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Targeting accuracy of frameless linear accelerator thalamotomy

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INTRODUCTION

Radiosurgical thalamotomy is one method to treat medically refractory tremor for patients that are not candidates for deep-brain stimulation. It ablates aberrant cerebello-thalamo-cortical circuitry by targeting the dentato-rubro-thalamic tract (DRTT) within the ventral intermediate nucleus (VIM) of the thalamus.

AIM

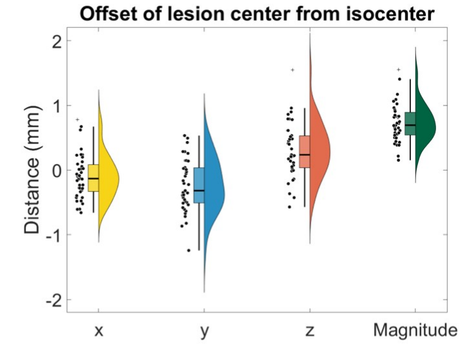
To evaluate the accuracy of radiosurgical thalamotomy using a linear accelerator equipped with a multileaf collimator (MLC), a thermoplastic mask for immobilization, and surface-imaging for intra-fraction motion monitoring.

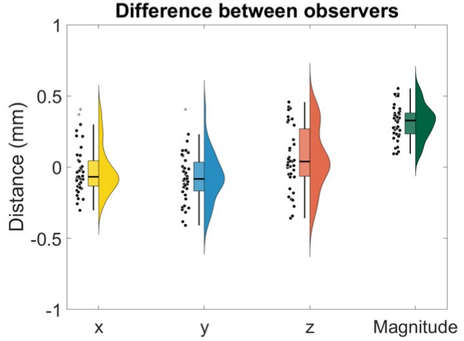
METHOD

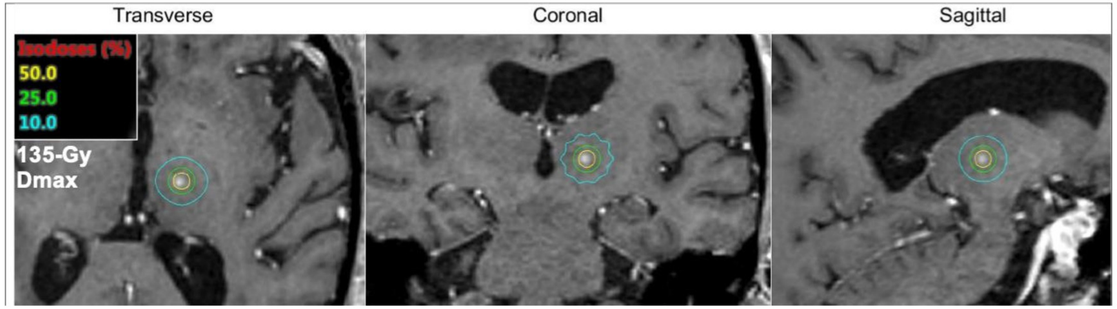
40 patients underwent SRS thalamotomy on a linear accelerator on an IRB-approved clinical trial (ClinicalTrials.gov Identifier: NCT03305588).

- Patients immobilized using a non-invasive thermoplastic immobilization system (Encompass™ SRS Fibreplast® System, CQ Medical, Avondale, PA).
- Treatment planning CT obtained with 0.8 mm slice spacing.
- Planning MR images obtained using MPRAGE and FGATIR sequences.
- MR images registered to the CT and the VIM identified using stereotactic coordinates based on the anterior and posterior commissure locations.
- Virtual cone technique[1] used to deliver 135 Gy to isocenter using the 10MV flattening-filter-free beam of an Edge linear accelerator equipped with an MLC having 2.5 mm central leaf width (Varian Medical Systems, Palo Alto, CA)
- Isocenter was placed at the VIM and then moved medial to limit internal capsule D0.03cc < 25 Gy.
- Patient position was monitored real-time during treatment using optical surface imaging.
- At 3, 6, and 12 months after treatment, post Gadolinium-contrast T1 images were acquired on a 3T MRI scanner. For each patient, the first image set for which a lesion was clearly visible was selected and registered to the treatment planning CT using mutual information rigid registration. The lesion was manually segmented by two investigators, a radiation oncologist and a medical physicist.
- For each lesion, the centroid of the segmented volume was determined. The mid-point of the two centroids was compared with the isocenter position.

RESULTS







Post-treatment imaging data was available for 39/40 patients. A lesion was identified on follow-up imaging for all 39 patients. An example post-treatment image T1-post Gadolinium-contrast MPRAGE image with overlaid isodose lines is shown above.

The offsets between the centroids of the lesion segmentations and the isocenter are shown in the upper-left figure.

- The mean distance between the centroid mid-points and the isocenter was 0.7 mm (range 0.2-1.6 mm, interquartile range 0.4 mm).
- The mean difference (standard deviation) in the x, y, and z directions of the treatment planning CT coordinate system was -0.1 (0.3), -0.2 (0.4), and 0.3 (0.4) mm, respectively.

The distances between the lesion centroids identified by the two observers are shown in the bottom-left figure.

- The mean distance was 0.3 mm (range 0.1-0.6 mm, interquartile range 0.1 mm).
- The mean difference (standard deviation) in the x, y, and z directions of the treatment planning CT coordinate system was 0.0 (0.2), -0.1 (0.2), and 0.1 (0.2) mm, respectively.

CONCLUSIONS

Our findings demonstrate sub-millimeter accuracy of frameless MLC-based linear accelerator SRS using optical surface imaging for intra-fraction position monitoring. These results are comparable to accuracies reported using other techniques for radiosurgical thalamotomy and to open surgical lesioning/stimulation procedures.

REFERENCES

1. Popple RA, Wu X, Brezovich IA, Markert JM, Guthrie BL, Thomas EM, et al. The virtual cone: A novel technique to generate spherical dose distributions using a multileaf collimator and standardized control-point sequence for small target radiation surgery. *Adv Radiat Oncol.* 2018 Sep;3(3):421-430.

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