Abstract Booklet

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Monte Carlo Modeling of IORT Dose Distributions in a Commercial Treatment Planning System

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Purpose

IORT dose distributions for flat and surface applicators were measured at our institution. For real-time 3D rendering of patient dose, a Monte Carlo (MC) based dose calculation algorithm has been recently developed and implemented in a commercial treatment planning system (TPS). We compare measured and MC based IORT doses in realistic phantoms consisting of tissue, air, and bone materials.

Methods and Materials

Using a 50-kV INTRABEAM X-ray device equipped with flat and surface applicators, percent depth-dose (PDD), dose-profiles (DP) and output factors (OF) were obtained. The effect of tissue inhomogeneities on dose distributions was examined by placing air-cavities and bone and tissue equivalent materials of different density (ρ), atomic number (Z), and thickness (t = 0-4mm) between applicator and detector(film or ion chamber). For dose calculations, a hybrid MC model that accounts for photoelectric and Compton interactions (≤ 50kV X-rays) was used. The MC model uses applicator geometry information, measured dose in water and a genetic algorithm to fit the X-ray energy spectra. Implementation in a commercial TPS (Radiance, GMV Spain) further allows fast real-time CT dose calculation. The latter can be used for IORT pre-planning (realistic dose calculations, dose prescription, and applicator selection) and quality assurance (treatment time verification).

Results

The hybrid MC model has been shown to be robust in water medium providing good agreement (1%/1mm) with measured doses. Based on our inhomogeneity measurements, dose enhancement due to 1mm, 2mm, 3mm and 4mm air cavities was 10%, 16%, 24%, and 35% respectively. X-ray attenuation by 2mm thick cortical bone resulted in a significantly large (58%) dose decrease. These results are currently being validated using hybrid MC model. Our subsequent goal is to calculate accurate doses in patient treatment geometries.

Conclusions

Fast and accurate real-time calculation of IORT dose distributions is now feasible within a hybrid MC model. Coupled with a commercial TPS, this can radically improve IORT planning, delivery and documentation.

Optimized Monte-Carlo based dose computation for low energy X-rays IORT implemented in Radiance TPS.

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Introduction

Intra-Operative Radiation Therapy with low energy X-rays (XIORT) is largely used for breast cancer treatment [1] and more and more centers are now involved in other clinical applications such as kyphoplasty [2] and superficial intraoperative radiotherapy [3]. These treatment areas are heterogeneous and dose gradients are very high. Users need a precise and fast method to compute dose distributions in patient data. This work proposes a fast and precise method to calculate dose distributions delivered by INTRABEAM® (Carl Zeiss editec) from pre-processed Monte-Carlo phase space data, optimized to user provided simple experimental data.

Methods

We developed a strategy to determine realistic Phase Space (PHSP) files. On one hand, monoenergetic PHSP files were generated with a full Monte-Carlo simulation using the penEasy [4] code, a simulation for each energy up to 50 keV, in 1 keV bins. It takes several hours of CPU time to build up a database, but this only needs to be done once. These monochromatic PHSP files were binned and parameterized in terms of the relevant variables to make them easy to manipulate. On the other hand, percentage depth dose (PDD) curves were computed from each of the monoenergetic PHSP. A combination of those PDD is fitted to the experimental PDD of each applicator by means of a genetic algorithm [5] which optimized the energy spectrum. Finally, the binned precomputed monoenergetic PHSP files and the energy spectrum obtained by the genetic algorithm were combined to build the PHSP file optimized to describe the dose distribution of the considered applicator. From the final optimized PHSP file, the dose is computed by an in-house hybrid Monte Carlo algorithm [6] which takes into account condensed history simulations of both photoelectric and Compton interactions for X-rays up to 50 keV. The whole dose optimization and computation process was validated against Monte-Carlo simulations performed with penEasy as well as with gafchromic films dose measurements both in water and heterogeneous phantoms (bone, lung, air) for the spherical, needle, surface and flat applicators.

Results

Once the monoenergetic PHSP files and PDD database has been computed and stored, building the PHSP file optimized to a particular depth-dose curve in water only takes a few minutes in a single core (i7@2.5 GHz), for all the applicators considered in this work. From that PHSP file, the hybrid Monte Carlo code is able to compute dose distributions within 5 minutes. For all the applicators, dose distributions computed with the proposed strategy are in good agreement with the Monte Carlo simulations performed with penEasy. Gamma index calculation shows that more than 95% and 90% of the voxels fulfill the dose distance criteria of 2%/1mm in water and in the heterogeneous phantoms respectively.

Conclusion

The Monte Carlo PHSP files fitted to the experimental PDD for each applicator as described here, combined with the hybrid MC dose calculation tool compute fast and precise dose. This method is implemented into Radiance® (GMV SA, Spain), an IORT Treatment Planning System, for spherical, needle, surface and flat INTRABEAM® applicators.

References

[1] Vaidya, J. S. *et al*. 2010. TARGIT-A trial. Lancet, 376, 91-102.

[2] Schneider, F *et al*. 2011. Int J Radiat Oncol Biol Phys. 81(4):1114-9.

[3] Schneider, F. *et al*. 2014. J Appl Clin Med Phys, 15, 4502.

[4] J. Sempau *et al*. 2011. Med. Phys. 38(11), 5887.

[5] C. Fernández-Ramírez *et al*. 2008. Phys. Rev. C 77(6), p. 065212.

[6] M. Vidal *et al*. 2014. Radiother. & Oncol. 111(S1).