tumor size, and depth in the body. Grid therapy is clearly advantageous for treating melanoma cells if the fraction dose is at least 15 Gy. Our theoretical model confirmed clinical observations.

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2978 Mathematical Modeling of Dose Volume Histograms (DVHs) among Patients undergoing Radiation Therapy for Prostate Cancer

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Purpose/Objective(s): Dose volume histogram (DVH) is a preferred quantitative tool to evaluate target coverage and potential toxicity to critical structures during a course of radiation therapy. Mathematic modeling of DVH not only allows more accurate calculations of normal tissue complication probability (NTCP) with DVH parameters but also enables time series analysis of DVHs which has important implications with respect to adaptive planning. This work has proposed and validated a method to parameterize DVHs among patients undergoing prostate gland irradiation.

Materials/Methods: There are generally two different formats of DVH: differential DVH (dDVH) and cumulative DVH (cDVH). Although cDVHs are more commonly used for radiation treatment plan evaluation, dDVHs were used in our study to test the parameterization, as mathematically, the differential format preserves more details than the cumulative/integral format. Patients previously irradiated to the prostate gland for adenocarcinoma at our institution were selected for the study. For these patients, the total dose was 7400cGy prescribed to 95%-98% of the planning target volume (PTV). The treatments were planned using a 7-9 field IMRT technique. It was found that the rectal dDVH of at least 2/3 of such patients could be characterized (fitted) by two normal functions plus a linear function, which described the background dose. Fifteen such patients were selected and their rectal DVHs were fitted in such way. It is found that not only could the individual DVH be parameterized, the averaged DVH of the group of patients could also be parameterized in the same manner. Parameters regularly used for the treatment plan evaluations, e.g. V_{60}, V_{70}, mean dose and generalized mean dose (GMD), from the original DVHs were compared with those from fitted DVHs. cDVHs generated directly from dDVHs were also examined for the goodness of fit.

Results: The fittings of the rectal DVHs yielded relatively acceptable results with adjusted R-squares between 0.65 and 0.9. Fit parameters are: for the individual dDVHs, the centers of the two peaks were 477.0 ± 83.1 cGy and 7539.9 ± 61.1 cGy, respectively. The standard deviations were 86.0 ± 23.4 cGy and 60.5 ± 21.5 cGy, respectively. For the averaged dDVH, the center of the first peak was 480.3 cGy and the center of the second peak was 7503.7 cGy. The standard deviations were 110.0 cGy and 93.4 cGy, respectively. For V_{60} and V_{70}, the absolute differences are within 3%, comparing original and fitted DVHs. For mean dose and GMD, the relative differences are also within 3%.

Conclusions: DVHs could be represented by several parameters. Rectal DVH of patients undergoing irradiation to the prostate gland could successfully be parameterized using two Gaussian functions plus one linear function.

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2979 An Electronic Phantom for Testing and Quality Assurance of Dose Volume Histogram Calculations used in Data Analysis for Multi Institutional Clinical Trials

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Purpose/Objective(s): Digitally submitted DVHs lack consistency due to algorithmic differences among treatment planning systems (TPS). To maintain consistency among cases in multi institutional clinical trials, the Image Guided Therapy QA Center (ITC) recalculates DVHs from submitted 3D dose distributions and structures. In instances where there are steep dose gradients and small structures, the DVHs calculated at an institution can be significantly different from those recalculated at the ITC (Straube, et al. AAPM 2005). In order to test the relevant parameters for these discrepancies we have constructed an electronic phantom that can be imported into TPS.

Materials/Methods: Using the POSDA, open-source DICOM toolkit (http://www.posda.com), an electronic phantom was constructed which consists of a cylinder of water density medium with imbedded structures of varying volume and geometry. The structures are contoured and exported with CTs from POSDA in DICOM format. This phantom has been imported into several TPS. Analysis of recently submitted institutional data and previous studies indicate that the parameters to investigate are structure volume, dose grid spacing, and CT slice spacing.

Results: Analysis of submitted data shows discrepancies between ITC's calculated DVHs and submitted DVHs, which are most severe for small volumes and high dose gradients. A sampling of structure volumes in submissions from a single TPS for an IMRT phantom shows a trend toward less discrepancy (% difference) as slice thickness decreases (CC=0.9) for a 15 cc structure. This information guided construction of a phantom that allows variation of parameters. The phantom consists of a 3.11 L circular cylinder of water containing higher density contoured spheres with nominal volumes of 5, 25.2, and 50 cc. Also included are a right circular cylinder and a pair of stacked cones: 26.2 and 4.2 cc nominal volumes respectively. The slice thickness can be varied, although a slice thickness of 3 mm represents current clinical submission for H&N IMRT cases on RTOG 0522 (60% of cases, slice thickness =3.00 mm; 92% slice thickness $\geq$ 2.5 mm).

Conclusions: An electronic phantom with varied geometric structures and slice thicknesses has been used to investigate parameters that effect discrepancies in volume and DVH calculation for commercial TPS used to submit data for multi institutional clinical trials. The ease with which phantom datasets can be generated using POSDA allows variation of parameters that influence the results of algorithms. This phantom is also useful in determining the effects of dose sampling on DVH

calculation. Recommendations and implications for clinical trials protocol development can be made through the use of this phantom.

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2980 Sterilization Effect on MD-55-2 Radiochromic Film for *In Vivo* Dosimetry in Electron Intraoperative Radiotherapy

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Purpose/Objective(s): To study the effect of standard gas plasma sterilization method on the response of MD-55-2 radiochromic film for in vivo IORT dosimetry.

Materials/Methods: From a single sheet of Gafchromic MD-55-2 film (batch no. Q0304MDV2) 27 small pieces of 1.5 cm x 1.5 cm were cut. Film fragments were prepared by the same procedure intended for clinical use: every film was packed between two 2 cm x 2 cm pieces of transparent polyester film, fastened together with adhesive tape and hermetically enveloped with transparent dressing Tegaderm. The 27 pieces were randomly split into 3 groups of 9 pieces. One group was left unirradiated, another one was irradiated with 10 Gy, and the last one with 20 Gy. Irradiation was performed with an Elekta Precise linac, 20 cm x 20 cm standard applicator at SSD 100 cm, 12 MeV electrons, at dose maximum depth, between PMMA slabs. After irradiation, the 9 films from each dose level (0, 10, and 20 Gy) were randomly split into 3 groups of 3 pieces. For each dose level, one group was left unsterilized, as control group, other group was sterilized one time and the third one sterilized two times. Films were sterilized with standard gas plasma method at 50 °C during 52 min (STERRAD 100S System). Measurements were made 48 hours after irradiation, without enveloping material, with a flatbed scanner Epson Perfection V700 Photo. Every piece was positioned in the center of the scanning area, in the same orientation with regard to the coating direction. Scanning was made in TIFF format, 50 dpi resolution and turning off all scanner corrections. Films images were analyzed with ImageJ 1.37v, separating the scan data from the red color channel and determining mean and standard deviation of pixel values within a 1 cm x 1 cm centered ROI. Sterilization effect was estimated by the relative differences of mean pixel value between sterilized and unsterilized films for the same dose level. Statistical significance was assessed with the one factor ANOVA test.

Results: The unirradiated films showed a mean pixel value variation of 0.2% for one time sterilization and 0.3% for two times sterilization. Films irradiated with 10 Gy showed a variation of 1.8% and 1.2% for one and two times sterilization. For 20 Gy films variations were 2.4% and 1.5%. ANOVA test showed statistical significance of differences for 0 Gy and 10 Gy films ($p = 0.045$ and 0.007), but not for 20 Gy films ($p = 0.13$), probably due to the larger standard deviations at higher optical densities.

Conclusions: Gas plasma sterilization affects MD-55-2 film incrementing its response about 1.7%. This moderate effect permits sterilization of enveloped film, without impairing dosimetry accuracy, if a correction factor is used. Additional work for uncertainty determination of this correction factor is needed.

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2981 Dose-response Parameters for Different Tumors and Normal Tissues

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Purpose/Objective(s): For the performance of radiotherapy treatment plan optimization, radiobiological models have been developed. These models associate the delivered treatment with the clinical outcome. For the clinical implementation of radiobiological treatment plan evaluation, it is necessary to determine the radiobiological parameters of these models from clinical patient databases. The purpose of this study is to setup a database with the parameters, which characterize the dose-response relations of different tumors and normal tissues for different radiobiological models.

Materials/Methods: The dose-response relations of a large number of tumors and normal tissues have been investigated. These data have been determined from patient materials or collected from the literature. The Poisson, relative seriality, k-model, LKB, critical volume, and parallel are the dose-response models for which radiobiological parameters were collected. The dose, which cause response to 50% of the patients (usually denoted as D_{50}), the steepness of the dose-response curve (usually denoted as γ or m), and the volume dependence of the tissue (usually denoted as *s-relative seriality*, k or n) are the parameters that characterize the shape of these dose-response relations. The values of these parameters are derived for a certain reference volume of the tissue at hand. Furthermore, they are related to a certain α/β ratio, which accounts for the fractionation effects when different fractionation schedules are involved.

Results: It can be observed that the γ values are rather high ranging between 2.4 and 4 in well defined tumor stages, which are characterized by a uniform size. The volume of the irradiated tissue and the acceptable treatment complication rates play a significant role in the estimation of the values of those radiobiological parameters because they are related to the part of the dose-response curve, which is covered by the clinical data. The response of normal tissues is affected significantly by the volume dependence (volume effect), which is related to the spatial arrangement of their functional subunits. Usually, dose-response curves are employed to illustrate the radiosensitivities of tumors and normal tissues. The collected radiobiological parameters are the numerical expression of these curves, which show the expected rates of tumor control or normal tissue complications for a range of uniform doses. These plots associate the clinical data as they appear in the treatment plan and follow-up records.