OPTICAL TOPOGRAPHIC IMAGING FOR SPINAL INTRAOPERATIVE 3D NAVIGATION IN MINIMALLY INVASIVE APPROACHES: INITIAL PRECLINICAL EXPERIENCE

Authors: Daipayan Guha[1], Raphael J akubovic[2], Shaurya Gupta[1], Albert Yee[1,3],Victor Yang[1,3]

ABSTRACT

Background: Computer-assisted3Dnavigationmayguidespinalinstrumentation.Anovel optical topographic imaging (OTI) system for spinal navigation has been developed and described separately. Although it offers comparable accuracy and significantly faster registration relative to current navigation systems, OTI to date has been applied only to open posterior exposures. Here, we explore the utility of OTI in minimally invasive (MIS) approaches.Methods: Mini-open midline posterior exposures were performed in 5 human cadavers. The spinous process and medial half of the bilateral laminae were exposed at T2, T6, T10 and L3. The retractor widthwas increased serially to create exposures of 25, 30, 35 and 40 mm^2. The exposed anatomy at each size was then registered to a pre-operative thin-slice computed tomography (CT) scan. Using the second-smallest exposure resulting in successful registration, screw tracts were created using a tracked awl and gearshift probe, and an appropriately sized screw was placed. Navigation data were compared with screw positions on postoperative CT imaging, and the absolute translational and angular deviations were computed.

Results: Thirty-seven cadaveric screws were analyzed: 8 pedicle screws at T2, 10 pedicle screws at T6, 9 pedicle screws at T10, and 4 pedicle and 6 cortical screws at L3. Overall absolute translational errors were 1.79 mm ± 1.43 mm and 1.81 mm ± 1.51 mm in the axial and sagittal planes, respectively. Absolute angular deviations were 3.81° ± 2.91° and 3.45°± 2.82°, respectively. There were no differences in errors between levels, nor between L3 cortical and pedicle screws. The number of surface points registered by the navigation system correlated positively with the likelihood of successful registration (odds ratio 1.02, 95% CI 1.009–1.024, $p < 0.0001$), but not with any absolute navigation error, independent of the size of the exposure. Conclusion: Optical machine vision is a novel navigation technique previously validated for open posterior exposures. OTI has comparable accuracy for mini-open MIS exposures, with the likelihood of successful registration affected more by the geometry of the exposure than its size.

Partners: [1]University of Toronto, Toronto, Ont.; [2] Ryerson University, Toronto, Ont.; and [3]Sunnybrook Health Sciences Centre, Toronto, Ont.

Full Article: http://www.thespinejournalonline.com/article/S1529-9430(17)30849-5/fulltext

Published: October, 2017

OPTICAL TOPOGRAPHIC IMAGING FOR INTRAOPERATIVE 3D NAVIGATION IN THE CERVICAL SPINE: ACCURACY VALIDATION AND INITIAL CLINICAL FEASIBILITY

Authors: DaipayanGuha[1],RaphaelJakubovic[2],Shaurya Gupta[1],Michael Fehlings[1,3], Albert Yee [1,3], Victor Yang[1,3]

ABSTRACT

Background: Computer-assisted 3D navigation may guide spinal instrumentation. Current systems are hampered by cumbersome registration and inability to account for intraoperative tissue movement. A novel optical topographic imaging (OTI) system was developed for craniospinal neuronavigation and has been described previously in the thoracolumbar spine. Here, we validate its accuracy in the mobile cervical spine.

Methods: Initial validation was performed in 4 human cadavers. Intraoperative registration was performed to thin-slice preoperative computed tomography (CT). A tracked drill guide was used to navigate screw tracts at all levels. Lateral mass screws were placed at C1 and C3–6, pars screws at C2 and pedicle screws at C7. Navigation data were compared with screw positions on postoperative CT scans, and the absolute translational and angular deviations were computed. Clinical validation was subsequently performed in 6 patients undergoing open posterior cervical instrumentation.

Results: Fifty-three cadaveric screws were analyzed: 5 lateral mass screws at C1, 32 at C3–6, 8 pars screws at C2 and 8 pedicle screws at C7. Absolute translational errors were 1.66 mm ± 1.18 mm and 2.08 mm ± 2.21 mm in the axial and sagittal planes, respectively. Absolute angular deviations were 4.11° ± 3.79° and 6.96° ± 5.40°, respectively. In hierarchical linear modelling, adjusting for differences between cadavers, C7 pedicle screws demonstrated decreased axial translational error relative to all other screws (0.51 mm ± 0.36 mm, $p = 0.001$). Twenty-two clinical screws were analyzed: 2 pars crews at C2, 14 lateral mass screws at C3–5 and 6 pedicle screws at C7. Absolute translational errors were 1.52 mm ± 1.32 mm and 1.06 mm ± 0.97 mm in the axial and sagittal planes, respectively. Absolute angular deviations were 3.69° ± 2.63° and 2.83° ± 2.65°, respectively. There were no differences in errors between levels. There were no facet, canal or foraminal violations and no neurovascular injuries.

Conclusion: OTI is a novel navigation technique allowing efficient initial and repeat registration. Accuracy, even in the more mobile cervical spine, is comparable to current spinal neuronavigation systems.

Partners: the [1]University of Toronto, Toronto, Ont.; [2]Ryerson University, Toronto, Ont.; [3]Toronto Western Hospital, Toronto, Ont.; and [4]Sunnybrook Health Sciences Centre, Toronto, Ont.

Presented: 17th Annual Scientific Conference of the Canadian Spine Society, February 22-23, 2017

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

Authors: Daipayan Guha[1], Raphael Jakubovic[2], Shaurya Gupta[1], Albert Yee[1,3], Victor Yang[1,3]

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.

Partners: the [1]University of Toronto, Toronto, Ont.; [2]Ryerson University, Toronto, Ont.; and [3]Sunnybrook Health Sciences Centre, Toronto, Ont.

Full Article: http://www.thespinejournalonline.com/article/S1529-9430(17)30635-6/fulltext

Presented: 17th Annual Scientific Conference of the Canadian Spine Society, February 22-23, 2017

PRE-CLINICAL AND INITIAL CLINICAL EXPERIENCE OF A NOVEL RAPID INTRA-OPERATIVE REGISTRATION TECHNIQUE OF OPTICAL MACHINE-VISION TO PRE-OPERATIVE IMAGING FOR SPINAL SURGICAL NAVIGATION

Authors: Raphael Jakubovic[2], MSc; Daipayan Guha[1], MD; Michael Lu[3]; Shaurya Gupta[1]; David W.Cadotte[1],MSc,MD;Chris Heyn[3],MD,PhD;Peter Howard[1],MD;Todd Graham Mainprize[3],MD; Albert Yee[1,3],MD;VictorXiaoDongYang[1,3],MD,PhD,MSc,BSc

ABSTRACT

Introduction: Computer-assisted navigation is standard for most cranial procedures, and is employed in the spine to guide instrumentation, bony decompression and soft-tissue resection. Current navigation techniques register patient surface anatomy to either pre- or intra-operative imaging. The former is hampered by lengthy setup and registration protocols as well as an inability to account for intra-operative tissue movement; the latter requires setup of cumbersome imaging units, and exposes patients to additional intra-operative radiation.

Methods: Anovelstructured-light-basedopticaltopographicimaging(OTI)systemwas developed for spinal neuronavigation (Fig. 1). Initial validation was performed in 4 adult swine, followed 2017 Meeting Abstracts: AANS/CNS Joint Section on Disorders of the Spine and Peripheral Nerves Neurosurg Focus Volume 42 • March 2017 A44 by clinical validation in 53 patients undergoing open posterior thoracolumbar instrumentation. Registrations to thin- slice preoperative CT imaging were performed using OTI and benchmarked to existing neuronavigation systems (StealthStation/O-Arm, Nav3i). Navigation data was compared to post-operative imaging, and the absolute deviation of final screw positions from intra- operatively planned trajectories computed (Fig. 2). Final screw positions were also graded clinico radiographically using the Heary classification, independently by 7 raters.

Results: For 71 screws placed in 4 adult swine, translational and angular median(95%) errors were 1.67mm(5.12mm)/4.37°(12.95°) and 1.63mm(7.81mm)/6.50°(17.76°) in the axial and sagittal planes, respectively. In human clinical trials, with 129 screws placed with OTI in 22 patients and 209 screws placed with benchmark systems in 31 patients, OTI registration was achieved using 2251+/-1047 surface points per vertebral level (mean+/-SD). Registration and manual verification of navigation accuracy were performed significantly faster than both benchmark systems (mean 40s vs. 258s and 794s). Translational and angular median(95%) errors of 1.21mm(2.99mm)/1.80°(6.60°) and 1.45mm(3.57mm)/2.02°(7.62°) in the axial and sagittal planes, respectively, were achieved with OTI. No significant differences in clinicoradiographic grading or absolute quantitative errors between OTI and benchmark systems were observed.

Conclusion: Optical machine vision is faster and comparably accurate for spinal neuronavigation. Rapid structured-light illumination allows efficient initial and repeat registrations with minimal workflow disruption

Partners:[1]Universityof Toronto,Toronto,Ont.;[2]RyersonUniversity,Toronto,Ont.; and Sunnybrook Health Sciences Centre, Toronto.

Presented: March,2017

COMPUTER-ASSISTED INTRAOPERATIVE 3D NAVIGATION: TRENDS AND OUTCOMES AMONG ONTARIO SPINAL SURGEONS

Authors: Daipayan Guha[1], Ali Moghaddamjou[1], Albert Yee [1,3], Victor Yang[1,3]

ABSTRACT

Background: Computer-assisted navigation (CAN) has become the standard of care incranial neurosurgery for the localization of subsurface structures. In spinal procedures, CAN guidance has been proven to increase the accuracy of instrumentation. However, adoption remains limited owing to workflow restrictions, steep learning curves and high costs. Here, we aim to assess the usage of spinal CAN among Ontario surgeons to identify potential gaps in application and impact on patient outcomes.

Methods: A prospectively collected database of billed provincial health insurance fee codes and corresponding diagnostic codes was reviewed retrospectively from 2002 to 2014. Patients undergoing instrumented spinal fusions or percutaneous vertebroplasty/ kyphoplasty were identified. A combination of fee codes and ICD-9 codes were applied to distinguish the surgical approach, spinal level and indication for surgery (i.e., trauma, degenerative, deformity, infection, tumour). The use of intraoperative navigation was determined for each identified case.

Results: A total of 4607 cases of instrumented spinal fusion were identified, with more than half performed between 2010 and 2014. A total of 35.3% of patients were older than 65 years, with no sex predilection. Most (63.2%) procedures were performed by orthopedic surgeons, with the remainder by neurosurgeons. Most (86.0%) identified cases occurred in an academic institution. Of 2239 cases with identifiable etiology, CAN was used in 8.8%. In univariate analyses, CAN was used more often by neurosurgeons than orthopedic surgeons (20.9%v. 12.4%, $p = 0.002$) and in academic institutions than in community hospitals (15.9%v. 12.3%, $p = 0.008$), and it was performed more often in/after 2010 than earlier (18.9%v. 8.9%, $p < 0.001$). Differences in CAN usage by specialty and year remained significant in multiple logistic regression modelling.

Conclusion: Intraoperative navigation for spinal procedures has proven benefit for instrumentation accuracy, but is used preferentially by neurosurgeons at large academic institu- tions. The substantial increase in CAN usage after 2010 may reflect improvements in available technologies; however, significant gains must be made in cost and usability to improve access among all surgical disciplines and in smaller institutions. This is a preliminary analysis, with results forthcoming on the impact of CAN usage on surgical revision rates.

Partners: the [1]University of Toronto, Toronto, Ont.; [2]Ryerson University, Toronto, Ont.; [3]Toronto Western Hospital, Toronto, Ont.; and [4]Sunnybrook Health Sciences Centre, Toronto, Ont.

Presented: 17th Annual Scientific Conference of the Canadian Spine Society, February 22-23, 2017

SPINAL INTRAOPERATIVE 3D NAVIGATION: CORRELATION BETWEEN CLINICAL AND ABSOLUTE ENGINEERING ACCURACY

Authors: Daipayan Guha[1], Raphael J akubovic[2], Shaurya Gupta[1], Albert Yee[1,3], Naif Alotaibi[1], Victor Yang[1,3]

ABSTRACT

Background: Spinalcomputer-assistednavigation(CAN)mayguideinstrumentationplacement, reliably reducing screw breach rates. Definitions of screw breach, if reported, vary widely across studies. Absolute quantitative error is theoretically a more precise and generalizable metric of navigation accuracy. It has also been computed variably and reported in less than one-quarter of clinical studies of CAN-guided pedicle screw accuracy. Here, we characterize the correlation between clinical pedicle screw accuracy based on postoperative imaging and absolute quantitative navigation accuracy.

Methods: We reviewed a prospectively collected series of 209 pedicle screws placed with CAN guidance in 30 patients undergoing open posterior thoracolumbar instrumentation. All patients underwent postoperative computed tomography (CT). Screws were graded clinically by multiple independent raters using the Heary and 2 mm classifications. Absolute screw accuracies were quantified by the translational and angular error in each of the axial and sagittal planes.

Results: Acceptable screw accuracy was achieved for significantly fewer screws based on 2 mm grade versus Heary grade (92.6%v. 95.1%, $p = 0.036$), particularly in the lumbar spine. Interrater agreement was good for the Heary classification and moderate for the 2 mm grade, significantly greater among radiologists than surgeon raters. Mean absolute translational/angular accuracies were 1.75 mm/3.13° and 1.20 mm/3.64° in the axial and sagittal planes, respectively. There was no correlation between clinical and absolute navigation accuracy. Surgeons appear to compensate for perceived translational navigation error by adjusting screw medialization angle.

Conclusion: Radiographic classifications of pedicle screw accuracy vary in sensitivity across spinal levels as well as in interrater reliability. Correlation between clinical screw grade and absolute navigation accuracy is poor, as surgeons appear to compensate for perceived navigation registration error. Future studies of navigation accuracy should report absolute translational and angular errors. Clinical screw grades based on postoperative imaging may be more reliable if performed in multiple by radiologist raters.

Partners: the [1]University of Toronto, Toronto, Ont.; [2]Ryerson University, Toronto, Ont.; and [3]Sunnybrook Health Sciences Centre, Toronto, Ont.

Presented: 17th Annual Scientific Conference of the Canadian Spine Society, February 22-23, 2017