

Introduction

For this study DICOM files of clinical Rapidarc plans were modified with in-house developed software to mimic leaf alignment errors and gravitation shifts. The effects of these simulated errors were investigated through quality assurance measurements with the Octavius 2D-ARRAY (PTW-Freiburg) in sagittal and coronal orientation and the Delta4 device (Scandidos). We also establish a connection between the passing rate of QA measurements with both devices for small leaf alignment errors and their clinical significance by recalculating the manipulated plans in Eclipse.

Methods and Materials

Based on the idea of a Matlab based prototype of MLC editor software provided to us by Prof. Wayne Beckham at the BCCA and Mike Oliver (Oliver & al, 2010)¹, we developed this software into a stand-alone and user-friendly software tool so it could easily be used by service engineers or customers for troubleshooting or to support the commissioning of their Rapidarc program.

Different errors were simulated and applied to five prostate (two arcs), three 2-arc head&neck and three 3-arc head&neck cases: (1) both MLC banks are opened by 0.25mm, 0.50mm and 1.00mm in opposing directions resulting in larger fields, (2) both MLC banks are closed by 0.10mm, 0.25mm and 0.50mm, (3) both MLC banks are shifted in the same direction for lateral gantry angles to simulate effects of gravitational forces onto the leaves by 1mm, 2mm and 3mm. In order to detect the modifications the QA measurements were evaluated according to a gamma-index criterion of 2mm/2% and a passing rate of 90%. All modified plans are recalculated in Eclipse and the dose volume histograms are analyzed with respect to the minimum, maximum and mean dose to the PTV.

MLC modification	1. error	2. error	3. error
Type 1 (open MLC leaf banks)	0.25mm	0.50mm	1.00mm
Type 2 (close MLC leaf banks)	0.10mm	0.25mm	0.5mm
Type 3 (gravitational shift)	1mm	2mm	3mm

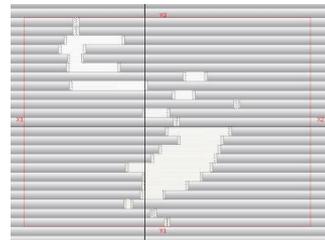


Fig. 1: Homogeneity Index (average and standard deviation)

Results

The opening of both MLC banks has a direct effect on the mean dose, increasing it by 3%-6% for the largest modification of only 1mm. These plans fail the passing criteria for both devices. Closing the leaves has a similar effect, decreasing the mean dose by >3% for prostate cases and >1% for head&neck cases. Simulated gravitation shifts drastically change the minimum and maximum dose of the PTV while the mean dose stays within ±2% even for a 3mm shift. Although a 2mm shift shows a >8% decreased minimum and >3% increased maximum dose to the PTV the QA measurements fail a >90% passing rate only in half of the cases. With the standard criteria (3mm, 3%) even the largest modifications would satisfy a >90% passing rate. This indicates that a global criterion for the passing rate would not be sufficient in all cases. All unmodified plans and the majority of the plans with the smallest modification pass the g-index criterion of 2%/2mm with >90%.

Discussion and Conclusion

Both devices are able to detect MLC positional errors of the investigated magnitude. A stricter g-index (2mm, 2%) is necessary in order to detect MLC positional errors and a passing rate of >90% should be expected. This still does not always guarantee that positional errors with clinical significance are detected. A closer look as to where discrepancies occur and professional judgment is needed when interpreting the g-index analysis.

¹Oliver, M., & al, e. (2010). Clinical significance of multi-leaf collimator positional errors for volumetric modulated arc therapy. *Radiotherapy & Oncology*.

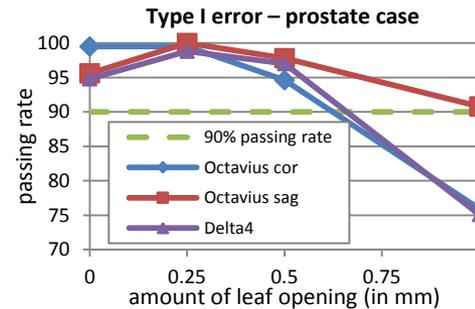


Figure 2: 2%/2mm Gamma passing rates changed with an increase of the magnitude of a type 1 error for a prostate case.

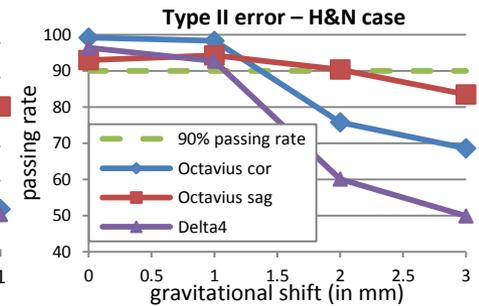


Figure 3: 2%/2mm Gamma passing rates changed with an increase of the magnitude of a type 2 error for a prostate case.

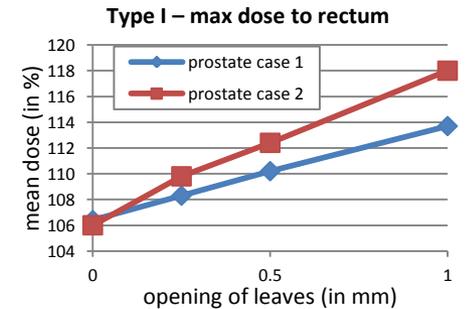
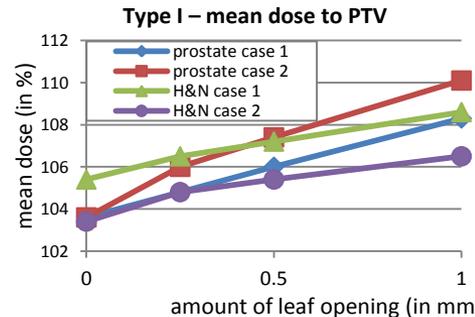


Figure 4: The two graphs show the change in mean dose to the PTV (left) and maximum dose to the rectum (right) for an increase of the magnitude of a type 1 error

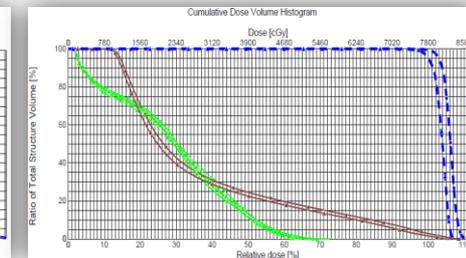
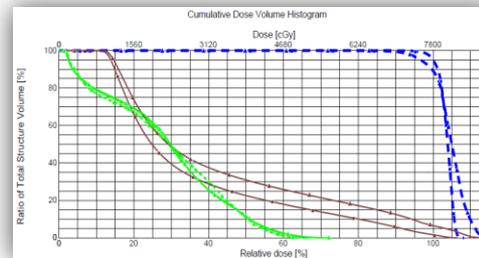


Fig. 5: Two DVHs of prostate cases comparing the original plan (Δ) and (a) type 1 modified plan with a 0.50mm MLC leaf bank opening (◻) and (b) type 3 modified plan with a 2mm gravitational shift. Displayed are the curves for the PTV (blue), the rectum (brown) and the left and right femoral heads (green).