Feasibility of pseudo 4pi approach for stereotactic radiosurgery on a linear accelerator with on-board MRI

Eenas A. Omari, K. Stoeckigt, E. Melian, T. Thomas, S.Hoffman, J. Ingram, A. Sethi, T. Refaat, J. Roeske, and I. Rusu

Loyola University Chicago, Maywood, IL

JULY 12–16 2020 VIRTUAL JOINT AAPM | COMP MEETING
EASTERN TIME [GMT-4]

INTRODUCTION

Magnetic resonance images (MRI) are commonly utilized in stereotactic radiosurgery (SRS) for target delineation. The current available radiation delivery system with on-board MRI capabilities allows for daily accurate registration and real-time monitoring for motion management.

To obtain good conformal SRS plans, non-coplanar beams are used during treatment planning. The MRI-linac (Viewray Inc) has limitations due to non-rotational jawless double stacked MLCs and mechanical motion of the couch therefore not allowing for non-coplanar beams. The system is only capable of step-and-shoot delivery, therefore, volumetric modulated arc therapy (VMAT) cannot be performed.

In this study we investigate a pseudo 4pi approach for planning in comparison to VMAT planning for SRS.

AIM

To investigate the feasibility of a pseudo 4pi treatment planning and delivery approach for a MRI-linac with jawless double stacked MLCs, no couch rotational capabilities, and a step-and-shoot delivery technique for fractionated stereotactic radiosurgery (SRS).

METHODS

- Ten previously treated SRS patients with 1-2 brain lesions (N=15 lesions, 27Gy in 3fxs) were re-planned using a pseudo 4pi technique and VMAT.
- The IMRT pseudo 4pi technique was implemented to allow a couch motion in the longitudinal and vertical directions by performing isocenter shifts. 2-4 isocenters plans have been generated. Figure 1 shows the isocenter locations for a 4 isocenter plan with maximum separation of 6 cm. Figure 2 shows beam arrangement and beams associated with 2 isocenters for a 3 isocenter IMRT plan.

METHODS

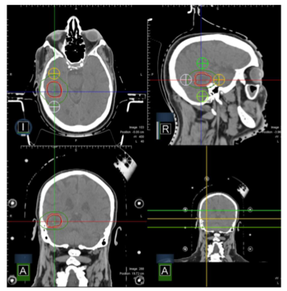

Figure 1: Isocenter locations for a 4 iso pseudo 4pi plan.

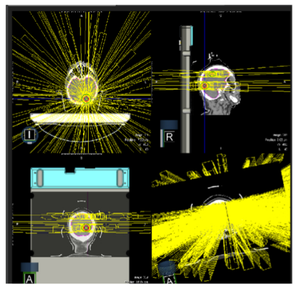

Figure 2: Beam arrangement for a pseudo 4pi plan.

- VMAT plans were generated using single isocenter, 3-4 arcs for comparison as shown in Figure 3.

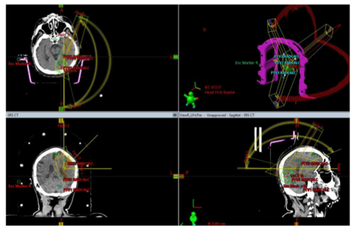

Figure 3: Single isocenter 2 target 3 arc arrangement for volumetric modulated arc therapy (VMAT) planning.

- The SRS plans were evaluated qualitatively and quantitatively, using the following metrics: Paddick's conformity index (CI), Paddick's gradient index (GI), RTOG quality of coverage (Q), and RTOG homogeneity index (HI).
- Radiation necrosis indicators for normal brain V_{18Gy} and V_{21Gy}, and the maximum dose to the brainstem and optic pathways were also evaluated.
- Planning objectives for organs at risk (OAR)and target volumes are listed in Table 1

Table 1: Planning objects for PTV and OAR.

Organ/Volume of Interest	Parameter	Goal
PTV	V99	>95%
	V95	>99%
Normal Brain - PTV	V18 Gy	<=23 cc
Optic Pathway	Max Dose	12 Gy
Brainstem	Max Dose	12 Gy

RESULTS

The pseudo 4pi technique provides clinically acceptable plans compared with the non-coplanar VMAT plans (one way ANOVA, not significant at $p>0.01$), however, the pseudo 4pi technique shows less rapid dose falloff (CI &GI, $p<0.01$). Figure 4 shows the dosimetric distribution for a single metastasis target using, a) IMRT Pseudo 4pi planning with 4 isocenters, and b) using VMAT planning with 4 non-coplanar arcs.

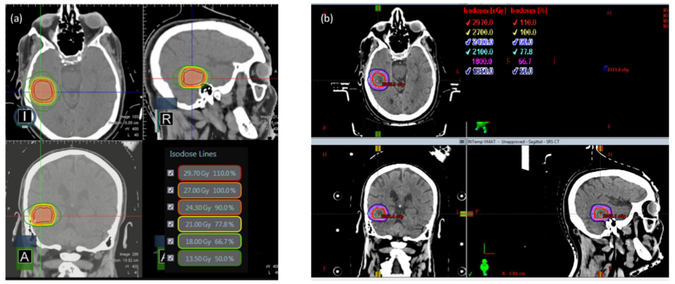

Figure 4: Dosimetric distribution for a single metastasis target using, a) IMRT Psudo 4pi planning with 4 isocenters, and b) using VMAT planning with 4 non-coplanar arcs.

Figure 5 shows the dosimetric distribution for two metastasis targets using, a) IMRT Pseudo 4pi planning with 3 isocenters, and b) using VMAT planning with 3 non-coplanar arcs.

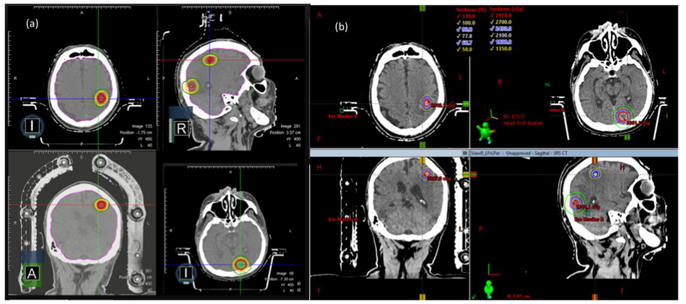

Figure 5: Dosimetric distribution for two targets using, a) IMRT Pseudo 4pi planning with 3 isocenters, and b) using VMAT planning with 3 non-coplanar arcs.

RESULTS

Quantitative metrics were as follows for the pseudo 4pi plans and VMAT non-coplanar plans, respectively: CI (0.81-0.92 & 0.85-0.97), GI (3.36-6.5 & 2.23-3.28), Q (0.88-1 & 0.98-1), and HI (1.22-1.29 & 1.23-1.26).
Table 2 shows the quantitative metrics for 11 patients (N = 15 lesions). Brain V_{18Gy} and V_{21Gy}, the optic pathways and brainstem doses all met the planning objectives.

Table 2: Quantitative metrics for SRS plans generated using VMAT planning and psedue 4pi technique. CI: Conformity Index, GI: Gradient Index, Q: Quality of Coverage, HI: Homogeniety Index.

Patient ID	# Mets	CI (VMAT)	CI (VR)	GI (VMAT)	GI (VR)	Q (VMAT)	Q (VR)	HI (VMAT)	HI (VR)
1	2	0.91	0.84	2.67	4.6	0.99	0.99	1.25	1.24
		0.85	0.82	3.27	6.26	1	0.99	1.24	1.24
2	2	0.88	0.81	3.28	4.46	1	0.99	1.24	1.24
		0.92	0.84	2.66	3.82	0.99	0.99	1.25	1.26
3	2	0.91	0.89	2.5	4.11	0.99	0.99	1.25	1.24
						0.99	0.99	1.25	1.24
4	1	0.9	0.88	2.93	4.35	1	1	1.23	1.24
5	1	0.96	0.92	2.23	3.36	0.99	0.99	1.24	1.26
6	1	0.97	0.9	2.59	3.72	0.99	0.94	1.25	1.26
7	1	0.94	0.88	2.52	3.61	0.98	0.995	1.25	1.24
8	1	0.93	0.9	2.55	3.6	0.99	0.97	1.25	1.24
9	1	0.91	0.823	3.35	4.98	0.99	0.88	1.23	1.22
10	1	0.93	0.89	2.43	5.29	0.99	0.97	1.23	1.23
11	2	0.95	0.86	2.82	4.28	1	0.98	1.25	1.29
		0.96	0.92	2.47	3.73	0.98	0.91	1.26	1.28

CONCLUSIONS

Pseudo 4pi planning generated clinically acceptable SRS plans with Q and HI comparable to the VMAT plans. CI and GI was more favorable with VMAT compared with 4pi plans, however within acceptable clinical variation based on the published SRS metrics. Future work includes film measurements and quality assurance for treatment delivery feasibility.

CONTACT INFORMATION

Eenas A. Omari, Ph.D.
Eenas.madison@gmail.com
(414)-526-9474