Margin Assessment for Intracranial SRS Localization and Linac-Based Delivery Techniques

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INTRODUCTION

Historically, management of intracranial metastases with radiation has been performed with whole brain radiation therapy (WBRT)[1,2]. Nevertheless cognitive outcomes have been found to be significantly worse with WBRT and the standard of care for patients with limited intracranial disease, being stereotactic radiosurgery (SRS) [3,4,5] . Studies estimate the localization accuracy of intracranial procedures under image-guidance (i.e cone-beam CT, ExactTrac) are sub-millimeter [6,7].

AIM

With such advanced techniques for intracranial SRS treatments, there is an increased need to properly evaluate the level of accuracy and precision of treatment delivery process, especially in the context of tumor margin assessment. The goal of this study was to assess localization accuracy of ExacTrac and CBCT via end-to-end testing of Eclipse and Brainlab Elements intracranial SRS plans.

METHOD

A total of 17 irradiations were performed using a LUCY® 3D QA phantom. Radiochromic film was prepared with fiducial markers (<1mm thickness) placed on the film to mark the target position (1 or 3 targets), and the film was placed in the LUCY phantom insert. Target contours were defined on CT images by a uniform expansion of 1 cm diameter from the center of the fiducial markers. Based on a SRS prescription dose of 12 Gy, treatment plans were computed using Multi-Mets or Cranial SRS modes with Brainlab Elements (ver 2.0) and Dynamic Conformal Arc or VMAT plan with Eclipse (ver 15.5). An identical non-coplanar arc template was used in all as to limit geometric plan variability. All plans were delivered using CBCT and/or ExacTrac based localization on a Varian Truebeam STx.

Figure 1: (Top) Illustration of target(s) center mark-up, (middle), the radiochromic film insert that was placed in the center of the phantom, (bottom) and the LUCY® 3D QA with insert inside and external localization wires around the surface

RESULTS

The average separation between marked target center and radiation center was 0.513±0.156 mm with CBCT localization alone, 0.652±0.135 mm when using CBCT and ExacTrac (0.7 mm/0.7 deg tolerance). The average separation was 0.364±0.133 mm when both imaging techniques were used but ExacTrac localization was set to 0.5 mm/ 0.5 deg tolerance, and finally 0.41±0.103 mm when ExacTrac localization (0.5 mm/ 0.5deg) was solely used.

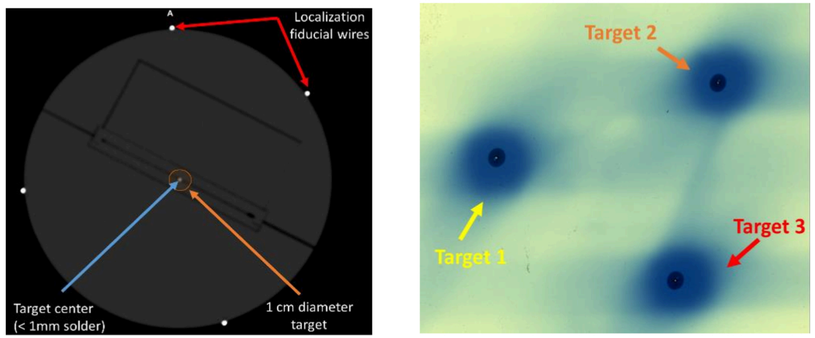

Figure 2: (Left) axial CT image of Lucy phantom with surface localization wires with target at the center surrounded by 1cm diameter spherical target (Right) Illustration of radiation delivered to film for three 1 cm spherical targets for analysis of marked target center with radiation center.

Table 1: Comparison of end-end testing of target center and radiation delivery center after imaging localization for Eclipse (dynamic conformal arc (DCA) and VMAT) and BrainLab Elements (Multiple Mets (MME) and Cranial SRS) using CBCT, ExacTrac (ExT).or both. The ExT imaging tolerances used for each test are listed.

# Mets	Plan Type	Localization Technique	ExT. Tolerances	Film Orientation	Lat. Error (mm)	Long. Error (mm)	Vert. Error (mm)	RMSE Total Error (mm)
1	DCA	CBCT	-	Horiz	0.254	0.508		0.568
1	VMAT	CBCT	-	Vert	-	0.222	0.762	0.794
1	MME	CBCT	-	Horiz	0.318	0.159		0.355
1	VMAT	CBCT	-	Horiz	0.413	0.095		0.424
3	VMAT	CBCT	-	45 deg	0.381	0.191		0.426
1	Cranial SRS	CBCT, ExT.	0.7degs, 0.7mm	Horiz	0.381	0.286		0.476
3	MME	CBCT, ExT.	0.7degs, 0.7mm	45 deg	0.826	0.222		0.855
3	MME	CBCT, ExT.	0.7degs, 0.7mm	45 deg	0.603	0.159		0.624
1	Cranial SRS	CBCT, ExT.	0.7degs, 0.7mm	Vert	-	0.254	0.603	0.655
1	Cranial SRS	CBCT, ExT.	0.7degs, 0.7mm	Horiz	0.254	0.318		0.407
1	MME	CBCT, ExT.	0.5degs, 0.5mm	Horiz	0.445	0.222		0.497
1	DCA	CBCT, ExT.	0.5degs, 0.5mm	Horiz	0.222	0.064		0.231
1	Cranial SRS	ExT.	0.5degs, 0.5mm	Horiz	0.413	0.064		0.418
1	MME	ExT.	0.5degs, 0.5mm	Horiz	0.349	0.222		0.414
3	MME	ExT.	0.5degs, 0.5mm	45deg	0.445	0.318		0.546
1	DCA	ExT.	0.5degs, 0.5mm	Horiz	0.127	0.191		0.229
3	DCA	ExT.	0.5degs, 0.5mm	45deg	0.445	0.032		0.446

DISCUSSION

Table 1. shows the axial, horizontal, and vertical profile coincidence measurements along the axis of the target for different orientations of the LUCY phantom during irradiation. It can be seen that minimizing the total root mean square error (RMSE) is driven by ExacTrac imaging tolerances. Moreover there seems to be little variation among plan type for a given imaging tolerance.

CONCLUSIONS

Based on the uncertainties for the imaging localization and positioning, a 0.5 mm target margin is warranted. Moreover, ExacTrac imaging tolerances showed higher accuracy in overall localization when used as the primary localization technique or in conjunction with CBCT when used with smaller imaging tolerances.

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