The setup accuracy of an IGRT system for single-isocentre, multiple target, non-coplanar SRS deliveries

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AIM

To measure the localization accuracy of an IGRT system for a single isocentre, multiple target technique that is used in the stereotactic radiosurgery (SRS) treatment of multiple brain metastases.

METHOD

1. Treatment planning and phantom setup

- A modified end-to-end test was performed with an anthropomorphic head phantom to evaluate the setup accuracy of an IGRT system for single isocentre multiple target SRS treatments. The phantom had a total of 8 radio-opaque markers (BBs) inserted at various positions, each one representing a treatment target.

- The treatment process included (i) fitting an immobilization mask to the head phantom, (ii) acquiring a high resolution CT scan for treatment planning, (iii) target localization using a cone beam CT (CBCT), (iv) treatment delivery and (v) target position verification using a megavoltage (MV) imager.

- The treatment plan consisted of 14 Non-coplanar static fields whose beam arrangement closely resembled the geometry used in stereotactic treatments. Each treatment field had multiple rectangular ports exposing the radio-opaque markers. The ports were defined by the TrueBeam High Definition MLC (HDMLC). Figure 1 shows a digitally reconstructed radiograph (DRR) of one of the treatment fields.

- Head phantom localization was performed by registering a CBCT to the planning CT. A six degree of freedom couch (6DoF) was utilized to move the phantom into position. MV images of the non-coplanar treatment fields were acquired with the detector positioned at 180 cm from the source generating the largest image magnification possible.

2. Data analysis

Figure 2 shows an MV image of a treatment field. The field edges detected in the MV image are shown by the green contours, and the blue rectangles are the field edges calculated from the treatment plan. The BB centers detected from the MV image are indicated by the green dots, while the BB positions from the planning system are indicated as blue dots.

For every treatment field, the localization accuracy (Δx, Δy) of each port was determined by comparing the expected displacement $(\vec{d}_E)$ and the measured displacement $(\vec{d}_M)$ of the BB center with respect to the field center of each port. The inset in Figure 2 illustrates how this displacement is determined on the portal images. Note that the displacement vector itself is not representative of the localization accuracy of the system. The localization accuracy is determined by comparing the measured displacement with the displacement expected from an ideal setup.

METHOD (CONTINUED)

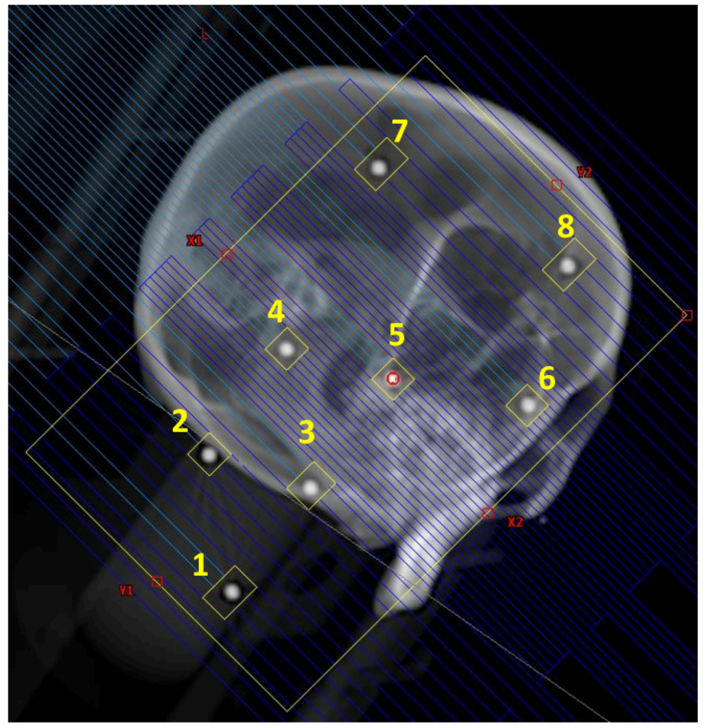

Figure 1. A digitally reconstructed radiograph (DRR) of one of the treatment fields (Gantry=225°,Table=315°,Couch=315°) showing a total of 8 targets exposed to rectangular fields. Isocentre location coincided with target 5.

(i) Calculation of the Expected displacement $(\vec{d}_E)$

An algorithm was developed to calculate the expected positions of the field edges and the BB centers on the DRR. The calculation was automated and the only user input required was the determination of the BB center coordinates from the planning CT.

(ii) Determination of the measured displacement $(\vec{d}_M)$

A specialized algorithm was developed to automatically analyze the multiport images of the head phantom for this study.
Analysis consists of the following steps:
1) Counting the number of fields (or ports) in an image and finding the coordinates of each ports center.
2) Detecting the position of the radio-opaque marker within each port.
3) Calculating the displacement of the radio-opaque marker with respect to the field center.

(iii) The target localization accuracy $(\vec{\Delta}_i)$

The target localization accuracy for each treatment port was determined by comparing the expected and measured displacements in the cross-plane and in-plane directions..

$$\Delta x = dx_E - dx_M$$
$$\Delta y = dy_E - dy_M$$

RESULTS

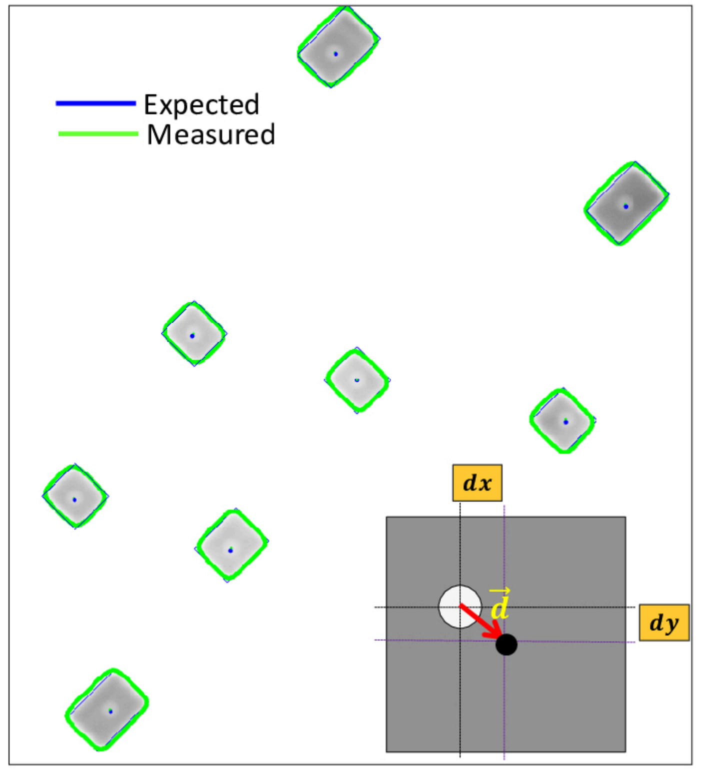

Figure 2. A MV image of the field shown in Figure 1. The expected and measured field edges and target centers are superimposed on the image. The inset illustrates how the displacement vector $(\vec{d})$ between the field center and the BB center is obtained.

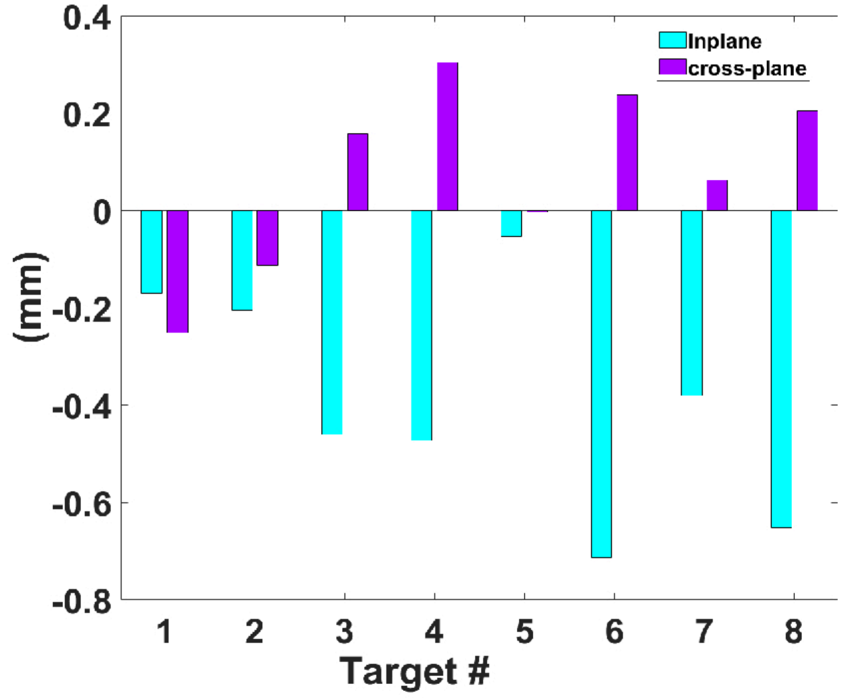

Figure 3. Target localization accuracy (Δx and Δy) measured in the "in-plane" and "cross-plane" directions for the field geometry shown in Figures 1 and 2.

RESULTS (CONTINUED)

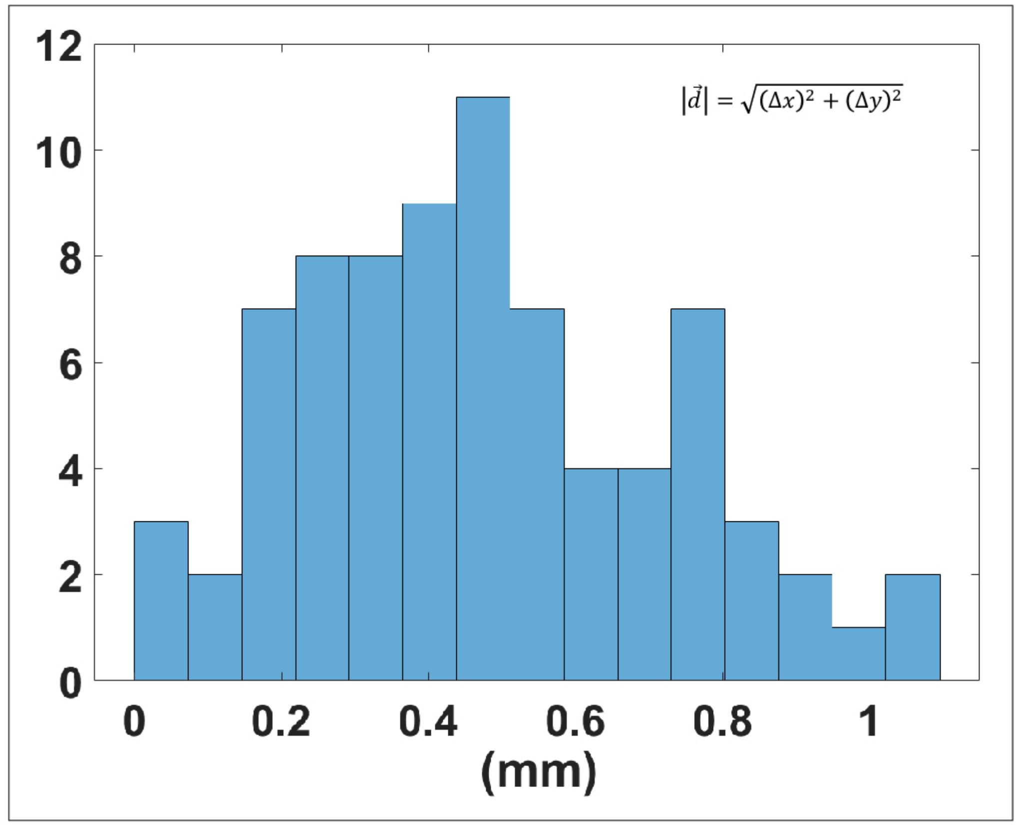

Figure 4. A histogram plot of the 2D localization error for a total of 76 treatment ports exposed at various treatment configurations. The magnitude of the localization error ranged between 0 mm to 1.1 mm with a mean and standard deviation of 0.48 mm and 0.25 mm respectively.

CONCLUSION

An automated QA method has been developed to measure the setup accuracy of a cranial SRS delivery system for central and off-axis targets. The analysis tools developed in this work allow for routine monitoring of the setup accuracy of a SRS delivery system.

ACKNOWLEDGEMENTS

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