VMAT for SSRS in C-spine cases: Using partial dual arcs and full dual arcs

Jose Berlanga, B.S.; Lillian Bratvedt, B.S.; Hai Nhu Ho, B.S.; Yosan Okbamichael, B.S.; Shirly Kuruvila, B.S., C.M.D.; Dennis Mackin, Ph.D.; Lori Simmons, M.S., C.M.D.

The University of Texas at MD Anderson Cancer Center School of Health Professions

THE UNIVERSITY OF TEXAS MD Anderson Cancer Center

ABSTRACT

The purpose of this study is to evaluate the quality of volumetric modulated arc therapy (VMAT) for cervical spine (C-spine) stereotactic radiosurgery (SSRS) relative to intensity-modulated radiation therapy (IMRT).

Planning C-spine cases is difficult due to the proximity of organs at risk (OARs). IMRT is one of the preferred methods to treat C-spine SSRS since it allows the dosimetrist to select beam angles that avoid entering or exiting critical structures such as the spinal cord.

Ten C-spine cases, retrospectively treated with IMRT, were selected and re-planned with two different VMAT methods. The first method used four posterior partial arcs (partial-dual arcs), and the second method consisted of two full arcs (full-dual arcs).

After evaluating the dose volume histogram (DVH) and dose statistics, VMAT was able to achieve better improvements in conformality, OAR sparing, and target coverage than the IMRT plans. Depending on the location of the disease, VMAT showed better improvement as it reduces patient time on the table and minimizes the chance of setup error during treatment.

INTRODUCTION

A concern that has kept SSRS treatment from transitioning to VMAT is the need to spare OARs. IMRT is a method for treating spinal metastases due to the specific beam angles necessary to avoid treating through OARs, such as the shoulders, esophagus, larynx, pharynx, brachial plexus, and spinal cord. However, it is possible to achieve comparable coverage of target volumes while sparing the majority, if not all, OARs when planning with VMAT. For some critical structures, VMAT could spare OARs with greater results compared to IMRT.

One of the goals in treating SSRS cases is achieving target coverage and a steep dose fall-off from the tumor to the spinal cord. Patient comfort and safety are also important during radiation treatment, and another benefit VMAT can offer is the rapid delivery of radiation that allows for improved patient comfort and reduction in intrafraction motion. Any slight movement by the patient can cause an overdose of radiation to normal tissues.

The working theory is that VMAT will perform either just as good or better than IMRT for cervical SSRS when evaluating target coverage, OAR dosage and dose conformality. VMAT yields plans where the low dose is more conformal to the targets, and this study will attempt to give evidence of better controlled low dose, target coverage and OAR sparing.

CONTACT

Jose Berlanga
MD Anderson Cancer Center
Email: jlberlanga@mdanderson.org
Phone: 281 726 6661

METHODS

The ten selected IMRT cases were each replanned with VMAT. Each patient was prescribed either 27 Gy in 3 fractions, 24 Gy in 1 fraction, or 18 Gy in 1 fraction to the gross tumor volume (GTV). The first plan utilized one full dual arc with gantry angles starting at 182° to 178° clockwise followed by 178° to 182° counterclockwise with collimator angles of 85°. The second plan consisted of using two partial dual arcs starting at 182° to 265° followed by 95° to 178° with collimator angles of 85° and 95° respectively. The same objectives were used in both plans for each case to eliminate bias.

Conformity index (CI) was analyzed where an index value between 0 and 1 is acceptable for the given isodose level, and a value closer to 1 indicates a more conformal plan. The index is defined as the ratio between the region of interest volume covered by the isodose and the total isodose volume.
The max point dose of 0.1cc volume (D0.01cc) was evaluated and had to be less than 10 Gy or 12 Gy depending on the prescription. Furthermore, due to a possibility of recurrence, the spinal cord tolerance was prioritized and needs to receive the lowest dose or as low as reasonably achievable (ALARA).

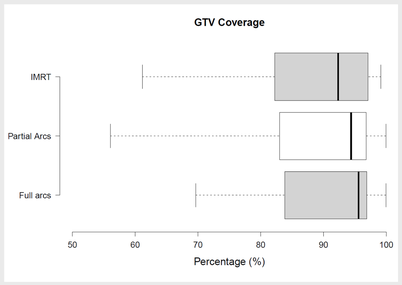

Figure 1. GTV Coverage

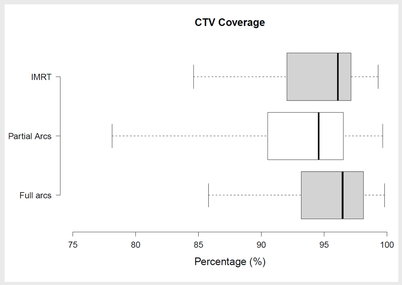

Figure 2. CTV Coverage

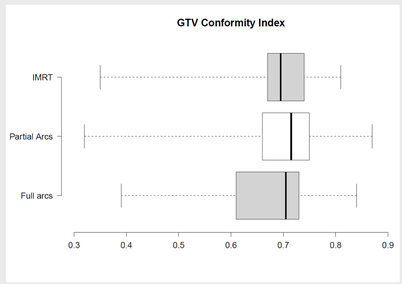

Figure 3. GTV Conformity Index

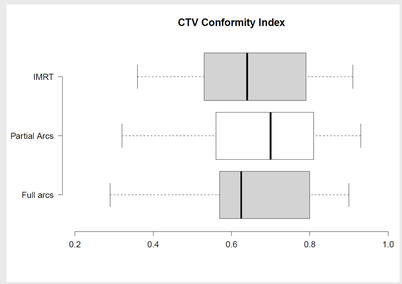

Figure 4. CTV Conformity Index

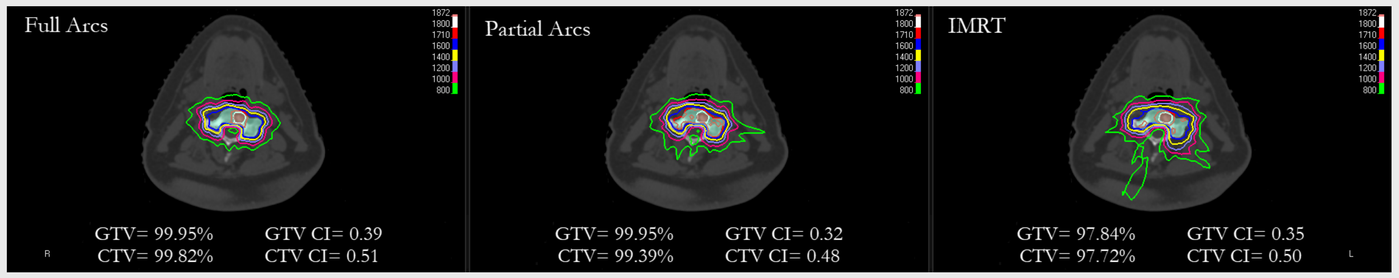

Figure 5. 3 Plan Comparison for 18 Gy Prescription

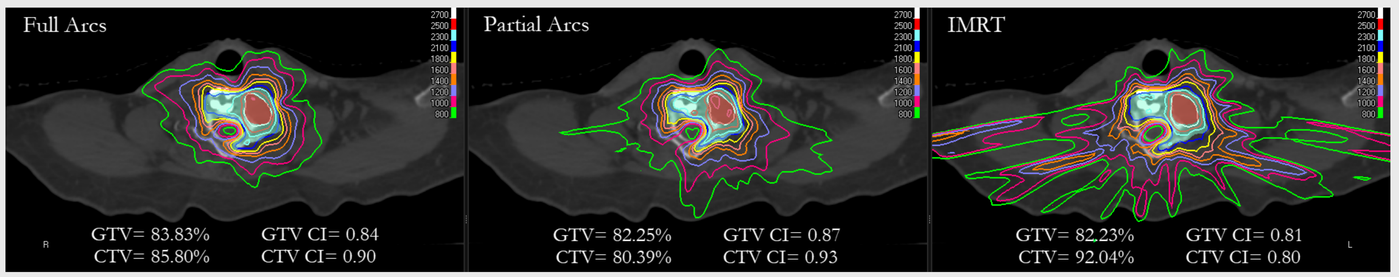

Figure 6. 3 Plan Comparison for 27 Gy Prescription

OAR Mean Comparison for 18 Gy, 24 Gy, 27 Gy Prescription

			Full Arcs	Partial Arcs	IMRT	Percent Difference (%)	
Prescription	OAR	Constraint	Mean	Mean	Mean	Full Arcs	Partial Arcs
18 Gy	Spinal Cord	V_{10Gy}	0.13 ± 0.17	0.15 ± 0.18	0.41 ± 0.40	-67.21	-63.93
		$D_{0.01cc}$	11.66 ± 0.23	11.76 ± 0.40	12.05 ± 0.93	-3.24	-2.41
	Pharynx	$D_{0.01cc}$	16.23 ± 0.53	16.71 ± 0.27	16.52 ± 0.43	-1.76	1.19
24 Gy	Spinal Cord	V_{10Gy}	0.09 ± 0.08	0.05 ± 0.05	0.44 ± 0.29	-78.95	-88.72
		$D_{0.01cc}$	11.21 ± 1.00	10.79 ± 1.06	12.02 ± 0.23	-6.74	-10.24
	Pharynx	$D_{0.01cc}$	16.99 ± 1.37	17.49 ± 0.70	17.07 ± 1.24	-0.44	2.46
	Lt Brachial Plexus	$D_{0.01cc}$	21.98	21.87	23.49	-6.43	-6.90
	Rt Brachial Plexus	$D_{0.01cc}$	15.73	16.00	15.34	2.54	4.30
27 Gy	Spinal Cord	V_{9Gy}	0.06 ± 0.02	0.06 ± 0.05	0.05 ± 0.02	9.52	19.05
		$D_{0.01cc}$	9.68 ± 0.32	9.76 ± 0.39	9.79 ± 0.27	-1.15	-0.33
	Pharynx	$D_{0.01cc}$	21.93 ± 1.77	21.78 ± 2.83	18.50 ± 4.19	18.52	17.69
	Lt Brachial Plexus	$D_{0.01cc}$	25.15 ± 2.64	22.78 ± 3.80	26.14 ± 4.19	-3.80	-12.87
	Rt Brachial Plexus	$D_{0.01cc}$	24.08 ± 6.30	21.94 ± 5.46	24.92 ± 4.35	-3.37	-11.96

Table 1. OAR Mean Data Comparing VMAT to IMRT

RESULTS

A negative value indicates less dose was received to that structure, whereas a positive value reflects more dose. With respect to the OARs, a negative percentage was deemed a success, and a positive percentage was desired for target structures.

For the plans prescribed to 18 Gy in one fraction, coverage to the GTV and CTV increased with both VMAT modalities. Full arcs were able to achieve higher coverage to the targets than partial arcs. The CI for the VMAT plans presented an increase in the mean percent difference indicating that the VMAT plans had better conformality than the IMRT plans. Additionally, VMAT plans achieved more coverage while reducing the maximum allowable dose to the targets. The spinal cord constraints showed significant sparing for the VMAT plans compared to the IMRT plans.

For the plans prescribed to 24 Gy in one fraction, partial arcs achieved better GTV coverage and CI values than the full arcs plans. The minimum 15 Gy (Dmin15Gy) to the GTV was evaluated for all three plans. This constraint is important to achieve in SSRS cases to reduce the probability of recurrence. The mean percent difference for the Dmin15Gy for both VMAT plans were significantly lower than IMRT. One reason why the Dmin15Gy was not met is because a portion of the GTV overlapped with the spinal cord making it difficult to achieve a plan that met both target coverage and OAR tolerance. The maximum allowable dose to the targets was significantly reduced for the VMAT plans. The spinal cord and larynx constraints showed significant sparing. The mean constraints for the right brachial plexus increased compared to IMRT. However, it is worth mentioning that this was the only case that tracked dose to the brachial plexuses for cases to 24 Gy; therefore, it lacks adequate data comparison.

For the plans prescribed to 27 Gy in three fractions, full arcs and partial arcs showed contrasting advantages with target coverage versus sparing dose to OARs when compared to the IMRT plan. Plans with full arcs performed significantly better in terms of target coverage, but OAR sparing was subpar. On the other hand, partial arcs resulted in lower target coverage but decreased dose to the OARs. One possibility could be due to the limitations of the gantry angles. The partial arcs delivered dose posteriorly, and their smaller number of control points provided less coverage than the full arcs. This supposition could explain the lack of target coverage and lower dose to critical structures. One would have to ascertain whether the increase in target coverage is worth the decrease in OAR sparing.

CONCLUSIONS

Overall, dose conformality and target coverage increased while dose to OARs decreased. VMAT plans have shown to be more conformal than the IMRT plans, and the CI for most plans only varied by ± 0.01-0.03. It was expected that the CI would have increased more for the VMAT plans given how well the low dose was controlled. For the 18 Gy and 24 Gy prescriptions, VMAT was able to spare the spinal cord better than IMRT. However, for 27 Gy, IMRT was able to better spare the cord. When evaluating which method to use, tumor location, prescription, and surrounding OARs should be considered.

More studies should be conducted to help determine if VMAT continually outperforms IMRT in the parameters listed above. The researchers suggest using the same prescription and having the same baseline objectives for each plan or having one dosimetrist plan the cases. Planning time should also be measured when evaluating the different treatment modalities to procure if VMAT planning time had an advantage over IMRT.