Intraoperative Navigation in Minimally Invasive Transforaminal Lumbar Interbody Fusion and Lateral Interbody Fusion

James A. Stadler III, MD, Nader S. Dahdaleh, MD*,
Zachary A. Smith, MD, Tyler R. Koski, MD

KEYWORDS

• Minimally invasive • Transforaminal lumbar interbody fusion
• Minimally invasive pedicle screw placement • Intraoperative navigation

KEY POINTS

- Advanced intraoperative navigation technologies are currently being applied to a wide variety of minimally invasive spine surgical procedures.
- These advanced intraoperative navigation technologies carry many advantages with decreased radiation exposure and improved accuracy of hardware placement.
- The technique for use of neural navigation for minimally invasive placement of pedicle screws is discussed.

INTRODUCTION

Minimally invasive spine techniques have been developed with the aim of preserving the surrounding anatomy and avoiding unnecessary muscle disruption and damage, which has translated clinically into decreased blood loss, infection rates, length of hospitalization, narcotic use, and physiologic stress.[1] Importantly, outcomes following minimally invasive approaches are favorable compared with open techniques for many procedures, as increasingly demonstrated in the literature.[1–5]

Similarly, advances in intraoperative navigation technology have increased the safety and efficacy of spine surgery. Navigation is critical for a wide range of spinal procedures to facilitate localization and instrumentation. Traditional 2-dimensional techniques like fluoroscopy are progressively being augmented or replaced by advanced systems, such as cone-beam computed tomography (CT) or 3-dimensional fluoroscopy. As with traditional navigation, advanced imaging guidance can be used for multiple applications in any area of the spine.[6] Navigation has been applied during minimally invasive transforaminal interbody fusion, and there is to date only one report demonstrating feasibility of navigation during lateral interbody fusion.[7]

Advanced intraoperative navigation techniques carry many advantages when applied to minimally invasive spine surgeries, which are primarily driven by radiographic anatomy.[8] Beyond localization, an important advantage of advanced navigation is the

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Department of Neurological Surgery, Northwestern University Feinberg School of Medicine, 676 North Saint Clair Street, Suite 2210, Chicago, IL 60611, USA
* Corresponding author.
E-mail address: nsdahdaleh@gmail.com

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increased accuracy of pedicle screw placement and instrumentation.[9] Critical structures, including neural elements, major vessels, and viscera, can be avoided with real-time feedback. A meta-analysis of nonnavigated pedicle screws in the thoracolumbar spine showed a satisfactory pedicle screw position of only 79%.[10] In a separate meta-analysis of traditional fluoroscopic navigation, this rate improved to 87%.[11] However, individual reports of nonnavigated and traditional fluoroscopic techniques achieved have demonstrated satisfactory pedicle screw placement rates of up to 98.3% and 93.8%, suggesting variability between individual surgical results.[12,13] These rates compare to a reported accuracy of 98.2% and 98.8% with the use of advanced intraoperative navigation in recent studies.[14,15] Although the current data have largely focused on navigation in open cases, consideration of these findings seems appropriate for minimally invasive approaches as well.[4,6,16]

A significant concern in any spinal fusion is optimization of instrumentation biomechanics. It has been demonstrated that pedicle screw medialization, greater screw outer diameter, and greater cortical engagement contribute to improved screw pullout strength; increased screw inner diameter separately improves fatigue strength.[17] Advanced navigation allows the surgeon to maximize these variables intraoperatively with direct pedicle measurements and real-time adjustments to obtain biocortical or tricortical purchase.

Radiation exposure, to both the patient and the surgeon, during minimally invasive spine surgery is not insignificant. Multiple studies have demonstrated significant decreases in surgeon and staff radiation exposure with the use of intraoperative navigation.[4,14,18,19] Although the dose of radiation delivered to the patient intraoperatively may be similar or higher with these techniques, this difference becomes somewhat mitigated if routine postoperative CT scans are used to confirm the accuracy of nonnavigated instrumentation.[20]

There are additional notable benefits of advanced intraoperative navigation. Approach planning may be optimized to reduce incision length. This technique is a useful adjunct for resident training, because it provides real-time feedback to both the surgeon and the trainee. Beyond pedicle screw placement, navigation is also useful during decompression, in approaching and exploring of the disc space, and for interbody measurements.

Although minimally invasive surgical approaches were initially limited to a few procedures, the scope of applications continues to expand.[1,21,22] Advanced reconstructive imaging helps safely advance the indications as these interventions become more complex.[23]

SURGICAL TECHNIQUE FOR THE USE OF NAVIGATION FOR MINIMALLY INVASIVE OR MINI-OPEN PEDICLE SCREW PLACEMENT

Preparation and Patient Positioning

The patient is positioned on an OSI open Jackson table to maintain appropriate lumbar lordosis. All pressure points are appropriately padded.

Surgical Procedure

The patient presented underwent an anterior lumbar interbody fusion at L4/5 and L5/S1.

Step 1

The base of navigation reference frame is embedded firmly into posterior superior iliac crest following a small stab incision (**Fig. 1**). Two paraspinal incisions are marked 4.5 cm away from the midline on both sides.

Step 2

The camera of the navigation system recognizes the reference frame, and the surgical instruments to be used in the operation are registered for intraoperative navigation onto the station by placing them on the reference frame (**Fig. 2**).

Step 3

With the camera recognizing the reference frame and the O-Arm, the O-Arm is used to generate a 3-dimensional intraoperative CT of the lumbar spine level of interest (**Fig. 3**).

Step 4

Live intraoperative images in the axial, sagittal, and coronal planes are generated. The smallest dilator (attached to spherical sensors) is recognized by

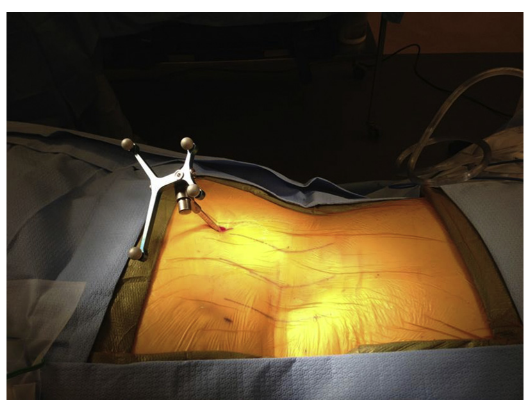

Fig. 1. The reference frame is embedded in the posterior superior iliac crest.