Navigation for Thoracic Spine Surgery

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Introduction

Current intraoperative spinal navigation techniques have evolved from previous standards of direct visualization, serial radiography and C-arm fluorescence analysis. These techniques, commonly referred to as image guidance or image-guided surgery, provide simultaneous multi-planar visualization of spinal anatomy [1]. This allows us to track almost any surgical instrument in real time, referring to the anatomical structures shown. This is especially useful when a spine surgeon places instruments or implants on unexposed or partially exposed spine structures that are not directly visible, such as pedicles or spine. While a thorough knowledge of surgical anatomy and techniques remains the most important aspect of spinal surgery navigation, the information obtained through image maps can help even the most experienced surgeons. The impact of image-guided surgery on the safety and accuracy of various spinal instrument procedures is well documented in the medical literature [1].

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In thoracic spine surgery, navigation can be useful in various fields such as intervertebral disc herniation, ossification of posterior longitudinal ligament, ossification of ligamentum flavum, interbody fusion, posterior screw fixation, and endoscopic neural decompression.

Background of Navigation

Computer-assisted technology was introduced in the clinical practice of spinal surgery in the early 1990s. Computerized surgical quidance techniques are constantly evolving. Preoperative CT (computed tomography) scan and MRI (magnetic resonance imaging) allow surgeons to plan the operation in detail. However, it was hard to transfer the preoperative plan directly to the surgical situation. Surgical procedures and implants are becoming more complex. Spinal surgeons need new methods for making successful surgery, improve safety, and reduce the risk of complications [2].

The concept of minimally invasive spinal surgery requires the use of some form of surgical navigation guidance. Traditionally, fluoroscopy was necessary for certain procedures. However, fluoroscopy has a lower accuracy, and there is a risk of radiation exposure for the surgical team, leading to its being supplanted by computer-assisted navigation. Computed tomography (CT) scan-based navigated screw placement has

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evolved into an acceptable modality by which surgical accuracy can be improved. However, during minimally invasive spinal surgery, preoperative CT image-based navigation cannot be applied, as the common posterior spinal anatomical landmark is generally not visible, making surgeon-dependent registration impossible. Furthermore, there is also a change in the intersegmental anatomy between the preoperative supine position and the final intraoperative prone position. These problems have been addressed by the introduction of intraoperative imaging-based navigation. The advent of intraoperative CT (O-arm) has eliminated the need for registration of vertebral levels for spinal image guidance, as was required in previous point-matching techniques. The advent of intraoperative CT has eliminated the need for registration of vertebral levels for spinal image guidance, as was required in previous point-matching techniques. However, optimal navigation accuracy also depends on the position of the dynamic reference frame (DRF). Ideally, the DRF should be fixed to the spinal level being instrumented, but whereas this is straightforward in large open spinal procedures, reliable placement of the DRF is difficult during minimally invasive spinal surgery. Placement of the DRF on an adjacent spinous process would require a separate incision, and the close proximity of the DRF may interfere with the surgical procedure itself. [3–5]

Fig. 1 Navigation system including work station, monitor, and infrared camera

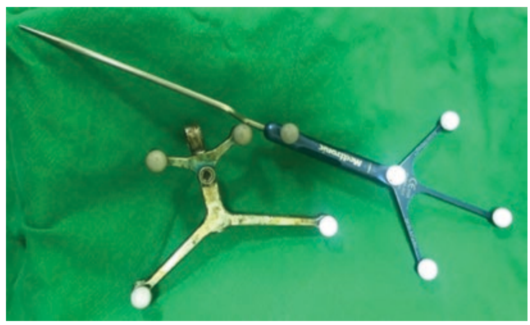

Fig. 2 Reference frame and stereotactic instrument

Navigation Set and Operation Room

To use navigation, a navigation system, an infrared camera system, a reference frame, and a stereotactic instrument are needed (Figs. 1 and 2). When the reference frame is mounted on the patient's body and the O-arm (Fig. 3) is taken and the image is transferred to the navigation work station, the navigation machine recognizes the three-dimensional shape of the patient's real-time spine, adjacent tissues and the reference frame (Fig. 4). When the stereotactic instrument is approached the patient's body, the infrared camera recognizes the stereotactic instrument and the reference frame (Fig. 5). Then, it projects the stereotactic instrument onto the pre-photographed CT image that could identify the surgical site.

The navigational spine operating room should have an O-arm including a monitor, navigation machine, and anesthesia machine, a radio-permeable operating bed and monitor capable of using the O-arm.

Surgery with Navigation

O-arm navigation system for thoracic spine surgery provides a secure and safe operation with a small incision. Before the incision, the lesions

Fig. 3 Intraoperative O-arm

Fig. 4 Reference frame attached to the patient's body

Fig. 5 The reference frame is positioned out of the way of the surgeon

can be measured using the navigation, and then the skin can be incised and approached to reach the lesion. We reached directly to the place of thoracic disc herniation and removed the herniated intervertebral disc to avoid nerve injury. Stereotactic instruments helped the surgical approach by presenting virtual extension lines showing the approach on three-dimensional images. The surgeon can reduce the incision by minimizing additional incisions to identify anatomical structures, and use navigation to distinguish between the structures to be removed and the structures to be preserved (Figs. 6 and 7).

Navigation for Endoscopy

In endoscopic thoracic spine surgery, navigation can enable accurate endoscope placement and removal of lesions. Unlike vascular surgery, endoscopic thoracic surgery is performed by inserting only the endoscope tube. Navigation shows the correct endoscope path, allowing the endoscope to reach the lesion. When fluoroscopy is used, the operator and the patient are exposed to radiation and use only two-dimensional images, but when endoscopic surgery is performed using the navigator, they are not exposed to radiation and provide more accurate and safe operation through three-dimensional images (Figs. 8, 9, and 10).

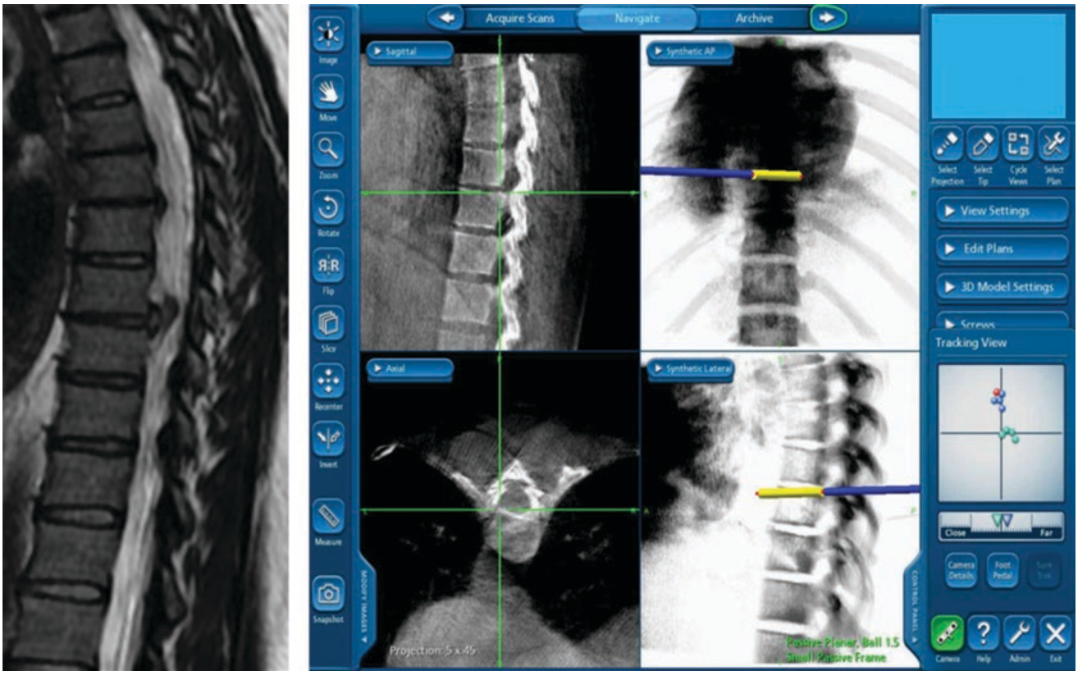

Fig. 6 Thoracic discectomy through posterolateral approach using navigation (T8–9)

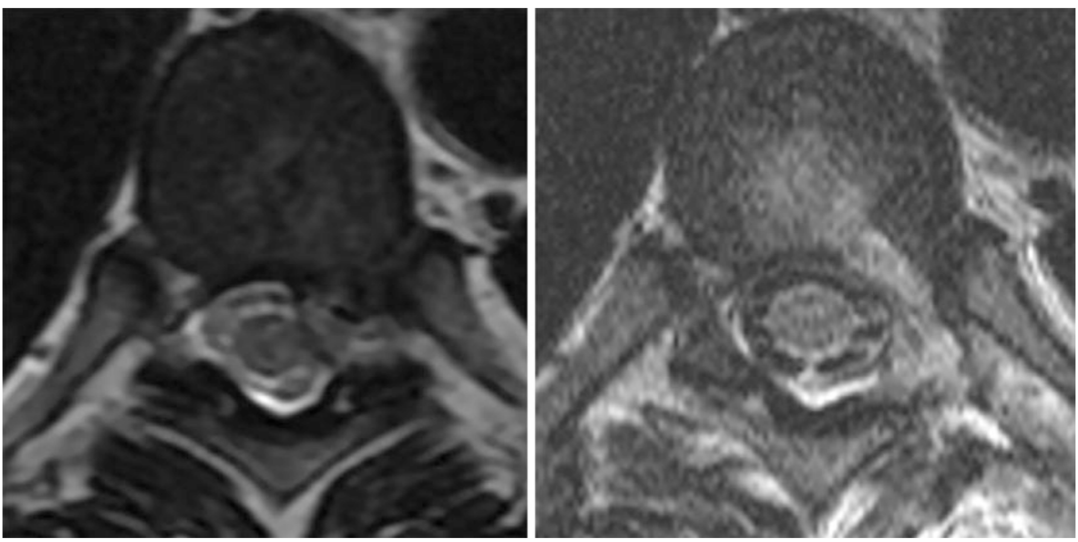

Fig. 7 Preoperative and postoperative MR images after thoracic discectomy using navigation

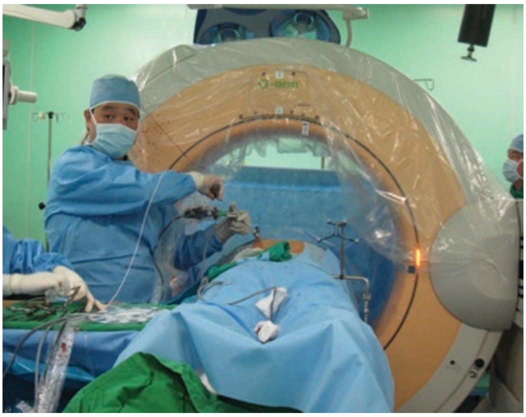

Fig. 8 Endoscopic thoracic discectomy using navigation and O-arm

Summary

Advances in navigation are useful surgical tools that provide accurate and safe surgery. Accurate removal of lesions and complications during spinal surgery allows for a successful surgical procedure with smaller incisions. In the future, this advanced technology can be further developed and the progress of spinal surgery can be expected.

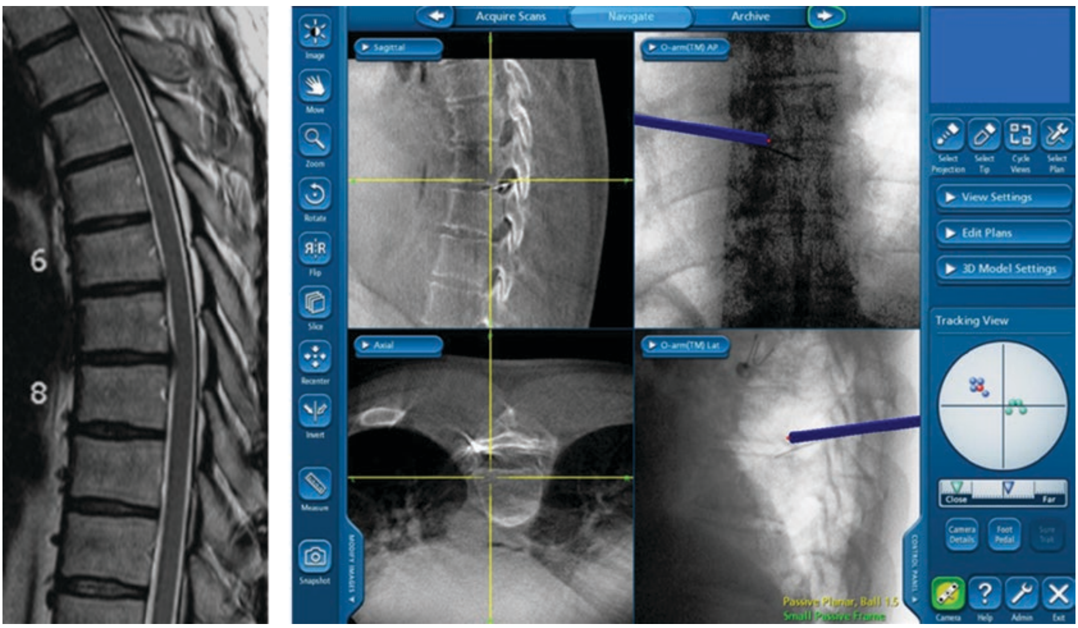

Fig. 9 Endoscopic thoracic discectomy using navigation and O-arm (T7–8)

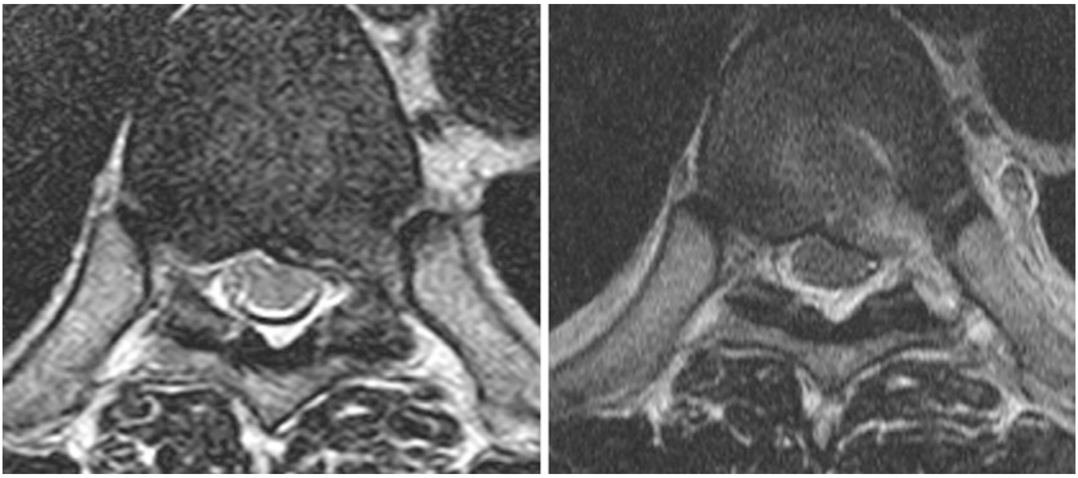

Fig. 10 preoperative and postoperative MR images after thoracic endoscopic discectomy using navigation

References

1. Holly LT, Foley KT. Intraoperative spinal navigation. Spine (Phila Pa 1976). 2003;28(15S):S54–61.
2. Dietrich S, Timo L, Teija L. Computer-assisted spine surgery. Eur Spine J. 2000;9(Suppl 1):S57–64.
3. Cho JY, Chan CK, Lee S, Lee HY. The accuracy of 3D image navigation with a cutaneously fixed dynamic reference frame in minimally invasive transforaminal lumbar interbody fusion. Comput Aided Surg. 2012;17(6):300–9.
4. Zausinger S, Scheder B, Uhl E, Heigl T, Morhard D, Tonn JC. Intraoperative computed tomography with integrated navigation system in spinal stabilizations. Spine (Phila Pa 1976). 2009;34:2919–26.
5. Best NM, Sasso RC, Garrido BJ. Computer-assisted spinal navigation using a percutaneous dynamic reference frame for posterior fusions of the lumbar spine. Am J Orthop. 2009;38:387–91.