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Geometrical calibration of a Monte Carlo simulated linear accelerator

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Purpose/Objective: Standard dose calculation algorithms are imprecise in some situations, especially if tissues with different density are taken into account. The most accurate result is achieved by MC-Algorithms. However due to its required computing resources, it is normally not available in commercial treatment planning systems. The goal of this work is to achieve a customized geometrical model of our linear accelerator to ensure a high accuracy in the dose deposition calculation. This geometrical calibration is necessary due to the rounded MLCs (1).
(1) Philip Vial, Lyn Oliver, Peter B Greer, Clive Baldock (2006) An experimental investigation into the radiation field offset of a dynamic multileaf collimator, Physics in medicine and biology 51 (21) p. 5517-38.

Materials and Methods: The chosen MC Code is GEANT4 (2), due to its flexibility with primary particles and geometry modelling. From target to collimators, the clinical accelerator 'Precise' (Elekta) available in our clinic is modelled in close collaboration with the manufacturer. Different profiles were measured with an ionization chamber in a water phantom and the same geometries simulated. According to manufacturer specifications, measurements of the fields were done with the isocenter placed at the maximum of the PDD. The calibration was done for the photon energy of 6 MeV and individual calibration functions were estimated for both leafbanks, backup collimators and X-collimators.

Results: Firstly we represented the difference between measured and simulated distance to central axis (DTCA) of each leaf bank or collimator to analyse which type of function is needed to calibrate the corresponding position. As conclusion, a second grad polynomial is a good choice (Figure 1). With the estimated parameters we simulated new fields, and calculated the DTCA for the left-right profile (Y-backup collimator and MLC together) (Table 1). We also used the Gamma Index Criteria from Low in one dimension (3mm/3%) to compare normalized simulated and measured dose profiles. The agreement was above 95%.

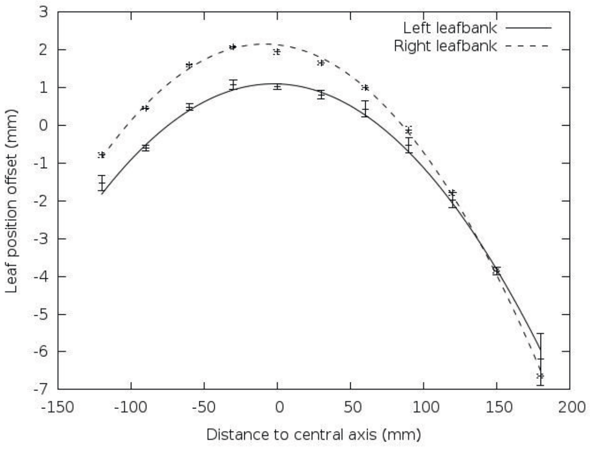
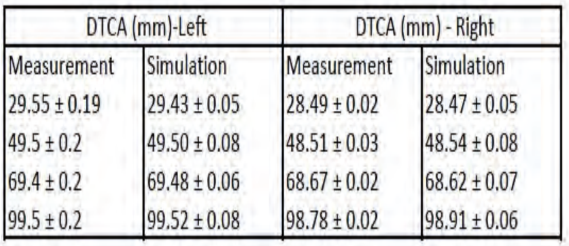


Figure 1.- Difference between measured and simulated DTCA of both leafbanks



DTCA (mm)-Left		DTCA (mm) - Right	
Measurement	Simulation	Measurement	Simulation
29.55 ± 0.19	29.43 ± 0.05	28.49 ± 0.02	28.47 ± 0.05
49.5 ± 0.2	49.50 ± 0.08	48.51 ± 0.03	48.54 ± 0.08
69.4 ± 0.2	69.48 ± 0.06	68.67 ± 0.02	68.62 ± 0.07
99.5 ± 0.2	99.52 ± 0.08	98.78 ± 0.02	98.91 ± 0.06

Table 1.- Measured and simulated DTCA of right and left collimators

Conclusions: The simulation is validated with dose measurements, and also with the DTCA determination. We have a model of our lineal accelerator in Geant4 which ensures us not only high accuracy in dose deposition but also in geometrical setup. This precision is required to do 4D simulations, which is the objective of this project.

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The energy dependency of radiophotoluminescent dosimeters for electron beams

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Purpose/Objective: Radiophotoluminescence (RPL) dosimetry with silver-activated-metaphosphate glass dosimeters has been used for six decades in environmental and personal dosimetry. In some extent RPL dosimetry has also been used for in-vivo photon dosimetry in radiotherapy. The purpose of this study was to measure the energy dependency of a commercially available RPL-system (Asahi Techno Glass Corporation/ATG, Shizuoka, Japan) in high-energy electron beams. Before this study there have been only a few short experiments published using RPL for electron dosimetry.

Materials and Methods: The RPL-system includes glass rod dosimeters GD-302M and an automatic UV-laser reader FGD-1000. All measurements were performed in a water phantom with a digitally controlled positioning frame (PTW, Freiburg, Germany). Each dosimeter was put into the other end of a thin water filled plastic straw that was attached to the positioning frame from the other end to allow some distance between the dosimeter and the metallic frame. Small pieces of bolus material were used to stop the dosimeter from moving along the straw. The highest available electron beam energy (Varian Clinac iX, 20 MeV, VMS, Palo Alto, USA) was chosen to cover as wide range of energies as possible. The dosimeters were irradiated one by one at the central axis of a 20 x 20 cm^2 field at SSD 100 cm at various depths to 2.0 Gy and each measurement was repeated four times. In addition, 0.1 Gy, 0.5 Gy and 1.0 Gy doses were irradiated to measure linearity. Mean energy at surface of the phantom was calculated as defined in the IAEA TRS-398 code of practise and the mean electron energies at measurement depths were determined according to published Monte Carlo calculated data. Linear regression was used to model RPL reading versus energy.

Results: The coefficient of determination (R^2) for the linear regression to doses from 0.1 Gy to 2.0 Gy was 0.9996. The reading of the RPL dosimeter decreases as the depth increases i.e. as the mean energy decreases (Figure 1). The overall change over the range of electron energies investigated in this work is approximately 9% and we propose that it can be estimated with a linear energy correction of 0.5% MeV^{-1}. The R^2 was 0.49 for the linear regression to the readings at different energies which we accept considering that the general uniformity for RPL dosimeters is around 1-2%.

Conclusions: We conclude that RPL dosimeter is linear in electron beams as well as in photon beams and to achieve best accuracy over the entire clinical electron energy range an energy correction of 0.5% MeV^{-1} is recommended, i.e. an energy correction factor from 1.056 at E_d = 2 MeV to 0.971 at $E_d = E_0$ = 19.6 MeV.