**Comparative analysis of $^{60}$Co intensity-modulated radiation therapy**

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## Abstract

In this study, we perform a scientific comparative analysis of using $^{60}$Co beams in intensity-modulated radiation therapy (IMRT). In particular, we evaluate the treatment plan quality obtained with (i) 6 MV, 18 MV and $^{60}$Co IMRT; (ii) different numbers of static multileaf collimator (MLC) delivered $^{60}$Co beams and (iii) a helical tomotherapy $^{60}$Co beam geometry. We employ a convex fluence map optimization (FMO) model, which allows for the comparison of plan quality between different beam energies and configurations for a given case. A total of 25 clinical patient cases that each contain volumetric CT studies, primary and secondary delineated targets, and contoured structures were studied: 5 head-and-neck (H&N), 5 prostate, 5 central nervous system (CNS), 5 breast and 5 lung cases. The DICOM plan data were anonymized and exported to the University of Florida optimized radiation therapy (UFORT) treatment planning system. The FMO problem was solved for each case for 5-71 equidistant beams as well as a helical geometry for H&N, prostate, CNS and lung cases, and for 3-7 equidistant beams in the upper hemisphere for breast cases, all with 6 MV, 18 MV and $^{60}$Co dose models. In all cases, 95% of the target volumes received at least the prescribed dose with clinical sparing criteria for critical organs being met for all structures that were not wholly or partially contained within the target volume. Improvements in critical organ sparing were found with an increasing number of equidistant $^{60}$Co beams, yet were marginal above 9 beams for H&N, prostate, CNS and lung. Breast cases produced similar plans for 3-7 beams. A helical $^{60}$Co beam geometry achieved similar plan quality as static plans with 11 equidistant $^{60}$Co beams. Futhermore, 18 MV plans were initially found not to provide the same target coverage as 6 MV and $^{60}$Co plans; however, adjusting the trade-offs in the optimization model allowed equivalent target coverage for 18 MV. For plans with comparable target coverage, **critical structure sparing was best achieved with 6 MV beams** followed closely by $^{60}$Co beams, with 18 MV beams requiring significantly increased dose to critical structures. In this paper, we report in detail on a representative set of results from these experiments. The results of the investigation demonstrate the potential for IMRT radiotherapy employing commercially available $^{60}$Co sources and a double-focused MLC. Increasing the number of equidistant beams beyond 9 was not observed to significantly improved target coverage or critical organ sparing and static plans were found to produce comparable plans to those obtained using a helical tomotherapy treatment delivery when optimized using the same well-tuned convex FMO model. While previous studies have shown that 18 MV plans are equivalent to 6 MV for prostate IMRT, we found that the 18 MV beams actually required more fluence to provide similar quality target coverage.