Imaging-guided costotransversectomy for thoracic disc herniation

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The surgical management of thoracic disc disease remains challenging. Outcomes after laminectomy had been poor, and modern posterolateral, lateral, and anterior approaches have evolved to replace this older procedure. Each has its own set of complications, and all are hampered, to varying degrees, by the limited visualization of the ventral disc space and spinal cord during decompression. The authors present their early experience with computer-assisted image guidance as an adjunctive tool for preoperative planning and navigation in the treatment of thoracic disc disease. Five consecutive patients underwent image-guided costotransversectomies between January 1999 and April 2000. The levels of herniation were T8–9 in three and T7–8 and T5–6, respectively, in the other two. There were four centrolateral herniations and one midline herniation. Three discs were soft and two hard. Two patients had previously undergone failed disc excisions. All patients had axial pain and myeloradiculopathies preoperatively. Three were unable to walk.

Four patients enjoyed good or excellent outcomes, with return of ambulation. One patient experienced only mild improvement in her severe paraparesis. Image-guidance was invaluable in planning the corpectomy and aiding visualization in situations in which the dura or disc were obscured; its use allowed successful surgical excisions in the most challenging circumstances.

KEY WORDS • thoracic discectomy • costotransversectomy • computer-assisted surgery

The incidence of symptomatic thoracic disc herniations is estimated to be one in 1,000,000 in the general population, and thoracic discectomy procedures constitute only 0.25 to 1% of all disc surgeries. Indeed, a typical neurosurgeon during training may not be exposed to the necessary number of cases to undertake any of these approaches with comfort.

We have chosen to enhance visualization with the lateral approach by using computerized frameless stereotaxy as an adjunct to our costotransversectomy and lateral extracavitary dissections. In this report we describe our preliminary experience with image-guidance technology, which we used successfully to remove symptomatic thoracic disc herniations in five patients.

CLINICAL MATERIAL AND METHODS

Patient Population

Between January 1999 and April 2000, five consecutive patients with symptomatic thoracic disc herniations underwent image-guided thoracic discectomy at our institution. There were three women and two men, ranging in age from 35 to 67 years (mean age 47 years). The levels of herniation were T8–9 in three patients and T7–8 and T5–6, respectively, in two patients. Discs were soft in three patients and calcified in two. Except for one patient with a central disc herniation, all the patients had centrolateral herniations (Table 1).

All patients presented with axial pain preoperatively. Three patients were nonambulatory and incontinent prior to surgery.
to surgery; the remaining patients had disabling pain and numbness. Duration of symptoms preoperatively ranged from 6 months to 5 years (mean 20.4 months). Two patients had previously undergone failed surgery. One of these patients (Case 1) had undergone a costotransversectomy performed at the level above the disc herniation due to a misidentified level intraoperatively. The other patient (Case 2) had undergone a thoracoscopic approach that was aborted due to severe pleural adhesions. Another patient (Case 4) underwent a T10–11 laminectomy for spondylotic thoracic stenosis concurrently with her T8–9 discectomy. In all patients thoracic spine MR images were obtained; these documented significant spinal cord compression.

Preoperative Preparation and Planning

One patient underwent 1-mm CT scanning of the thoracic spine, and in the other four we obtained CT myelograms of the thoracic spine inclusive of the vertebral segments adjacent to the disc herniation. The CT data were imported into a computer workstation (StealthStation; Medtronic Surgical Navigation Technologies, Broomfield, CO) and 3D reconstruction was performed by the system. Six to eight fiducial markers were chosen from the orthogonal and 3D images by selecting points on the spine most likely to be identified once the surgical exposure was obtained (Fig. 1). Typically points on the spinous processes, transverse processes, and facets of adjacent vertebrae were chosen. After the disc herniation was viewed in relation to the surrounding structures, the extent of pedicular and rib resections and the dimension of the corpectomy trough were planned (Fig. 2).

Surgical Technique

The patients were placed prone on vertical bolsters with the side ipsilateral to the disc herniation slightly elevated. Intraoperative x-ray films were obtained to confirm the correct spinal level prior to skin incision. Semilunar incision and dissection for costotransversectomy were performed in a lateral-to-medial direction. The exposure was carried medially to the spinous processes to allow placement of the dynamic reference frame and to permit use of the spinous process as an anatomic fiducial marker. After the dynamic reference frame had been secured to the base of the spinous process, paired-point and surface-matching analyses were performed (in that order) to achieve a predicted accuracy (an estimate of the registration error from the center of the fiducials to any point 6 cm away) of 0.6 mm or less. Registration was performed using fiducial markers from two vertebrae adjacent and ipsilateral to the disc herniation. This improved the registration and minimized potential error caused by thoracic-segment motion. The actual accuracy was visually confirmed prior to bone resection and at frequent intervals during the surgery. A costotransversectomy and thoracic discectomy were performed under microscopic magnification by using the image-guidance system to provide live images of the probe and surgical instruments.

RESULTS

In all five patients a thoracic spine MR image was obtained postoperatively that documented successful disc resection. Postoperative follow-up periods ranged from 4 to 19 months (mean 9.2 months). All patients had experienced axial pain preoperatively; this pain either improved significantly or resolved in all nonambulatory patients. Three patients with myelopathy experienced improvement; however, only two patients regained the ability to walk. Thus far, there has been no recurrence of disc herniation or instability requiring fusion. One patient with a history of wound dehiscence from another surgical procedure developed a wound dehiscence, but this resolved secondarily (Table 2).

ILLUSTRATIVE CASES

Case 1

This 46-year-old woman presented with a longer than 1 year history of back pain and a 6-month history of lower-extremity weakness leading to paraplegia and incontinence. A workup with MR imaging revealed a large right-sided T5–6 centrolateral calcified disc herniation with

### Table 1

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Consistency</th>
<th>Location in Canal</th>
<th>Herniation</th>
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<tbody>
<tr>
<td>1</td>
<td>calcified</td>
<td>centrolateral</td>
<td>T5–6</td>
</tr>
<tr>
<td>2</td>
<td>soft</td>
<td>centrolateral</td>
<td>T8–9</td>
</tr>
<tr>
<td>3</td>
<td>calcified</td>
<td>centrolateral</td>
<td>T8–9</td>
</tr>
<tr>
<td>4</td>
<td>soft</td>
<td>centrolateral</td>
<td>T8–9</td>
</tr>
<tr>
<td>5</td>
<td>soft</td>
<td>central</td>
<td>T7–8</td>
</tr>
</tbody>
</table>

Fig. 1. Case 3. Three-dimensional reconstructed CT view of thoracic spine with eight fiducial markers (numbered circles) selected for registration. Subtle differences in the morphological structure of the spinous processes are used to help confirm the spinal level prior to bone resection.
severe spinal cord deformation. The patient had previously undergone attempted disc removal via costotransversectomy by another neurosurgeon, but postoperative imaging revealed a misidentification of the level of disease at the initial surgery with a T-5 rib resection and significant residual disc herniation. She was then referred to the primary author and underwent image-guided thoracic microdiscectomy via a T-6 costotransversectomy using the same semilunar skin incision. Preoperative planning was performed using the computer workstation to determine the length of the rib resection necessary to allow discectomy instruments to reach the calcified disc without manipulating the spinal cord (Fig. 2). We were able easily to estimate the extent of corpectomy and pedicular resection necessary for complete disc resection based on the sagittal views. Intraoperatively, the calcified disc was noted to have an intradural extension; central and contralateral extension of the calcified disc could not be directly visualized. An image-guidance probe was used intraoperatively to track the location of the instrument to ensure that the spinal cord was not manipulated. A CT scan was obtained postoperatively, and the data were imported into the computer workstation to verify the extent of bone resection and to confirm successful disc resection (Fig. 3). Postoperatively the patient experienced resolution of her back pain, with minor improvement in lower-extremity strength; however, she remained nonambulatory.

Case 2

This otherwise healthy 35-year-old man presented with a 5-year history of midthoracic axial pain. This condition worsened progressively and he developed numbness and tingling involving his left side down to the leg. He was diagnosed at another institution as having a T7–8 disc herniation with deformation of the spinal cord, which was noted on MR imaging, and conservative treatment was recommended. When his symptoms became disabling, he was referred to us for a second opinion. With computer-assisted image guidance we performed a left T-8 costotransversectomy with resection of the soft T7–8 central disc herniation. Although the field of view was obscured due to intermittent bleeding at the operative site, an image-guidance probe was used to visualize the surrounding structures and confirm adequate disc excision. Postoperative imaging studies revealed good thoracic disc resection with limited bone resection, and the patient experienced complete resolution of his axial pain and dysesthesias. (Fig. 4).

TABLE 2

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Axial Pain</th>
<th>Myelopathy</th>
<th>Radiculopathy</th>
<th>Disc Recurrence</th>
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<td>nonamb</td>
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<tr>
<td>2</td>
<td>67, M</td>
<td>yes</td>
<td>improved</td>
<td>nonamb</td>
<td>amb</td>
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<tr>
<td>3</td>
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<td>resolved</td>
<td>nonamb</td>
<td>amb</td>
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<tr>
<td>4</td>
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<td>resolved</td>
<td>yes</td>
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<tr>
<td>5</td>
<td>35, M</td>
<td>yes</td>
<td>resolved</td>
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* Abbreviations: amb = ambulatory; nonamb = nonambulatory.

DISCUSSION

Image-guidance systems are now commonly used by neurosurgeons for intracranial procedures such as biopsies, tumor resections, and functional interventions. Until recently, spinal applications have largely been limited to placement of lumbar pedicle screws. Bolger and colleagues recently reported their experience with 120 image-guided procedures in the cervical and thoracic spine. Included in this series were 13 patients who underwent image-guided thoracic pedicle screw insertion,
five of whom had previously undergone anterior thoracic fusions with Kaneda instrumentation. The image-guidance system was used effectively to avoid the previously placed anterior screws during pedicle screw implantation.

The primary advantage of frameless stereotaxy is that it provides the surgeon with accurate knowledge of the spatial relationship between the surgical instrument or appliance and the surrounding structures not directly visible in the operative field. This information is critically important in thoracic disc surgery, in which the risk of inflicting spinal cord injury is significant. Dickman, et al.,9 reviewed 15 patients with residual disc herniation after thoracic discectomy and noted that either the posterolateral or lateral approach was used in 11 of these patients. The most common reasons for failure of adequate disc excision were inadequate visualization (eight cases) and surgery at the wrong level (five cases). In three cases, the surgery was stopped due to spinal cord injury. In contrast, these authors achieved complete discectomies by using anterior approaches including thoracoscopy and thoracotomy. Anterior approaches afford the most extensive view of the ventral spinal canal and disc. Lateral approaches provide the next most inclusive view. The advantage of lateral approaches is that they afford concurrent visualization of the disc and dura during decompression, in contrast to anterior procedures, during which the dura may be obscured until the disc is almost completely excised.24

We used image-guidance with the primary intent of addressing the visualization problem inherent in all of these surgical approaches. We chose costotransversectomy as our initial approach, because of the broad visualization that it provides. With more experience, however, we intend to use image guidance for surgical approaches that it may augment even more effectively: namely, the transpedicular or transpedicular faced-sparing approach, in which the view of the disc, canal, and cord relationships is even more limited. We believe that image guidance may also be valuable in anterior approaches; however, further work remains to be done to improve the reliability of anterior fiducial marker registration.

Despite the good visual perspective afforded by lateral approaches, these methods still suffer from this significant drawback: if a disc herniation extends centrally, visualization is often inadequate.24 This can prevent complete disc resection and increase the risk of spinal cord injury.

In attacking the problem of limited visualization with image guidance, we found the system quite useful in addressing other problems common to thoracic discectomy. These include confirmation of the appropriate spinal level, preoperative planning of rib resection and corpectomy, and continuous navigational monitoring of the position of the surgical instruments in relation to the spinal cord as a means to augment visual inspection.

During each procedure, frameless stereotaxy was used to confirm the correct spinal level prior to registration; this was accomplished by looking at the 3D reconstructed view of the spinous processes. Subtle differences in the morphological structure, angle, and surface topology of the thoracic spinous process, not discernible on x-ray or CT scans, became obvious when the 3D reconstructed views were compared with the intraoperative view after surgical exposure was achieved. Next, the length of rib resection necessary to safely achieve a complete disc excision was determined by planning the shortest instrument trajectory needed to reach the herniated disc while avoiding the spinal cord. More importantly, the minimum cor-
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pectomy defect necessary to achieve a complete discectomy was planned and intraoperatively monitored by image guidance to minimize the risk of creating instability.

Finally, and most important, image guidance was constantly used intraoperatively to monitor the location of the surgical instrument in relation to both the disc herniation and the spinal cord. This proved crucial when the surgical anatomy was unfamiliar or when venous or bone bleeding obscured the surgical field.

CONCLUSIONS

Historically, dismal experiences with simple laminectomy to approach thoracic disc herniations led to the development of posterolateral and transthoracic approaches. Posterolateral approaches are more familiar to most neurosurgeons but are often limited in that they provide inadequate visualization of the pathology; hence many surgeons favor anterior approaches. The thoracoscopy approach, in particular, is quite promising as a minimally invasive technique. Frameless stereotaxy is becoming widely available, and many neurosurgeons already use this technology for cranial applications. The addition of technology to a posterolateral approach provides the surgeon with augmented visualization that rivals that afforded by anterior approaches, while avoiding the morbidity associated with the later. Image-guidance also allows expansion of the lateral approach to include calcified central disc herniations and affords the visual exposure necessary to accomplish safe and complete spinal cord decompression, even under the most challenging circumstances.

Disclosure

None of the authors received any monies or services from conflicting sources related to the techniques or instrumentation discussed in this paper.

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