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Simultaneous optimization of photon, electron and proton beams

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Introduction
Recent research has shown the feasibility to combine the respective dosimetric advantages of photon and electron beams to achieve superior treatment plan quality (mixed beam radiotherapy MBRT) in comparison to pure photon therapy. Tumor treatment with proton beams on the other hand has distinct benefits in terms of reduced integral dose to a patient compared to photon beams. The purpose of this work is to develop a new and potentially superior treatment modality, called triple beam radiation therapy (TBRT), to exploit the advantages of photon, electron and proton fields.

Materials and Methods
The Eclipse treatment planning system (version 15.6), is used to set up beam directions for photon and electron fields and proton spot candidates for TBRT plans. The Swiss Monte Carlo Plan (SMCP) is used to calculate beamlet dose distributions for all three particle types. In order to investigate the potential of TBRT plans, a 4PI field setup for photons and protons is chosen. For the electrons, a coplanar setup with source to surface distance between 70-90 cm is chosen. A fluence map optimization (FMO) is performed to simultaneously optimize all three particle types to generate a TBRT plan. These FMO optimized 4PI TBRT plans are compared to MBRT plans in terms of DVH parameters for two academic, a clinical head and neck and a pelvic case. The PTVs in the two academic cases are located partly superficial and reaching into depths of up to 10 cm. The clinical head and neck case contains a mostly superficial PTV. For the pelvic case, the PTV is located between 0.5 to 7.5 cm within the body.

Results
While allowing three instead of just two (electron and photon) beam types, superior plan quality is achieved throughout all studied clinically motivated and academic cases. TBRT plans achieve better sparing of organs at risk (OARs). For instance, in the clinical pelvic case, the mean dose received by the bladder and the bowel is 36% and 73% lower for TBRT than for MBRT, respectively. The PTV homogeneity HI95 (V95-V107) improves by 2% and HI98 (V98-V102) improves by 18% for the TBRT plan in comparison to the MBRT plan. In the TBRT plan, each beam type contributes substantially to the dose distribution in the target. The mean dose fraction of each beam type delivered to the PTV in studied clinical cases are 40.5% electrons, 11.1% photons and 48.4% protons for the pelvic case and 19.8% electrons, 50.6% photons and 29.6% protons for the head and neck case.

Conclusion
A framework to simultaneously optimize photon, electron and proton beams based on Monte Carlo calculated beamlet dose distributions was successfully developed. FMO optimized triple beam treatment plans show dosimetric advantages, especially in sparing OARs in comparison to MBRT plans. The research is partially supported by Varian Medical Systems.

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