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 mm ± 0.38 mm) and craniocaudal axes (0.65 mm ± 0.45 mm). Anteroposterior displacement was greater in the lower thoracic spine (0.65 mm ± 0.31 mm) than in the cervical (0.51 mm ± 0.50 mm) or lumbar spine (0.38 mm ± 0.08 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 mm ± 0.84 mm) and craniocaudal planes (1.02 mm ± 0.92 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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