The ability to localize an intraoperative spinal level and correlate that level with the pathology observed on preoperative imaging is of paramount importance. In certain patients it is difficult to precisely define the level with existing imaging technology. C-arm fluoroscopy and conventional radiography have a limited field of view. These technologies are accurate for the rostral and caudal ends of the spine, but defining the intervening levels requires moving the frame of reference while counting. This has an inherent potential for error and often requires extended surgical time and increased radiation exposure to the patient and to the operating room personnel.

Wrong-level spine surgery remains a prevalent problem, with nearly 50% of surgeons having performed a wrong-level surgery at least once during their career, according to a recent survey by the American Association of Neurological Surgeons. Such an error fails to resolve the pathological condition and alleviate the patient’s symptoms.

Identifying the correct spinal level intraoperatively is critical to optimizing the patient’s surgical outcome, thereby eliminating any adverse consequences associated with wrong-level spine surgery. Multiple factors can increase the difficulty of spinal localization, including osteoporosis, obesity, scapular/humeral shadow, anatomical variations in the number of vertebrae, and ribs. Although various techniques have been proposed to facilitate intraoperative localization of the vertebral level, none has achieved widespread use.

In this paper a new technique to localize pathology within the thoracic spine is presented. We propose the placement of a radiopaque marker into the vertebral pedicle of the identified pathological level combined with postplacement MRI verification provides an advantage over previously proposed techniques in the literature.

Methods

A patient presented with symptoms of progressive myelopathy referable to an MRI-documented thoracic...
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disc/osteophyte compression at T10–11. The patient had an anatomical variation with 14 thoracic vertebrae as shown on MRI and large-plate radiography.

Fluoroscopic Pedicle Marking

As a first stage, prior to the definitive decompressive spine surgery, the patient was taken to the interventional radiology suite for the placement of the pedicle marker. With the patient in the prone position, biplane fluoroscopy was used to determine the affected level by counting the pedicles from the cervical spine to T-11. Under sterile technique, a local anesthetic (1% lidocaine) was used to anesthetize the soft tissue, including the periosteum. A 13-gauge bone biopsy needle was then passed into the pedicle until it reached the junction of the vertebral body. The trocar was removed, and under fluoroscopic guidance a 3 × 5-mm Tornado Vortex Embolization coil (Cook Medical) was placed at the junction between the pedicle and the vertebral body on the left (Fig. 1). The coil was deployed and compacted down with the trocar needle, and the entire biopsy needle was removed (Fig. 2). Hemostasis was achieved with manual pressure, and the patient tolerated the procedure without any complications.

Preoperative Imaging Conformation

After the pedicle had been marked in the interventional radiology suite, thoracic spine MRI without Gd was performed to document the location of the implanted coil (Fig. 3). Magnetic resonance imaging confirmed agreement with the fluoroscopic images in relation to the pathological level.

Operative Imaging

A C-arm fluoroscope was used in the operating room to obtain anteroposterior (AP) images of the spine (Fig. 4). The pathological level as marked by the pedicle coil was immediately identified. The incision and muscular exposure were minimized due to this precise localization. The site was rapidly and confidently exposed after approximately 3 seconds of fluoroscopy due to the ease of identifying the radiopaque coil marker.

Results

As described above, this patient presented with thoracic myeloradiculopathy. Initial MRI of the patient’s thoracic spine revealed a T10–11 herniated disc osteophyte with spinal cord myelomalacia. Scout MRI also identified some mild scoliosis and 14 thoracic vertebrae, counting from the cervical spine down.

Following the above technique of preoperative pedicle marking, and performing intraoperative localization via AP C-arm fluoroscopy, a T-11 thoracic laminectomy and transpedicular approach was performed to decompress the anterior compression of the spinal cord from the T10–11 disc osteophyte pathology. Through this exposure, the implanted coil was identified and removed, leaving no foreign material in place. The patient tolerated both the pedicle marking and surgical decompression without any complications and is currently free of symptoms.

Discussion

Determining the desired pathological spinal level with the currently available intraoperative imaging techniques can often be difficult. A recent survey by Mody et al. found that 1 in 2 spine surgeons have performed a wrong-level surgery at least once, and 50% of these cases were not discovered until after the surgery was completed. Wrong-level surgery is a preventable complication and an unnecessary morbidity for the patient.

Intraoperative fluoroscopy is routinely used in spinal localization by counting the vertebrae from the craniocervical and lumbosacral junctions. For the majority of patients, this technique is performed without difficulty; however, in certain clinical situations a patient with challenging anatomy may benefit from alternate localization techniques. For example, using an oblique fluoroscopic view, the gantry angle of the fluoroscope is parallel to the plane of the opposite lamina and gives a radiographic “target sign” similar to the transpedicular image commonly used in pedicle screw placement. This technique may be particularly useful when a true AP or lateral image is obscured, which makes it difficult to count the

Fig. 1. Anteroposterior fluoroscopic image obtained during cannulation of the left T-11 pedicle with a Jamshidi needle.

Fig. 2. Preoperative AP (A) and lateral (B) fluoroscopic images following coil placement.
number of ribs to confirm the pedicle level. Although this could be a method for localizing vertebral bodies, it is not ideal due to the amount of radiation exposure to the patient.

To accurately identify the correct spinal level, prolonged fluoroscopic exposure is often necessary for accurately counting vertebrae, exposing the patient and operating room personnel to significant radiation. A recent study showed that the duration of radiation exposure can vary depending on the type of spine surgery from 0.22 minutes for a lumbar laminectomy to 1.74 minutes for lumbar instrumentation. The total duration of fluoroscopy used in our operating room procedure was 0.05 minutes (3 seconds).

Nonpermanent preoperative techniques have been proposed in the literature to facilitate intraoperative localization. Examples include use of adhesive radiopaque skin markers prior to MRI or CT scanning and percutaneous injections of methylene blue dye to mark the spinous process at the intended surgical level. The advantages to these methods are that they are nonpermanent and cost-effective; however, there are drawbacks, such as tissue shifting and bleeding of the dye away from the injected site, respectively. Neither of the methods “anchor” to a fixed anatomical position, thus making them susceptible to movement that may decrease their accuracy for localization.

On the other hand, more invasive preoperative techniques have been suggested. Computed tomography–guided placement of a flexible hook-wire, first described for the localization of breast lesions, has been adapted for spinal pathologies as well. The main downside of this procedure is the wire protruding through the skin, thus necessitating immediate surgical intervention. Other invasive techniques, such as percutaneous vertebroplasty, fiducial screw implantation under CT guidance, and placement of a detachable coil in the soft tissue at the adjacent pathological level, have also been described.

Binning and Schmidt described a case series in which they used detachable coils as a radiopaque marker. The difference between our technique and that of those authors is that they placed the coil into the soft tissue on top of the pedicle, whereas in our technique we placed the coil directly into the pedicle. In addition, their coil remained in the soft tissue and was not removed during or after surgery, whereas in our technique the coil was removed during the transpedicular approach to the thoracic disc. By removing the coil, artifact signals will be avoided in future imaging studies and also will eliminate the possibility as a source for infection.

Preoperative considerations for this technique had the primary objectives of safely identifying the correct spine level and decreasing radiation exposure for the entire surgical team. The secondary objective was cost consideration. The Tornado Vortex Embolization coil cost...
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approximately $60, and a repeat thoracic MRI, to confirm the coil placement, cost approximately $1080 at our institution. In the future, simple scout MRI of the spine would be sufficient to identify the coil in relation to the spinal pathology. The placement of the coil in the interventional radiology suite required 15 seconds of fluoroscopic time. The amount of radiation used in interventional radiology can be considered minimal compared with that of live fluoroscopy with a C-arm in the operating room counting pedicles in the thoracic spine, especially when there are abnormal numbers of vertebral bodies. Computed tomography–guided placement of the coil is another option that would eliminate radiation exposure to the surgeon; however, multiple scans would be needed to confirm coil placement into the pedicle at the right level, including advancement of the bone biopsy needle, thus exposing the patient to higher doses of radiation. Overall, total fluoroscopic time between pre- and intraoperative procedures lasted approximately 18 seconds, which is reasonable for the amount of radiation exposure to ensure accurate localization of difficult spinal pathology.

Limitations of this technique would be encountered by centers without an interventional radiology suite and an interventionist or surgeon who can place the coil with a minimal duration of radiation exposure. Although medical resources and cost are issues, these can be minimized by choosing a coil suitable for removal and performing scout MRI to confirm the pathology with the coil, where the pathology alone would otherwise not be readily identifiable with CT scans, intraoperative fluoroscopy, and radiography. Further cost analysis is needed to compare this procedure against the cost of a rare, but expensive, wrong-level surgery event.

In addition, the coils can be placed on an outpatient basis hours to days before the procedure, and they can be left in place or removed during the operation. In this report the patient was taken directly to the operating room after coil placement; however, other patients have come on an outpatient basis for pedicle marking and return for surgery on a different day.

Conclusions

Preoperative placement of radiopaque markers along with postplacement MRI is a safe and effective method for the confident intraoperative localization of spinal pathology that otherwise would not be visible on intraoperative radiography. There are multiple benefits, including improved reliability and accuracy of localization, minimal discomfort for the patient, and decreased radiation exposure to the patient and operating room personnel. Such procedures can be completed in the outpatient setting and take minimal resources and time to perform. It is believed that this is a significant improvement over previously proposed techniques, and, furthermore, it is appropriate for use in a multitude of spinal pathologies.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

References


Author contributions to the study and manuscript preparation include the following. Conception and design: Young, Wind. Acquisition of data: Olan. Analysis and interpretation of data: Young, Caputy. Drafting the article: Young, Prasad, Wind. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Young. Administrative/technical/material support: Olan. Study supervision: Caputy.

Address correspondence to: Anthony J. Caputy, M.D., 2150 Pennsylvania Ave. NW, Ste. 7-420, Washington, DC 20037. email: acaputy@niaf.gwu.edu.

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