Intraoperative Image-guided Navigation Techniques:

Novel Applications

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DISCLOSURES

Consultant: Medtronic/Medtronic Navigation
Consultant/Shareholder: Zimmer Biomet LANX
Research Sponsor: Medtronic Navigation

Some of the clinical applications described in this presentation may be “off-label.” These applications reflect the presenter’s experience only, and in no way represent any industry-sponsored promotion.
Mapping “image space” to “surgical space” to create an interactive relationship between the patient and the images
IMAGE-GUIDED SPINAL NAVIGATION

- Links CT MRI Fluoroscopy imaging data to surgical anatomy
- Manipulation of multi-planar images
- Precise orientation to unexposed spinal anatomy
What’s wrong with fluoro?

• Accuracy
• Only 2-D images
• Radiation
• Ergonomics
• Lead
Why navigation in lumbar cases?

• Start out with simpler straightforward cases.
• Facilitates cases where anatomy is hidden, distorted, or unfamiliar:
  – MIS
  – Trauma
  – Deformity
  – Revision
  – Novel techniques
• May increase speed, accuracy, and decrease radiation exposure.
Why Navigation?
Need for Improvement?

- Thoracic and Lumbar Spine - Open
  - Misplacement rates vary from 5-55%
Advantages of Image-guided Spinal Navigation

- Enhanced/expanded visualization
- Improve accuracy
- Minimize / eliminate need for intraoperative imaging
- Improved ergonomics
- Reduce radiation exposure
- Enable techniques not possible with standard intraoperative imaging
- Excellent teaching tool
Disadvantages of IGS

- Cost
- Learning curve
  - Additional OR time in early cases
- Segmental tool
  - 3D navigation
- Accuracy limits
  - IGS systems don’t replace surgical judgment
Background

- Historically, adoption of image-guided navigation technology in spinal surgery has been limited.
  - Inefficiencies of early systems.
  - Concerns regarding accuracy.
  - Cost.
Current State

• Presently, there has been an increase in adoption of these techniques.
  – “Real-time” imaging.
  – Automatic registration.
  – Higher fidelity imaging.

• Cone beam computed tomography (O-arm)
  – 3-D data.
  – High fidelity images.
  – Large field size.
Questions Remain

• Accuracy
• Efficiency
• Radiation exposure
  – Surgeon -> 0
  – Patient ?
IGS Accuracy

- Cadaveric study
- Fluoronav versus fluoro
- Protocol: rate, grade, and severity of breaches
- Radiation exposure
Mirza – Results/Conclusions

• Increased time to place screws with IGS.
• Single-reference Fluornav associated with high rate and severity of breach, and is "highly inaccurate and unsafe".
• Multiple-reference Fluoronav more accurate but increases radiation exposure.
• Using standard fluoroscopy, radiation exposure is “minimal” (surgeon 16 mrem/procedure, cadaver 121 mrem/specimen).
IGS Accuracy

- Clinical series, retrospective
- Fluoronav, ISO-C 3-D
- Mirza protocol: rate, grade, and severity of breaches
IGS Accuracy - Results

• Rate of unintentional perforation low, related to pedicle diameter.
• No difference between Fluoronav and ISO-C 3-D.
• Rate, grade, and severity of breaches low (much lower than described by Mirza).
• No severe or medial perforations.

Tabaraee E, Gibson AG, Karahalios DG, Potts EA, Mobasser JP, Burch S.

Abstract

Study Design: Cadaveric laboratory study
Objective: To compare the accuracy, efficiency, and safety of intraoperative cone beamed computed tomography with navigation (O-ARM) to traditional intraoperative fluoroscopy (C-ARM) for the placement of pedicle screws.

Summary of Background Data: Radiation exposure remains a concern with traditional methods of intraoperative imaging in spine surgery. The use of O-ARM has been proposed for more accurate and efficient spinal instrumentation. Understanding radiation imparted to patients and surgeons by O-ARM is important for assessing risks and benefits of this technology, especially in light of evolving indications.

Methods: Four surgeons placed 160 pedicle screws on eight cadavers without deformity. Eighty pedicle screws were placed using O-ARM and C-ARM each. Instrumentation was placed bilaterally in the thoracic (T1-6) spine and lumbosacral junction (L5-S1) using a standard open technique while MIS technique was used at the lumbar 3-4 (L3-4) level. A "post-operative" CT scan was performed on cadavers where instrumentation was done using the C-ARM. An independent musculoskeletal radiologist assessed final images for screw position. Time requiring set-up and instrumentation was recorded. Dosimeters were placed on multiple aspects of cadavers and surgeons to record radiation exposure.

Results: There were no differences in breach rate between O-ARM and C-ARM group (5 vs. 7, Chi2 = 0.63, p = 0.4). The set up time for the O-ARM group was longer than for the C-ARM group (592 seconds vs. 297, p <0.05). However, the average total time was statistically the same (1629 vs. 1639 seconds, p = 0.96). Radiation exposure was higher for surgeons in the C-ARM group and cadavers in the O-ARM group. When a "post-operative" CT scan was included in the estimation of the total radiation exposure, there was less of difference between the groups, but still more for the O-ARM group.

Conclusion: In cadavers without deformity, O-ARM use results in similar breach rates as C-ARM for the placement of pedicle screws. Time for instrumentation is shorter with the O-ARM, but requires a longer set-up time. The O-ARM exposes less radiation to the surgeon, but higher doses to the cadaver.
Accuracy Results

- All breaches lateral.
- No difference in accuracy between C-arm and O-arm.

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Time Results

- Set up time faster with C-arm.
- Implant time faster with O-arm.
- No statistically significant difference in total time.
Conclusions

• O-arm at least as accurate fluoro.
• No increase in procedure time.
• Radiation exposure:
  – C-arm exposure to patient acceptable.
  – C-arm exposure to surgeon may exceed limits.
  – O-arm eliminates all radiation exposure to surgeon and staff.
  – O-arm doses to patient are higher than with C-arm, but less of a difference if confirmatory CT is performed.
Applications
Cervical Applications

- Condyle screw fixation
- C1 lateral mass screws
- Odontoid screw fixation
- C2 pars and pedicle screws
- C1-2 transarticular screws
- Subaxial lateral mass screws
- Subaxial pedicle screws
Cervical Lateral Mass
Computer-assisted posterior instrumentation of the cervical and cervico-thoracic spine
Cervical Pedicle Screws
C1-2 Transarticular Screws
C2 Pedicle Screws
C1 Lateral Mass Screws
Occipital Condyle Screws


Cadaveric study for placement of occipital condyle screws: technique and effects on surrounding anatomic structures

Laboratory investigation

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3D Anatomy in Motion
Occipital Condyle Fixation
Occipital Condyle Fixation
Cervical Subaxial Transarticular Screws

- Fixates 2 vertebral segments
- Engages multiple cortices
Odontoid Fracture
Odontoid Screw Fixation - MIS
Odontoid Screw Fixation
Odontoid Screw Fixation
Odontoid Screw Fixation
Thoracic Lumbar & Sacropelvic Applications

- Pedicle screws (deformity)
- Direct lateral approach (DLIF)
- Transarticular/transverse vertebral pedicle screws
- Facet screws
- Translaminar facet screws
- Alar screws
- Iliac bolts
- S2 alar screws
- Sacroiliac fusion
Deformity
Navigated DLIF
Navigated DLIF
Navigated DLIF
Navigated DLIF
Transvertebral Pedicle Screws

- Fixate 2 vertebral segments
- Purchase multiple cortical layers
Anterior transvertebral interbody cage with posterior transdiscal pedicle screw instrumentation for high-grade spondylolisthesis

Technical note

WILL FOREST BERINGER, D.O., JEAN-PIERRE MOBASSER, M.D., DEAN KARAHALIOS, M.D., AND ERIC ALFRED POTTS, M.D.
L5-S1 Transvertebral Fixation
Sacral Alar Screws

- Substitute or adjunct to S1 PS
- May place L5 root at risk
- Location at anterior inferior border of sacrum
Iliac Bolts

B.J. Garrido and K.E. Wood / The Spine Journal 11 (2011) 331–335

Advocate Health Care
Reference Arc – Perc Pin
S2-iliac Screws

- Alternative to iliac bolts
- Multiple cortices engaged
- Screw head aligns more readily with the S1 pedicle screws
Sacroiliac Joint Fusion
Sacrectomy Reconstruction
Non-instrumented Applications

• Cervical corpectomy
• Cervical foraminotomy
• Trauma (decompression)
• Tumor (biopsy and resection)
Trauma and Tumor

adequacy of decompression
Anterior Cervical Decompression

- Reference arc attached to Mayfield
- Keeps decompression centered
Posterior Cervical Decompression

- Reference arc attached to Mayfield
- Limits incision
- Better delineation of lower cervical region
Conclusions

- Image-guided spinal navigation
  - Fast, accurate, safe
  - Not just for pedicle screws any more
  - Enabling technology
    - MIS techniques
    - Novel procedures
  - Excellent educational tool
Thank You