VMAT SRS Comparison on IROC Houston SRS Phantom

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Introduction

HyperArc is a new treatment methodology offered by Varian Medical Systems for TrueBeam linear accelerators. HyperArc consists of up to 3 non-coplanar arcs and 4 couch positions that change with a single beam on while keeping the isocenter stable. This method of treatment can be used to treat brain lesions smaller than a centimeter, treat multiple lesions with a single isocenter, or treat multiple isocenters in a single patient, all while maintaining excellent conformality and gradient. When compared to VMAT or other traditional methods of intensity modulated radiation therapy (IMRT) treatment planning, HyperArc consistently has smaller R25 (the radius of a normalized sphere of volume 25% of RX) and R50 values and a smaller gradient measure (GM). The goal of this project was to assess the contributions of adding couch positions or arcs and, based on their impacts on the R25, R50, and GM values, to determine which of these parameters were ultimately more impactful on the radiation therapy treatment plan. We showed that the addition of Non-Coplanar arcs through couch positions and, to a lesser extent, the addition of additional coplanar arcs aid in reducing R25, R50, and GM values until they converge upon the treatment beam configuration that is included in the Hyperarc planning methodology.

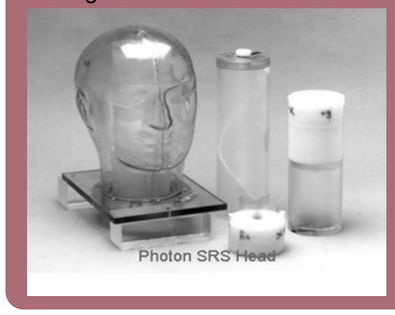

Figure 1: Houston IROC SRS Phantom

Methodology

The necessary techniques and tools to record this data included a Varian TrueBeam 4.0 multiple energy linear accelerator with Millennium 120 Leaf Collimator and the 6FFF (Flattening Filter-Free) energy beam with a high dose rate of 1,400 MU per minute (Figure 2). The planning was completed using the Eclipse 16.1 planning system and the phantom SRS (Figure 1). The technique **first** used was coplanar VMAT, which involved the utilization of varying numbers of coplanar arcs that were optimized in Eclipse. The **second** technique was non-coplanar VMAT, which utilizes varying numbers of noncoplanar arcs that were optimized in Eclipse. The **third** and final technique used was HyperArc, specifically the Varian HyperArc protocol (Figure 4), which utilizes discrete markers in a predetermined configuration associated with specific facemask immobilization to nominally define couch and patient position and then applies a series of coplanar and non-coplanar arcs (1 and 3, respectively) using couch rotational changes. All plans were then normalized to the conformity index such that 100% of the prescription dose covered 95% of the target volume. This allowed for direct comparison of the plans. For the metric of comparison, the GM value was the most appropriate due to it being related to the quality of both the R25 and R50 values.

Figure 2: Varian TrueBeam 4.0

Data and Tables

Three ring structures were made according to University of Alabama technique (Figure 3). The inner ring was made by expanding 5mm outside PTV, the middle ring by expanding1cm outside PTV, and the outer ring by expanding 3cm outside PTV. Boolean Subtraction was used to remove all overlapping regions of the rings and PTV. Using the Acuros algorithm from Varian *Medical Systems* and a calculation grid of 1mm, the rings were optimized to minimize the low dose regions beyond the PTV.

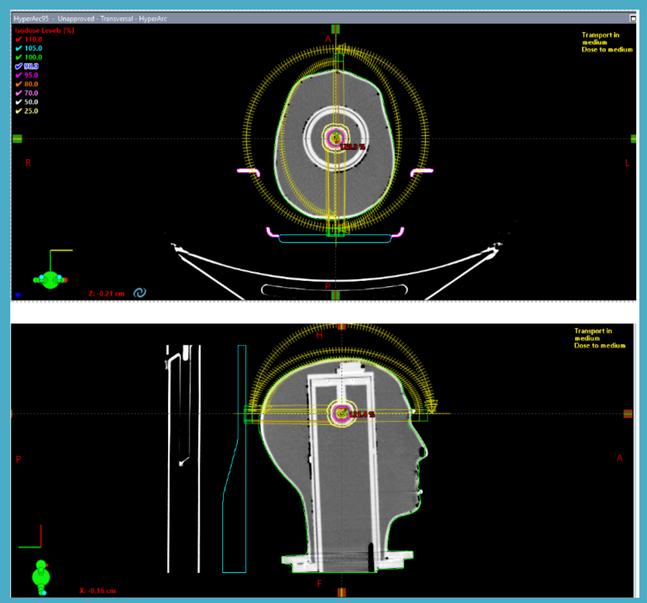

Figure 3: Ring Structures

Planned VMAT beam configurations consisted of 2 Full Arcs Coplanar, 2 Full Arcs Non-Coplanar (+/- 15° Couch Rotation Incrementation), 4 Full Arcs Coplanar, 4 Full Arcs Non-Coplanar (+/- 15° Couch Rotation increments), and HyperArc 4 Arcs Non-Coplanar. HyperArc configuration consisted of 1 full arc and 3 partial arcs including couch rotation from 0° to 90°. This was normalized to the Conformality index of 95% and evaluated on the GM. In figure 4 below, the first value is the number of couch positions, while the second is the number of arcs.

Number of Couch Positions, Number of Arcs	R25 (cm)	R50 (cm)	Gradient Measure (cm)
0,1:	2.3458	1.4973	0.53
0,2:	2.328	1.498	0.53
0,3:	2.3301	1.4962	0.53
0,4:	2.3068	1.489	0.52
2,2:	2.054	1.4485	0.48
2,3:	2.0932	1.4485	0.49
2,4:	2.0604	1.4462	0.48
3,3:	2.093	1.4489	0.49
3,4:	2.0604	1.4458	0.48
Hyper Arc:	1.85	1.36	0.39

Table 1: Tabulation of Treatment Data

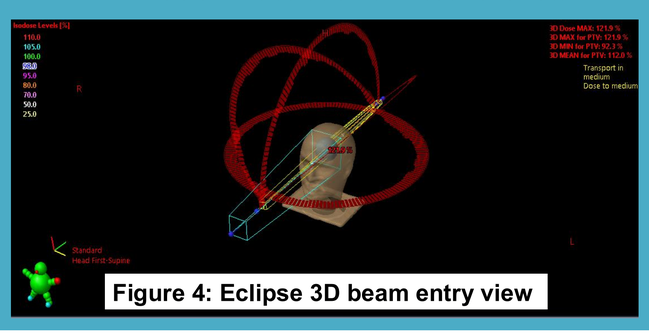

Figure 4: Eclipse 3D beam entry view

Results

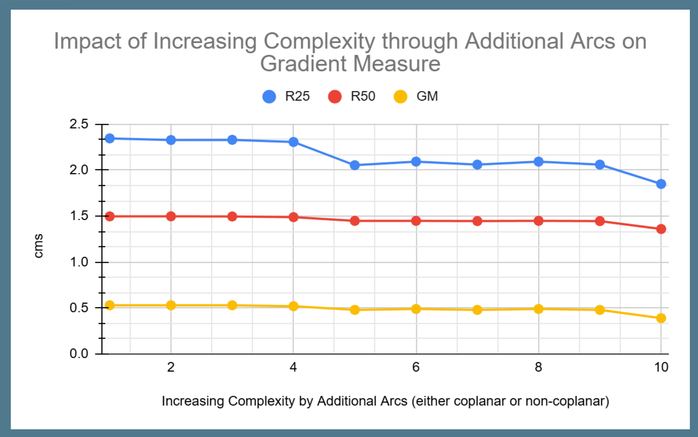

Figure 5: Graph of Relative Contribution

There are four trends to be observed concerning the number of arcs (Figure 5). Every point with an odd number of arcs was visibly worse in terms of its R25, R50, and GM values compared to the data points with an even number of arcs. These points were 1, 3, 6, and 8. The second observed trend is that the addition of couch kicks demonstrated an immediate drop in R25, R50 and GM values, as seen in point 5. However, that trend had a diminutive impact, as seen with the addition of couch positions on data point 8. This could be attributed to it having an odd number of arcs. Thirdly, the HyperArc data in point 10 demonstrated another visibly dramatic drop in R25, R50, and GM values. The last trend to be observed would be that while the addition of arcs did lower the R25, R50, and GM values, the biggest drops occur at points 5 and 10, which are the first addition of a couch position and the HyperArc respectively.

Conclusion

The HyperArc technique with the large couch rotations and vertex arc was able to best restrict the spread of the low dose scatter, as evidenced by the R50 and R25 value without distorting the Conformity Index (CI). In this very simplified case in which the results are very similar, the VMAT arc plans performed similarly scaling with the degrees of rotation: increased degrees of rotation in the couch yielded shorter R25, R50, and GM values. In treatment plans with real-world patient anatomy complexities, this difference will likely become more pronounced as the algorithm deals with tissue inhomogeneities and dose optimization criteria. Lastly, as seen by the data, as more couch positions and arcs were added, they began to approach the values achieved through the HyperArc plan and, as the data showed, the addition of non-coplanar arcs impacted the final GM of each plan to a greater degree than simply adding additional arcs.

Sources

- SRS Head:
Stereotactic Radiosurgery Head phantom. (n.d.). https://irochouston.mdanderson.org/rpc/services/Anthropomorphic_%20Phantoms/Phantom_SR_Head.htm

- Three Ring Definition and Houston IROC SRS Phantom:
Clark GM;Popple RA;Prendergast BM;Spencer SA;Thomas EM;Stewart JG;Guthrie BL;Markert JM;Fiveash JB; (n.d.). *Plan quality and treatment planning technique for single isocenter cranial radiosurgery with volumetric modulated arc therapy*. Practical radiation oncology. https://pubmed.ncbi.nlm.nih.gov/24674169/