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Volumetric modulated arc therapy for spine SBRT patients to reduce treatment time and intrafractional motion

Ahmad Amoush, Allison Dalton, Bryan Rabatic, Ke Huang, Ahmad Al-Basheer

Department of Radiation Oncology, Georgia Regents University, Augusta, Georgia, USA

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Case Report

Abstract

Volumetric modulated arc therapy (VMAT) is an efficient technique to reduce the treatment time and intrafractional motion to treat spine patients presented with severe back pain. Five patients treated with spine stereotactic body radiation therapy (SBRT) using 9 beams intensity modulated radiation therapy (IMRT) were retrospectively selected for this study. The patients were replanned using two arcs VMAT technique. The average mean dose was 104% ± 1.2% and 104.1% ± 1.0% in IMRT and VMAT, respectively (p = 0.9). Accordingly, the average conformal index (CI) was 1.3 ± 0.1 and 1.5 ± 0.3, respectively (p = 0.5). The average dose gradient (DG) distance was 1.5 ± 0.1 cm and 1.4 ± 0.1 cm, respectively (p = 0.3). The average spinal cord maximum dose was 11.6 ± 1.0 Gy and 11.8 ± 1.1 Gy (p = 0.8) and V_{10Gy} was 7.4 ± 1.4 cc and 8.6 ± 1.7 cc (p = 0.4) for IMRT and VMAT, respectively. Accordingly, the average number of monitor units (MUs) was 6771.7 ± 1323.3 MU and 3978 ± 576.7 MU respectively (p = 0.02). The use of VMAT for spine SBRT patients with severe back pain can reduce the treatment time and intrafractional motion.

Keywords: VMAT; SBRT; Spine

Introduction

Spine stereotactic body radiation therapy (SBRT) delivers high ionization radiation to provide adequate dose to the target while sparing the surrounding normal structures. Doses usually ranges from 16 to 24 Gy in a single fraction or 24 to 35 Gy in 2 to 5 fractions.[1] The tight planning margins and steep dose gradients require accurate targeting and immobilization of the target during irradiation. Patients with spinal metastasis usually present with a back pain and some neurologic problems.[2-3] The difficulty in applying radiosurgery for spinal patients is due to intrafractional motion associated with the pain. Even with a good immobilization technique, the patient can move during the treatment therefore shortening the irradiation time is an efficient factor to reduce the intrafractional motion.

Ryu *et al.* [4] reported a precision for a given isocenter between simulation and actual treatment position of 1.36 mm ± 0.11 mm. Li *et al.* [5] quantified the interfractional and intrafractional motion for spine SBRT patients using different immobilization devices. They reported the results based on cone-beam computed tomography (CBCTs) on initial setup residual error and the mid- and post- treatment CBCTs. For mid-treatment intrafractional motions, they reported standard deviation (SDs) of < 1 mm for vacuum fixation and S-frame cohorts but increased to 1.1 mm for evacuated cushion. For post-treatment, they reported intrafractional motion of < 1 mm for vacuum fixation and 1.3 mm for evacuated cushion and S-frame groups. Maximum translational displacements at mid-treatment and post-treatment CBCTs were 3.4 mm in the lateral direction (vacuum fixation), and 4.5 mm in the lateral direction (evacuated cushion), respectively. These results suggested using the vacuum fixation to reduce the intrafractional motion. Also, shortening the treatment time will reduce the intrafractional motion especially when patient presents with severe back pain.

Volumetric modulated arc therapy (VMAT) is a rotational intensity modulated radiation therapy (IMRT) that can be delivered by varying the MLC leaf speed, dose rate and gantry speed. The advantage of VMAT when compared to the fixed field IMRT delivery is reduction of the treatment time while maintaining the similar, if not superior plan quality as the fixed field IMRT.[6, 7, 8] Matuszak *et al.* [9] compared VMAT with fixed field IMRT for spine SBRT treatment and concluded that VMAT improved the isodose conformality and reduced the treatment time by 37%. The Eclipse treatment planning system uses a 3D pencil beam superposition-convolution algorithm (AAA) for dose calculations. Rana *et al.* [10] compared the AAA with Acuros XB (AXB) for lung SBRT and concluded that both algorithms satisfy the lung SBRT protocol. In this study, we are presenting five cases which were treated at our institution with SBRT for spine metastases using Intensity Modulated Radiation Therapy (IMRT). The cases were replanned using VMAT (Vari-

Corresponding author: Ahmad Amoush; Department of Radiation Oncology, Georgia Regents University, Augusta, Georgia, USA.

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an-RapidArc system) to study the reduction in treatment time, monitor units, and conformality index.

Methods and Materials

Patient selection

Five patients were retrospectively selected for this study. All patients were treated at our institution with spine SBRT using 9 fields IMRT plans. The treatment sites ranged from T5-L5 and the volume ranged from 25 to 100 cc (**Table 1**). Patients were treated following the recommendations of Radiation Therapy Oncology Group 0631 (RTOG-0631) [11] and Task Group 101 of the American Association of Physicists in Medicine (AAPM-TG 101).[12] Varian Trilogy and 23IX linear accelerators (Varian Medical systems, Palo Alto, CA) were used to deliver radiation. Only 23IX at our institution has the ability to deliver RapidArc plan. Both machines are equipped with kilovoltage cone beam computed tomography (kV-CBCT) and a 120 leaf dynamic millennium multileaf collimator (DMLC).

TABLE 1: Spine SBRT patient data and treatment techniques.

Pt. No.	Site	PTV Volume (cc)	Technique
1	L4	25.5	9 Fields-IMRT
2	T7-8	100.1	9 Fields-IMRT
3	T5	40.5	9 Fields-IMRT
4	L3-L4	83.8	9 Fields-IMRT
5	T11-12	36.7	9 Fields-IMRT

Treatment plan design

Treatment plans were designed to achieve the recommendations of RTOG-0631 and AAPM TG-101 for SBRT.[11, 12] The prescription dose was 18 Gy in a single fraction to 95% of the target volume. Image fusion between simulation computed tomography (CT) and T2-weighted and T1-weighted MRI with contrast was used to delineate the radiosurgery target and the partial spinal cord. No margins were added to the target volume. The partial spinal cord was contoured from 5-6 mm above to 5-6 mm below that target volume. Only 6 MV photon energy was used with a standard dose rate. Eclipse 10.0 (Varian Medical systems, Palo Alto, CA) was used to design the RapiArc plans. For each plan, the progressive resolution optimizer (PRO) algorithm allows the variation of MLC leaf positions, gantry speed, and dose rate to produce a plan based on dose-volume objectives.

Final dose calculation using the analytical anisotropic algorithm (AAA) was performed with a grid size of 2.5 mm. Two partial arcs were selected as recommended by Wu *et al.*[13] The arcs angles were (1) counterclockwise (CCW) from 0.1^0 to 359.96^0 with avoidance sector from 129.9^0 to 230.1^0 (2) clockwise (CW) from 359.9^0 to 0.1^0 with avoidance sector from 129.9^0 to 230.1^0. Collimator angles were ranged from 30^0 to 90^0. **Figure 1** shows the IMRT and RapidArc beam setup. The planning objectives for the RapidArc and IMRT optimization are listed in **Table 2**.

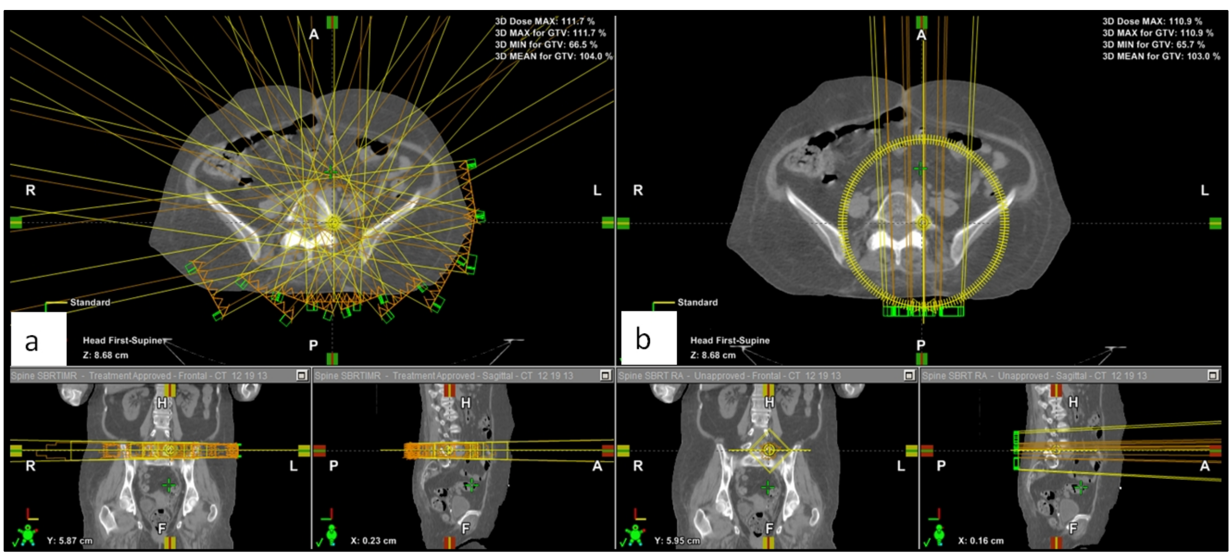

FIG. 1: Beam setup for (a) IMRT plan with 9 beams; and (2) RapidArc with two arcs.

TABLE 2: Planning objectives for IMRT and RapidArc planning.

Volume	Objective
Target	$D_{95\%}$ = 16Gy
Cord	V_{10Gy} < 10% Max < 14Gy
Maximum dose outside the PTV	< 110% of the RX dose
Dose outside the PTV + 1 cm	< 105% of the RX dose

Plan evaluation

Dose volume histograms (DVHs) were evaluated for the target and spinal cord. For the target, the dose to 95% of the volume (D95%), the maximum dose to 1cc (Dmax1cc), number of MUs, and the conformity index (CI), and the dose gradient (DG) in centimeters (cm) were assessed. Conformity index is defined by International Commission on Radiation Units and Measurements (ICRU) no. 62 [14] as the total volume receiving the prescription dose (cc)/volume of target (cc). Gradient in cm is defined as the difference between the equivalent sphere radius of the prescription and half-prescription isodoses. Cord maximum dose and volume receiving 10Gy (V_{10Gy}) were evaluated as well. A quality assurance (QA) was performed for all patients using Portal Dosimetry 10.0 software (Varian Medical systems, Palo Alto, CA). The QA images were acquired on amorphous silicon (aSi) EPID. Gamma index values for IMRT and RapidArc were compared. Gamma values such as maximum gamma (γ_{max}), average gamma (γ_{avg}), and percentage of the field area with a γ value greater than 1.0 (γ>1) were used to evaluate the QA plans.

Results

Target volume coverage

For each case, the target volume receiving 100% of the prescription dose was 95% ($V_{100\%}$ = 95%). The CI, D_{min} (%), D_{max} (%), D_{mean} (%), and DG for the target were essentially equivalent. **Table 3** summarizes the dosimetric indices of the target. Single factor ANOVA showed no differences between the three groups. Conformal index was not significant among the groups. **Figure 2** shows the dose distribution for IMRT and RapidArc for Pt. 1 in **Table 1**.

TABLE 3: Summary of dosimetric results for the planning target volume (PTV).

	IMRT	RapidArc	*P*-value (ANOVA)
	Average±SD	Average±SD	
D_{mean} (%)	104.1±1.2	104.1±1.0	0.9
CI	1.3±0.1	1.5±0.3	0.5
D_{max} (%)	113.1±5.9	113.6±5.6	0.9
D_{min} (%)	78.9±16.3	79.4±15.7	0.9
DG (cm)	1.5±0.1	1.4±0.1	0.3

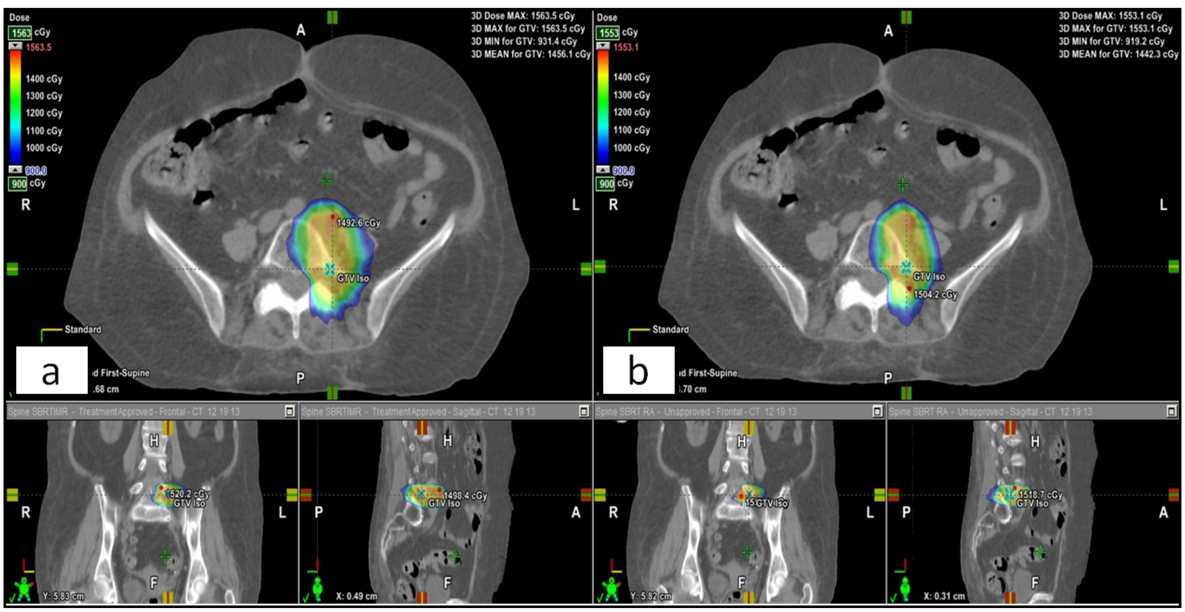

FIG. 2: Dose distribution in color wash for pt. no. 1 in **Table 1** (a) IMRT plan; and (b) RapidArc plan.

Spinal cord dose sparing

Maximum dose to the Cord and the volume receiving 10 Gy were within the tolerances as recommended by RTOG-0631 and AAPM TG-101. **Table 4** summarizes the results.

TABLE 4: Summary of the dosimetric results for spinal cord.

	IMRT	RapidArc	*P*-value (ANOVA)
Dmax	11.6±1.0	11.8±1.1	0.8
V_{10Gy}	7.4±1.4	8.6±1.7	0.4

TABLE 5: Summary of the average MUs for 2.5 mm, 4 mm, and 5 mm MLC leaf width.

Technique	Average MU	*P*-value (ANOVA)
IMRT	6771.7±1323.3	0.02
RapidArc	3978±576.7	

Total number of MUs and gamma evaluation

Table 5 summarizes the average number of MUs delivered for each technique. The data shows clearly that the number of MUs using RapidArc technique was reduced significantly compare to the IMRT technique (p = 0.02). Gamma evaluation showed a good agreement between the two techniques. The area of gamma < 1.0 was above 90% in both techniques.

Discussion

Spine SBRT requires a delivery of high dose to irregularly shaped target. The dose falloff outside the target necessary should be rapid to avoid any injury to the spinal cord. In this study we investigated the influence of using RapidArc on the plan quality and delivery time as shown in **Tables 4** and **5.** The target coverage, CI, DG, minimum dose, mean dose and maximum dose were equivalent with no significant differences. The spinal cord dosimetric indices were equivalent among the two techniques with no significant differences. The number of MUs was reduced by ~60% using the RapidArc. As a result of that, the treatment time would be reduced significantly by if RapidArc was used for treatment. Li *et al.*[5] reported maximum translational displacements at mid-treatment and post-treatment CBCTs as 3.4 mm in the lateral direction (vacuum fixation), and 4.5 mm in the lateral direction (evacuated cushion), respectively. This intrafractional motion can be due to the long treatment time especially for patients with severe back pain so using RapidArc for spine SBRT patients will reduce the treatment time and intrafractional motion significantly.

Conclusion

The use of RapidArc for planning spine SBRT patients achieved the same plan quality as the IMRT and as recommended by RTOG-0631 and AAPM TG-101. It can also significantly reduce the treatment time and the intrafractional motion. Reduction in treatment time and intrafractional motion can reduce the treatment uncertainties specially for patients presented with severe back pain.

Conflict of interest

The authors declare that they have no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

References

1. Sahgal A, Larson DA, Chang EL. Stereotactic body radiosurgery for spinal metastases: a critical review. *Int J Radiat Oncol Biol Phys* 2008; 71:652-65.
2. Loblaw DA, Laperriere NJ. Emergency treatment of malignant extradural spinal cord compression: an evidence-based guideline. *J Clin Oncol* 1998; 16:1613-24.
3. Ryu S, Jin R, Jin JY, *et al.* Pain control by image-guided radiosurgery for solitary spinal metastasis. *J Pain Symptom Manage* 2008; **35**:292-8.
4. Ryu S, Fang Yin F, Rock J, *et al.* Image-guided and intensity-modulated radiosurgery for patients with spinal metastasis. Cancer 2003; **97**:2013-8.
5. Li W, Sahgal A, Foote M, *et al.* Impact of immobilization on intrafraction motion for spine stereotactic body radiotherapy using cone beam computed tomography. *Int J Radiat Oncol Biol Phys* 2012; **84**:520-6.
6. Otto K. Volumetric modulated arc therapy: IMRT in a single gantry arc. *Med Phys* 2008; **35**:310-7.
7. Cozzi L, Dinshaw KA, Shrivastava SK, *et al.* A treatment planning study comparing volumetric arc modulation with RapidArc and fixed field IMRT for cervix uteri radiotherapy. *Radiother Oncol* 2008; **89**:180-91.
8. Oliver M, Ansbacher W, Beckham WA. Comparing planning time, delivery time and plan quality for IMRT, RapidArc and Tomotherapy. *J Appl Clin Med Phys* 2009; 10:3068.
9. Matuszak MM, Yan D, Grills I, Martinez A. Clinical applications of volumetric modulated arc therapy. *Int J Radiat Oncol Biol Phys* 2010; 77:608-16.
10. Rana S, Rogers K, Pokharel S, Cheng C. Evaluation of Acuros XB algorithm based on RTOG 0813 dosimetric criteria for SBRT lung treatment with RapidArc. *J Appl Clin Med Phys* 2014; 15:4474.
11. Radiation Therapy Oncology Group RTOG 0631. Phase II/III study of image-guided radiosurgery/SBRT for localized spine metastases; 2009. Available from www.rtog.org
12. Benedict SH, Yenice KM, Followill D, *et al.* Stereotactic body radiation therapy: the report of AAPM Task Group 101. *Med Phys* 2010; **37**:4078-101.
13. Wu QJ, Yoo S, Kirkpatrick JP, *et al.* Volumetric arc intensity-modulated therapy for spine body radiotherapy: comparison with static intensity-modulated treatment. *Int J Radiat Oncol Biol Phys* 2009; **75**:1596-604.
14. International Commission on Radiation Units and Measurements ICRU Report 62. Prescribing, recording, and reporting photon beam therapy (Supplement to ICRU Report 50) ICRU, Bethesda, MD, 1999.