Table Ia. Maximum total skin dose (Gy) over the whole course of the treatment on a dose profile along the centre of the strip. Mean and standard deviations of three measurements.

		Table top			
		Exact couch top		IGRT couch top	
Treatment plan	Dose map	Dose	sd	Dose	sd
Head and Neck IMRT	Posterior right	23,4	0,7	**35,28**	0,2
	Posterior left	23,1	0,7	**41,98**	0,17
Breast IMRT	Anterior	19,58	0,19	18,3	0,3
	Posterior	19,91	0,17	**28,58**	0,15
SBRT lung	Anterior	3,73	0,02	3,62	0,02
	Posterior	5,59	0,09	6,85	0,06
SBRT liver	Anterior	5,21	0,13	5,02	0,04
	Posterior	7,1	0,7	11,16	0,12

Table Ib. Relative increase (I) in skin dose due to the IGRT couch top *vs* the Exact Couch top on a dose profile along the centre of the strip: Maximum and average values, and size of regions with double dose.

Treatment plan	Dose map	Max	u(k=2)	Average	Size(I>2) (cm)
Head and Neck IMRT	Posterior right	**2,8**	0,4	1,47	**2,8**
	Posterior left	**2,25**	0,12	1,38	**4,1**
Breast IMRT	Anterior	1,03	0,02	0,95*	-
	Posterior	**1,83**	0,18	1,27	-
SBRT lung	Anterior	1,9	1,0	0,97*	-
	Posterior	**2,7**	0,6	1,20	**1,6**
SBRT liver	Anterior	1,0	0,2	0,94*	-
	Posterior	**3,0**	0,2	1,41	**2,5 & 2,3**

***Average values in anterior dose maps are <1 due to the larger attenuation of the IGRT couch**

Conclusion

· IMRT techniques can deliver skin doses above the threshold for deterministic effects.
· The main factor affecting skin dose is the table top.
· The skin dose for the IGRT Couch Top can be the triple than that for the IGRT Couch top.

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[1]Detector comparison for dose measurements in the build-up zone. M.A Duch et al. 3rd ESTRO FORUM. 2015.

PO-0799 Fast protocol for radiochromic film dosimetry using a cloud computing web application

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Purpose or Objective

To propose a fast protocol to evaluate plans computed by a treatment planning system (TPS) by using radiochromic film dosimetry.

Material and Methods

Gafchromic EBT3 films and an Epson V750 Pro scanner were used in this study as dosimetry system. Film dosimetry was conducted using the triple-channel method implemented in a cloud computing application (www.radiochromic.com). Batch calibration curve (up to 5 Gy) was obtained using several film pieces that were scanned 24 hours after exposure (24 h-calibration).

So far, radiochromic film dosimetry has been performed in our department for patient specific quality assurance (QA) by scanning the films 24 hours after their irradiation. However, in this study we have investigated the feasibility of a "fast protocol" that enables to obtain measurement results within 1 hour for dose verification. This protocol combines the 24-h calibration and measurements acquired using three film pieces: 1) one is exposed to the clinical plan (verification film); 2) a film piece is homogenously irradiated to the expected maximum dose of the clinical plan, and 3) an unexposed film piece. The three films are simultaneously digitized in the fast protocol in order to obtain the absolute dose distribution in the verification film.

To evaluate this fast protocol, ten IMRT plans (sites: prostate, breast, brain, lung and head and neck) were delivered onto EBT3 films on a Varian linac. Absolute dose distribution of verification film was derived for each plan by digitizing simultaneously the three film pieces at 15, 30, 45 minutes and 24 hours after completing irradiation (15 min-protocol, 30 min-protocol, 45 min-protocol, 24 h-protocol, respectively). The four dose distributions obtained for each plan were compared with the calculated one by the TPS (Eclipse v 10.0) to demonstrate the equivalence of results. The comparisons (measured-calculated) were done using a global gamma evaluation (3%/3 mm). Gamma passing rates obtained for 15 min, 30 min and 45 min post-exposure dose maps were compared with those for 24 hours by using a paired t test.

Results

No significant differences respect to 24 h-protocol were found in the gamma passing rates obtained for films digitized 15 minutes (96.6% *vs* 96.3%, p= 0.728), 30 minutes (95.6% *vs* 96.2% , p= 0.640) and 45 min (94.9% *vs* 96.2%, p= 0.485).

Conclusion

The 15 min- protocol provides gamma passing rates similar to those that would be obtained if the verification film had been scanned under identical conditions to the calibration films (24 h).

PO-0800 Log file based performance characterization of a PBS dose delivery system with dose re-computation

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Purpose or Objective

The dose distribution administered by quasi-discrete proton pencil beam scanning (PBS) is controlled via a dose delivery system (DDS). Delivered proton fluences deviate from the planned ones due to limitations of the DDS in precision and accuracy. The delivered particle fluences and resulting dose distributions were evaluated in this study with a special focus on the DDS performance as a function of the number of particles (NP) per spot.

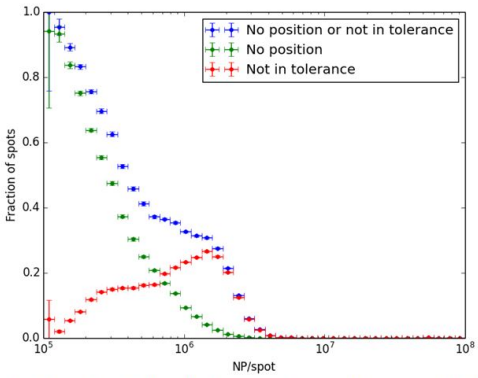
Material and Methods

Software tools for the DDS performance evaluation based on treatment log files and the re-computation of the corresponding dose distribution in the TPS RayStation (RaySearch Labs, Stockholm) were created. For this purpose, DICOM RT ion plans with the measured spot positions and NP/spot were generated and were imported into the TPS. Re-computing dose for the delivered particle fluences allowed comparing delivered against the planned dose distributions. A set of 95 delivered treatment plans for regular-shaped targets were analysed for this study. The plan set encompassed plans with various spot spacing distances and different values for the allowed minimum NP/spot. Also settings outside the foreseen clinical parameter ranges were included. Notably, a minimum NP/spot of 1×10^5 was set for some plans. A configurable DDS spot position tolerance triggers an interlock if spots above a given weight are outside the set tolerance. For low-weighted spots, counts may be so low that the DDS is not able to determine a position.

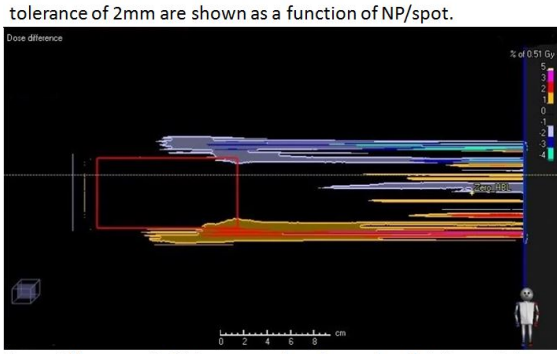
Results

The DDS performance degrades for lower NP/spot steadily. Figure 1 (left) shows, as a function of NP/spot, the fraction of spots for which no position can be determined and the fraction of spots which are out of a position tolerance of 2mm. For NP/spot>2×10^6, a feedback position correction loop improves positioning notably (not shown). Hence, most particles are delivered with a deviation of the spot position smaller than ±0.1mm. For NP/spot<1×10^6, a systematic deviation of requested vs delivered particles is observed, up to about 2%. However, contribution of these spots to the total delivered dose is generally small. Figure 1 (right) displays dose differences in % between the planned and delivered dose distributions for a rectangular box irradiated with 0.5Gy. For this plan, a minimum NP/spot constraint of 0.5×10^6 was set. Small dose discrepancies were seen specifically for the

penumbra of the proximal end of the SOBP, where NP/spot were generally low and spot position inaccuracies were larger.



The fraction of spots for which no position is determined by the DDS and the fraction of spots which are out of a position tolerance of 2mm are shown as a function of NP/spot.



Dose differences in % between the planned and delivered dose distributions are displayed for a rectangular box (6x6x12cm³, shown as red contour) irradiated with 0.5Gy.

Conclusion

This study indicate limitations of the DDS used for proton PBS and provides guidance on the selection of adequate treatment planning parameters for clinical application. In particular, it allows choosing an admissible minimum NP/spot which leads to clinically acceptable dose deviations. In future, the established analysis tools may be employed for the analysis of the beam intensity selection, patient-specific log file QA and dose accumulation studies.

PO-0801 Benchmarking Gate/Geant4 for oxygen ion beams against experimental data

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Purpose or Objective

Oxygen ions are a promising alternative to carbon ion beams in particle beam therapy due to their enhanced linear energy transfer, which is expected to yield a higher relative biological effectiveness and a reduced oxygen enhancement ratio. In order to facilitate research on oxygen ion beams using Monte Carlo (MC) simulation under well-defined conditions, a benchmark against the existing experimental data was performed.

Material and Methods

Several available physical models in Geant4 (version 10.2.p01) were benchmarked using the GATE (version 7.2) environment. The nuclear models recommended for radiation therapy such as the quantum molecular dynamics model (QMD) or the binary cascade model (BIC) were investigated. Integrated depth dose (IDD) distributions of three energies (117, 300 and 430 MeV/u) measured at Heidelberg Ion-Beam Therapy Center (HIT) and partial charge changing cross sections measured at Gesellschaft für Schwerionenforschung (GSI) were used as reference data.

Results

For all physics lists, the relative dose differences up to the Bragg peak were found to be less than 4% compared to measurements. Beyond the Bragg peak, in the so-called fragmentation tail, differences increased notably, by up to one order of magnitude. However, the absolute dose difference in the fragmentation tail was comparable to the absolute difference before the Bragg peak. The QMD model systematically overestimated whereas the other models underestimated the dose in the fragmentation tail. Overall, deviations to the measurement were less than 2% of the maximum dose for all models, disregarding the dose fall off region due to the steep dose gradient. Partial charge changing cross sections simulated with the BIC, BERT and QBBC models deviated up to 60% from the measurements, INCLXX up to 38% and the QMD model up to 24%. However, the significance on fragmentation in particle therapy is limited by the high energy equal to 630 MeV/u used in the measurements.

Conclusion

IDDs simulated with Gate/Geant4 agreed well with measurements for all models under investigation, although notable deviations were observed in the fragmentation tail. Measured partial charge changing cross sections could best be reproduced using the QMD model, whereas the BIC model showed considerable discrepancies. Therefore, Gate/Geant4 can be considered a valid dose calculation tool for oxygen ion beams and will further on be used for the development of a pencil beam algorithm for oxygen ions. The QMD model is recommended in order to obtain accurate fragmentation results, which is essential for radiation oncology purposes.

PO-0802 Experimental validation of single detector proton radiography with scanning beams

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Purpose or Objective

Proton radiography represents a potential solution to solve the uncertainties of dose delivery in proton therapy. It can be used for in-vivo beam range verification; patient specific Hounsfield unit (HU) to relative stopping power calibration and improving patient set-up. The purpose of this study is to experimentally validate the concept of the energy resolved dose measurement for proton radiography using a single detector with Pencil Beam Scanning (PBS).

Material and Methods

A 45 layers imaging field with a size of 30 x 30 cm^2 and energies between 226 MeV and 115 MeV is used to deliver a uniform dose. The dose per spot is 4.25 mGy with spot spacing equal to the beam sigma. The imaging field is first delivered on wedge shaped water phantom to produce calibration library of Energy Resolved Dose Functions (ERDF) between 0 cm and 30 cm. Then, the same imaging field is delivered in three different configurations: a stack of solid water in a stairs shape with thicknesses between 1 mm and 10 mm – that determines the accuracy with which the WEPL (water-equivalent path length) can be retrieved, CIRS lung phantom – that illustrates the accuracy on the density of multiple materials and a head phantom – which represents a realistic case of heterogeneous target.

As shown in Figure 1, proton radiographs are recorded with a commercial 2D detector (Lynx, IBA-Dosimetry, Schwarzenbruck, Germany) which has an active area of 300 × 300 mm^2 with an effective resolution of 0.5 mm.