Efficient collimator transport for photon Monte Carlo treatment planning

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Introduction

With increasing complexity of application techniques in radiotherapy, the demand on accurate treatment planning is increasing. The Monte Carlo (MC) technique is the most appropriate method in order to fulfill this demand. One limitation of MC treatment planning is its long computation time, hence, optimization of the MC calculations is essential. This study investigates the impact of different radiation transport methods in collimators on beam characteristics, dose distributions and efficiency.

Material and Methods

This study was performed using the Swiss Monte Carlo Plan (SMCP) [1]. Within SMCP different methods are available to simulate the radiation transport through the collimators. Besides the MC codes EGSnrc [2], VMC++ [3] and Pin (an in-house developed MC code), additional transport methods were implemented: Considering the collimators as totally absorbing, considering attenuation only, considering first order Compton scatter or considering all Compton scatter. Furthermore, either a simple or an exact geometry can be selected for the absorbing or attenuation method. Thereby, the simple geometry is realized by collapsing the exact geometry to a 2D plane perpendicular to the central axis.

In order to characterize these transport methods radial mean energy and energy fluence distributions are analyzed using phase space files. This has been performed for 6 and 15 MV beams of a Varian Clinac 2300 for the following situations: a $10\times10\ cm^2$ field shaped by the jaws and the MLC, respectively, a treatment field of a clinical 3DCRT case and for an IMRT treatment field of a clinical prostate and head and neck case, respectively, applied with dynamic MLC. For all these cases dose distributions in a $30\times30\times30\ cm^3$ water phantom at SSD = 100 cm have been calculated using VMC++ as dose calculation algorithm. Additionally, the efficiency is determined for all the different situations.

Results and Discussion

For all transport methods, differences in the radial mean energy distribution are within 1% inside the geometric field. Below the collimators first Compton and transmission methods overestimate the mean energy of up to 15% and a factor of 2, respectively. While for non-IMRT cases the agreement for the radial energy fluence within the geometric field is within 1% for all transport methods, for IMRT treatment fields the absorbing method underestimates the dose up to 30% within the treatment field. Below the collimators the energy fluence is underestimated for the non-full MC transport methods ranging from 5% for all Compton to 100% for absorbing. Gamma analysis using EGSnrc calculated doses as reference shows that the number of voxels fulfilling a 1%/1mm-criterion decreases from 99% when using VMC++ to 80% (non-IMRT) and 40% (IMRT) when the absorbing method in a simple geometry is used. However, compared with EGSnrc calculations, the gain in efficiency is a factor of 10 for VMC++ and 90 for the absorbing method. The simpler the transport method the higher the efficiency and the lower the accuracy of the dose distribution compared with EGSnrc calculation.

Conclusion

The results of this investigation suggest to use a simple transport technique in the initial treatment planning process and to use the more accurate transport methods at the end of the planning process accepting longer calculation time. This work was supported in part by Varian Medical Systems.

References

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