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Image-Guided Spinal Navigation for C1-C2 Instrumentation: Part I

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Disorders of the spine are one of the oldest known human maladies, with descriptions found in ancient medical literature. As in many other areas of medicine, treatment of patients with these disorders has undergone rapid progress over the last century. Among treatment modalities, spinal instrumentation has been a significant technical advancement. Increased use of spinal instrumentation has spurred the need for accurate positioning of screws/instrumentation and enhanced stability of the construct. Traditionally, these have been placed using anatomic landmarks and intraoperative fluoroscopy.

In patients with advanced degenerative disease or trauma, or in those with severe curvature deformity, anatomy can be of limited help. With intraoperative fluoroscopy, limited visualization can be a significant issue, especially in patients with a large body habitus. Image guidance, by providing live, accurate information for placement of instrumentation, significantly improves upon these issues. Image guidance has been used in neurologic surgery during recent decades. It was employed initially for intracranial applications,

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including treatment of brain disorders, with significant benefits and is now used routinely as an important adjunct tool in the operating room for intracranial neurologic surgery. Only more recently has image guidance been used in spine surgery.

Background

Within the past few decades, spinal instrumentation has advanced from its origin in the lumbar spine to the thoracic region, as well as the cervical spine, including instrumentation at the C1-C2 (axial) spine. Adequate intraoperative imaging and meticulous surgical technique are required for safe insertion of instrumentation, especially pedicle screw placement in the mid- and upper thoracic regions and lateral mass or pars screws or other constructs in the axial or subaxial cervical spine. This is also very important in complex deformity operations in patients with significant curvature, or when the anatomy is obscured as a result of severe degenerative disease, inflammatory spondyloarthropathy or after previous arthrodesis, and in the pediatric patient with a small pedicle diameter.

Clinical and cadaveric studies have demonstrated a 2.8% to 23% rate of pedicle cortex violation during screw insertion in the cervical and thoracic spine when guided by landmark anatomy or fluoroscopy. Meta-analyses by Verma et al., and Shin et al., favored the use of image guidance with reduction in the rate of cortical breaks and/or neurologic complications.

Recent 3-dimensional (3D) intraoperative imaging and CT techniques have helped increase accuracy and improve visualization with the use of these techniques. There are still some limitations hampering universal adoption, including the need for extra equipment in the operating room, additional set-up time, and lack of familiarity with the equipment. Intraoperative CT eliminates the need for preoperative imaging, reduces surgical time, provides good accuracy, and eliminates the need for registration with a paired-point technique but can be more costly as a capital expense.

Operative Technique

Thin-slice CT of the region of interest is obtained during preoperative evaluation, and the images are uploaded to the navigation system. Multiple points are selected on the reconstructed images, usually bony landmarks. After patient positioning, clear visibility of the navigation system by the surgeon and the assistant is confirmed (Figure 1). Surgical exposure of the posterior elements is then performed, including a spinous process below the lowest proposed level for instrumentation; the clamp for the navigation tracker is placed on it in a rigid fashion. Alternatively, the tracker can be inserted into the iliac crest with pins. Two microscrews, 4 mm in length, one on each lamina of the vertebra with proposed instrumentation, are placed as landmarks for anatomic rescue points. An intraoperative image is then obtained using a 3D C-arm image intensifier. This image is then merged with the preoperative CT scan.

Once good accuracy is confirmed, the merged image is used to select a starting point for screw placement along with anatomic landmarks and confirmed with fluoroscopy as needed. An instrument of surgeon preference (eg, a Lenke probe), with a navigation pointer attached,

is used to access the pedicle (Figure 2). The navigation system is also used to measure appropriate diameter and length for the screw, by use of a virtual tip. The screw is then placed using an instrument with live navigation guidance (Figures 3 and 4). Fluoroscopy is used to confirm good screw placement in lateral and anteroposterior views as needed.

The advantage of this method is the ability to place instrumentation using a high-resolution preoperative CT scan. Before each screw is placed, the rescue points (the 4-mm microscrews) are checked for accuracy, along with anatomic landmarks, to confirm precision. This is necessary as anatomy can shift with movement or with any decompression performed up to this stage, although bony decompression (eg, a laminectomy) is generally performed after placement of instrumentation. Many of these steps can be minimized with the availability of intra-operative CT, although it is not yet widely available.

Summary of Steps

Placement of spinal instrumentation proceeds according to the following sequence:

1. Obtain/import preoperative thin-slice CT images (confirm patient identity and date of the study).
2. Set local correlations, including the levels of interest through which the system will merge. Correlate the pre-operative CT scan to the intraoperative scan (ie, draw a box around C1 and match it with the C1 level in the intra-operative images). After the images are merged, it is also possible to adjust the percentage of preoperative and intra-operative image visualization in each image.
3. Place/select anatomic landmarks (ie, 4-mm microscrews) at each level, which will act as verification points and, in case the position changes during the surgery, act as rescue points.
4. Intraoperative 3D fluoroscopy (or intraoperative CT) is performed if available. The patient tracker can either be affixed on the spinous process before this step is performed, or only kept in view of the navigation camera during intraoperative image acquisition and then placed on the spinous process later. Alternatively, iliac pins can be used to mount the tracker in a rigid fashion.
5. Calibrate instruments, including pedicle probes, drills, and screwdrivers.
6. Proceed with placement of instrumentation.

Conclusions

The use of navigation for placement of spinal instrumentation can reduce pedicle breach rate, intraoperative time, and radiational exposure, while adding to the precision and safety of the procedure. This is especially helpful for placement of pedicle screws in the thoracic or axial cervical spine; in children with small pedicle diameters; in patients with pedicle asymmetry, vertebral rotation, severe spinal deformities, tumors, or scar formation; in the setting of reoperation; or in patients with challenging anatomy of the axial cervical spine.

Readings

1. Ao J, Jin AM, Zhao WD, et al. Biomechanical evaluation of asymmetrical posterior internal fixation for transforaminal lumbar interbody fusion with transfacetopedicular screws. *Nan Fang Yi Ke Da Xue Xue Bao*. 2009; 29:959–961. 965. [PubMed: 19460720]
2. Barsa P 1, Fr hlich R, Beneš V 3rd, et al. Intraoperative portable CT-scanner based spinal navigation—a feasibility and safety study. *Acta Neurochir (Wien)*. 2014; 156(9):1807–1812. [PubMed: 25056633]
3. Bridwell KH. Cotrel-Dubousset instrumentation. *Orthop Nurs*. 1988; 7:11–16. [PubMed: 3344140]
4. Chang A, Lad EM, Lad SP. Hippocrates' influence on the origins of neuro-surgery. *Neurosurg Focus*. 2007; 23:E9.
5. Di Silvestre M, Parisini P, Lolli F, et al. Complications of thoracic pedicle screws in scoliosis treatment. *Spine (Phila Pa 1976)*. 2007; 32:1655–1661. [PubMed: 17621214]
6. Dickson JH, Harrington PR. The evolution of the Harrington instrumentation technique in scoliosis. *J Bone Joint Surg Am*. 1973; 55:993–1002. [PubMed: 4586408]
7. Harrington PR. The history and development of Harrington instrumentation by Paul R. Harrington, 1973. *Clin Orthop Relat Res*. 1988; 227:3–5. [PubMed: 3276423]
8. Harrington PR. Treatment of scoliosis. Correction and internal fixation by spine instrumentation. *J Bone Joint Surg Am*. 1962; 44-A:591–610. [PubMed: 14036052]
9. Heary RF, Bono CM, Black M. Thoracic pedicle screws: postoperative computerized tom ography scanning assessment. *J Neurosurg*. 2004; 100:325–331. [PubMed: 15070139]
10. Heary RF, Madhavan K. The history of spinal deformity. *Neurosurgery*. 2008; 63:5–15. [PubMed: 18812933]
11. Isaacs RE, Hyde J, Goodrich JA, et al. A prospective, nonrandomized, multicenter evaluation of extreme lateral interbody fusion for the treatment of adult degenerative scoliosis: perioperative outcomes and complications. *Spine (Phila Pa 1976)*. 2010; 35:S322–330. [PubMed: 21160396]
12. Kanter AS, Bradford DS, Okonkwo DO, et al. Thoracolumbar spinal deformity: part I. A historical passage to 1990: historical vignette. *J Neurosurg Spine*. 2009; 11:631–639. [PubMed: 19951014]
13. Knox JB, Dai JM 3rd, Orchowski JR. Superior segment facet joint violation and cortical violation after minimally invasive pedicle screw placement. *Spine J*. 2011; 11(3):213–217. [PubMed: 21377603]
14. Kumar K. Spinal deformity and axial traction. *Spine (Phila Pa 1976)*. 1996; 21:653–655. [PubMed: 8852326]
15. Roy-Camille R, Saillant G, Mazel C. Plating of thoracic, thoracolumbar, and lumbar injuries with pedicle screw plates. *Orthop Clin North Am*. 1986; 17:147–159. [PubMed: 3945476]
16. Shin BJ, James AR, Njoku IU, et al. Pedicle screw navigation: a systematic review and meta-analysis of perforation risk for computer-navigated versus freehand insertion. *J Neurosurg Spine*. 2012; 17(2):113–122. [PubMed: 22724594]
17. Verma R, Krishan S, Haendlmayer K, et al. Functional outcome of computer-assisted spinal pedicle screw placement: a systematic review and meta-analysis of 23 studies including 5,992 pedicle screws. *Eur Spine J*. 2010; 19(3):370–375. [PubMed: 20052504]
18. von Jako R, Finn MA, Yonemura KS, et al. Minimally invasive percutaneous transpedicular screw fixation: increased accuracy and reduced radiation exposure by means of a novel electromagnetic navigation system. *Acta Neurochir (Wien)*. 2011; 153:589–596. [PubMed: 21153669]
19. Wang MY. Percutaneous thoracolumbar pedicle screw fixation: is it time to revisit spinal fracture treatment? *World Neurosurg*. 2010; 74:570–571. [PubMed: 21492619]
20. Weinstein JN, Spratt KF, Spengler D, et al. Spinal pedicle fixation: reliability and validity of roentgenogram-based assessment and surgical factors on successful screw placement. *Spine*. 1998; 13:1012–1018. [PubMed: 3206294]

Learning Objectives

After participating in this CME activity, the neurosurgeon should be better able to:

1. Describe the present methods of image guidance and their limitations.
2. Describe computer-assisted, image-guided spinal navigation technique for instrumentation including indications, methodology, and limitations.
3. Highlight the potential use of image-guided spinal navigation and its advantages in modern spine surgery.

Figure 1.
Schematic for the operating room set-up for spinal neuronavigation.

Figure 2.
Screen shot for a screw trajectory using navigated probe.

Figure 3.
Navigated probe used for obtaining optimal screw trajectory.

Figure 4.
Navigated instrument/screwdriver for pedicle screw placement.