

Comparison of Image-guidance Modalities for Cranial Stereotactic Radiosurgery (SRS) and Radiotherapy (SRT)

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Purpose

To compare image-guidance shifts derived from a six-degree-of-freedom (6DOF) stereoscopic x-ray imaging system (ExacTrac, BrainLAB) to shifts derived from 4DOF volumetric cone-beam computed tomography (CBCT) imaging (OBI, Novalis TX, Varian/BrainLAB) for frameless intracranial stereotactic radiosurgery (SRS) and radiotherapy (SRT).

Methods

- ❖ Two hundred and forty-five paired clinical ExacTrac/CBCT acquisitions formed the basis of this study.
- ❖ Pre-positioning alignment was based on automatic detection of infrared marker configuration on each patient's thermoplastic mask (Orfit) using the ExacTrac system.
- ❖ Frameless image-guided repositioning for brain SRS/SRT was based on online 6DOF stereoscopic x-ray imaging followed by online 4DOF and offline 6DOF CBCT (for residual error assessment) and subsequently 6DOF stereoscopic x-ray imaging (for intra-treatment motion evaluation).
- ❖ Isocenter localization accuracy of stereoscopic x-ray imaging relative to CBCT imaging was quantified by anthropomorphic phantom measurements.
- ❖ For the purpose of this data analysis, CBCT was defined as the gold-standard for data comparison. The difference in residual setup errors between ExacTrac and CBCT was computed. The impact of rotations on the difference was evaluated offline.

Results

- ❖ Standardized phantom measurements showed a relative system agreement between ExacTrac x-ray imaging and CBCT of 0.08 ± 0.18 mm (lateral), 0.13 ± 0.31 mm (longitudinal), and -0.16 ± 0.32 mm (vertical).
- ❖ Pre-positioning alignment errors were -0.04 ± 1.45 mm (lateral), -0.65 ± 2.07 mm (longitudinal), and -1.62 ± 1.97 mm (vertical).
- ❖ A slight difference in residual errors was found between ExacTrac system and 4DOF CBCT: 0.40 ± 0.72 mm (vertical), 0.24 ± 0.56 mm (longitudinal), and -0.06 ± 0.67 mm (lateral).

- ❖ The observed root-mean-square (RMS) of the differences for translations was <1.73 mm.
- ❖ Rotation setup difference between the ExacTrac and CBCT systems was minor but not negligible, based on offline 6DOF CBCT assessments: $0.08 \pm 0.70^\circ$ (lateral/pitch), $-0.06 \pm 0.46^\circ$ (longitudinal/roll), and $0.05 \pm 0.38^\circ$ (vertical/yaw).
- ❖ ExacTrac monitored intra-treatment patient-motion based errors were 0.04 ± 0.58 mm (lateral), 0.00 ± 0.73 mm (longitudinal), and -0.19 ± 0.53 mm (vertical).

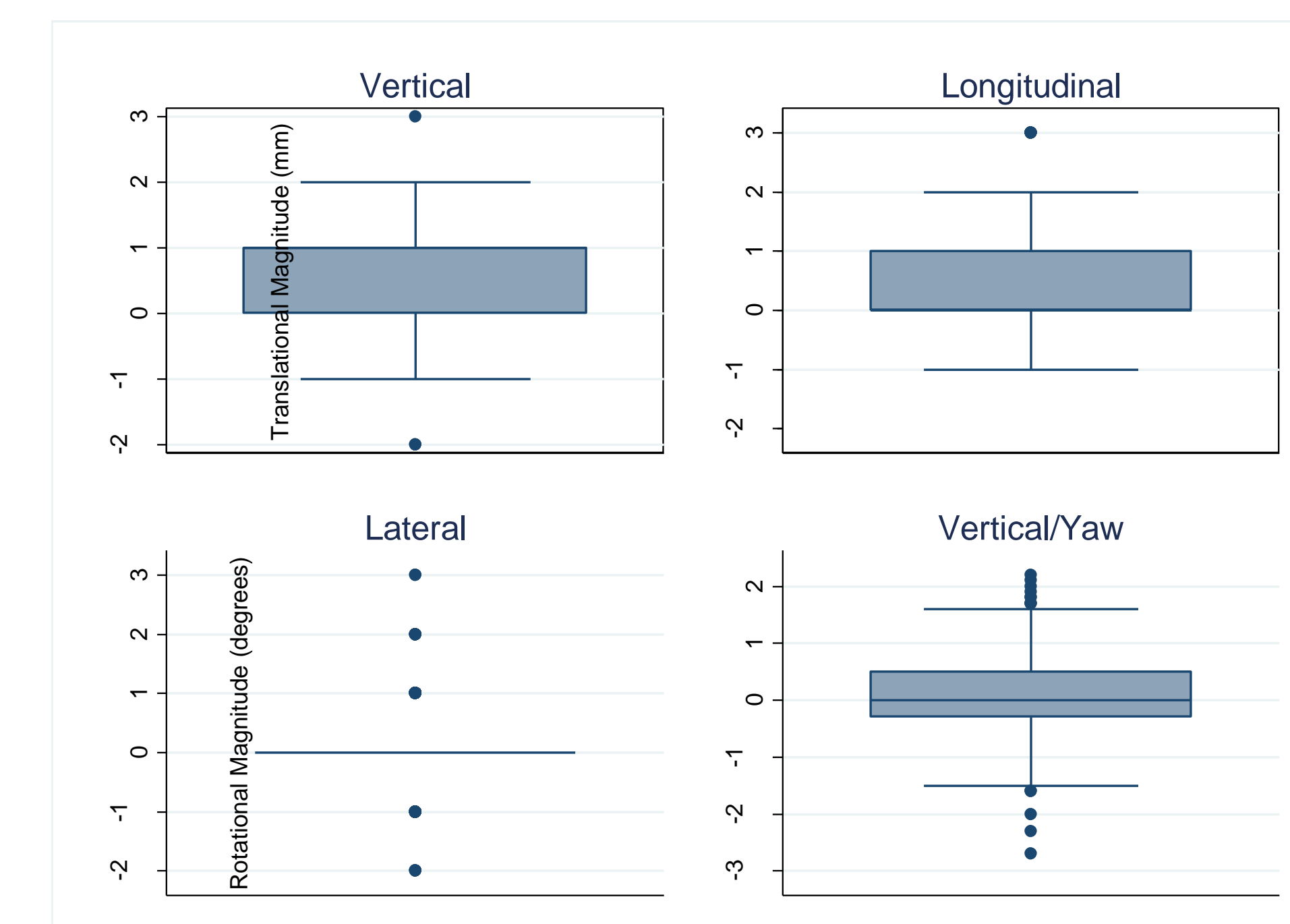


Figure 1: Online residual displacement

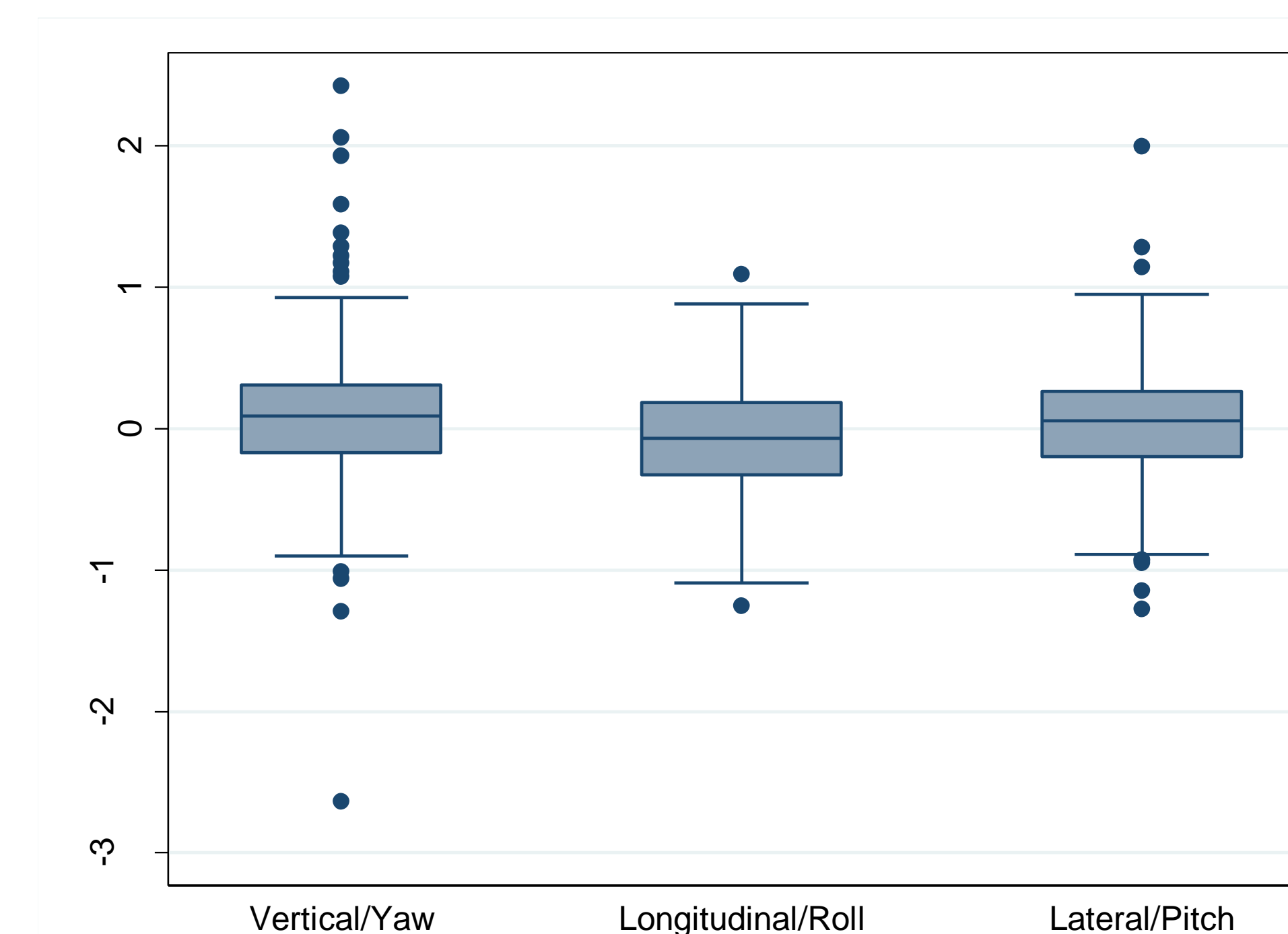


Figure 2: Offline residual rotational displacement

Conclusions

- ❖ Bony anatomy-based target positioning for image-guided frameless SRS/SRT resulted in accuracy comparable to frame-based alignment.
- ❖ ExacTrac and CBCT image-guidance resulted in comparable shifts. Furthermore, ExacTrac requires less time to assess patient setup in 6DOF, and can be considered superior in clinical use.
- ❖ Intra-treatment positioning monitoring significantly contributes to the precision of frameless intracranial SRS/SRT.