Is spot-scanning proton beam therapy ready for the single target brain stereotactic radiosurgery? A dosimetric study among VMAT, SPArc and IMPT

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INTRODUCTION

Stereotactic Radiosurgery (SRS) is a noninvasive alternative that is playing an increasingly prominent role in the treatment of brain tumors such as brain metastases, recurrent glioma, or meningiomas. Proton beam therapy offers the potential for more brain sparing because of rapid dose fall-off beyond the distal edge of the target; however, clinical situations in which protons maybe superior to photons are not well described. We hypothesized that the superiority of proton SRS would be dependent on tumor size and location.

AIM

Spot-scanning Proton Arc (SPArc) therapy has been merging as a new treatment technique because of its superior dosimetric quality and robustness compared to the conventional Intensity Modulated Proton Therapy (IMPT). The study explore the possibility of such technique has any dosimetric advantage over the conventional IMPT and VMAT in the brain SRS.

METHOD

A brain SRS model is established to set as an clinical decision tool among different treatment modalities. The model simulates different target locations and different sizes. A Gross Tumor Volume (GTV) (0.3cc) was inserted in the deep central and peripheral region of a head CT set, then the GTV was expanded with a uniform margin every 2mm increments, corresponding to a different target volume (from 0.3cc; to 24.42cc) (Fig. 1). Three planning groups: IMPT, SPArc) and VMAT were generated in RayStation ver. 9A using the same planning objective functions and robust optimization parameters (2mm setup and 3.5% range uncertainty for proton planning and 2mm setup uncertainty for VMAT planning). Prescription was 18Gy (RBE) in 1 fx with at least 96% of GTV received full prescription dose in the worst-case-scenario robustness evaluation (Fig. 2). Multiple dosimetric metrics were analyzed to assess the plan quality such as dose Conformity Index (CI) (Ratio of the target volume to 100% Prescription isodose volume); R50 (Ratio of 50% Prescription isodose volume to the target volume); V12Gy; and mean dose of brain. Seven brain mets patient previous treated with Gamma Knife were selected for this retrospective study to test the brain SRS model.

RESULTS

In comparison with IMPT, VMAT clearly showed its advantage in the CI and R50 in any target size (<24.42cc) or locations where a sharp dose fall-off is clinically desired. However, IMPT showed advantage over VMAT in any target in terms of brain mean dose. In comparison with VMAT, SPArc has an equivalent or better CI in any size of peripheral targets and deep centrally located targets which were bigger than 7.32cc. At meanwhile, SPArc significantly reduced the normal brain tissue dose. For the deep centrally located tumor smaller than 7.32cc, VMAT plan still offered better dose CI. Seven clinical cases shows a similar trend and dosimetric results compared to the brain SRS model. A clinical decision of an optimal treatment could be made according to the size and location of the brain mets.

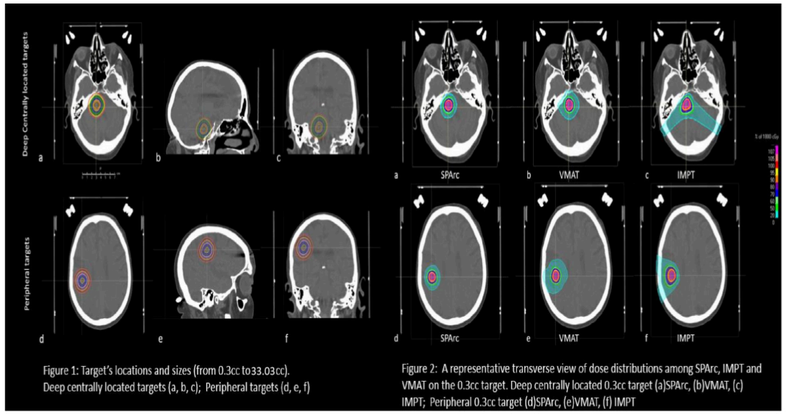

Figure 1: Target's locations and sizes (from 0.3cc to 33.03cc). Deep centrally located targets (a, b, c); Peripheral targets (d, e, f)

Figure 2: A representative transverse view of dose distributions among SPArc, IMPT and VMAT on the 0.3cc target. Deep centrally located 0.3cc target (a)SPArc, (b)VMAT, (c) IMPT; Peripheral 0.3cc target (d)SPArc, (e)VMAT, (f) IMPT

Table 1. validation of optimal brain sparing modality based on tumor size and location for 9 patients

Patient	Tumor location	Tumor volume(cc)	CI			R50			V12(brain)			Mean dose(brain)		
			VMAT	IMPT	SPArc	VMAT	IMPT	SPArc	VMAT	IMPT	SPArc	VMAT	IMPT	SPArc
1	deep central	1.66	1.00	0.71	1.00	5.09	10.28	5.34	3.55	7.43	4.06	77.00	53.00	37.00
2	peripheral region	3.53	1.00	0.93	1.00	4.75	9.07	5.11	6.21	13.23	6.81	81.00	41.00	53.00
3	peripheral region	14.65	0.98	0.76	1.00	3.20	4.91	2.62	12.62	22.75	10.38	148.00	80.00	81.00
4	peripheral region	4.13	0.96	0.94	1.00	4.07	7.17	4.31	6.57	12.20	7.07	79.00	44.00	48.00
5	peripheral region	8.34	1.00	1.00	1.00	4.63	6.84	4.29	17.42	32.77	18.37	161.00	104.00	79.00
6	deep central	11.04	0.99	0.99	1.00	3.60	5.40	3.17	13.11	25.28	12.56	167.00	110.00	93.00
7	deep central	20.76	0.97	0.97	1.00	2.93	3.85	2.44	21.00	35.46	18.60	226.00	132.00	120.00
8	peripheral region	24.7	0.99	0.89	1.00	2.71	3.63	2.48	15.78	26.04	15.05	180.00	107.00	110.00
9	deep central	28.65	1.00	0.93	1.00	2.90	3.03	2.39	27.99	37.02	24.76	343.00	229.00	194.00

CONCLUSIONS

The validated treatment decision model presented here is a useful and practical clinical tool to determine when proton SRS should be considered a priori. Tumor size and location are important determining factors in generating deliverable brain SRS plans with either protons or photons. When feasible, protons should be considered as the modality of choice for tumors larger than 6mm in any locations to potentially reduce radiation-induced toxicity.

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