

ERROR PROPAGATION IN SPINAL INTRAOPERATIVE NAVIGATION FROM NONSEGMENTAL REGISTRATION: A PROSPECTIVE CADAVERIC AND CLINICAL STUDY

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ABSTRACT

Background: Computer-assisted navigation may guide spinal instrumentation. Current systems rely on a dynamic reference frame (DRF) for image-to-patient registration and tool tracking. Displacement of levels distant to the DRF may generate inaccuracy from intersegmental mobility. We quantify intraoperative vertebral motion from patient respiration and surgical manipulation.

Methods: Respiration-induced vertebral motion was quantified from 13 clinical cases of open posterior instrumented fusion. Patients were positioned prone on a Wilson frame, with a head clamp for cervical fusions. The absolute position of a spinous-process clamp was tracked by an optical navigation system over about 12 respiratory cycles. Vertebral motion during screw tract formation was quantified in 4 human cadavers. Following an open posterior exposure, the position of a tracked awl was quantified before and after exertion of force to create pilot holes for pedicle screw tracts.

Results: Peak-to-peak respiration-induced vertebral motion was maximal in the anteroposterior ($0.57 \text{ mm} \pm 0.38 \text{ mm}$) and craniocaudal axes ($0.65 \text{ mm} \pm 0.45 \text{ mm}$). Anteroposterior displacement was greater in the lower thoracic spine ($0.65 \text{ mm} \pm 0.31 \text{ mm}$) than in the cervical ($0.51 \text{ mm} \pm 0.50 \text{ mm}$) or lumbar spine ($0.38 \text{ mm} \pm 0.08 \text{ mm}$). In multivariate regression, both tidal volume and end-expiratory pressure were positively correlated with anteroposterior and 3D displacement. Manipulation during screw tract formation caused displacement predominantly in the mediolateral ($0.71 \text{ mm} \pm 0.84 \text{ mm}$) and craniocaudal planes ($1.02 \text{ mm} \pm 0.92 \text{ mm}$). Mediolateral displacement was greater in the thoracic and lumbar spines than in the cervical spine (mean 0.96 mm , 0.73 mm and 0.45 mm , respectively), while craniocaudal displacement was greater in the lumbar than the cervical and thoracic spines (mean 1.38 mm , 0.92 mm and 0.82 mm , respectively).

Conclusion: Vertebral motion is unaccounted for during image-guided surgery when performed at levels distant from the DRF. Respiration and manipulation-induced vertebral motion are greater than 2 mm in 6%–15% of cases, varying with spinal region and ventilator parameters. Respiration-induced motion is significantly underestimated in this study. These errors should be compensated for in image-guidance systems to minimize navigation inaccuracy.

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