Automatic source model tuning for a Varian 6 MV linear accelerator

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Introduction

Accurate dose calculation in treatment planning becomes crucial in modern radiotherapy. It is widely accepted that Monte Carlo (MC) methods deliver the most accurate results. Key input parameters for MC photon treatment planning are the mean energy of the electrons (E_e) incident on the Bremsstrahlungstarget and their spatial distribution (σ_e). Instead of performing MC simulations of the accelerator for each treatment plan, source models corresponding to the parameters E_e and σ_e are used [1]. Since the output of each individual linear accelerator differs even among the same model from the same vendor, these MC input parameter and the source model, respectively, need to be adjusted which is a tedious work requiring MC expertise. The aim of this work was to develop an automatic tuning method which determines the key parameters E_e and σ_e and consequently the according source model without any user interaction.

Material and Methods

As reference data, depth dose curves and dose profiles at 1.5, 5.0, 10.0, 20.0, and 30.0 cm depth in water for a 6 MV photon beam (2300C/D, Varian) were measured with an ionization chamber (CC04, Wellhöfer) for field sizes of 3x3, 10x10, 20x20, and 30x30 cm².

Prior to the automatic tuning, histogram-based source models were built for σ_e's of 0, 0.025, 0.050, and 0.075 cm with constant $E_e = 6.2$ MeV as well as for E_e's of 5.8, 6.0, 6.2, and 6.4 MeV with constant $\sigma_e = 0.050$ cm [2]. Furthermore, dose distributions using the setup used to measure the reference data for all combinations of E_e and σ_e are pre-calculated.

The automatic tuning starts with the comparison of the measured reference data with the pre-calculated doses in terms of the gamma index with 1%/1 mm criteria. Then the combination of E_e and σ_e resulting in the largest fraction of dose points passing gamma is determined. This fraction together with the fraction of dose points passing gamma for the nearest neighbour combinations of E_e and σ_e are used as input for a parabolic fit whose maximum leads to a proposed combination of E_e^{next} and σ_e^{next} for the next iteration step. This step starts with interpolating the histogram values of the source models used in the parabolic fit in order to achieve the histograms for the combination of E_e^{next} and σ_e^{next}. Then the according dose distributions using the source model for E_e^{next} and σ_e^{next} are calculated before the next iteration of the tuning procedure starts again with the comparison between calculated and measured doses. The iteration continues until more than 95% of all dose points pass the gamma criteria 1%/1 mm resulting in the final source model with respect to E_e^{final} and σ_e^{final}.

Results

For the measurements provided, the tuning procedure estimated $E_e^{final} = 6.15$ MeV and $\sigma_e^{final} = 0.038$ cm. For the 10x10 and 20x20 cm² fields, all dose points fulfilled the 1%/1 mm criteria. For the 3x3 and the 30x30 cm² fields, the fraction of doses passing gamma were 87% and 83%, respectively. Overall 98% of all doses are passing gamma. Dose points failing the gamma are mainly located outside the geometric field size.

Discussion

The tuning procedure developed in this work determines the MC input parameters E_e and σ_e and hence the source model automatically. The resulting dose distributions are well below the required clinical criteria of 2%/2 mm. The procedure could also be used to tune other Varian linear accelerator.

References

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