Accuracy Validation in the Cervical Spine of a Novel, Rapid, Optical Intraoperative Spinal Navigation System: Initial Clinical Feasibility

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Introduction

Computer-assisted frameless stereotactic navigation may be employed in the spine to guide hardware placement, improving the accuracy of pedicle screw instrumentation (1). Current systems register to pre - or intra-operative imaging with point-matching systems, and are hampered by cumbersome and lengthy registration procedures, additional radiation exposure, and inability to account for tissue movement between imaging and navigation (2). A novel structured-light illumination machine-vision system was developed for craniospinal neuronavigation (Figs. 1,2). Here, we validate its accuracy in the mobile cervical spine.

Methods

We retrospectively reviewed 6 patients from a cohort of 118 enrolled in a prospective trial of our machine-vision system, who underwent posterior cervical instrumentation +/- decompression. All patients underwent thin-slice preoperative CT imaging, with intraoperative patient registration performed to the preoperative scan. Navigation data were compared to screw positions on postoperative imaging, and the absolute translational and angular deviation in axial and sagittal planes computed (Fig. 3). All procedures were performed by a single surgeon (VY).

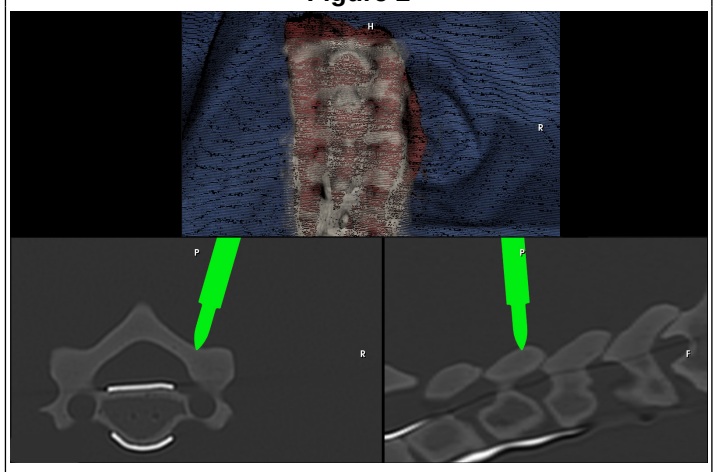
Results

22 screws were analyzed; 2 pars screws at C2, 14 lateral mass screws at C3-5, and 6 pedicle screws at C7. Absolute translational errors were 1.52 +/- 1.32mm and 1.06 +/- 0.97mm in the axial and sagittal planes, respectively; absolute angular deviations were 3.69 +/- 2.63 degrees and 2.83 +/- 2.65 degrees, respectively (mean +/- SD). There was no difference in translational or angular errors between pars (C2), lateral mass (C3-5) and pedicle (C7) screws. The tip of one C2 pars screw breached by <1mm, intentionally for bicortical purchase, without clinical sequelae. There were no violations of facet joints, intervertebral foramina, foramen transversaria or spinal canal, and no neurovascular injuries.

Figure 1

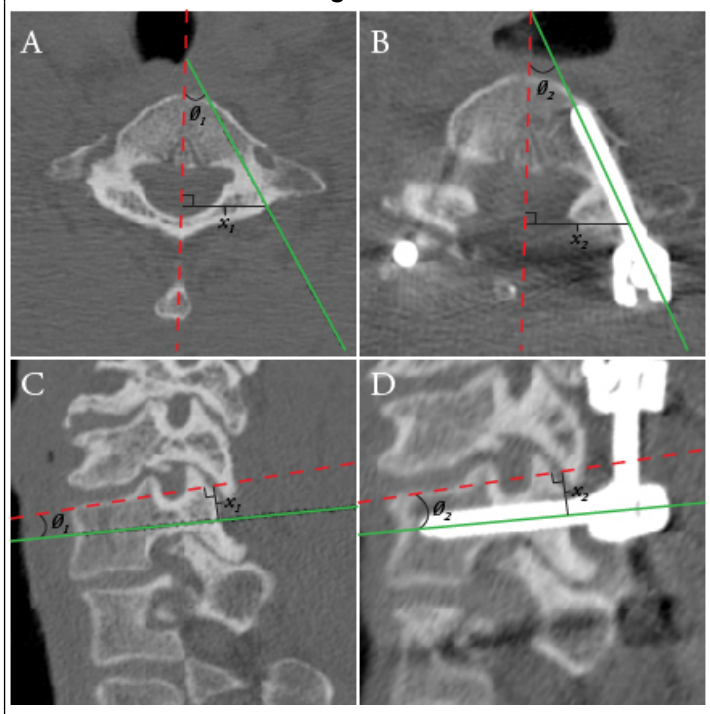
Prototype optical topographic navigation device (center light-head)

Figure 2



Representative point-cloud (top) generated based on structured-light deformation, allowing image-to-patient registration and surgical tool tracking (bottom)

Figure 3



Pre-operative (A,C) and post-operative (B,D) CT imaging of a left C7 pedicle screw insertion. Translational deviation = x2-x1, and angular deviation = 2-1, in axial (A,B) and sagittal (C,D) planes, respectively

Conclusions

Optical machine-vision is a novel technique for craniospinal navigation that allows efficient initial and repeat registration with minimal workflow interruption. Accuracy even in the more-mobile cervical spine is comparable to, and well within the error tolerances for, current spinal neuronavigation systems.

References

1) Mason A., et al. The accuracy of pedicle screw placement using intraoperative image guidance systems: a systematic review. JNS Spine 2014.

2) Hartl R., et al. Worldwide survey on the use of navigation in spine surgery. World Neurosurg 2013.