks.

Results: Our patient post surgery and Radiotherapy had significant improvement in symptoms but CT scan brain done post treatment showed residual disease and is presently kept on close follow up.

Conclusion: Patients with Metastatic Malignant Melanoma with Unknown Primary especially brain metastasis have poor prognosis in spite of optimal local treatment

P2085

PROGNOSTIC FACTORS INFLUENCING THE SURVIVAL OF 109 CONSECUTIVE PATIENTS WITH BRAIN METASTASES FROM BREAST CANCER AND TREATED BY LEKSELL GAMMA KNIFE RADIOSURGERY.

Daniel Devriendt^{1, 2, 3} Nicolas Massager^{1, 3} Françoise De Smedt^{1, 2, 3}

(1) Gamma Knife Center of ULB, Brussels, Belgium (2) Institut Jules Bordet, Brussels, Belgium (3) Erasme Hospital, Brussels, Belgium

Objective: to analyse the prognostic factors associated with a better survival in patients presenting with brain metastases (BM) from breast cancer and treated by Leksell Gamma Knife radiosurgery.

Material and Methods: 109 consecutive patients (107 females and 2 males) with breast cancer constitute the study group for this analysis. All patients has been treated by radiosurgery with a Leksell Gamma Knife 4C model.

Results: Among those 109 patients, 58 % were Her2/Neu positive. About 50 % of patients received WBRT. Median age is 47 years. Most of patients received a systemic treatment. Median Karnofsky score is 80 %. Median survival (MS) for the entire population is 18 months. In univariate analysis, the favourable prognostic factors are a Karnofsky score of at least 80 with a median survival of

20 vs 10 months ($p < 0.05$) and the positive Her-2/Neu status with a median survival of 23 vs 12 months ($p < 0.05$). The number of lesions, the age, the status of the primary and the extracranial disease are not significant. Moreover, the power of the classical classification is only significant for RPA score 1 and 2 vs 3 ($p < 0.05$), the SIR score 4 to 10 vs 1 to 3 ($p < 0.05$) and the BSBM score 2 and 3 vs 0 to 1 ($p < 0.05$).

Conclusions: BM from breast cancer are different in comparison from BM from other cancers such as lung cancer and melanoma. The only significant prognostic factors are the KPS and the status of the Her-2/neu.

P2086

GAMMA KNIFE RADIOSURGERY FOR INTRACRANIAL HEMANGIOPERICYTOMA

Satoshi Suzuki¹ Katsuya Ishido²

(1) Nippon Steel Yawata Memorial Hospital, Kitakyushu, Japan (2) Shin-Koga Hospital, Kurume, Japan

Purpose: Hemangiopericytoma (HP) is locally aggressive, potentially malignant tumor, which frequently causes distant metastases. There remains a controversy about the best way to manage HP, and little information exists concerning the role of Gamma Knife radiosurgery (GKRS). Here we examined the role of GKRS for the management of intracranial HP.

Materials and Methods: Between July 1998 and October 2009, 2871 patients were treated by GKRS in Shin-Koga Hospital Gamma Knife Center. Of them, 11 patients (0.38%) with histologically confirmed intracranial HP were included in this study. Ten tumors were primary intracranial HP and 1 was a metastasis from the lower limb. Seven were males and 4 were females.

Results: Their mean age at the diagnosis and at GKRS was 48 years-old and 54 years-old, respectively. The mean interval between the diagnosis and GKRS was 68 months, ranging from 0 to 237 months. The mean volume of the tumor was 9.0 mL, ranging from 1.9 to 29.9 mL. The mean dosage delivered onto the tumor periphery was 20 Gy, ranging from 15 to 22 Gy. After a mean follow-up of 44 month, ranging from 4 to 109 months, 6 patients were alive and 5 have died. The cause of death in 5 patients was the progression of the tumor in distant metastatic sites. The intracranial tumor was controllable even though repetitive GKRSs were necessary in 3 cases (27%). Local recurrence was observed 7-25 months (mean 17 months) after GKRS. Distant metastases were observed in 7 cases, and the interval was 0-57 (mean 22) months after GKRS and 17-240 (mean 108) months after the diagnosis, respectively. Median survival and distant metastases free survival after GKRS was 77 months and 52 months, respectively by Kaplan-Meier analysis. Local recurrence did not affect the survival period ($p=0.89$). All patients without distant metastases were alive for 8-109 (mean 44) months after GKRS ($p=0.08$).

Conclusion: GKRS is efficacious in controlling intracranial HP locally. However, distant metastasis is the most critical factor for survival and meticulous follow up is mandatory to avoid a delay in treating metastatic tumor.

P2087

CEREBELLAR LIPONEUROCYTOMA: A CASE REPORT

Nitya Patanjali¹ Brindha Shivalingam¹ Michael Buckland¹

(1) Royal Prince Alfred Hospital , Sydney, Australia

Aim: To describe a case of cerebellar liponeurocytoma in a 63 year old woman. Cerebellar liponeurocytoma is a rare intracranial tumour, with less than 50 cases reported in the literature. Although the majority of cases pursue a benign clinical course, this case illustrates the potential for recurrent disease, post surgical excision, and the role of fractionated stereotactic radiation therapy in treating recurrent cerebellar liponeurocytoma.

Methods: Mrs A is a 63 year old woman initially presenting in 2008 with a 2 month history of headache, gait ataxia and in-coordination. Imaging revealed a heterogeneous, mixed cystic and solid, right sided cerebellar mass measuring 45mm x 39mm x 31mm, with partial effacement of the 4th ventricle and early hydrocephalus. Surgery was undertaken with the aim of maximal tumour debulking. Post operative residual disease was noted abutting and invading the brainstem. Histopathology confirmed cerebellar liponeurocytoma (WHO grade II).

On subsequent MR imaging, growth of the residual disease abutting the brainstem in the right cerebellopontine angle was noted, as well as new, nodular enhancing disease lining the tumour cavity. Given this, radiotherapy was recommended. Radiotherapy was delivered using a fractionated stereotactic 7 field intensity modulated radiotherapy (IMRT) technique, to a total dose of 54 Gy in 30#, given over 6 weeks, dosed to 100% (1.8Gy per day, 5 fractions per week).

Results: Mrs A tolerated the treatment well, with mild nausea and headache during treatment, but no other significant toxicity during the 6 week course of radiotherapy. She was well at clinical follow up 6 weeks post radiotherapy. Results of the first progress MRI, performed 3 months post completion of radiotherapy, are pending.

Conclusion: Fractionated stereotactic radiotherapy can be safely delivered with minimal acute morbidity for treatment of recurrent cerebellar liponeurocytoma.

P2088

EARLY OR DELAYED RADIOSURGERY FOR WHO GRADE II ASTROCYTOMAS

Kyung-jae Park¹ Hideyuki Kano¹ Douglas Kondziolka¹ Ajay Niranjani¹ John C. Flickinger¹ L. Dade Lunsford¹

(1) University Of Pittsburgh Medical Center, Pittsburgh, USA

Object: The purpose of this study was to evaluate the role of gamma knife stereotactic radiosurgery (SRS) in the management of newly diagnosed (early) or progressive (delayed) WHO grade II astrocytomas.

Methods: The authors assessed tumor control, survival, and complications in 25 consecutive patients with pathologically proven WHO grade II astrocytomas who had underwent SRS between 1987 and July 2009 at the University of Pittsburgh. The median patient age was 30 years (range 8-68 years). Sixteen patients had early SRS after stereotactic biopsy (n=14), resection (n=1) or radiation therapy (n=1), and 9 underwent delayed SRS for progression after surgical resection

(n=3), radiation therapy (n=4) or both (n=2). The median tumor volume was 3.7 cm³ (range 0.6-17.0 cm³) and the median margin dose was 14 Gy (range 11-20 Gy).

Results: At a median of 65 months of follow-up (range 6 - 208 months), tumor control was observed in 13 patients (52%). The progression-free survival rates after SRS at 1, 5 and 10 years were 91.3, 54.1 and 37.1 %, respectively. On both univariate and multivariate analysis smaller tumor volume (<6cm³), higher marginal dose (≥ 15 Gy) and absence of contrast enhancement on imaging studies were associated with better progression free-survival.

Conclusions: Gamma knife SRS is an additional option for patients with small volume, deep seated, and well-demarcated WHO grade II astrocytomas, and does not preclude later conventional fractionated radiation therapy, if needed. It may also benefit patients with residual or recurrent tumors that have progressed after surgery, radiation therapy or both.

P2089

LOW GRADE GLIOMAS TREATED USING LEKSELL GAMMA KNIFE- RESULTS

Gabriela Simonova¹ Roman Liscak¹ Jitka Semnicka¹

(1) Hospital Na Homolce, Prague 5, Dominican Republic

Purpose: to evaluate treatment Results, radiation related toxicity, and prognostic factors for progression free survival (PFS) in patients with low grade gliomas irradiated using the Gamma Knife.

Materials and Methods: A total of 88 patients with glioma (45 grade I, 43 grade II) underwent hypofractionated stereotactic irradiation at the Leksell Gamma Knife. 14 patients received the treatment in a single fraction, 1 patient in 2 fractions, 71 patients in 5 fractions and 2 patients in 10 fractions. Median of minimum dose to the planning target volume (PTV) was 25 Gy (12 - 35 Gy). The dosage was prescribed with respect to the following conditions: number of fractions (alpha/beta considered 2 Gy), previous irradiation (29 patients received previous radiotherapy), PTV (median 3,95 cm³, range 0,2 - 25 cm³), and age (median 18 years, range 3 - 62). 3 patients were lost during the follow up at 52, 60, and 63 months after the treatment; otherwise the shortest follow up period was 91 months. The radiation related toxicity and severity of neurological symptoms (NFC) were evaluated using RTOG/EORTC scoring system. In our group of patients we analyzed variables affecting the PFS after the treatment and radiation induced late toxicity (grade, age, volume, biologically effective dose (BED), previous radiotherapy, NFC score before treatment). We used univariate (Kaplan-Meier with Log-rank test) and multivariate analysis (Cox regression) to detect differences in survival curves and correlation analysis to detect variables associated with toxicity. For all statistical procedures we used PASW Statistics v. 18 (SPSS Inc., USA).

Results: Overall detected surviving fraction after 10 years was 78%. As expected, we found greater surviving fraction of grade I patients, (91% surviving at 5 years, 88% at 10 years) than grade II patients (79% surviving at 5 years, 67% at 10 years), p=0,010 Log-rank, p=0,025 Cox. Among other mentioned variables we detected as significant positive prognostic factors: age < 30 years (p = 0,044 Log-rank), BED 85 -110 Gy, which is an intermediate category, (p = 0,019 Log-rank), not previously irradiated (p =0,032 Log-rank, p=0,075 Cox).

In our group of patients we observed grade 3 late toxicity in 10% of cases. Among analyzed variables we did not found any associated with the incidence of toxicity.

Conclusion: Radiosurgery represents an alternative treatment modality for small residual or reoccurrence volumes of low grade gliomas with relatively long term local control.

P2090

FRACTIONATED STEREOTACTIC REIRRADIATION AND CONCURRENT TEMOZOLOMIDE IN PATIENTS WITH RECURRENT GLIOBLASTOMA

Giuseppe Minniti¹, ³ Veronica Armosini¹ Teresa Falco¹ Maurizio Salvati³ Gaetano Lanzetta³ Paola Caporello² Riccardo Maurizi Enrici¹

(1) Department of Radiation Oncology Sant' Andrea Hospital, University "La Sapienza", Rome, Italy (2) Department Medical Oncology Sant' Andrea Hospital, University "La Sapienza", Rome, Italy (3) 2Department of Neurological Sciences, Neuromed Institute, Rome, Italy

Objectives: To evaluate the efficacy of fractionated stereotactic radiotherapy (FSRT) and concomitant temozolomide (TMZ) as salvage treatment option in patients with recurrent glioblastoma (GBM).

Patients and Methods: Between May 2006 and December 2009, thirty-six patients with recurrent GBM received FSRT plus concomitant TMZ at University of Rome La Sapienza, Sant-TM Andrea Hospital. All patients had Karnofsky Performance Score ≤ 60 and were previously treated with standard conformal RT (60 Gy) with concomitant and adjuvant TMZ for 6-12 cycles. The median time interval between primary RT and reirradiation was 14 months. At the time of recurrence all patients received FSRT plus concomitant daily TMZ at the dose of 75 mg/m², given 7 days per week from the first day of RT. Radiation dose was 37.5 Gy delivered in 15 fractions over 3 weeks.

Results: Median overall survival (OS) after FSRT was 9.7 months, and the 6-month and 12-month survival rates were 84% and 33%, respectively. The median progression-free survival (PFS) was 5 months, and 6-month and 12-month PFS rates were 42% and 8%, respectively. In univariate analysis KPS ($P = 0.04$), interval between primary RT and reirradiation ($P = 0.02$), and MGMT methylation status at the time of diagnosis ($P = 0.009$) had effect on survival; however in multivariate analysis only MGMT methylation was statistically significant ($P = 0.03$). In general FSRT was well tolerated and the treatment was completed in all patients. Neurological deterioration due to radiation-induced necrosis occurred in 3 patients (8%).

Conclusions: FSRT plus concomitant TMZ is a feasible treatment option associated with survival benefits and low risk of complications in selected patients with recurrent GBM. The potential advantages of combined chemoradiation schedules in patients with recurrent GBM need to be explored in future studies.

P2092

STEREOTACTIC RADIOSURGERY IN THE TREATMENT OF PATIENTS WITH RECURRENT HIGH GRADE GLIOMAS : INSTITUTIONAL EXPERIENCE

Kita Sallabanda¹ Rafael García^{1, 1} Tamara García^{1, 1} Graciela García^{1, 1} Elvira Kodzma¹ Jose Carlos Bustos¹ Juan Antonio Gutierrez¹ Carmen Peraza^{1, 1} Jose Samblas¹

(1) GRUPO IMO, Madrid, Spain

BACKGROUND. To describe the Results of a study of stereotactic radiosurgery (SRS) in the treatment of patients with recurrent malignant glioma.

Methods: Twenty eight patients with recurrent glioblastoma multiforme (GBM) and anaplastic astrocytoma, were treated for 28 lesions with SRS from 1992 to 2008. Nine patients were male and 19 were female. The median age at primary diagnosis of the tumor was 52 years (range, 33-69 yrs). At the time of initial diagnosis a total neurosurgical resection was performed in eleven patients, a subtotal resection in 8 (1p plus Gliadel), and a biopsy in 9 patients . Histology evaluations revealed 14 p with glioblastoma multiforme (WHO Grade IV) and 14p anaplastic astrocytoma (WHO Grade III). In all patients radiotherapy was performed as the first-line therapy, applied as fractionated external beam radiotherapy. Median dose 60 Gy. The median dose applied was 13 Gy (range, 8-20 Gy) prescribed to the 90% isodose line that encompassed the target volume. No concomitant chemotherapy was applied. We found out, in the cases of anaplastic astrocytoma, the local control and overall survival more better than the cases of GBM.

Results: Treatment was well tolerated by all patients. No acute toxicities _ CTC Grade III occurred. No severe long-term toxicities were observed. All patients died of tumor progression during follow-up excepted one diagnosed of anaplastic oligoastrocitoma. The median overall survival from primary diagnosis of the tumor was 29 months (range, 11-120 mo). Median overall survival after SRS was 11±2 months (range: 8-19 mo). The median time from SRS to radiological relapse was 5 month (range: 2-12 mo)

Conclusions: SRS offers effective treatment as a salvage therapy for a subgroup of patients with smaller lesions of recurrent GBM and anaplastic astrocytoma.

P2093

GAMMA KNIFE STEREOTACTIC RADIOSURGERY AS A SALVAGE TREATMENT FOR RECURRENT MALIGNANT GLIOMAS

James Miller¹ Mark Henderson² Thomas Witt¹ Achilles Fakiris³ Robert Worth^{1, 2}

(1) Indiana University Department of Neurological Surgery, Indianapolis, USA (2) Indiana University Department of Radiation Oncology, Indianapolis, USA (3) Goodman Campbell Brain and Spine, Indianapolis, USA (4) Indiana University Department of Radiation Oncology, Indianapolis, USA

Approach: Malignant gliomas are the most common brain tumors in adults and are defined by the World Health Organization (WHO) as grade III and IV gliomas. The standard treatment is maximally safe resection followed by adjuvant chemotherapy and radiation. Despite aggressive treatments, tumor recurrence is inevitable and unfortunately the median survival is 12 months. A population of 24 patients treated at Indiana University Medical Center between 1997 and 2009 were treated

with Gamma Knife stereotactic radiosurgery (GKSRS) to malignant glioma recurrences as a salvage treatment. We performed a retrospective chart review of these patients to determine the progression free survival and the overall survival. All of the patient's tumors had well demarcated tumor borders on gadolinium enhanced MRI. The patients were treated with a median dose of 15 Gy to the 50% isodose curve. Statistical analyses were performed using Fisher's exact test to perform univariate analyses. Kaplan Meier survival curves were calculated using the log-rank test.

Relevance and innovation: In patients with well-demarcated areas of recurrent tumor growth, salvage radiotherapy by GKSRS is appealing. GKSRS allows delivery of a high single dose of radiation with less morbidity than surgical resection which can be limited due to tumor location.

Results: Data on local control was available for 18 patients. Of those, 13 (72%) experienced progressive disease at a median of 3 months post-GKSRS (range 1.1 to 23.5 months), 3 (17%) had stable disease, and 2 (11%) had a partial response. The median progression-free survival (PFS) was 5.7 months. Tumor volume was the only variable significantly affecting PFS ($p = 0.044$). Kaplan-Meier analysis demonstrated median PFS to be 23.5 months for patients with tumors $< 7 \text{ cm}^3$ and 1.7 months for patients with tumors $> 7 \text{ cm}^3$ ($p = 0.001$). The median overall survival (OS) was found to be 7.7 months, with a 10-month overall survival rate of 40%. A statistically significant difference in overall survival was found in those patients with tumors less than 7 cm^3 (median survival of 12.9 months vs. 6.2 months, $p = 0.037$).

Conclusions: Gamma Knife stereotactic radiosurgery is an effective salvage treatment in patients with recurrent malignant gliomas. Our data demonstrate a significant advantage for a subset of patients with median tumor volumes of less than 7 cm^3 .

P2094

DOSIMETRIC COMPARISON OF THE RELATED PARAMETERS BETWEEN SIMULTANEOUS INTEGRATED BOOST INTENSITY-MODULATED RADIOTHERAPY AND SEQUENTIAL BOOST CONFORMAL RADIOTHERAPY FOR POSTOPERATIVE MALIGNANT GLIOMA OF THE BRAIN

Qian Shao¹ Ji-Bin Li¹

(1) Shandong Tumor Hospital, Jinan, China

Objective Compare the dosimetric of different parameter of simultaneous integrated boost intensity-modulated radiotherapy (SIB-IMRT) with sequential boost conformal radiotherapy (SB-CRT) for postoperative malignant glioma of the brain.

Methods: Ten patients with malignant glioma of brain were selected to study. Each patient was simulated all by CT and MRI, and the imagings of CT and MRI were all sent to Pinnacle3 planning system. The fusion technology with MR-CT imaging was used on Pinnacle3 planning system. The target volume was delineated and defined based on MRI. The postoperative residual lesion and resection cavity were defined as gross tumor volume (GTV) and expanded GTV. Some scope was defined as clinical target volume (CTV). The margins of GTV expanded 10mm and 25mm were defined as CTV1 and CTV2 respectively. CTV1 and CTV2 all enlarged 5mm were defined as PTV1 and PTV2 respectively. The plans of simultaneous integrated boost intensity-modulated radiotherapy and sequential boost conformal radiotherapy were respectively designed for each patient using Pinnacle3 planning system and the dosimetric of different parameter was compared. The prescribe dose of SIB-IMRT was PTV1: 62.5Gy/25f, PTV2: 50.0Gy/25f; and SB-CRT was PTV1: 66.0Gy/33f,

PTV2: 50.0Gy/25f. The dosimetries of different parameters of SIB-IMRT and SB-CRT were compared by using Paired-Samples T Test.

Result: The maximum and mean dose of PTV1,PTV2, and brainstem were significant difference ($p<0.05$) in two plans; and the mean dose of whole brain was significant difference ($p<0.05$) in two plans. The conformity index(CI) and heterogeneity index(HI) of SIB-IMRT were superior to SB-CRT($p<0.05$). But the maximum dose of lens and optic nerves was not significant difference ($p>0.05$).

Conclusion: The SIB-IMRT plan is berrer than the SB-CRT plan.The CI and HI of SIB-IMRT are superior to SB-CRT. At the same time, it can preserve the important organs such as brainstem and reduce the mean dose of whole brain.On the other hand it can shorten the total period of therapy time.

P2095

LINEAR ACCELERATOR RADIOSURGERY FOR RECCURENT GLIOMAS

Elena Slobina¹ Alexey Yakovenko¹ Igor Yakubovich¹

(1) N.N. Alexandrov National Cancer Center of Belarus, Minsk, Belarus

Aims & Objectives: To assess the efficacy and side effects of linear accelerator (LINAC)-based stereotactic radiosurgery (SRS) performed with a reduced dose of therapeutic radiation for patients with surgically inaccessible recurrent gliomas.

Materials & Methods: Between August 2009 and October 2010, 12 patients with recurrent gliomas after combined treatment were treated with SRS, Table 1. 8 of these patients were treated with surgery followed a SRS boost and 4 patients were treated with SRS as the primary treatment. The median prescribed dose was 24 Grays (Gy) (range, 8 Gy-34 Gy) with a median of a median 85% isodose line (range, 50%-90%).

 Male:female ratio 5:7

Mean age (years) 56

Age range (years) 30-71

Histology

Glioblastoma 5

Gemangioblastoma 1

Astrocytoma 3

Oligodendroglioma 3

 Table 1. Study population.

Results: The median follow-up was 5 months (range, 1-12 months). All 12 patients are alive. After SRS treatment of 12 brain recurrent lesions, 11 lesions demonstrated stable disease, and 1 lesion demonstrated progressive disease. There was evidence of progression of disease in 1 case of recurrent glioblastoma in opposite part of brain at 8 month due to it was given monochemotherapy of temozolomide 75 mg/m2 and the actuarial local control rate at 6 months was 11/12 (91.6%).

Maximum tumor dimension, concurrent chemotherapy, and a tumor volume were found to be significant factors for local tumor control. One patient had a grade 3 toxicity (according to National Cancer Institute Common Terminology Criteria for Adverse Events).

Conclusions: LINAC-RS using a lower therapeutic radiation dose achieved local recurrent tumor control. The treatment Results in low toxicity. However, the lower therapeutic radiation dose did not prevent radiation-induced damage of brain tissue completely. LINAC-RS is a very useful modality when a surgical approach or other is not possible.

P2096

MULTIMODAL SONOGRAPHY MICROSURGERY, ENDOSCOPY, RADIOSURGERY GAMMA KNIFE IN GLIOMAS, WITH CONCEPT OF PHILOSOPHY MINIMAL INVASION

Marco Antonio Barajas R¹ Héctor Velázquez² Vinicio Toledo¹ Xerxes Domínguez¹ Porfirio Sánchez¹ Ramiro López²

(1) Hospital San Javier, Guadalajara, Mexico (2) Hospital Juan I Menchaca, Guadalajara, Mexico

Objectives: Demonstrate the support of multimodal approach in Gliomas grade I,II, sonography, micosurgery, endoscopy and Radiosurgery Gamma Knife as a tools in the armamentarium of the neurosurgeon with the philosophical base, of minimally invasive techniques in neurosurgery.

Methods: A retrospective review of 40 patients trated between January 2005 to October 2010 was conducted. The median follow up was 60 months. We used the multimodal approach in 40 patients with gliomas grade I,II, of 3 to 70 years old, in 7 patients with tumor in eloquent area awake surgery was made, on ten patients was complement with chemotherapy

Results: Median clinical progression free was 50 months and median radiological progression free survival was 42 months. in 7 patients with tumor in eloquent area, awake surgery was made, on ten patients was complemented with chemotherapy. Mortality due to surgery 0, morbidity 3%, mortality due tumor progression, occurred in 2 patients. Complications due to Gamma Knife were seen in 3 patients, Of these, two resolved after dexamethasone for 3weeks and one patient suffered a permanent neurological deficit from treatment.

Conclusion: Multimodal treatment is safe when we use combination of different technicals with concept of philosophy Minimal Invasión in low-grade glomas.

P2097

AVAILABILITY OF METHIONINE PET AT PLANNING OF STEREOTACTIC RADIOTHERAPY FOR GLIOBLASTOMA

Kazutaka Yatsushiro¹ Mikio Ogita¹ Ryutaro Higashi¹ Katsumi Nakamura¹ Hirofumi Hirano² Kazunori Arita²

(1) Fuimoto-Hayasuzu Hospital, Miyakonojo, Japan (2) Kagoshima University, Kagoshima, Japan

Purpose: The fact that there is dissociation between contrast enhanced lesion and accumulated lesion with methionine PET in glioblastoma patients was well-known. We have been applying methionine PET images for planning of stereotactic radiotherapy in the patients with glioblastoma.

In this paper, we evaluated availability of methionine PET at planning of stereotactic radiotherapy with cyberknife for glioblastoma.

Material and Methods: Between 2006 and December 2008, 34 newly diagnosed patients with glioblastoma were engaged on this study. The patients were received craniotomy and established pathological diagnosis. After the operation, external beam irradiation (EBI) of 40 Gy / 20 fx was performed for T2 hyperintensity area under administration of temozolomide. After EBI, methionine PET images were taken and used for planning of stereotactic radiotherapy boost by cyberknife with 30 - 35 Gy / 5 fx. We evaluated dissociation between MRI and methionine PET images, recurrence pattern of the tumor, progression free survival and overall survival time.

Result: Dissociation between MRI and methionine PET images was shown in 50 % patients. The lesions revealed by methionine PET were larger than them by MRI. When we irradiated strongly hot lesions revealed by methionine PET, 50% of tumor recurrence was observed from the marginal area of the tumor removal cavity without accumulation of methionine PET. Nineteen percent of tumor recurrence site was remote area from the removal cavity and only 31% of the recurrence was shown in the area of accumulation of methionine PET. Progression free survival time was 10.5 months and 7.0 months in the patients treated by cyberknife with methionine PET and in the patients treated by conventional radiotherapy, respectively. Overall survival time was 20.0 months and 14.8 months in the patients with cyberknife boost and with conventional radiotherapy, respectively.

Conclusion: Methionine PET was proven to be useful in the patients with glioblastoma, when we planned and performed stereotactic radiotherapy boost by cyberknife.

P2098

EFFICACY OF GAMMA KNIFE RADIOSURGERY IN RECURRENT OLIGODENDROGLIOMAS

Seung-yeob Yang¹ Dong Gyu Kim²

(1) DongGuk University Graduate School, Seoul, Korea (2) Seoul National University College of Medicine, Seoul, Korea

Object: To evaluate the efficacy of stereotactic Gamma knife radiosurgery (GKRS) performed as an adjuvant treatment in 35 patients with recurrent low- and high-grade oligodendrogliomas.

Methods: Between December 1997 and April 2009, 35 patients with recurrent low- and high-grade oligodendrogliomas (12 Grade II and 23 Grade III) were treated using GKRS in a single institution. The mean patient age was 43.4 years (range, 11-71). Of these 35 patients, 28 received a full course of radiotherapy after primary diagnosis with a median dose of 55.4Gy in conventional fractionation and 12 received at least one chemotherapeutic regimen including procarbazine, cyclophosphamide, and vincristine (PCV). The mean time between microsurgery and GKRS was 60.9 months (range, 4.1-146.0). The mean target volume was 5.10 cm³ (range, 0.04-25.60) and the mean margin dose was 16.2Gy (range, 10-23).

Results: At a mean of 54.1 months of follow-up (range, 6.8-141.0) after GKRS, 18 patients were dead and 17 were living. Mean overall survival after primary diagnosis was 162.8 months for patients with oligodendroglioma and 89.5 months for patients with anaplastic oligodendroglioma. Mean survival after GKRS was 119.7 months for patients with oligodendroglioma and 50.3 months for patients with anaplastic oligodendroglioma. Postradiosurgical chemotherapy and histology were significant in influencing survival after GKRS. Mean progression-free survival after GKRS was

71.5 months for oligodendroglioma and 26.3 months for anaplastic oligodendroglioma. Factor associated with an improved progression-free survival was histology. At tumor progression after GKRS, tumor resection was conducted in 13 patients and chemotherapy was performed in 11 patients, including the administration of temozolomide, bevacizumab, irinotecan, or PCV, taking into consideration prior systemic treatments.

Conclusion: GKRS offers considerable treatment option as a salvage therapy for a subgroup of patients with smaller lesions of recurrent oligodendrogliomas.

P2099

HYP0-FRACTIONATED HIGH-DOSE IRRADIATION USING IMRT PLANNED BY METHIONINE PET FOR THE TREATMENT OF GLIOBLASTOMA MULTIFORME

Kazuhiro Miwa^{1, 3} Masayuki Matsuo² Jun Shinoda^{1, 3} Kazutoshi Yokoyama³ Jitsuihiro Yamada³ Hirohito Yano⁴ Toru Iwama⁴

(1) Chubu Medical Center for Prolonged Traumatic Brain Dysfunction, Gifu, Japan (2) Department of Radiation Oncology, Kizawa Memorial Hospital, Gifu, Japan (3) Department of Neurosurgery, Kizawa Memorial Hospital, Gifu, Japan (4) Department of Neurosurgery, Gifu University Graduate School of Medicine, Gifu, Japan

Objectives: This study was designed to evaluate the clinical significance of hypo-fractionated high-dose irradiation by intensity-modulated radiation therapy (Hypo-IMRT) in defining the target volume with complementary 11C-methionine (MET)-PET data for the treatment of GBM, with temozolomide (TMZ) chemotherapy.

Materials & Methods: A total of 45 patients with GBM were treated with Hypo-IMRT after surgery. The gross target volume-1 (GTV-1) was defined as the MET-PET avid region. The GTV-2 was defined as the MET-PET moderate region. The GTV-1 and GTV-2 were expanded by 5 mm and 2 mm, to generate the planning target volumes (PTVs) PTV-1 and PTV-2, respectively. The contrast-enhanced lesion or resection cavity on T1-weighted MRI were included in PTV-1. Hypo-IMRT was performed using tomotherapy in 8 fractions; planning the dose for GTV-1 was escalated to 68 Gy and that for PTV-1 escalated to 56 Gy, while keeping the dose delivered to the PTV-2 at 40 Gy. Concomitant and adjuvant TMZ chemotherapy was administered according to the regimen of Stupp et al.

Results: At a median follow-up of 15.7 months, median overall survival (OS) was 20.0 months, and median progression-free survival (PFS) was 13.0 months. The 1- and 2-year OS rates were 71.2% and 26.3%, respectively. The 1- and 2-year PFS rates were 52.6% and 20.6%, respectively. Adjuvant TMZ chemotherapy was significantly predictive of OS on multivariate analysis. CSF dissemination was the most frequent failure pattern of all recurrent cases. No Grade 3-4 acute toxicities were reported. Late toxicity included 9 cases of Grade 2-4 radiation necrosis, 1 case of Grade 3 cerebropathy, and 2 cases of Grade 3-4 intra-tumoral hemorrhage.

Conclusions: Hypo-IMRT with TMZ chemotherapy in defining target volume with the complementary use of MET-PET data yielded favorable outcomes in OS and PFS for patients with GBM, with a 4-week shortening of the overall treatment time.

P2100

EPENDYMOMAS IN CHILDREN AT THE NATIONAL INSTITUTE OF ONCOLOGY IN RABAT

Hanane Chenna¹ Hanane El Kacemi¹ Khalid Hassouni¹ Karima Nouni¹ Fatima Zahra El M'rabet² Omar El Mesbahi² Hanane Berhil¹ Tayeb Kebdani¹ Noureddine Benjaafar¹ Brahim Khalil El Gueddari¹

(1) National Institute of Oncology, Rabbat, Morocco (2) Service of Onocology, CHU of Fes, Fes, Morocco

Introduction: The intracranial ependymoma is a rare childhood tumor. It represents less than 15% of brain tumors and less than 5% of all cancers encountered in this age of life.

Objectives: To study the epidemiological, clinical, histological, therapeutic and prognostic of ependymomas in children.

Materials and Methods: Retrospective study in a series of 07 children, aged under 16 years treated in our department between 1999 and 2008.

Results: The median age of patients was 7 years (2-14 years). There was no sex predominance. The average period of consultation was 4 months (1 month - 11 months). The circumstances of discovery were dominated by a syndrome of intracranial hypertension in 06 cases (86%), neurological deficits in 5 cases (71%) and visual disturbances in 04 cases (57%). All patients underwent brain imaging (CT and or MRI). The tumor was infratentorial in 50% of cases. The histological diagnosis was made by surgical biopsy in 4 cases. Anatomico-clinical study has concluded an ependymoma. The 7 patients were operated, 3 patients had a ventricular derivation. The excision was incomplete in 4 cases (58%) and complete in 3 cases (42%). Postoperative imaging (MRI or CT) was performed in 2 patients (28%). Residual tumor was found in 2 cases (28%). 4 patients (58%) received radiotherapy with a mean time between surgery and radiotherapy of 60 days. 1 patient (14%) received adjuvant chemotherapy. The median is 6 months (3 - 12 months). 3 patients (43%) are alive and are followed by disease, 1 patient (14%) died and 3 patients (43%) were lost to view.

Conclusion: The prognosis of these tumors remains poor. The 5-year survival ranges from 16 to 67% depending on the series. Few factors are predictive of changes unanimously. It seems that the very young age, the existence of a residual tumor after surgery, the occurrence of recurrence and the absence of irradiation on the tumor bed are more readily associated with a poor outcome.

P2101

INTENSIFICATION RADIATION DOSE IN HIGH GRADE GLIOMAS: NEUROCOGNITIVE EVALUATION AND OUTCOMES.

Silvia Chiesa¹ Giuditta Chiloire¹ Laura De Filippo¹ Stefania Manfrida¹ Giuseppe Roberto D'agostino¹ Vincenzo Frascino¹ Giuseppe Maria Di Lella² Maria Antonietta Gambacorta¹ Carmelo Anile³ Mario Balducci¹

(1) Department of Radiotherapy Catholic University of the Sacred Heart, Rome, Italy (2) Department of Radiology Catholic University of the Sacred Heart, Rome, Italy (3) § Department of Neurosurgery Catholic University of the Sacred Heart, Rome, Italy

Purpose: In this phase II study we evaluated the late neurotoxicity in patients with High Grade Glioma (HGG- III and IV grade WHO), treated by 3D-Conformal Radiation Therapy (3D-CRT) plus

Fractionated Stereotactic Conformal Radiation Therapy (FSCRT) and Temozolomide (TMZ). We also analysed the outcomes in terms of disease free survival (DFS) and overall survival (OS).

Materials and methods: Patients (≥ 18 yrs) with CTV ≤ 8 cm were enrolled. Total radiation dose was administered using a combination of 2 schedules: total radiation dose was 69.4Gy; 3D-CRT dose was 50.4Gy in case of concomitant plus sequential FSCRT boost or 59.4Gy in case of sequential FSCRT boost. These 2 schedules were tailored depending on CTV1 diameter (<6 cm or >6 cm and ≤ 8 cm). Concomitant TMZ (75mg/m²) was administered during the first 2 or 4 weeks of radiotherapy related to FSCRT modality. Adjuvant TMZ (150-200mg/m²) was administered for at least 6 cycles. Acute toxicity was evaluated according to RTOG score. Neurocognitive functions were evaluated in patients with an OS >14.6 months (median OS of Stupp's study) according to Mini-Mental-State-Examination (MMSE) (total score-TS =30): space-time orientation (TS=10), short-term memory (TS=3), attention and ability to calculate (TS=5), memory (TS=3), language (TS= 8) and construction skills (TS=1).

Results: We enrolled 43 pz (38 Glioblastoma-GBM): 27 (63%) male and 16 (37%) female. Median age was 53 years (range 25-72). With a median follow up of 72 months (range 23-81), 13 patients were alive with a median DFS of 10 months (GBM: 10 months) and median OS of 29 months (GBM: 26 months). Two-years DFS was 32,6% (GBM: 26,3%) and OS was 55,8% (GBM: 50%). Acute neurological toxicity G1/2 and G3 were 12% and 3%, respectively. Late neurological toxicity included 2 cases of radio-necrosis. Neurocognitive functions were evaluated in 11 out of 33 eligible patients. With a mean TS of 27,9, we observed a complete preservation of short-term memory and language functions in all patients; mean score of space-time orientation was 9,6 (4 patients obtained 9/10); the attention and the calculation were the more damaged skills (mean TS of 4,1), but it may be correlated to the scolarity level; mean memory score was 2,2 and only 1 patient presented difficulties in construction skill.

Conclusions: FSCRT boost associated to 3D-CRT and TMZ is well tolerated with a good preservation of neurocognitive functions; moreover it seems to increase outcomes in patients with HGG.

P2102

A NOVEL EYE FIXATION AND TRACKING SYSTEM FOR FRACTIONATED TREATMENT OF THE CHOROIDAL MELANOMA ON GK PERFEXION

Mostafa Heydarian^{1, 2} Graham Wilson¹ Monique Van Prooijen¹ Young-bin Cho¹ Arjun Sahgal¹,
² Hatem Krema^{1, 2} David Payne^{1, 2} Norm Laperriere^{1, 2}

(1) Princess Margaret Hospital, Toronto, Canada (2) University of Toronto, Toronto, Canada

Purpose: To develop Gamma Knife PerfexionTM (PFX) fractionated treatment technique for the Choroidal Melanoma (CM) using a novel eye fixation and tracking system for monitoring eye motion to ensure accurate radiation dose delivery.

Materials/Methods: A new technique is being developed for treating CM cases on PFX machine, as an alternative to our current practice using Linac-based stereotactic radiotherapy (LB-SRT). A relocatable head frame was designed by Elekta with our collaboration to perform fractionated techniques. A real-time eye monitoring device has also been designed at PMH to ensure eye fixation during planning CT simulation and treatment. Real time position of the eye during treatment is compared with the reference image and audio visual warnings are given if deviation exceeds preset

values. Dosimetric comparison was performed between PFX treatment plans and LB-SRT for five previously treated CM cases of small, medium and large size tumors.

Results: Averaged normalized tumors mean and maximum doses for LB-SRT plans were 73.17 Gy (range 71.41 to 75.10) and 74.58 Gy (range 72.02 to 77.83) and for PFX plans were 102.08 Gy (range 97.11 to 106.98) and 134.48 Gy (range 126.15 to 146.76), respectively. Overall LB-SRT mean and maximum doses to the lens were 5.44 and 11.17 Gy and to anterior chamber 2.93 and 7.05 Gy, whereas the corresponding values for PFX were 8.84 and 15.53 Gy for the lens and 6.52 and 14.09 for anterior chamber. PFX plans were more conformal, so that mean doses to non-tumor parts of the eye and retina were 23.90 and 34.82 Gy compared to 35.15 and 48.78 Gy for LB-SRT plans. Also PFX plans had much smaller high-dose volumes, so that their averaged V20 (total volume receiving a minimum dose of 20 Gy) was less by a factor of 4, although this trend was reversed for very small doses.

Conclusion: The eye tracking system is an essential part of the CM treatment on PFX, due to very long treatment time. We have shown that LB-SRT and PFX provide dosimetrically comparable treatments for Choroidal Melanoma. The former delivers more uniform dose to the tumor and the latter delivers more conformal dose to the tumor and therefore has a lower integral dose (dose x volume) to normal structures. Overall PFX mean integral dose to healthy parts of treated eye and retina were around 30% less. This may result in less chance of developing treatment complications such as neovascular glaucoma (NVG).

P2103

LINAC BASED RADIOSURGERY FOR INTRAOCULAR MELANOMA, SHEBA EXPERIENCE

Dror Alezra¹ Uzi Nisim² Roberto Spigelman² Vicktoria Vishnevskia-dai³ Raphael Pfeffer¹

(1) Sheba medical center, Oncology Dept., Tel Hashomer, Israel (2) Sheba medical center, Neurosurgery Dept., Tel Hashomer, Israel (3) Sheba medical center, Eye Dept., Tel Hashomer, Israel

Purpose: To examine the feasibility of treating intra ocular melanoma with a LINAC based radiosurgery system, when the melanoma is too large for plaque brachytherapy.

Methods: The intra ocular Melanoma was close to the ciliary body of the left eye of a 70 y female patient, with dimensions of 12x12x15 mm (15mm height). For the planning CT and treatment an internet camera with a light spot was installed on an adjustable arm attached to the patient's head ring in order to actively align and monitor the eye. The eye was immobilized with a retro-orbital block.

iPlan TPS was used based on CT fused with MRI. Patient was planned and treated with 5 arcs and circular cones RS treatment with a single fraction of 35Gy calculated to the 80% isodose.

Results: In general we were confident with treatment setup and accuracy. Treatment was well tolerated and few weeks after treatment patient vision improved.

P2104

STEREOTACTIC RADIOSURGERY OF POSTERIOR UVEAL MELANOMA.

Miron Šramka¹ Alena Furdova¹ Omelian Trompak¹ Martin Chorvath¹ Alla Trompak¹ Iveta Waczulikova¹

(1) Clinic of stereotactic radiosurgery st. Elisabeth Oncological Institute, Bratislava, Slovakia

Introduction: LINAC based stereotactic radiosurgery of posterior uveal melanoma is a Methods of -æconservative- attitude to treat uveal melanoma. Radiosurgery of ocular disorders necessitates a close teamwork with an ophthalmologist.. Multidisciplinary approach is necessary for patients selection, follow up and treatment.

Methods: Retrospective clinic-based study - clinical findings of patients with posterior uveal melanoma in stage T2/T3 who underwent SRS at LINAC accelerator or combined Methods s in period 2001- 2008. Eye immobilization of the treated eye to the stereotactic frame was achieved mechanically by 4 stitches through extraocular direct muscles. This eye fixation technique showed very good stability and rigidity in time. Best-corrected visual acuity (BCVA) was evaluated in each patient every six months.

Results: Thirty-nine patients with posterior uveal melanoma treated with SRS, patient age ranged from 25 to 80 years with a median of 54 years. Median tumor volume at baseline was 0.6 cm3 (with range from 0.2 to 1.3 cm3). Median of maximal dose applied was 49.0 Gy (range from 37.0 to 60.0 Gy). Nine of the 39 patients (23%) had 20/40 (0.5) or better acuity in the eye, 23 (59%) 20/50 (0.4) to 20/400 (0.05), and seven (18%) had worse than 20/400 (0.05) in the eye at the baseline (investigation before performing SRS). In the patients with visual acuity of 20/40 or better, the median rate of BCVA decline was significantly higher than the rate of decline in the complementary group of patients with BCVA less than 20/40 ($P = 0.0077$; Mann-Whitney U test).

Conclusion: One step LINAC based stereotactic radiosurgery with a single dose 35.0 Gy is a Methods to treat middle stage posterior uveal melanoma and to preserve the eye globe.

P2105

GAMMAKNIFE RADIOSURGERY FOR UVEAL MELANOMA: 5 CASES EXPERIENCE

Noriko Tamura¹

(1) Noriko Tamura, Tokyo, Japan (2) Morohio Hayashi, Tokyo, Japan (3) Yoshikazu Okada, Tokyo, Japan

Purpose: In Japan, uveal melanoma is very rare primary ocular malignant tumor in adults. The estimated annual incidence is 30 per population. We present our treatment protocol and evaluate the result of Gammaknife Radiosurgery (GKRS) in treating patient with uveal melanoma.

Methods: Five patients with uveal melanoma were treated with the Leksell GammaKnife at our instate between 2002 and 2009. The main outcome measures were local tumor control, metastasis, eye retention rate and radiation-related complications.

All patients were followed up by ophthalmologists and neurosurgeons at 3-6 months interval.

Results: The mean follow up time was 37 months(range 6-95 months). The mean peripheral and maximum dose to the tumor were 39.3 Gy and 74.5 Gy. Mean treated tumor volume was 0.31 cc. Local tumor control achieved in 5 cases (100%). During follow-up ,metastases and deaths were not

observed.

Conclusion: GKRS for uveal melanoma can be considered an alternative to enucleation. =

P2106

NTCP ESTIMATION BY THE LYMAN-KUTCHER-BERMAN METHODS DOES NOT PREDICT SPINAL CORD TOLERANCE TO RADIOSURGERY

Megan Daly¹ Gary Luxton¹ Clara Choi¹ Iris Gibbs¹ Steven Chang² John Adler² Scott Soltys¹

(1) Stanford University Department of Radiation Oncology, Stanford, Ca, USA (2) Stanford University Department of Neurosurgery, Stanford, Ca, USA

Purpose: To determine if normal tissue complication probability (NTCP) analyses of the human spinal cord using the Lyman-Kutcher-Burman (LKB) model predict the risk of myelopathy from partial-volume spinal stereotactic radiosurgery (srs).

Methods and materials: From November 2001 to July 2008, 24 spinal hemangioblastomas in 17 patients were treated with SRS. Seventeen tumors received 1 fraction with a median dose of 20 Gy (range, 18-30 Gy), and 7 lesions received 20-25 Gy in 2-3 sessions with corresponding spinal cord maximum doses (DMax) of 22.7 Gy (range, 17.8-30.9 Gy) and 22.0 Gy (range, 20.2-26.6 Gy), respectively. Using conventional parameters for α/β , n, TD50, and m, a computationally-simplified implementation of the LKB model was used to calculate the biologic equivalent uniform dose (BEUD) and NTCP for each treatment. Exploratory calculations were performed with alternate values of α/β and n to obtain a best-fit curve to the clinical data.

Results: Among 24 treated lesions, there was 1 case (4%) of spinal cord myelopathy. The LKB NTCP model, using radiobiologic parameters from both Emami and Schultheiss data, overestimated the complication rates, predicting 13 (54%) and 18 (75%) complications, respectively. Increasing the spinal cord volume parameter, n, to assume a greater degree of parallel organization, improved the predictive value of the LKB model but continued to overestimate the toxicity risk.

Conclusions: The human spinal cord tolerance to the dosimetry of spinal SRS is higher than predicted by the LKB NTCP model using any set of accepted parameters. For small-volume, high-dose spinal cord irradiation, assuming increased parallel organization for the cord improves the model fit but does not fully explain the observed data. This finding emphasizes that radiobiologic models traditionally used to estimate NTCP of the spinal cord may not be applicable with the partial-volume dosimetry of SRS. Further research with additional NTCP models is needed.

P2107

CYBERKNIFE RADIOSURGERY FOR VERY LARGE SPINAL TUMORS

Jan Eckermann¹ Robert Lieberman¹ Hyunki Park¹ Tenaya West¹ Bowen Jiang¹ Scott Soltys² Iris Gibbs² John Adler¹ Steven Chang¹ - -¹

(1) Department of Neurosurgery, Stanford University Medical Center, Stanford, Ca, USA (2) Department of Neurosurgery, Soonchunhyang University Hospital, Seoul, Korea

Objective: Stereotactic radiosurgery (SRS) is a well-established treatment for many primary and metastatic spinal tumors. Its safety and efficacy are well documented, but information regarding

the treatment of the largest tumors is limited. In this study, we sought to evaluate the safety and efficacy of using SRS to treat spinal tumors over 50, 75, and 100 cubic centimeters (cc).

Methods: With IRB approval, we searched the Stanford CyberKnife database to identify patients with spinal tumors larger than 50, 75, and 100 cc. Clinical data, treatment parameters, and outcomes were abstracted. We contacted patients and their referring for additional information as needed.

Results: We identified 79 patients with spinal tumors whose radiographic lesion volumes exceeded 50 cc, 47 with tumors larger than 75 cc, and 21 with tumors over 100 cc. For the 47 patients with lesions over 75 cc in volume, the median age was 62.5 years (range 26-86) and the median tumor volume was 122 cc (range 75.3-390). For this group, the median marginal dose was 24 Gy (range 14-30) and the median maximal dose was 30 Gy (range 17-40). Treatment was delivered in a median of 3 sessions (range 2-5). The median conformality index was 1.38 and the median modified conformality index was 1.28. Pathologies included lung (7), renal (4), poorly differentiated adenocarcinoma (4), colon (3), prostate (3), breast (2), thyroid (2), endometrial cancer (2), pancreas (2), one each of nasopharyngeal carcinoma, mucoepidermoid carcinoma, cervical carcinoma, mesothelioma, melanoma, lymphoma, desmoid tumor, malignant nerve sheath tumor, atypical meningioma, leiomyosarcoma, chondrosarcoma, angiosarcoma, plasmacytoma, sarcoma, and «other» (4). Follow-up ranged from 3 months to 5 years. Radiographic and clinical local tumor control rates both exceeded 90%. Although overall survival was limited by the underlying pathology, complications related to radiosurgery were rare. Data for lesions of over 50 cc and those over 100 cc were similar.

Conclusions: CyberKnife radiosurgery appears to be a safe and effective treatment for large spinal primary tumors and metastases.

P2108

CHARACTERIZATION OF THE NEUROPROTECTION MECHANISMS OF IONIZING RADIATION IN A SPINAL CORD TRAUMATIC INJURY

Claudia Katuska González-valdez¹, ² Sergio Moreno-jimenez¹ Araceli Díaz- Ruiz² Sergio Montes-lópez² Hermelinda Salgado-ceballos ⁴ Mariana Hernández-bojórquez ³ Miguel Angel Celis- López ¹ José M. Larraga- Gutierrez ³ Camilo Ríos-castañeda ² F. Pérez Severiano²

(1) Instituto Nacional de Neurología y Neurocirugía, Unidad de Radiocirugía, Mexico City, Mexico (2) Instituto Nacional de Neurología y Neurocirugía, Neuroquímica, Mexico City, Mexico (3) Instituto Nacional de Neurología y Neurocirugía, Lab. Física Médica, Mexico City, Mexico (4) IMSS Proyecto CAMINA, Mexico City, Mexico

Introduction: Spinal cord traumatic lesions usually result in irreversible and severe disabling consequences. In previous studies, it has been shown that ionizing radiation has neuroprotection effects. Their Results indicate that rats treated with a 2 Gy dose 2 h after a traumatic lesion had an increment in the motor function, as well as a larger spinal cord tissue preservation compared to the control group. Based on these findings, in the present work the possible antioxidant and anti-inflammatory effects of ionizing radiation in a traumatic spinal cord lesion in a rat model was studied.

Materials and Methods: In this study a total of 96 female Wistar rats, weighing 200 to 250 g were used. The rats were subject to a traumatic spinal cord lesion by a moderate contusion at the T9 level

imparted by a New York, Spinal Cord Impactor. The radiosurgery was performed 2 h post contusion with a dedicated 6 MV Novalis linear accelerator (Brain Lab, Inc.). The rats were sacrificed 24 h later to perform biochemical analysis to assay lipid peroxidation (LP) and myeloperoxidase (MPO). At 72 h after contusion, the inducible nitric oxide synthase activity (iNOS) was measured.

Conclusions: Our Results indicate that ionizing radiation has a partial antioxidant and anti-inflammatory effects after a spinal cord lesion. Even though ionizing radiation has been proved to generate free radicals, it maintains the LP, iNOS and MPO levels below those observed in rats which received no radiation dose. It is necessary to explore other mechanics which could explain the neuroprotective effects of ionizing radiation on a traumatic spinal cord lesion.

References:

- [1] Hildebrandt G, Loppnow G, Jahns J, Hindemith M, Anderegg U, Saalbach A, Kamprad F. Inhibition of the iNOS pathway in inflammatory macrophages by low-dose X-irradiation in vitro. Is there a time dependence? *Strahlentherapie Onkologie* 2003; 179:158-66.
- [2] Schae D, Marples B, Trott KR. The effects of low-dose Xirradiation on the oxidative burst in stimulated macrophages. *International Journal of Radiation Biology* 2002; 78: 567-576
- [3] Diaz-Ruiz A, Ibarra A, Perez-Severiano F, Guizar-Sahagun G, Grijalva I, Rios C. Constitutive and inducible nitric oxide synthase activities after spinal cord contusion in rats. *Neurosci Lett.* 2002; 319: 129-132

P2109

PRECLINICAL DEVICES AND MODELS FOR INVESTIGATION OF STEREOTACTIC IRRADIATION

Timothy Solberg¹ Kwang Song¹ Rajesh Pidikiti¹ Strahinja Stojadinovic¹ Michael Speiser¹ Debu Saha¹

(1) UT Southwestern Medical Center, Dallas, USA

With the advent of advanced image-guidance technologies, stereotactic body radiation therapy (SBRT), the application of an ablative dose of radiation given in one or few fractions and delivered with high accuracy, has emerged as a promising modality in the treatment of cancer. Despite this success, the basic mechanisms governing response are poorly understood. There is a clear need to better optimize treatment, alone or in combination with radio-modulating compounds. In this regard, pre-clinical studies are essential for systematically evaluating response and predicting and validating clinical protocols. To be most effective, pre-clinical experiments must mimic clinical application as closely as possible; in the case of SBRT, it is critical to deliver a highly localized radiation dose to the desired target while sparing normal tissue. Due in part to the lack of sophisticated equipment necessary to provide precise stereotactic radiation delivery to mice and rats, systemic small animal SBRT studies have thus far been limited.

In this work, we describe the development and application of a system for preclinical irradiation which utilizes image guidance to provide high accuracy in target localization and radiation delivery in a manner that mimics clinical SBRT delivery. An x-ray source operating at 250 kVp provides excellent depth dose characteristics in small animals; a high dose rate (up to 20 Gy/min) allows high dose delivery in a clinically-relevant time frame. Precise target localization (≤ 1 mm), using collimators ranging from 1 to 10 mm in diameter, is achieved using x-ray image guidance; an

optical camera has recently been added for bioluminescence targeting of pathologic disease. The system has been used successfully to investigate response to ablative doses in a number of models, including: orthotopic lung tumors in rats, orthotopic prostate tumors in rats, brain tumors in mice, and normal lung in mice. Findings illustrate how these models may enable the design and testing of new strategies for stereotactic irradiation of patients.

P2110

QUALITY AND SAFETY IN STEREOTACTIC RADIOSURGERY AND STEREOTACTIC BODY RADIATION THERAPY: MORE CAN BE DONE

Timothy Solberg¹ Paul Medin¹

(1) UT Southwestern Medical Center, Dallas, USA

Stereotactic radiosurgery (SRS) has been an effective modality for the treatment of benign and malignant cranial disease for 50 years. Increasingly, the stereotactic approach, ablative doses of radiation delivered in a highly focused manner to a target of interest, is being applied in a number of extracranial disease sites. Stereotactic body radiation therapy (SBRT) holds significant potential for improving tumor control rates across a range of locations and histologies. Both SRS and SBRT require specialized technology, meticulous procedures, and dedicated personnel. Several recent high-profile medical radiation events have generated considerable attention within the media, and serve to remind the profession that close attention to ongoing quality improvement is a fundamental responsibility.

The purpose of this abstract is to: 1) Discuss radiation error prevention efforts undertaken by the World Health Organization (WHO), the International Commission on Radiological Protection (ICRP), the National Health Service (NHS) and other organizations, 2) Review reported errors in SRS/SBRT commissioning, dosimetry and delivery, 3) Provide broad ranging recommendations (staffing, training, credentialing, resource identification, patient-specific quality assurance) for SRS / SBRT processes and procedures that may be beneficial in understanding and reducing risks inherent to the modalities.

P2111

HUMAN RE-IRRADIATION SPINAL CORD TOLERANCE FOR SPINAL RADIOSURGERY

Arjun Sahgal¹ Lijun Ma¹ Vivian Weinberg² Iris Gibbs³ Sam Chao⁴ Ung-kyu Chang⁶ Maria Werner-wasik⁷ Liliyanna Angelov⁴ Eric Chang⁸ Moon-jun Sohn⁹ Scott Soltys³ Daniel Letourneau¹ Sam Ryu¹⁰ Peter Gerszten⁵ Jack Fowler¹¹ Shun Wong¹ David Larson²

(1) University of Toronto, Toronto, Canada (2) University of California San Francisco, San Francisco, USA (3) Stanford University, Stanford, USA (4) Cleveland Clinic, Cleveland, USA (5) University of Pittsburgh, Pittsburgh, USA (6) Korea Institute of Radiation and Medical Science, Seoul, Korea (7) Thomas Jefferson University Hospital, Philadelphia, USA (8) M.D. Anderson Cancer Center, Texas, USA (9) Inje University, Seoul, Korea (10) Henry Ford Hospital, Detroit, USA (11) University of Wisconsin, Madison, USA

Purpose: We reviewed the treatment for patients with spine metastases who initially received conventional external beam radiation (EBRT) and were re-irradiated with 1-5 fractions (fx)

of stereotactic body radiotherapy (SBRT) who did or did not subsequently develop radiation myelopathy (RM).

Materials and Methods: Spinal cord dose volume histograms (DVHs) for 5 RM patients (5 spinal segments) and 14 no-RM patients (16 spine segments) were based on thecal sac contours at re-treatment. Dose to a point (Pmax) within the thecal sac which receives the maximum dose, and doses to 0.1 cc, 1.0 cc, and 2.0 cc volumes within the thecal sac were reviewed. The biologically effective doses (BED) using $\alpha/\beta=2$ Gy for late spinal cord toxicity were calculated and normalized to a 2 Gy equivalent dose (nBED = Gy2/2).

Results: The initial conventional radiotherapy nBED ranged from ~30-50 Gy2/2 (median ~40 Gy2/2). The SBRT re-irradiation thecal sac mean Pmax nBED in the no-RM group was 20.0 Gy2/2 (95% CI: 10.8-29.2), which was significantly lower than the corresponding 67.4 Gy2/2 (95% CI: 51.0-83.9) in the RM group. The mean total Pmax nBED in the no-RM group was 62.3 Gy2/2 (95% CI: 50.3-74.3), which was significantly lower than the corresponding 105.8 Gy2/2 (95% CI: 84.3-127.4) in the RM group. The fraction of the total Pmax nBED accounted for by the SBRT Pmax nBED for the RM patients ranged from 0.54-0.78 and that for the no-RM patients ranged from 0.04-0.53.

Conclusions: SBRT given at least five months after conventional palliative radiotherapy with a re-irradiation thecal sac Pmax nBED of 20-25 Gy2/2 appears to be safe provided the total Pmax nBED does not exceed approximately 70 Gy2/2, and the SBRT thecal sac Pmax nBED comprises no more than approximately 50% of the total nBED.

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THE NANOPORATION PROJECT: TOWARDS MR GUIDED ULTRASOUND-ACTIVATED TARGETED DRUG DELIVERY FROM NANO-ENCAPSULANTS

Fabian Arditti³ Bjoern Gerold², ¹ Dana Gourevich¹, ³ Muhammad Athamna³ Dun Liu¹ Alexander Volovick¹, ² Sandy Cochran¹ Jallal Gnaim³ Paul Prentice¹ Lijun Wang¹ Yoav Medan² Eyal Neria³ Andreas Melzer¹

(1) Institute for Medical Science and Technology, Dundee, UK (2) InSightec, Tirat Carmel, Israel (3) CapsuTech, Nazareth, Israel

Introduction: Ultrasonic drug release has been a focus of many research groups for stimuli-responsive drug release. Most of the groups are concentrating their efforts on liposomal drug carriers, whereas we are studying the drug release from cyclodextrin based polymers developed by CapsuTech Ltd, Nazareth, Israel. The main purpose of the study reported here is to investigate the effects of ultrasound and MR guided focused ultrasound (MRgFUS) on the cellular uptake, the polymer and biological drug carriers and therapeutic efficacy of an anticancer drug.

Methods: The MRgFUS experiments were conducted using an ExAblate 2000 system (InSightec, Tirat Carmel, Israel), a 1.5Tesla HDx MRI system (GE Healthcare, Milwaukee, USA). In addition in-house built single element transducers of different frequencies were used to determine possible frequency dependence of targeted drug delivery.

Cells were seeded into 96-well plates and heat treated at 37 - 55 C for 2 - 10 min. Cell viability was determined using the colorimetric MTT assay. Cells were also subjected to MRgFUS and the degree of cell viability was determined by the same Methods. Further work has been conducted using bespoke experimental hardware, including a specialised system for laser-facilitated ultrasound-

induced cavitation.

Results: Significant decrease in cell viability due to heat (temperatures higher than 41C) in the presence of Doxorubicin (DOX), in comparison with DOX at normal culture temperature (37C) was observed. In addition, we have confirmed that ultrasound induced cavitation causes cell necrosis and have observed laser facilitated cavitation effects in detail in real time with high speed photomicroscopy.

Discussion: The Results to date are promising but further investigation is needed to optimize the potential of image guided acoustic surgery to enhance cellular uptake of therapeutic agents. The novel delivery nano-vehicle is investigated using acoustic surgery Methods for its potential as a stimuli-responsive delivery system, including the possibilities of thermal and cavitation response mechanisms.

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RADIATION INJURY AFTER STEREOTACTIC IRRADIATION: ESPECIALLY LONG FOLLOW-UP BENIGN OF TARGETS

Takayuki Matsuo¹ Kensaku Kamada¹ Kenta Ujifuku¹ Shiro Baba¹ Tomohito Hirao¹ Izumi Nagata¹

(1) Nagasaki university, Nagasaki, Japan

Objective: To analyses the result of Linac radiosurgery (LRS) for the treatment of intracranial benign lesions and to assess possible factors related to complications.

Methods: The authors retrospectively reviewed 204 patients treated LRS between May 1993 and December 2003. The study determined the correlation between radiosurgical complications including imaging changes after LRS and multiple factors such as radiosurgical parameters, location, volume and shape. We divided into three groups by MRI imaging changes and clinical symptom. Group1 (Gr.1): Imaging change only. Group2 (Gr.2): Imaging change with transient symptoms. Group3 (Gr.3): Image change with permanent symptoms.

Result: 93 patient with AVM: Gr.1, 8cases (8.6%), Gr.2, 1cases (1.1%), Gr.3, 2cases (2.1%). A significantly higher incidence of imaging change was noted in patient with AVM volumes greater than 10cc, irregular sharp of nidus and deep location. 58 patients with vestibular schwannomas(VS) : Gr.1, 6cases (10.3%), Gr.2, 1cases (1.8%), Gr.3, 2cases (3.4%). Imaging changes were seen mostly tumor volume greater than 5cc. 53patients with meningioma: Gr.1, 4cases (7.5%), Gr.2, 2cases (3.7%), Gr.3, 0case. Imaging changes were seen mostly in convexity, parasagittal, and falx meningiomas that were deeply embedded in the cortex. The symptom continued until last serial observation in four cases. We used various interventions in these patients include steroid, anticoagulant, surgical removal, and hyperbaric oxygen therapy; but these therapy was not effective.

Conclusion: LRS for each disease seems to be safe and effective treatment. However, once serious radiation injuries occur there is no effective therapy and it is important to have appropriate patients selection for radiosurgery.

P2114

EVALUATION OF DIFFERENT RADIOBIOLOGICAL MODELS FOR RADIOSURGERY AND STEREOTACTIC BODY RADIOTHERAPY

Bahram Andisheh¹ Margareta Edgren¹ Panayiotis Mavroidis^{1, 2} Mohammad A. Bitaraf³ Anders Brahme¹ Bengt K. Lind¹

(1) Department of Medical Radiation Physics, Karolinska Institutet and Stockholm University, Stockholm, Sweden
(2) Department of Medical Radiation Physics, Larissa University Hospital, Larissa, Greece (3) Department of Neurosurgery, Tehran University of Medical Sciences, Tehran, Iran

Many studies have shown that the linear-Quadratic (LQ) model is inappropriate to model high dose per fraction effects in stereotactic high dose radiotherapy. Alternative Methods are crucial for a better prediction of experimentally measured survival curves in the ablative, high dose range without losing the strength of LQ model around the shoulder. Repairable conditionally repairable (RCR) damage model and also other models such as the Universal Survival Curve (USC), Kavanagh-Newman (KN) and some other derivations of the LQ model were proposed for high dose responses. The aim of this study is to compare the RCR model with other fractionation correction Methods applied in high dose ablative radiotherapy.

Four independent data sets for CHOAA8 (Chinese hamster fibroblast), H460 (non small cell lung cancer), NCI-H841 (small cell lung cancer) and U1690 (small cell lung cancer) were used. The validity of eight different models for the whole dose range and doses beyond shoulder was studied and a comparison of the goodness-of-fit has been made by using the reduced chi-square test for 95% confidence interval.

The LQ model was not acceptable for high doses in all the studied cell lines as it was predicted. For the CHOAA8 dataset, all the models failed to predict survival for both the whole dose range (0-16 Gy) and a subgroup of medium and high doses (4-16 Gy). The RCR and LQ-based models are acceptable for the medium (4-12 Gy) and low range doses (0-4 Gy). Only the RCR model is able to predict the low dose hypersensitivity behaviour of cells. For the H460-NSCLC, the USC model has the best fit and is able to predict survival almost in all dose ranges, whereas the KN and MA models are fairly good at high and medium range doses and the RCR was rejected for all dose subgroups. For the NCI-H841 SCLC cell line, the USC, KN and MA were acceptable in the whole dose range. Finally, for U1690 cell line, the KN and RCR models are acceptable for the medium dose range and just the RCR is acceptable in the low dose range.

All the models have some disadvantages and none of them is able to be used for an accurate dose survival prediction for doses being used in stereotactic high dose radiotherapy and medium and low doses.

P2115

IMPROVING BIOLOGICAL EFFECTIVENESS VIA SHOT SEQUENCING FOR COMPLEX GAMMA KNIFE RADIOSURGERY TREATMENTS

Letitia Lee¹ Igor Barani¹ Shannon Fogh¹ Arjun Sahgal² Andrew Hwang¹ Michael Mcdermott¹ Penny Sneed¹ David Larson¹ Lijun Ma¹

(1) University of California San Francisco, San Francisco, USA (2) Oncology, Princess Margaret Hospital, Sunnybrook Health Sciences Centre, University of Toronto, Toronto, Canada

Relevance: Multiple isocenters or shots have been widely used in Gamma Knife radiosurgery of relatively large and complex lesions such as arteriovenous malformation (AVM). In this study, we investigated whether it is feasible to alter the biological effective dose of such treatments by varying the temporal dose distribution accumulated within a target according to the sequence of the shots being delivered.

Innovation: The Gamma Knife Perfexion has allowed multiple isocenters to be delivered rapidly with unprecedented efficiency. To our best knowledge, this is the first study of the potential effects of shot delivery sequencing on Gamma Knife radiosurgery.

Approach: Twenty AVM cases treated with Gamma Knife Perfexion since 2007 at our institution were retrospectively analyzed. The mean prescription isodose volume for the targets was 4.4 ± 3.8 mL and mean number of isocenters used was 15.8 ± 5.4 . For each case, we extracted the 3D dose matrix of each isocenter, and then randomly permuted the dose matrices for all the isocenters to create different temporal dose accumulation patterns in the target for a treatment delivery. For example, a 10-shot delivery yielded ~ 3.6 million (10!) dose accumulation patterns. The patterns were then randomly sampled and an equivalent uniform dose (EUD) was calculated for each pattern based on a generalized linear-quadratic model accounting for inhomogeneous dose distributions and intra-target dose rate effects of the treatment delivery. Finally, distributions of EUD values among all the cases were analyzed and a possible Methods of improving the variance of the distribution was investigated.

Results: Significant variations in the EUD values were observed for 7 out of 20 cases, all of which had 10% or higher deviations in the EUD values from the mean EUD value, which was nearly identical to the EUD of an actual treatment delivery. Of all studied cases, a mean standard error of $6.1 \pm 6.2\%$ (range, 1.5% to 17.7%) was found. In particular, the difference between the maximum EUD and minimum EUD of possible shot sequences exceeded 20% of the baseline prescription dose for few cases. However, if all the shots were sorted for delivery based on the maximum point dose rates inside the target, then the resulting EUD correlated with (linear $R^2 = 0.96$, $p < 0.01$) and matched within 5% of the maximum possible EUD values for each case.

Conclusions: Shot sequencing can significantly alter the biological effective dose in term of EUD for multi-isocenter Gamma Knife radiosurgery. Interplay between the target and the normal tissue EUDs for the gain of therapeutic ratio are being investigated and will be presented.

P2116

INTEGRATION OF NEW MRI MODALITIES INCLUDING MULTIVOXEL SPECTROSCOPY MAPPING TO RADIO SURGICAL TREATMENT USING ELEKTA GAMMAPLAN

Adyl Melhaoui^{1, 2} Youness Difaa³ Yasser Arkha^{1, 2} Mohamed Jiddane¹ Abdeslam El Khamlichi^{1, 2}

(1) Radiosurgical Unit, Gamma knife perfexion, National Centre of Rehabilitation and Neurosciences, Rabat, Morocco (2) Department of Neurosurgery ,Hopital des Specialites, O.N.O, Rabat, Morocco (3) Facultés des Sciences Université Mohamed V, Rabat, Morocco

Introduction: New MRI modalities such as MRI multivoxel spectroscopy mapping have been proven to be of high clinical help in surgical decision making. Unfortunately in daily practice they turn to be non compatible with current version of ELEKTA GAMMAPLAN 8.3 .The aim of this study was to develop a tool to allow the use of this new modality in the radio surgical treatment using ELEKTA GAMMAPLAN.

Material and Methods: Mutlivoxel spectroscopy DICOM images were analyzed to identify tags to be changed to set compatibility with GAMMAPLAN. Using Python language new software was designed to modify the identified tags and allow automatic conversion of images to fit with GAMMAPLAN requirements.

Results: We were able to identify four important tags to be modified for compatibility with GAMMAPLAN. We could develop new software for DICOM conversion, GAMMAPLAN CONVERTASE 1.0 that can treat any kind of DICOM image and make it compatible with GAMMAPLAN. Major developed functions were the conversion of non square Dicom images into square matrix compatible images. Integration of Multivoxel Spectroscopic images was feasible and could be used for radiosurgical planning in cases of glial tumors, other modalities such as diffusion imaging and BOLD functional MRI could also be imported in the GAMMAPLAN interface. Our developed algorithm for treatment of DICOM Tags could allow us to modify any image and make it compatible with GAMMAPLAN.

Conclusions: This work was a first step that opens the door for use of new MRI modalities in the radio surgical Planning using GAMMAPLAN. The next development steps are to evaluate the impact of these new modalities in the radio surgical treatment and develop Methods for integration of other imaging modalities such as three dimensional angiographic imaging.

P2117

PREOPERATIVE EVALUATION FOR SKULL BASE TUMORS USING CISS GADOLINIUM: TOTAL TREATMENT STRATEGY WITH MICROSURGERY AND RADIOSURGERY USING GAMMA PLAN

Motohiro Hayashi¹ Noriko Tamura¹ Takashi Maruyama¹ Akitsugu Kawashima¹ Yoshikazu Okada¹

(1) Tokyo Women's Medical University, Tokyo, Japan

Objective: For skull base tumors, Gamma knife surgery (GKS) is effective to control them. However, it is not possible to treat large tumors which compressed brain stem with GKS alone. Needless to say that, microsurgical resection must be considered. We propose that precise preoperative treatment design and intraoperative image supporting system are crucial for them for large tumor.

And then, we developed a system by incorporating a technique for Gamma Knife surgery to design a treatment plan before and during surgery.

Methods: Magnetic resonance imaging was performed without a stereotactic frame before treatment. Image data was imported to Leksell GammaPlan (LGP) with software «Preplan» to obtain 3D localization in order to understand anatomical relationship between the tumor and surrounding vital structures.

Results: For skull base meningiomas, the dura maters from which tumors arose were identified on LGP perfectly. Certain parts of the tumor should be spared by GKS, because there are the most important vital structures such as cranial nerves. Other parts should be then surgically removed as much as possible to be the best decompression in the tumor. For acoustic tumors, we identified facial and acoustic nerves as much as possible using this simulation technique. It can provide the best knowledge of anatomical relationship to neurosurgeons before and during surgery. Most of patients would not have experience with severe neurological deficits.

Conclusions: Sophisticated 3D computerized image data in LGP enabled us to perform surgery just as planned preoperatively. This new and simple treatment system will be a precursor of future surgical treatment strategies.

P2118

A COMPARISON OF KV- AND MV-BASED CONE BEAM CT FOR IMAGE GUIDED RADIOSURGERY OF THE SPINE

Einar Waldeland¹ Marius Røthe Arnesen¹ Martin Turzer² Eirik Malinen^{1, 3}

(1) Department of Medical Physics, The Norwegian Radium Hospital, Oslo University Hospital, Oslo, Norway (2) Department of Clinical Oncology, The Norwegian Radium Hospital, Oslo University Hospital, Oslo, Norway (3) Department of Physics, University of Oslo, Oslo, Norway

Background: Kilovoltage (kV) based cone beam CT systems are commonly used for image guided radiotherapy (IGRT), and are essential for tumor matching in e.g. stereotactic treatment of lung tumors.

Megavoltage (MV) cone beam (CB) CT is an option for some linear accelerators. When MV photons are used for imaging, the image quality is altered compared to using kV photons. The reduction in tissue contrast using MV CBCT limits the applicability of this modality. The purpose of this study was to compare MV and kV CBCT for image guided radiosurgery of the spine, where the reference structure for positioning is the vertebrae.

Materials and Methods: An anthropomorphic phantom was CT scanned and used for planning. Two vertebrae were outlined as reference structures in the dose planning software. The dose plan was exported to two treatment units: an Elekta Synergy equipped with an XVI kV CBCT and a Siemens Artiste with a MV CBCT. Phantom set-up was performed identically on the two units. Imaging, including matching, was performed using the respective unit's commercial software. Several CBCT scans, with different set-up errors, were acquired on both systems. Time consume, image quality, absorbed dose and other parameters were compared.

Results: Both systems gave images with satisfying contrast for vertebrae-based positioning. Automatic bone-matching in the XVI-system gave accurate matching when the set up error was small, while the RTT-system's (Siemens) automatic positioning generally needed manual

adjustments as well. The need for manual fine positioning in the RTT-system seemed to give higher standard deviation in the matching Results than what was the case for kV CBCT. Time consume and dose deposition resulting from the two imaging procedures seemed to be comparable, while the image quality is higher for the kV based system.

Conclusions: Both the kV- and MV-based CBCT systems are applicable for high precision positioning (within 1 mm) for image guided radiosurgery of the spine, although slight differences were found between the two systems.

P2119

THE DELINIATION OF TUMOUR RECURRENCE AND ADVERSE RADIATION EFFECTS, IMPROVED BY COREGISTRATION OF [18F] FDG PET/CT WITH MRI, SUGGESTS THAT THESE CONDITIONS USUALLY CO-EXIST

Michael Torrens¹ Julia Malamitsi¹ Pantelis Karaikos¹ Christos Stergiou¹ John Andreou¹

(1) Hygeia Hospital, Athens, Greece

Aim: The aim of our study was to re-evaluate the role of [18F] FDG PET/CT in the differential diagnosis of adverse radiation effect (ARE) from tumour recurrence after Gamma Knife radiosurgery and to assess the significance of electronic co-registration of [18 F] FDG PET/CT images with MRI in improving the comparative localization and diagnostic distinction of the abnormal areas that may occur on MRI's of the brain following radiosurgery.

Material and methods: 26 [18 F] FDG PET/CT studies were performed on 16 patients, who comprised 11 men and 5 women, age range 38-70. PET/CT studies were performed 3-55 months after radiosurgery. Ten of the 16 patients had multiple radiosurgery treatments. The co-planar [18 F] FDG PET/CT images were performed on a Siemens Biograph (Dual Slice) scanner and co-registered with MRI performed at another time using Oncentra MasterPlan 1.4 (Nucletron BV). The co-registration accuracy was >3mm. Long term clinical and radiographic follow-up was used to evaluate and interpret the PET/MRI Results, except in 3 patients with histopathological confirmation. Other radiography included perfusion MRI and T1/T2 matching.

Results: PET/CT was positive in all the studies in 6 patients, negative in all the studies in 6 patients, changing from negative to positive in one case and changing from negative to equivocal in one case. In two patients the PET/CT was both positive and negative in separate tumour foci. In all the 9 cases where the PET/CT was positive, the evaluation of the clinical features confirmed tumour in all patients. In 2 cases this led to retreatment with Gamma Knife and subsequent control of the tumour. In the cases where the PET/CT was negative in all the studies, 3 patients were diagnosed as ARE and 3 as tumour thus denoting 3 false negative Results. The case that changed from PET/CT negative to PET/CT positive is also regarded as a false negative. The case that changed from PET/CT negative to equivocal is presently regarded as ARE but is probably a mixed lesion. In some cases the accurate co-registration allowed the identification of tumour islands within areas of ARE.

Conclusion: [18F] FDG PET/CT has a high sensitivity (100%) but low specificity (64%) in detecting tumour. In reality 13/16 (and possibly more) patients appeared to have, or later progressed to, recurrent tumour. This is a higher rate than is usually reported after radiosurgery.

P2120

STUDY ON RELATION BETWEEN MRI PIXEL BANDWIDTH AND GAMMA KNIFE STEREOTACTIC LOCALIZATION BOX IMAGE DISTORTION

Lizhong Liu¹ Seonghwan Yee² Weidong Li¹ Daniel Bassano¹

(1) SUNY Upstate Medical University, Radiation Oncology, Syracuse, Ny, USA (2) SUNY Upstate Medical University, Radiology, Syracuse, Ny, USA

Purpose: Study the relation between the MRI pixel bandwidth and the Gamma-Knife stereotactic frame image distortions due to chemical shifts at material interfaces and magnetic susceptibility differences of the fiducials and the studied objects.

Materials and Methods: A phantom was constructed which contains fish oil capsules to benchmark the chemical shift. Gelatin was used to keep the position of the fish oil capsules stable. The phantom and the gamma Knife stereotactic localization box were put inside a head coil and imaged with different pixel bandwidth.

The phantom was scanned 7 times by a conventional spin echo sequence (TR=500 ms, TE=20 ms, Nex=1, FOV =250 cm, 11 slices with slice thickness = 3 mm, inter-slice gap 5 mm, acquisition matrix 256 x 256) in a Philips 1.5 Intera system. While the frequency encoding direction was set to anterior in the supine position, the pixel bandwidth for each scan was gradually changed in the range between 81.4 and 415.6 Hz, which respectively corresponded to the shift of 2.670 pixels to 0.523 pixels for the fat of 3.4 ppm chemical shift. The amount of the frame position shift relative to the bandwidth change was determined in analysis software, and was used to determine the chemical shift of the frame.

Results: Fat (fish oil capsules) showed a chemical shift of 3.4 ppm, while the Gamma Knife frame showed a chemical shift of 2.1-2.5 ppm, which is 62-74% of fat-water shift.

Conclusions: In order for the fat-water chemical shift to be insignificant (i.e. within the same pixel), the pixel bandwidth should be more than ~220 Hz at 1.5 T. As long as the pixel bandwidth meets this criterion, the chemical shift of the Gamma Knife frame should be insignificant.

P2121

FRAMED VS. FRAMELESS TREATMENTS: PATIENT PERCEPTION

Yehuda Herschman¹ Maged Ghaly¹ Michael Schulder¹

(1) Hofstra North Shore LIJ School of Medicine, Manhasset, USA

Introduction: We compared the perceptions of patients undergoing stereotactic radiosurgery (SRS) with and without the use of a stereotactic frame.

Patients and Methods: Patients undergoing SRS completed a one-page questionnaire after treatment. Since June 2009 the majority of patients were treated with frameless SRS with a linear accelerator based system (Novalis). Forty patients completed the evaluation form. Of these, 13 patients were treated with frame and 27 with frameless. Treatment was for a benign diagnosis in 14 patients and malignant diagnosis in the remaining 26. There were 27 female (64%) and 13 male (36%) patients. The mean patient age was 60.5 years.

Patients were placed into one of four groups, based on diagnosis and SRS Methods benign with

frame (BF, n=5), benign without frame (BFL, n=9), malignant with frame (MF, n=8), and malignant without frame (MFL, n=18). Univariate analysis was used to compare patients' perceptions of pain, their willingness to have a repeat treatment if necessary, and whether they would recommend SRS to other patients.

Results: Patients who perceived SRS to be painful included 80% of the BF group, 75% of MF, 16.7% of MFL, and 11% of BFL. When asked if they would repeat the SRS procedure if necessary, all patients in the BF, BFL, and MFL group would repeat, while only 75% in the MF group would do so. All patients in the BF, BFL, and MFL groups would recommend the treatment to others, compared with only 62.5% of patients in the MF group. Frameless treatments approached statistical significance ($p = 0.06$) as a measure of favorable perception.

Conclusions: Patients who undergo radiosurgery with frameless technique, perceive the procedure to be more tolerable than frame based SRS and would be more willing to repeat and recommend the treatment. Avoidance of frame placement is more important than benign diagnosis in patients having a favorable perception of SRS.

P2122

AVM CONTOURING IN RADIOSURGERY (SRS): COMPARISON OF VOLUME CONTOURED FROM DIFFERENT IMAGING MODALITIES, DSA ALONE OR MRI ALONE OR DSA MRI FUSION

Marco Italiani¹ Michelina Casale¹ Cesare Giorgi¹ Nevia Caputo¹ Anna Antonia Russo² Ernesto Maranzano¹

(1) 'S.Maria' Hospital, Terni, Italy (2) CNR, Roma, Italy

Purpose: We want to compare the geometrical characteristics of AVM volume contoured for SRS using different imaging modalities such as digital subtraction angiography(DSA), magnetic resonance imaging(MRI), or our integrated Methods based on DSA and MRI.

Methods and materials: The volume contouring of AVM cases for SRS requires different imaging modalities of which digital subtraction angiography (DSA) is the gold standard: the image fusion of DSA and MRI/CT produces a3D visualization of CTV.

In our institute, CTV contouring is performed using the stereotactic fusion DSA-MRI: both modalities help the physician to contour the CTV. The physician contours CTV using only DSA images and after the stereotactic image fusion DSA MRI modifies 3D MRI volume produced, using DSA and MRI informations.

In our study we evaluated the extent of the agreement of CTV contoured on DSA alone, MRI alone and DSA MRI combination.

20 patients with a AVM were included in this study, randomly selected from the group of patients treated by linac based SRS. To eliminate the inter-observer error, the same physician has contoured all the cases.

Our MRI acquisition protocol for AVM is based on TSE T1-weighted sequence after contrast medium. DSA imaging was performed with a frame rate based on AVM flow rate. The physician selected in general two orthogonal images used for contouring. The DSA/MRI stereotactic image fusion was performed by our treatment planning system(TPS-ERGO).

Results: For the different modalities we compare the absolute value of the different volumes, as well as the volume center coordinates. We calculate the distance (dDSA and dMRI)between DSA

and MRI volume center respect to treatment CTV center.

In 85% of cases the volume contoured on MRI (MV) is superior than volume contoured on DSA images (DV). In 60% of cases MV overestimate our treatment CTV and only in 25% of cases DV overestimate our treatment CTV.

In 60% of case dDSA is inferior than 4mm and the mean value is 4.8mm. In 60% dMRI of case is inferior than 4mm and the mean value is 4.5mm.

Conclusions: We know that the standard imaging for AVM contouring is DSA, but the data confirm it is necessary MRI not only to visualize but to control the volume contouring because this modality adds tridimensional and morphological informations to create a feedback with DSA. Our Results indicate that generally MV is superior than DV.

P2123

THE RADIOSURGERY MEDICAL INFORMATION SYSTEM DEVELOPED FOR MOSCOW GAMMA KNIFE CENTER IS DESCRIBED.

Valery Kostjuchenko¹ Vladimir Zaitcev¹ Andrey Golanov^{1, 2} Serguei Ilyalov¹

(1) OJSC, Moscow, Russian Federation (2) Burdenko Neurosurgery Scientific Institute, Moscow, Russian Federation

We present the Radiosurgery Medical Information System developed for the Moscow Gamma-Knife Center and integrating administrating, dosimetric, clinical, marketing and partly economical tasks. Developing approach is based on the iterational solving of small tasks ordered on their actuality. The system works on the Firebird database management system with multiuser web-interface developed on PHP and Java-Script with AJAX technology. Prototype SQL and PHP code is automatically generated from the XML description and then adjusted manually. Different reports for printing are generated in RTF format with possibility of additional changes. MIS interacts with LGP 5.34 (DVH, snapshots import) and TomoEd (KBIIS, Dubna, Russia, system for DICOM images treatment including volumetry) (volumes and liner sizes import). Every treated patient has a link to the file folder in the DB. As result we have the system useful for everyday tasks (by our evaluation it saves approximately 30-60 minutes of collecting data and preparing documents for each patient), continually developing and not limited to systematization already realized in the DB. Additionally, the system allows to set comments for arbitrary records in the DB. Comments used for entering data are not systematized yet and at the same time are used by programmers to create lists of the most actual tasks and to choose directions for potential developments.

The system solves two tasks at the same time organization of business processes and collecting clinical and dosimetric (PD, PI, DVH, volumes and linear sizes) data for future analysis. The data structured in common SQL DB make such analysis much more simple, than using more popular Excel sheets and electronic or paper plain-text documents. Some of the most used statistics are present already at the system interface, others, more sophisticated, will be introduced in the near future either directly in the web-interface or through exporting data to the widespread statistical software (e.g. Statistica).

The Moscow Gamma-Knife Center has been working already for six years and has treated more than 2000 patients with different pathologies. Treatment and follow up data of all treated patients are already saved at the DB. It is enough to start representative statistical analysis. And the fact that

currently we start programming of the statistical part of the system suggests that we have found the right strategy for system developing.

P2124

INTEGRATION OF ACCURATE PATIENT-SPECIFIC FUNCTIONAL MOTOR CORTEX LOCATION INTO STEREOTACTIC RADIOTHERAPY PLANNING SOFTWARE

Henri Hannula¹ Aki Kangasmäki² Tuomas Neuvonen¹ Timo Joensuu² Jarmo Laine^{1, 3}

(1) Nexstim Ltd, Helsinki, Finland (2) Docrates Clinic, Helsinki, Finland (3) Faculty of Medicine, University of Helsinki, Helsinki, Finland

Stereotactic radiosurgery carries the risk of new neurological deficits. Incidences of new motor deficits of up to 26% have been reported for radiosurgery of metastatic brain tumors in the motor cortex (1). To prevent complications, planning of radiosurgery is performed with the aim of minimizing the exposure of functionally critical cortex to radiation. In practice, planning software utilize standardized anatomy-based probabilistic maps of approximate locations of cortical functions. However, the maps do not allow for patient-specific variation and do not fully reflect the functional anatomy of the patient.

A non-invasive integrated navigated transcranial magnetic stimulation system (NBS) has received marketing authorization from FDA for localization and assessment of primary motor cortex for pre-procedural planning. In clinical studies in brain tumor surgery, the system localized the motor cortex in all patients to the same gyrus as intraoperative direct cortical stimulation (DCS). According to the neurosurgeons, the Results of preoperative mapping of the motor cortex with NBS were as accurate as DCS (2,3).

In order to determine whether the motor mapping Results obtained by NBS can be incorporated into planning software for stereotactic radiosurgery, a proof -of -» concept workflow study was performed.

A healthy adult male subject underwent an anatomic MRI (1.5T, T1, slice thickness 1mm) followed by functional mapping of the motor cortex with the NBS System (Nexstim, Finland). The data file of the mapping session was retrieved from the NBS System for post-processing. The maximum E-field locations were selected and verified before the motor mapping image - generated from the corresponding motor evoked potential (MEP) responses - was exported in DICOM format. The Dicom export file containing the NBS mapping data were overlaid to the subject-™s anatomical MRI in the BrainLab iPlan software (BrainLab, Germany) and the combined 3D image correlated with a sample CT image that would be utilized for actual radiation dose planning to be delivered by a linear accelerator (Varian, USA).

Results: A screenshot from Brainlab iPlan planning software demonstrating successful data integration. An artificial tumor (orange sphere) and the location of motor representation areas determined by NBS and imported in Dicom format (red) are visualized for planning purposes.

Conclusions: Accurate patient-specific motor mapping data can be successfully incorporated into planning software for stereotactic radiosurgery. Use of the combined data in radiation planning may provide an additional tool to decrease the likelihood of complications affecting the motor system.

P2125

COMPARISON OF OUTCOMES AFTER BRAIN RADIOSURGERY WITH AND WITHOUT USE OF DIFFUSION-TENSOR TRACTOGRAPHY

Tomoyuki Koga¹ Keisuke Maruyama¹ Masahiro Shin¹ Naoto Kunii¹ Kenji Ino² Yoshitaka Masutani² Nobuhito Saito¹

(1) Department of Neurosurgery, The University of Tokyo Hospital, Tokyo, Japan (2) Department of Radiology, The University of Tokyo Hospital, Tokyo, Japan

Objectives: This study was conducted to evaluate whether integration of diffusion-tensor tractography of the corticospinal tract into treatment planning could reduce motor complication after stereotactic radiosurgery.

Methods: We have integrated diffusion-tensor tractography of the corticospinal into treatment planning for gamma knife radiosurgery for patients with arteriovenous malformations (AVM) adjacent to the tract since February 2004. Maximum dose received by the corticospinal tract was attempted to be less than 20 Gy. Outcomes of patients who underwent treatment before and after introduction of tractography-integrated treatment were compared. Patients with AVM in the deep frontal lobe, deep parietal lobe, basal ganglia and thalamus who underwent gamma knife radiosurgery since January 2000 and were followed-up for more than 3 years were included in this study. Twenty-eight patients (group A) were treated before introduction of tractography-integrated treatment and 24 patients (group B) were treated after that. Tractography of the corticospinal tract were integrated into treatment planning for 19 patients among group B. Treatment outcomes including obliteration rate, motor complication and other adverse events were compared between groups A and B.

Results: Mean age at the time of treatment was 34.0 years in group A and 32.7 years in group B, which was not significantly different ($p = 0.76$). Volume of AVM nidus was significantly smaller ($p = 0.026$) in group A (mean 4.8cm³, range 0.2-13.7 cm³) compared with group B (mean 7.7cm³, range 1.1-22.4 cm³). Number of patients whose lesions involved the basal ganglia and thalamus was 10 (36%) in group A and 11 (46%) in group B, which was not significantly different ($p = 0.46$). Follow-up period was 36 to 113 months (median 62 months) in group A and 36 to 80 months (median 48 months) in group B. Obliteration rates were not significantly different between 2 groups ($p = 0.75$) and were 69% at 4 years in group A and 76% at 4 years in group B. Motor complication including transient paresis was observed in 5 patients in group A and 1 in group B and was significantly reduced in group B ($p = 0.021$). Sensory disturbance was observed in 1 patient in the both groups ($p = 0.89$).

Conclusions: Integrating tractography of the corticospinal tract into treatment planning contributed to reduction of motor complication after gamma knife radiosurgery for AVM without compromising obliteration rate.

P2126

DIFFUSION TENSOR TRACTOGRAPHY FOR RADIOSURGICAL PLANNING IN PATIENTS WITH ARTERIOVENOUS MALFORMATION LOCATED IN ELOQUENT CORTEX.

Giuseppe Minniti¹ Andrea Romano² Alessandro Bozzao² Enrico Clarke¹ Maurizio Valeriani¹ Mattia Falchetto Osti¹ Riccardo Maurizi Enrici¹

(1) Department of Radiation Oncology, University Hospital Sant'Andrea, Rome, Italy (2) Department of Radiology, University Hospital Sant'Andrea, Rome, Italy

Introduction: In the irradiation treatment of critically located lesions, the effort to minimize the risk of complication is essential. We report the initial experience with diffusion tensor (DT) tractography into treatment planning for stereotactic radiosurgery and radiotherapy.

Methods: Data from imaging studies performed in 5 patients who underwent stereotactic irradiation for treatment of arteriovenous malformations (AVMs) located adjacent to the corticospinal tract (CST) were used for treatment planning. Diffusion tensor images performed without the patient's head being secured by a stereotactic frame were used for DT tractography, and the CST was visualized. Data from stereotactic 3D imaging studies were coregistered with the data from DT tractography and functional magnetic resonance imaging (fMRI) for the localization of the primary motor cortex. The combined images were transferred to by BrainLAB I-Plan software treatment-planning workstation. Delivered doses and distances between the treated lesions and the CST were analyzed and correlated with posttreatment neurological changes.

Results: The use of DT tractography and fMRI resulted in reduction of radiation dose at eloquent areas (CRT and primary motor cortex) close to irradiated AVM. The subsequent follow-up showed no significant damage of eloquent areas close to AVMs or clinical motor complications after irradiation.

Conclusions: The integration of DT tractography seems useful in confirming the dose to the CST during stereotactic irradiation treatment planning and may represent a promising tool for preventing radiation-induced neurological complications.

P2127

3TESLA MAGNETIC RESONANCE, IMAGE DISTORTION IN COMMON SEQUENCES FOR GAMMA RADIOSURGERY.

Porfirio Díaz-Aguirre¹ Vinicio Toledo¹ Marco Antonio Barajas¹ Xerxes Domínguez¹ Johana Garnica¹ Mariana Leon-Quintero¹

(1) Hospital San Javier, Guadalajara, Mexico

We began LGKRS in 1995, in november 2007 we began procedures using images from 3T MR scanner. After a period acceptance test to factory loaded scan parameters, in which we detected several aspects concerning the magnetic field strength and the stereotactic frame (Leksell®) used by the patient during the whole procedure and Results, at the beginning, in a unacceptable image quality in terms of distortion. This effects were present with previous the magnetic fields of smaller intensity too but did not affect significantly the image quality used then. Therefore there was the necessity to optimize the scanning parameters to fulfill the requirements to be able to use these

images in the procedure and after evaluate the distortion as a function of time.

The requirements of the images to be used clinically are, geometric distortions below 1 mm, axial and coronal T1 and T2 weighted, isotropic 1 mm image resolution and in-patient optimal contrast. The mean distortion with previous 1.5 T scanner was (mean, max): 0.4, 0.8; 0.4, 0.8; 0.3, 0.7; and 0.5, 1.0; millimeters for axial T1 and T2, coronal T1 and T2 weighted images. Prior to optimization of 3T scanner the distortion was greater than 2.0 mm in all sequences, for coronal images the fiducial markers was no detectable. The actual mean distortion on sequences optimized for Gamma Knife use are (mm): 0.4, 0.7; 0.3, 0.6; 0.5, 0.9 and 0.4, 0.7; for axial T1 and T2, coronal T1 and T2 respectively. Besides metal implants in patients, the metallic parts of stereotactic frame and its contribution to local field inhomogeneities and induction of Eddy currents is a constant even after optimization of scan parameters in which that effects were minimized but not eliminated and there is a zone about 20mm close to frame edge that result in unacceptable images.

Acceptable images quality were obtained after initial optimization in terms of distortion, signal to noise ratio, resolution, and there was not measured deterioration of image quality with time, in 3 year resonator use for this 3T MR scanner. Further work with the scan protocols is needed to improve the clinical image quality, reduce the scanning times and minimize artifacts near to stereotactic frame which may compromise the overall accuracy of radiosurgery for lesions to be treated in the proximity of this zone.

P2128

SPINAL CORD DOSIMETRIC ANALYSIS IN 40 SPINAL TUMOR PATIENTS WHO WAS SAFELY TREATED WITH RADIOSURGERY AND SURVIVED LONGER THAN TWO YEARS

Ung-Kyu Chang¹ Dong-Han Lee¹ Mi-Sook Kim¹ Chul-Koo Cho¹

(1) Korea Institute of Radiologica and Medical Science, Seoul, Korea

Objective: There have been a few case reports on radiation myelopathy related to stereotactic spinal radiosurgery. We tried to find tolerable radiation dose to spinal cord in spinal tumor radiosurgery.

Methods: We retrospectively analyzed radiation doses to specified volumes of spinal cord (maximum point, 0.1 cc, 1.0 cc, 2.0 cc and 3.0 cc) in 40 patients of primary and metastatic spinal tumors who received radiosurgery and survived longer than minimum two years after treatment. All the patients showed no neurological complications related to radiosurgery. Their lesions were located above T12 level. The study population was composed of five primary tumors and 35 metastatic tumors. Radiation dose was calculated as single-fraction dose (SFD) and normalized 2-Gy-equivalent biological equivalent dose (nBED) with units Gy2/2 using α/β value of 3. Mean follow-up period was 44.1 months (24-96 months).

Result: The mean of lesion volume was 25.4 cc and exposed spinal cord volume was 2.6 cc. The mean value of maximum spinal cord dose was 13.0 Gy (SFD). The radiation dose to spinal cord volume of 0.1 cc, 1.0 cc, 2.0 cc and 3.0 cc were 11.6 Gy, 8.2 Gy, 8.0 Gy and 7.0 Gy (SFD). When the doses were calculated to nBED, maximum point dose was 43.8 Gy2/2, and those to spinal cord volume of 0.1 cc, 1.0 cc, 2.0 cc and 3.0 cc were 35.9 Gy2/2, 21.9 Gy2/2, 20.2 Gy2/2, and 17.2 Gy2/2. The spinal cord volume irradiated over than single-fraction dose of 8 Gy, 10 Gy, and 14 Gy were 1.52 cc, 1.08 cc, and 0.32 cc.

Conclusion: Until now, some of guidelines were suggested about safe radiation dose to spinal cord in stereotactic spinal radiosurgery. For single-fraction, 10 Gy to a maximum point was safe, and nBED of 30-35 Gy2/2 to the thecal sac were considered as a low risk of radiation myelopathy. Out data showed higher level of spinal cord irradiation could be performed without complication. The collection of more data on safe radiation to human spinal cord will set a new guideline for spinal cord tolerance to radiation.

P2129

TIME-EFFICIENT TREATMENT OF METASTASIS TO THE SPINE WITH IMAGE GUIDED RADIOSURGERY - A FEASIBILITY STUDY

Martin Turzer¹ Einar Waldeland² Åslaug Helland¹ Odd Terje Brustugun¹ Christina Ramberg²

(1) 1Department of Clinical Oncology, The Norwegian Radium Hospital, Oslo University Hospital, Oslo, Norway

(2) 2Department of Medical Physics, The Norwegian Radium Hospital, Oslo University Hospital, Oslo, Norway

Background: In our department approximately 700 patients receive radiation treatment because of metastases to the spine annually. The conventional treatment is 30 Gy in 10 fractions or a single fraction of 8 Gy. For patients with oligometastatic disease to the spine, we designed a feasibility study to investigate if the patients could be treated more time efficient compared to the conventional treatment, using image guided radiosurgery (IGRS) of the spine.

Methods: We intend to perform a clinical study treating 40 patients with IGRS of columna metastases. Inclusion criteria are verified malignancy, < 3 lesions in the spine, ECOG performance status < 3 and margins to the spinal cord >5 mm. Exclusion criteria are neurological deficit, compression of the spinal cord and indication for surgery. All patients will be followed 6, 12, 24 and 52 weeks after treatment with a physical examination, MRI spine, evaluation of quality of life (EORTC QLQ-C30) and toxicity (CTC-NCI 3.0).

We plan to prescribe a single dose of 24 Gy to the GTV for untreated patients and 20 Gy in 2 fractions for patients formerly treated with radiotherapy in the same region. If GTV affects the vertebra, the whole vertebra should be included in the PTV, which should at minimum receive 50% dose to 98% of the volume. 0.3 ccm of the spinal cord should not exceed a dose of 10 Gy. All patients should be immobilized in a comfortable and stable treatment position, and be on-line positioned using cone beam CT.

Results: A total of ten test patients were planned. For dose planning, a simplistic approach was chosen to reduce the planning time. A library plan with 9 static equidistant distributed coplanar beams was used, placing the isocenter in the spine. Each beam was adjusted to the PTV, and the spine was excluded from the field if it was in front of the target. A minimum of the prescription dose was achieved to the GTV without compromising the tolerance dose to the spinal cord. The intention of covering 98% of the PTV with the 50% isodose seems to be achievable for most patients. Planning time never exceeded 30 minutes.

Conclusion: A time efficient IGRS schedule for patients with metastasis to the spine seems to be feasible. Further clinical Results are needed to prove the efficacy of this Methods.

P2130

CYBERKNIFE RADIOSUGERY FOR THE TREATMENT OF METASTATIC TUMORS OF THE SPINE; EXPERIENCE IN 347 TUMORS

Ihl-Bohng Choi¹ Sang-Ho Lee² Jae-Hyuk Seo¹ Hun-Joo Shin¹ Myung-Ho Kim¹ Ji-Young Jeong¹ Jee-Soo Jang² Young-Nam Kang³ Byung-Ock Choi³ Hong-Seok Jang³

(1) The Catholic Univ.of Korea Incheon St. Mary's Hospital, Incheon, Korea (2) Department of Neurosurgery, Seoul Wooridul Hospital, Seoul, Korea (3) Department of Radiation Oncology Seoul St. Mary's Hospital, Seoul, Korea

Objective: Conventional radiotherapy and open surgery only performs a limited role in the treatment of metastatic tumors of the spine. The effectiveness of spinal radiosurgery as primary treatment for the spinal metastases was investigated.

Methods: From December 2007 to December 2009, a total of 167 patients were treated in the Cyberknife center of the Seoul Wooridul hospital. Our workload was 347 metastatic tumors (mean 2.07 per patients). Magnetic resonance imaging and PET for tumor response evaluation were taken at intervals of 3-6 months. Quality of life studies were taken at interval of 1-3 months for the Oswestry Disability Index, visual analog scale.

Results: The patients age ranges was 25-79 years with mean of 58 years. The most common metastatic tumors were breast cancer (36 cases), lung cancer (34 cases) and hepatoma (16 cases). The prescription dose range 8-40 Gy with a mean of 19.7 Gy. The most common indication for Cyberknife was pain in 92.2% (154/167) of patients. The mean Oswestry Disability Index score before Cyberknife was 24.3, and the mean visual analog scale score was 4.3 before radiosurgery. After Cyberknife, the mean Oswestry Disability Index score was increased up to 25.6. The mean of post-Cyberknife visual analog scale score was down to 3.2. The overall response rate of pain relief was 97%, and the local control rate including stable diseases was seen in 92% after radiosurgery. Multivariate logistic regression modeling found that the Oswestry Disability Index score at presentation was the only independent variable that correlated significantly with survival. Adjuvant invasive surgery as like laminectomy, corpectomy and vertebroplasty after Cyberknife was experienced by only 3.8% of tumors.

Conclusion: We expect Cyberknife radiosurgery to become a useful palliative and primary treatment of metastatic tumors of the spine. Noninvasive radiosurgery should be considered as the primary treatment modality rather than the invasive surgical approach for the spinal metastases.

P2131

STEREOTACTIC RADIOTHERAPY FOR SPINAL BONE METASTASES

Yoshimasa Mori¹ Chisa Hashizume¹ Yuta Shibamoto² Tatsuya Kobayashi¹ Takahiko Tsugawa¹

(1) Nagoya Radiosurgery Center, Nagoya Kyoritsu Hospital, Nagoya, Japan (2) Department of Radiology and Radiation Oncology, Nagoya City University Graduate School of Medicine, Nagoya, Japan

Spinal bone metastases frequently cause intractable pain and progressive neurological deficits and disturb patients' daily life. Stereotactic radiotherapy (SRT) has been reported as one of effective treatment options for localized spinal metastases. Advancement of imaging such as MRI and PET

enable better identification of active tumors and visualization of adjacent nerve structures and recent sophisticated radiation systems enable more accurate targeting at the tumor sparing the spinal cord. This study is aimed to evaluate the Results of SRT using Novalis for spinal metastases not only in local tumor control but also in improvement of patients' symptoms.

We treated 57 patients with 81 tumors by SRT since 2006. Indications of SRT were intractable pain (37 tumors), relapse after conventional radiotherapy (22), tumor enlargement (19), and neurological deficits (3). We chose the whole vertebral body alone or with unilateral or bilateral pedicles with or without posterior element as the clinical target volume, even if they were involved only partly. The planned target volume was decided with margin of 2 to 3 mm. We planned coplanar 5- or 7-beam SRT with intensity modulation. The lesions were covered at 95% or higher isodose level. The tumors of 4 to 373 ml (median 67 ml) in volume were treated with 30 to 35 Gy in 5 fractions or 30 to 42 Gy in 10 fractions. We decided treatment dose and fraction size considering expected survival time of the patient.

The treatment Results were evaluated with a median follow-up period of 8 months (range, 1 to 47 months) in 56 patients out of 57 (1 patient missed). The overall survival rate at 1 year was 45%. The median survival was 9 months. The local tumor control rate at 1 year was 91%. Even in any of relapse cases, temporary tumor shrinkage and pain relief had been obtained before recurrence of tumor developed more than 7 months after SRT. The pain relief rate was 100% and the subsequent recurrence rate of pain was 12%. In most cases improvement of pain was observed even in the treatment period of fractionation. Partial or complete improvement of neurological deficits was observed in 16 of 23 patients (69%). Severe complications (grade 3 or worse) due to SRT were not observed.

SRT with intensity modulation was seemed to be safe and effective treatment for spinal metastases. Rapid improvement of subjective symptoms including pain and neurological deficits can be expected.

P2132

STEREOTACTIC RADIO THERAPY FOR SPINAL INTRADURAL METASTASES DEVELOPING WITHIN OR ADJACENT TO THE PREVIOUS IRRADIATION FIELD: REPORT OF 3 CASES

Yoshimasa Mori¹ Chisa Hashizume¹ Yuta Shibamoto² Tatsuya Kobayashi¹ Takahiko Tsugawa¹ Masahiro Hagiwara¹ Hisato Nakazawa¹

(1) Nagoya Radiosurgery Center, Nagoya Kyoritsu Hospital, Nagoya, Japan (2) Department of Radiology and Radiation Oncology, Nagoya City University School of Medicine, Nagoya, Japan

Aims: We report the Results of stereotactic radiotherapy (SRT) for spinal intradural metastases developing inside or adjacent to the previous external-beam radiation therapy (EBRT) field in 3 cases.

Methods: We treated one case of spinal intramedullary metastasis and two cases of intradural extramedullary metastases using Novalis shaped-beam SRT. Case 1 developed an intramedullary metastatic tumor in C1 spinal medulla inside the previous whole brain EBRT field and another lesion adjacent to the field in C2 spinal medulla. Case 2 developed intradural extramedullary metastasis around C6-8 inside the previous EBRT field for the primary lung adenocarcinoma. Case 3 developed multiple spinal intradural extramedullary metastatic deposits after surgical resection and following whole brain radiation therapy for brain metastasis. We delivered 24 to 36 Gy in 5 to 12 fractions.

Results: The treated tumors were stable or decreased in size until the end of the follow-up period (Case 2, 13 months) or the patients' death from primary cancer (Case 1, 10 months; Case 3, 5 months). The patients' neurological symptoms were stable or improved.

Conclusion: Palliative SRT using Novalis is expected to be safe and effective treatment, even if the patients develop spinal intradural metastases within or adjacent to the previous irradiation field.

P2133

STEREOTACTIC BODY RADIATION THERAPY FOR SPINAL METASTASIS USING CYBERKNIFE XSIGHT SPINE TRACKING SYSTEM: FEASIBILITY AND EFFICACY

Ah Ram Chang¹

(1) Soon Chun Hyang University Hospital, Seoul, Korea

Purpose: Mostly conventional radiation has been used for palliation of spinal metastatic tumors, but its effectiveness is limited by spinal cord tolerance and moreover reirradiation is generally not possible. Stereotactic body radiation therapy (SBRT) causes a rapid fall-off within the cord to overcome this problem. With Cyberknife Xsight Spine Tracking System, precise radiation delivery can be provided without fiducial insertion. This retrospective analysis evaluated the efficacy and safety of SBRT using Cyberknife for spinal metastasis.

Patients and methods: A total of 20 lesions with spine metastases in 16 patients were treated with SBRT. Cancer patients were treated with SBRT between July 2008 and April 2010. Fourteen (87.5%) patients were given re-irradiation for their lesions including metastases in the spines adjacent to the site of previous radiotherapy. The gross tumor volume, with a 2-5 mm margin if possible, was treated in 3-6 fractions by Cyberknife Xsight Spine tracking system. Patients were evaluated at 4 weeks, 12 weeks, and every 3 months after SBRT.

Results: The median tumor volume of 20 spinal metastatic lesions was 18.13 cm³ (range 1.52 - 39.36 cm³). The SBRT dose ranged from 18 to 35 Gy (median 27 Gy) prescribed to the 73-83% isodose line that encompassed at least 95 % of the tumor volume except one re-cyberknife case. The spinal cord volume that received higher than 80 % of the prescribed dose was 0.01 ± 0.03 cm³. Follow up durations ranged from 1 to 22 months (median 9 months). Three cases developed local disease progression at 4, 5 and 7 months after SBRT. The progression free survival (PFS) rates at 12 months were 79.6%. No neuropathy or myelopathy was observed during follow-up periods.

Conclusions: SBRT with Cyberknife Xsight system provides a safe and effective treatment modality in spinal metastasis even after conventional radiotherapy.

P2134

CYBER KNIFE RADIOSURGERY (CKRS) TREATMENT FOR PATIENTS WITH EXTRACRANIAL NERVOUS SYSTEM LESIONS

Nuria Martinez¹ Elena Kusak¹ Jorge Gutierrez¹ German Rey¹ Roberto Martinez¹

(1) Gamma Unit. Hospital Ruber Internacional., Madrid, Spain

Introduction: Surgery is the first therapeutic option for patients with benign intra or paraspinal

lesions. In many cases local recurrences occur due to the nature of these tumors or residual tumor growth follows subtotal resections. The treatment of these cases by CKRS offers a new option after surgery. When high risk surgery is expected, CKRS can be offered as the first treatment. We analyze our three year experience of treatments with this radiosurgical system.

Methods: Between November 2006 and August 2009 twenty-five patients with different nervous extracranial or spinal lesions were treated and followed in our hospital with CKRS. Most of them were meningiomas (6), schwannomas (8) including two cases of neurofibromatosis, and paragangliomas (5). Mean age was 49 years (range: 26 - 83). Mean volume was 24-TM 88 cc (range: 0-TM 21 - 160). In four treatments multiple lesions were included. Sixteen patients had been operated on (mean of surgeries: 2). Four cases had received radiotherapy and two had been embolized (arteriovenous malformations). Radiosurgery was delivered using Cyber Knife with X-sight tracking system. The marginal dose varied according to the fractionation used and the nature of the tumor.

Results: Mean follow was 33-TM 56 months (range: 15 - 46). There is radiological stabilization (using MRI) in 74 % of cases, decrease in size of the lesion in 21 % and only one case of tumor progression. Sixty-nine percent of patients reported clinical improvement. One patient had recurrence of pain after a four month prior response. The rest remained stable. There has been no toxicity or new neurological symptoms to date. The arteriovenous malformations treated (2) have not experienced new bleeding.

Conclusions: CKRS appears to be an adequate therapeutic alternative for spinal and other extracranial sites lesions when incomplete surgery was performed or resection was not possible. CKRS is a simple and fast procedure, with good Results in terms of local control and toxicity. Our preliminary Results are supported by the wider experience of other centers with this technology.

P2135

PRELIMINAR EXPERIENCE ON THE TREATMENT OF VERTEBRAL METASTASIS WITH RADIOSURGERY USING NOVALIS LINAC & IMRT.

Ovidio Hernando Requejo¹ Carmen Rubio Rodriguez¹ Mercedes López Gonzalez¹ Jeannette Valero Albarran¹ Mariola García-aranda Pez¹ Emilio Sánchez Saugar¹ Daniel Zucca Aparicio¹ Juan María Pérez Moreno¹ Pedro Fernández Letón¹

(1) University Hospital Madrid Sanchinarro, Madrid, Spain

Introduction: Since 1920 several authors have developed different Stereotactic Radiotherapy systems for the treatment of vertebral tumors, most of them based firstly on Cartesian coordinate devices, and in the late 90's with direct spinous process fixation. With the technical advances raised on the late 10 years, we achieved the capacity for treating bone lesions with single high dose radiotherapy in stereotactic conditions without bone fixation, using Image Guided Radiotherapy (IGRT).

Methods: In our institution vertebral metastasis treatment is performed by a Novalis® LINAC (BrainLab, Germany). The Novalis® Shaped Beam Radiosurgery Unit utilizes image registration of anatomical structures such as vertebral bone in a non-invasive procedure. Images are taken on the simulation CT placing some external fiducials on the patient's skin, CT images are registered in the contouring module of the planning system (iPlan® 4.1.1) with a volumetric T1&T2 weighted MRI, the Radiation Oncologist and Physicist work in the contouring and dose planning. The external

fiducials are tracked by the infrared cameras of the ExacTrac® system and allow us to move the patient automatically to the treatment position in the treatment room. IGRT system consists on two stereoscopic x-rays images that are registered with the DRR obtained from the CT planning. Translation and rotational corrections can be done by the 6-D robotic treatment couch.

From November 2008 to April 2010 we have treated 9 patients with vertebral metastasis medium age 56 years [46-72], all the patients received single 18Gy dose to the entire body of the vertebra and the affected tranverse and spinous processes, the location of the vertebral metastasis was: cervical spine 2, thoracic spine 5, lumbar spine 2; none of the patients have had prior radiotherapy on the treatment field. The medium PTV volume was 51 cm³[30-95]. Three patients (33%) have pain VAS ≥ 5 and only one patient spinal cord compression.

Results: With 5 months follow up 8 patients have local control after treatment. No grade III (ctcae v 4.0) toxicity was found, absolute pain control was achieved in 4 (44%) of the patients, with a pain reduction in the rest of the patients (at 1.8 mean months from the treatment).

Conclusion: Spine Radiosurgery is effective and save for the treatment of spinal metastasis in our institution experience, as seen on larger literature series.

P2136

ARE THERE DOSIMETRIC DIFFERENCES BETWEEN A RIGHT-SIDED VERSUS LEFT-SIDED CYBERKNIFE FOR SPINAL RADIOSURGERY?

Anthony Ho¹ Scott Soltys¹ Sonja Dieterich¹ Iris Gibbs¹ Steve Chang¹

(1) Stanford University, Stanford, USA

Introduction: With CyberKnife treatments, a different set of treatment beams are available if the robot base is located on the right side of the patient as compared to the left side. We sought to determine if the location of the CyberKnife robot base affected the treatment planning for spinal metastases.

Methods: There are two CyberKnife units at Stanford University-one positioned on the patient right side (CK1-right) while the second (CK2-left) is on the patient left. For this study, all plans were originally calculated at CK1-right, and the same optimization parameters were used to re-optimize on CK2-left using Multiplan 3.5 with the same treatment scan and delineated structures. We investigated the difference in cord dose and target coverage between these two Cyberknife units.

Results: Maximal cord dose in cGy

Targeted site R T6 R T7-T9 L C7 T1-T3

Dose/Fractions 18Gy/1 24Gy/2 18Gy/1 24Gy/3

CK1-right 1409 1814 1077 1721

CK2-left 1433 1730 1152 1759

Cord volume (ml), receiving 8,10,12, or 15 Gy

Site R T6 R T7-T9 L C7 T1-T3

CK1 v10 0.465 v15 0.198 v10 0.013 v15 0.34

CK1 v8 1.34 v12 1.019 v8 0.247 v12 2.27

CK2 v10 0.378 v15 0.098 v10 0.023 v15 0.37

CK2 v8 1.24 v12 0.73 v8 0.238 v12 2.59

The re-optimized CK1 R T7-T9 plan gave similar cord dose as CK2, as well as similar tumor coverage: Maximal cord dose 1723 cGy, v15 0.06 ml, v12 0.58 ml.

Discussion: Comparing the beam distribution between CK1-right and CK2-left, there seems to be no major dosimetric difference for C spine and upper T spine cases. For the lower T spine cases, dosimetric differences were seen, likely from the fewer beams available on the far contralateral side of the patient due to robotic arm limitations. With a simple recalculation, the location of the robot base may affect the cord dose when the same planning parameters are used for the two units. However, to compensate for these differences, the plan can be re-optimized to obtain the required cord dose. In conclusion, the location of the robotic base (left or right) does not yield dosimetric differences in treatment plans once re-optimization is performed.

P2137

MULTISESSION STEREOTACTIC SPINAL RADIOSURGERY - CASE SERIES OF 11 PATIENTS

Azhar Rashid¹ Muhammad Ali Memon¹ A Sattar M Hashim¹

(1) Pakistan Gamma Knife & Stereotactic Radiosurgery Center, Karachi, Pakistan

Introduction: Stereotactic body radiosurgery (SBRS) & Stereotactic body radiotherapy(SBRT) are emerging options to treat spinal tumors effectively as the only treatment or as a part of multimodal treatment with minimal toxicity.

Objectives: To determine the safety and efficacy of multisession stereotactic radiosurgery in the primary and metastatic spinal tumors.

Methods: From 15.06.09 to 15.08.10, Ninety patients of various tumors were treated with the help of a modern linear accelerator (Synergy-S, Elekta: Crawley UK) having micro multileaf collimators, on board imager: cone beam CT (CBCT) and robotic couch.

Out of these 90 patients, 11 cases of spinal tumors were treated with multisession stereotactic radiosurgery. 8(72.7%) were male and 3 (27.3%) were female patients. Median age was 37 years (range: 20-58 years). 3 (27.3%) were of recurrent schwannoma, 2(18.2%) recurrent ependymoma, 1 (9.1%) chondrosarcoma, 1 (9.1%) giant cell tumor and rest of the 4 (36.4%) were spinal metastases from various primaries were treated. Location of the tumor was as follows: 3 (27.3%) patients were of cervical spine, 4(36.4%) of dorsal spine and 4(36.4%) of lumbosacral spine. Up to five fractions were used in most of the cases. PTV includes the involved vertebral part only; no extra uninvolved vertebrae were included. All the patients underwent pretreatment CT scan with the help of the on board CBCT. This set of CT (localization study) was registered with the DRRs (reference study) on bone window and mismatch was noted with XVI (X-ray Volume Imager). Given corrections were made with the robotic couch from the console and then treatment executed. Median follow-up time from the end of treatment was 245 days (range: 30 -355 days).

Results: All the patients tolerated treatment very well. Significant clinical improvement was observed during and soon after multisession SRS course. No acute toxicity was observed in 10(90.9%) patients, only 1 (9.1%) developed Grade II acute toxicity. 8 (72.7%) developed no late toxicity and three (27.3%) patients died till 6 months follow-up. Radiologic partial response was found in 3(27.3%) patients and stable disease was observed in 5(45.5%) patients. Overall disease control was 72.7 %. Three (27.3%) patients of spinal metastasis were died due to progression in

their extraspinal disease, while the treated site was having stable disease.

Conclusion: Linear accelerator based multisession stereotactic radiosurgery of spinal tumors is safe and having excellent local controls.

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CANCELLED

P2139

CYBERKNIFE RADIOSURGERY FOR SPINE TUMORS: FIRST YEAR EXPERIENCE

Antrey Golanov¹ Elena Vetlova¹ Mikhail Galkin¹ Svetlana Zolotova¹ Gennady Gorlachev¹ Natalia Antipina¹

(1) Burdenko Neurosurgery Institute, Moscow, Russian Federation

Objective: Burdenko Neurosurgery Institute (NSI) has started spine stereotactic radiation therapy in April 2009. It is first experience in Russia. We mostly afraid complications due to high doses of radiation per fraction not accepted in classic radiation therapy. To get filling of tolerance in our environment we summarized dose statistic for patients after half a year follow-up.

Materials and Methods: Totally 27 patients with spinal tumors were treated: 11 with metastasis, 5 hemangiopericytomas, 5 schwannomas, 3 metastatic ependymomas, 2 AVM, 1 astrocytoma. All tumors compress spinal cord. Radiosurgery undergo 4 patients with median dose to tumor volume 9, 14, 14, and 18 Gy respectively. Five patients were treated with 2 fractions by 9 to 12 Gy. 13 patients received 3 fractions from 5.5 to 9 Gy. 5 patients get from 5 to 7 fractions of 5 to 6 Gy. Fractionation was defined by histology, tumor volume, tumor location, and spinal cord dose. Tumor volume varied between 0.1 and 21 cc. Dose to 0.15, 0.3, and 1 cc of spinal cord was measured on DVH. 20 patients were evaluated at 6 month follow-up.

Results: Mean total doses to spinal cord volumes (0.15/0.3/1 cc) were as follows: 1 fraction -> 6.5/6.1/5 Gy; 2 fr -> 15.8/14.9/12.4 Gy; 3 fr -> 18.6/17.7/15 Gy; 5 fr -> 26/25.4/22.7 Gy; 7Fr -> 38.4/38.2/37.9 Gy.

Corresponding maximal in fraction group total doses: 1 fr -> 10.5/9.8/7.1 Gy; 2 fr -> 20.3/19.6/17.3 Gy; 3 fr -> 23.6/22.5/18.8 Gy; 5 fr -> 32.3/31.7/27.2 Gy; 7Fr -> 38.4/38.2/37.9 Gy. In terms of equaled dose of fractionation by 2 Gy per fraction at alpha-beta ratio equal 3 all doses were increasing up to 3 times with increasing number of fractions. Tumor growth control was observed in 15 patients. No patient experienced radiation myelitis.

Conclusion: Preliminary Results confirm a new site proper establishing and agree with a statement, that stereotactic irradiation of spine tumors with large doses per fraction is safe and efficient.

P2140

RE-IRRADIATION TO VERTEBRAL METASTASES WITHOUT SPINAL CORD OVERDOSE

Fumitaka Ito¹ Hidetoshi Kobayashi¹ Kazuhiro Katada¹ Takashi Mineta² Hitoshi Takagi³ Yumi Oie¹

(1) Fujita Health University, Toyoake, Japan (2) Nagoya Central Hospital, Nagoya, Japan (3) Ogaki Municipal Hospital, Ogaki, Japan

Introduction: Recently, SRT (fractionated Stereotatic Radiotherapy) using the linear accelerator is used for radiotherapy to bone metastatic lesions. SRT has a benefit to decrease doses to a spinal cord and to protect late radiation damages; esp. radiation myelopathy.

Methods: The patient is 57 years old female who suffered lung carcinoma (adenocarcinoma). She received 40Gy/20fr/4w irradiation cervical (C3-Th1) in 2008 April and lumbar (L1-5) vertebrae in 2009 July, because of feeled pain from bone metastases. 4.5 and 16 months after the first irradiation, cervical (C5-7) and lumbar (L2) vertebrae were undergone to re-irradiation becuse of vertebral bone metastases.

Result: IMRT was adapted to cervical and vertebral lesions. The cervical lesion was treated by seven beams and the vertebral lesion was treated by six beams. Irradiation planning was performed by I-plan with References with low intensity areas in MRI-T2WI and the margins of 3mm. The risk internal organ is the spinal cord within the limited the dose of D30 was 10Gy. The position collation went by bone collation using Exact trac of Novalis(BrainLAB,Germany). Both of irradiations were 18Gy/10fr/2weeks. The maximum dose of the cervical spinal cord was 2.3Gy and the maximum dose of the lumbar was 14 Gy. D50 dose of the lumbar was 4Gy, in DVH. The noxious radiation effects were not seen, and the irradiation was able to be completed without any troubles. Pathological bone fracture was prevented.

Discussion: Radiation myelopathy after the re-irradiation to vertebral bone metastases is dose dependent adverse effect, and can be avoided by using IMRT. The accuracy of Exact Trac was excellent.

Conclusion: Re-irradiation to the vertebral bone metastases by IMRT with Exact Trac was seemed to be useful and effective in clinical radiotherapies.

P2141

IMAGE-GUIDED SPINAL RADIOSURGERY: PATIENT SETUP AND IMMOBILIZATION UTILIZING THE HEXAPOD AND BODYFIX SYSTEMS

Arjun Sahgal¹ Lijun Ma² Derek Hyde¹

(1) University of Toronto, Toronto, Canada (2) University of California San Francisco, San Francisco, USA

Purpose: To evaluate the clinical targeting precision and patient immobilization of the HexaPOD treatment table and BodyFIX systems, utilizing cone-beam CT (CBCT) image-guided radiation therapy (IGRT) for spinal stereotactic radiotherapy (SBRT).

Methods and Materials: Patients were immobilized with the Elekta BodyFIX system. Cone-beam CT (CBCT) images of the spine were registered using the maximization of mutual information. The HexaPOD treatment table performed the translations and rotations required to correct the patient

position. Prior to treatment, a second CBCT image was acquired in order to verify the position of the patient and assess the residual setup error. Intra-fraction motion was assessed by mid-treatment (two of which were acquired for single fraction treatments) and post-treatment CBCT imaging. The CBCT image registrations were analyzed for 44 spinal lesions treated with 106 fractions.

Results: The CBCT verification images acquired after setup, but prior to treatment, illustrate the residual setup error. The absolute mean and standard deviation for all translations and rotations for the verification images was 0.5 ± 0.5 mm and $0.3 \pm 0.3^\circ$. The mean time between the setup and verification imaging was 10 ± 3 minutes. The intra-fractional and post-treatment CBCT image registrations demonstrate the patient immobilization during treatment. The absolute mean and standard deviation remained consistent, despite the increased mean time of 17 ± 4 minutes between image acquisitions (when intra-fraction patient motion could occur).

Conclusion: By means of CBCT image-guidance for spinal SBRT, we have demonstrated that the HexaPOD treatment table and BodyFIX immobilization system have a 95% confidence of localizing the target to within 1.2 mm and 0.9° .

P2142

FRACTIONATED STEREOTACTIC RADIOTHERAPY: THE PATIENTS PERCEPTION

Robert Smee¹ Janet Williams¹

(1) Department of Radiation Oncology, the Prince of Wales Cancer Centre, High St, Randwick, Sydney, Australia

Objectives: The perception is that patients tolerate stereotactic radiotherapy well since tightly conformal volumes are treated over a number of fractions. This review will evaluate the patients reaction to this procedure with prospectively collected data.

Methods: For this Ethics approved study all adult patients with a good command of English were eligible for this study if they were receiving SRT for an intra/extra cranial tumour, benign or malignant. Patient instructions were provided with a diary composed of a series of questions to determine their state of well being, the response to each question being to place a score along an analogue scale (Likert Scoring Scale), reflective of how they felt. The diary was to be filled out away from the department and mailed back; the time points for recording in relation to treatment were at day 1 of treatment, day 7 and 12 weeks post treatment completion.

Results: Between November 2006 and June 2010, 74 of 111 patients had completed and returned all 3 diaries. Baseline assessment was gained. Fatigue was present in 50% at the beginning of treatment, 37% were anxious and tense with low incidence of nausea. All parameters increased by it minimally after 1 week of treatment, at 3 months post treatment many features such as fatigue, and feeling anxious and tense still remained of concern to patients although there was progressive improvement. Initially 50% of patients had discomfort with the bite-piece oral fixation, this improved with time. Most patients felt there was adequate explanation of the procedure prior to beginning treatment and found the FSRT brochure at 1st consultation an valuable reference tool.

Conclusion: In the circumstances where patients are able to indicate how they feel away from the actual treatment environment, tenseness and anxiety occurs in one-third of patients and fatigue is frequent. Whilst there is an improvement 3 months post treatment many patients are still not normal, this feature needs to be incorporated into the informed consent process.

P2143

IMPLEMENTATION OF THE FIRST LINAC RADIOSURGICAL FACILITY IN A PUBLIC HOSPITAL RADIOTHERAPY DEPARTMENT IN CHILE. HOW WE DO IT

Gustavo Zomosa¹ Ariel Fariup^{>1} Gustavo Piris¹ Martin Mondaca¹

(1) instituto nacional cancer, Santiago De Chile, Chile

In 2009 as a consequence of the purchase of three new lineal accerators for the department of radioteraphy of the National Cancer Institute (Instituto Nacional del Cancer), public hospital in Chile, South America, the implementation of a LINAC Radiosurgical facility was performed. It consisted in a Varian Linear Accerator system with the Fast Plan planification system, which enables to use, depending on the target, a cones collimators based system or the multi-leaf (IMSRs) with the Eclipse system . We can use a frame invasive position system (ISPS) or frameless with an optic navigation system for irradiation control. Before the implementation of this facility the patients were treated in private clinics or abroad when it was possible, so that now this service is available for public patients from all regions of the country. The process of implmentation was rather difficult in a public hospital with a large number of patients who needed conventional radiotherapy and included changes in the way of working as a team: neurosurgeon, radiation oncologist, medical phisicists and medical technitian with the development of new protocols and strategies and in particular very strict quality controls that are needed for SRS. Finally after solving these problems and inexpected events that included an earthquake, the first patient was succesfully treated this year and showed us the right way to be succesfull in this difficult field and moved us to report this goal.

P2144

BURDENKO NEUROSURGICAL INSTITUTE: USING DIFFERENT LEADING STEREOTACTIC IRRADIATION TECHNOLOGIES (NOVALIS, CYBERKNIFE AND GAMMAKNIFE) IN ONE CENTER

Andrey Golanov¹ Gennady Gorkachev¹ Michael Galkin¹ Sergey Ilyalov¹ Sergey Maryashev¹ Valerij Kostuchenko¹ Natalija Antipina¹ Marina Zotova¹ Svetlana Zolotova¹ Elena Vetlova¹

(1) Burdenko Neurosurgical Institute, Moscow, Russian Federation

Objective: When irradiating CNS targets, dose regimen and technique can dramatically effect treatment Results Many factors such as patient's condition, histological features of the formation, location and volume should be taken into account when selecting treatment modality. Radiosurgery can be applied when small volumes are irradiated. Larger volumes irradiation significantly increases risk of complications. Location of the target in the immediate vicinity to critical structures limits radiosurgery application and favor to fractionated regimens. In this point of view Burdenko Neurosurgery Institute has unique possibility to select irradiation technique for neurosurgical patients. Here we present our 5-year experience and try identify criteria for irradiation technique and fractionation selection.

Materials and Methods: Burdenko Neurosurgery Institute is equipped with main apparatus for radiation delivery to intracranial and spinal space: Novalis, Primus, GammaKnife and CyberKnife. During the past 5 years more than 5000 patients with spinal and brain lesions were irradiated in

our Department. Among these about 10% were pediatric patients. Pathologies treated presented by skull base tumors (meningiomas, neurinomas, pituitary adenomas, craniopharyngiomas, chordomas) - 45%, metastases - 20%, gliomas - 21%, AVMs - 10% and other tumors and functional disorders - 4%. Stereotactic radiotherapy was carried out in about 2000 patients and radiotherapy in about 3000 patients. Treatment modality was chosen according to our team opinion on the basis clinical, anatomical and physical aspects.

Results: Treatment selection is based on certain principles. Firstly we decide if conventional fractionation with Novalis or Primus is absolutely necessary. If radiosurgery modality is obviously possible due to lesion size, location and proved protocols, then we select any of radiosurgery units. The most indefinite is hypofractionation regimen selection. Patients which are not suitable for radiosurgery with relatively small and simple shape one or two lesions without complex interaction with critical structures can undergo Novalis or CyberKnife treatment with comparable success. Multiple, complex shaped or adjacent to critical structures targets are mostly suitable for CyberKnife treatment. Attractive dose distributions can easily be achieved with truly inverse treatment planning.

From our point of view industry has big space for optimization algorithms development for conventional accelerators to get physical limit in dose distribution forming. We found, that high quality planning is more difficult for Novalis than for CyberKnife.

Conclusion: Availability of several apparatus within one department provides opportunity to select optimal (most effective and safe) irradiation modality for the patient with specific type of neurosurgical pathology.

P2145

DEVELOPMENT OF REMOTE GAMMA KNIFE TREATMENT PLANNING SYSTEM AND ITS BENEFIT

Koji Okudomi¹ Motohiro Hayashi^{1, 2, 3} Noriko Tamura^{1, 3} Mariko Nagai^{1, 3} Shoji Yomo^{1, 2} Masao Usukura¹ Makoto Suzuki² Yoshiyuki Konishi³ Masahiro Izawa¹ Yoshikazu Okada¹

(1) Tokyo Women's Medical University, Tokyo, Japan (2) Saitama Gamma Knife Center, Saitama, Japan (3) Kasai Gamma Knife Center, Tokyo, Japan

Objective: To report the development and clinical usage of our remote Gamma Knife treatment planning system.

Methods and Materials: In January 2010, we developed a remote Gamma Knife treatment planning system by connecting GammaPlan (Ver. 8.3) at 3 different locations via 10Mbps Ethernet Virtual LAN, establishing a communication connection between the main hospital (Tokyo Women's Medical University Hospital) and two other participating hospitals (Kasai Gamma Knife Center and Saitama Gamma Knife Center).

Six hundred and eighty-five patients were treated from January to October 2010 among the 3 facilities. Of the total, there were 555 metastases (81.0%), 56 meningiomas (8.2%), 18 vestibular schwannomas (2.6%), 13 trigeminal neuralgias (1.9%), 13 pituitary adenomas (1.9%), 12 arteriovenous malformations (1.8%) and 18 other tumors (2.6%).

Results: Preliminary Results showed some advantages of our system. We were able to directly display and confirm treatment plans created at the said participating facilities. Pre-treatment

Magnetic Resonance imaging data were exchangeable between the connected facilities. On the other hand, there were a few disadvantages. Our system did not enable the multiple facilities in different locations to manipulate treatment plan for use in, making it impossible to discuss the planning at the same time. The 10Mbps connection caused some time lags during treatment planning. In all treatment cases, there was no misidentification of patients and treatment planning. All private information was kept secure.

Conclusions: Although our system was experimentally used for only 10 months, our study indicated some benefits in clinical use. We presume that further improvements of the system will eventually contribute to higher quality Gamma Knife treatment in remote area and other developing countries in the near future.

P2146

FACTORS AFFECTING THE MOVEMENT OF PATIENTS DURING CYBERKNIFE IRRADIATION

Supaporn Nimsanguan¹ Saiyud Thowladda¹ Prasert Assavaprathuangkul¹ Taweesak Ukhumpun¹ Patchareporn Dechsupa¹ Mantana Dhanachai¹

(1) Radiosurgery center, Ramathibodi Hospital, Bangkok, Thailand

The cyberknife belong to a new class of radiotherapy techniques called IGRT (image-guided radiotherapy). The cyberknife is unique in that it uses a compact linear accelerator (linac) mounted on an image-guide robotic arm to deliver multiple beams of high energy x-ray to a target. The cyberknife is a frameless treatment, making use only of a thermoplastic mask (for head/neck) or vacbag (body mold). The cyberknife accomplishes this by accurately cross-firing approximately 150-250 beams of radiation at the target from multiple direction. The overall treatment time requires single or multiple sessions each of almost more than an hour for brain and spend more than two hour for the body. By irradiation, while the patient must cooperate and motionless. Patients' feels during irradiation are pain, nausea, vomiting, skin reaction, anxiety, fear. The author has studied that the patients can generally still in a period of time only. After that, the patients may be movement of the body. Due to various causes, some of which may be prevented by giving advice and encouragement for patients to make them feel relaxed. In addition to these factors, there are some factors due to the pathology of the patients that they would feel pain (not caused by the restriction of movement) may require treatment from a medical. To irradiation with CK successful efficiently and accurately

P2147

GAMMA KNIFE STEREOTACTIC RADIOSURGERY FOR INTRACRANIAL HEMANGIOPERICYTOMA AND NOVALIS STEREOTACTIC BODY RADIOTHERAPY FOR EXTRACRANIAL METASTASES: CASE REPORT

Tatsuya Kobayashi¹ Yoshimasa Mori¹ Chisa Hashizume¹ Takahiko Tsugawa¹ Yuta Shibamoto² Toshihiko Wakabayashi³

(1) Nagoya Radiosurgery Center, Nagoya Kyoritsu Hospital, Nagoya, Japan (2) Department of Radiology and Radiation Oncology, Nagoya City University Graduate School of Medicine, Nagoya, Japan (3) Department of

Neurosurgery, Nagoya University School of Medicine, Nagoya, Japan

Intracranial hemangiopericytoma is a rare malignant extraaxial tumor that thought to arise from pericytes. This tumor is notable for local aggressiveness, high rate of recurrence and proclivity for extracranial metastasis. We experienced a patient with hemangiopericytoma with repeat intracranial recurrence and multiple extracranial metastases. Gamma Knife radiosurgery (GKRS) and Novalis stereotactic body radiotherapy (SBRT) were applied for this patient and achieved tumor control.

A 23-year-old male underwent surgical resection of a left occipital tentorial tumor, the diagnosis of which was first mimicking meningioma. Local recurrence developed two years later and was treated with GKRS, which was once responded well. However, he suffered from repetitive intracranial recurrence and totally 5 procedures of GKRS and conventional whole skull external-beam radiation therapy (EBRT) was done. Intracranial lesions have been controlled so far. On the other hand, multiple extracranial systemic metastases occurred. A biopsy of extracranial metastatic tumor at the sacrum provided a definitive diagnosis of hemangiopericytoma. EBRT for very large sacral metastasis and Novalis SBRT for metastases of multiple spinal bone from cervical through lumbar spine, liver, left costa, left hip joint, and sternum were performed. Zoledronic acid hydrate injection was followed for multiple bone metastases. This patient tolerates these therapies well and still survives until 6 and a half year from first craniotomy. Pain caused by spinal metastases and thoracic bone metastases were well relieved after Novalis SBRT.

Palliative GKRS and Novalis SBRT in addition to conventional EBRT to large sacral metastasis and dissemination in brain surface were effective management for this patient with recurrent hemangiopericytoma with systemic metastases considering survival and relief of symptoms.

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