Thoracoscopic discectomy and instrumented fusion using a minimally invasive plate system: surgical technique and early clinical outcome

ERICA F. BISSON, M.D., GREGORY F. JOST, M.D., RONALD I. APFELBAUM, M.D., AND MEIC H. SCHMIDT, M.D.

Department of Neurosurgery, Clinical Neurosciences Center, University of Utah, Salt Lake City, Utah

Object. The use of minimally invasive noninstrumented fusions has increased as thoracoscopic approaches to the spine have evolved. The addition of instrumentation is infrequent, in part because of the lack of a minimally invasive spinal system. The authors describe a technique for thoracoscopic plating after discectomy and report early clinical outcomes.

Methods. After a standard endoscopic discectomy and partial corpectomy and before exposure of the ventral thecal sac, the authors implanted a polyaxial screw and clamping element under fluoroscopic guidance. Reconstruction involves placement of autograft in the defect and subsequent placement of the remainder of the screw/plate construct with 2 screws per vertebral level.

Results. Twenty-five patients underwent thoracoscopic and thoracotomy-assisted discectomies and fusion in which the aforementioned plate system was used. Of 19 patients presenting with pain, 10 had 6-month clinical follow-up with a greater than 50% reduction in visual analog scale score, which continued to improve up to 2 years postoperatively. There were 3 cases of pneumonia, 3 CSF leaks, 1 chyle leak, and 1 death due to a massive pulmonary embolus on the 1st postoperative day.

Conclusions. The authors conclude that thoracoscopic discectomy and plate-instrumented fusion can be achieved with acceptable results and morbidity. Further studies should evaluate the role of instrumented fusions after thoracoscopic discectomy in larger groups of patients and during a longer follow-up period.

(DOI: 10.3171/2011.1.FOCUS10309)

KEY WORDS • thoracic discectomy • thoracic fusion • thoracoscopic technique • minimally invasive surgery

Although thoracic disc herniation is a common finding on MR imaging in asymptomatic individuals, it accounts for less than 1% of clinically significant herniated discs and less than 2% of surgical discectomies. A lower incidence of disc herniation in the thoracic spine than in the cervical and lumbar regions is attributed to the coupling of the thoracic spine to the rib cage and the costovertebral articulations, which increase spinal stability and minimize spinal flexion. Despite their rarity, symptomatic thoracic herniated discs can result in a range of neurological symptoms, including radiculopathy and axial pain as well as myelopathy. Most patients can undergo conservative management, but in patients in whom conservative therapy fails or those who present with progressive myelopathy, surgery is advocated. The operative approach to the thoracic disc has evolved over the last several decades to enhance visualization while minimizing morbidity. Current options include various posterior, posterolateral, and anterior approaches, each suited for specific pathoanatomy and patient characteristics. More recently, with the introduction of endoscopic techniques, the anterior thoracic spine can now be accessed through a minimally invasive approach.

Biomechanical studies indicate that thoracic discectomy results in increased range of motion as well as significant perturbation of the neutral zone, indicating instability, but the necessity of fusion with thoracic discectomy is still the subject of debate. Although the use of screw/plate instrumentation has been shown to decrease the pseudarthrosis rate and obviate the need for postoperative orthosis in other spinal regions, this technique has been used infrequently in the thoracic spine. An additional deterrent to its use in thoracoscopic procedures has been the lack of a minimally invasive implant system.

The purpose of this study is to describe a minimally invasive surgical technique for thoracoscopic plating after discectomy, with fusion and early clinical outcomes.

Abbreviations used in this paper: EBL = estimated blood loss; LOS = length of stay; VAS = visual analog scale.
Methods

Under an institutional review board–approved protocol, data were collected prospectively from April 2003 through September 2009 at the University of Utah to evaluate clinical outcomes after thoracoscopic discectomy and instrumented fusion using the MACS-TL plating system (Aesculap), a screw/plate construct that allows for 2 screws per vertebral level. The plate system gained US FDA approval in 2002, with an implant cost of approximately $6000 US. In all patients surgery was performed by one of two senior surgeons (R.I.A. and M.H.S.). Outcome data included operative time, blood loss, hospital LOS, complications, and postoperative pain.

Operative Technique

Preoperative evaluation included plain radiography as well as thoracic MR and CT imaging to delineate the disc disease and the bony anatomy for placement of a screw/plate construct and interbody graft. The CT scan is also important to determine whether the disc is calcified and to indicate the position of the aorta in relationship to the spine. In addition to routine laboratory testing, an electrocardiogram and a chest radiograph should be obtained to evaluate for potential pleural fluid or other contraindicative lung conditions.

The patient is intubated using a double-lumen endotracheal tube to achieve single-lung ventilation for maximal surgical exposure. The patient is positioned as previously described by Amini et al. Electrophysiological monitoring, including somatosensory evoked potentials and motor evoked potentials, is used during the procedure. A left-sided approach is preferred for access to the thoracolumbar junction because it avoids the liver, and a right-sided approach is preferred for the middle to upper thoracic spine to avoid the great vessels. However, if the herniated disc is eccentric, the approach is on the side of the protrusion.

The technique used for a thoracoscopic discectomy and instrumented fusion is summarized below (Video 1).

**Video 1**. Video demonstrating a thoracoscopic discectomy and instrumented fusion technique. Click here to view with Windows Media Player. Click here to view with Quicktime.

The positioning and spinal exposure have been described in detail by Amini et al. In brief, a lateral spine image is obtained fluoroscopically and used to identify landmarks and portal sites on the patient’s skin. Counting the vertebral bodies and disc spaces identifies the appropriate level. More recently, we have also used a metallic marker that is placed preoperatively for identification of the correct level. The working portal is positioned directly over the affected disc; the camera portal is positioned caudal to the working portal for lesions in the upper or middle thoracic spine or 2–3 intracostal spaces cranial to the lesion for thoracolumbar lesions. The suction/irrigation portal and retractor portal are both positioned ventral to the working portal and slightly cranial or caudal, respectively (Fig. 1). Because of the risk of inadvertent injuries during placement of the portals, the first portal is placed at the site farthest from the diaphragm by using a mini-thoracotomy technique. In all cases, the surgeon should be prepared for the potential of injury that would necessitate conversion to a full thoracotomy. After the endoscope has been introduced, the other portals are placed under direct visualization.

The involved vertebral bodies and intervening disc space are identified using fluoroscopy, and the correct level of pathology is confirmed. A pleural flap is elevated, exposing the disc space and the cephalad and caudal vertebral bodies with their respective segmental arteries and veins, as well as the rib head overlying the disc space.

Once the vessels have been identified, coagulated or clipped, and cut, a standard endoscopic discectomy and partial corpectomy can be undertaken. First, the rib head is resected and kept as a source of graft for the fusion. The disc is then incised with an endoscopic knife and removed with rongeurs.

Prior to the exposure of the ventral thecal sac, fluoroscopy is used to insert a K-wire in either the proximal or distal vertebral body undergoing instrumentation. The MACS-TL polyaxial screw and clamping element is then placed over the K-wire under fluoroscopic guidance. This helps define the working area. Knowing the location of the posterior vertebral body at all times enhances safety and facilitates the operation.

Partial corpectomies are then performed with a Midas Rex drill equipped with a coarse diamond drill bit (Fig. 2 left). To access the ventral canal, a partial or complete removal of the caudal pedicle is performed. Once the bony removal is complete, the disc fragment is pulled into the defect using a combination of curettes and dissectors with care not to retract or pull on the thecal sac.

Reconstruction begins with the placement of structural and morselized rib autograft in the discectomy/partial corpectomy defect, filling the defect as completely as possible with the available graft material. The posterior screw in each vertebral body is placed over the K-wire using fluoroscopy and a specialized aiming device to ensure the screw is placed a safe distance from the posterior vertebral body wall to avoid canal penetration. The plate is sized using a caliper and then placed over the screw construct.
and secured with locking nuts (Fig. 2 right). Prior to plate placement, the working portal is removed and a speculum is introduced through the incision. The speculum allows for temporary dilation of the skin and soft tissue to provide access to the thoracic cavity for the plate (Fig. 3). The anterior screws are then placed convergently using an aiming device. Last, the locking screws are applied to secure the polyaxial mechanism. Before closure, a small chest tube is placed through one of the portal sites, and the lung is reinflated under direct endoscopic vision. The chest tube is usually removed on the 1st postoperative day, and a chest radiograph is obtained to rule out pneumothorax. Patients are mobilized immediately, and no postoperative orthoses are used. Patients return for postoperative follow-up visits at 1, 3, 6, 12, and 24 months.

Results

Twenty-five patients underwent thoracoscopic discectomies and instrumented fusion in which the MACS-TL system was used, including 19 for degenerative thoracic disc herniation, 5 for traumatic disc disruption, and 1 for discitis. These 25 patients comprised the study population. The mean preoperative VAS pain score in 19 patients presenting with pain was 6 (median 7, range 1–10). Most of the patients had lower thoracic and thoracolumbar disc disease. A summary of patient demographic characteristics, side and level of disease, and operative variables including EBL, operative time, and complications is shown in Table 1.

The mean operative time was 337 minutes (range 154–672 minutes). The mean and median EBL levels were 505 and 275 ml, respectively. In patients without postoperative complications, the mean LOS was 4.75 days (range 3–14 days). In patients with complications (3 cases of pneumonia, 3 CSF leaks, and 1 chyle leak) the mean LOS was 16.5 days (range 3.3–43 days). The chyle leak was an unusual complication that has been described previously.1 One patient died of a massive pulmonary embolus on the 1st postoperative day. In cases of CSF leaks, management involved intraoperative placement of fibrin glue and the initial postoperative placement of a chest tube for gravity drainage only, with early removal. The total perioperative complication rate in our series was 32%, slightly higher than the 21% complication rate reported by Anand and Reagan,3 the largest reported series of thoracoscopic discectomies with and without fusion, but lower than the 42.3% complication rate reported by Watanabe et al.20 in their evaluation of complication rates in endoscopic spinal surgery.

Among the 19 patients with pain symptoms, the mean VAS score improved by 33% at 1 month; a continued reduction to greater than 50% improvement was also seen at 6 months, and this was sustained at 2 years (Fig. 4). No patient required a reoperation for a symptomatic nonunion.

Discussion

Unique anatomical and regional features of the thoracic spine have led surgeons to develop varied approaches to the operative management of thoracic disc herniations. With a small disease incidence and a plethora of procedures, the optimal operative management has been controversial, although recently some consensus has developed. In a frequently quoted paper, Bohlman and Zdeblick5 advocated the use of an anterior approach for thoracic discectomy because it offers improved visualization of the thecal sac. Additionally, they advocated using fusion in which iliac crest allograft is combined with postoperative orthosis whenever the surgical approach necessitates significant bony decompression.5 The authors of a recent review of the literature proposed an algorithm that advocates anterior approaches for central or centrolateral and calcified thoracic discs.17 Thus, it appears that the use of an anterior approach as the optimal choice in most patients has developed some acceptance, but controversy remains regarding the necessity of adding a fusion. Furthermore, the safety and efficacy of adding screw/plate instrumentation to a thoracic discectomy and fusion have not been explored.

To investigate the biomechanics of thoracic discectomy and evaluate the need for fusion, Broc et al.6 performed nondestructive flexibility testing on human
CADVERIC THORACIC SPINES BEFORE AND AFTER MICRODISCECTOMY

E. F. Bisson et al.

Neurosurg Focus / Volume 30 / April 2011

The authors of this study investigated the effects of thoracic microdiscectomy on the mechanics and kinematics of the thoracic spine. They found that although the neutral zone, elastic zone, and range of motion increased significantly in all directions after discectomy, the magnitude of change was small. Additionally, there was no statistical difference in the instantaneous axis of rotation before and after discectomy. The authors concluded that thoracic microdiscectomy had small effects on the immediate mechanics and kinematics of the thoracic spine and did not overtly destabilize the motion segments. In contradistinction, Takeuchi et al. reported results obtained in a canine spine model of thoracic discectomy that showed the intervertebral disc regulates the stability of the thoracic spine in flexion-extension, lateral bending, and axial rotation. Moreover, the articulation of the rib head with the vertebral bodies provides stability to the thoracic spine in lateral bending and axial rotation. Unilateral resection of the rib head joint after partial discectomy produced significant coupled motions in lateral bending and axial rotation, resulting in a significant decrease in thoracic spinal stability and integrity.

Despite biomechanical studies that suggest that thoracic discectomy may cause a decrease in spinal stability that could be improved by fusion, comparison of clinical outcomes of thoracic fusion and nonfusion after discectomy showed equivocal findings. In 1988, Otani et al. reported on 23 patients treated surgically over a 16-year period for symptomatic thoracic disc herniation. They described a procedure consisting of total discectomy, intervertebral body fusion in which autogenous iliac bone was placed via an anterior approach, and postoperative immobilization with a plaster jacket for 10–12 weeks, which resulted in an excellent or good outcome in 79% of the cases and a fusion rate of 100% as assessed on the motion segments.

### Table 1: Summary of demographic data and operative variables

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Side of Approach</th>
<th>Level of Disease</th>
<th>Pathology</th>
<th>EBL (ml)</th>
<th>Op Time (min)</th>
<th>LOS (days)</th>
<th>Complication</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>47, M</td>
<td>rt</td>
<td>T6–7</td>
<td>HNP</td>
<td>700</td>
<td>360</td>
<td>4</td>
<td>none</td>
</tr>
<tr>
<td>2</td>
<td>47, M</td>
<td>lt</td>
<td>T10–11</td>
<td>HNP</td>
<td>500</td>
<td>345</td>
<td>7</td>
<td>none</td>
</tr>
<tr>
<td>3</td>
<td>45, F</td>
<td>lt</td>
<td>T9–10</td>
<td>HNP</td>
<td>100</td>
<td>240</td>
<td>3</td>
<td>none</td>
</tr>
<tr>
<td>4</td>
<td>48, F</td>
<td>lt</td>
<td>T12–L1</td>
<td>HNP</td>
<td>1300</td>
<td>359</td>
<td>4</td>
<td>none</td>
</tr>
<tr>
<td>5</td>
<td>58, M</td>
<td>rt</td>
<td>T6–7</td>
<td>HNP</td>
<td>650</td>
<td>364</td>
<td>6</td>
<td>none</td>
</tr>
<tr>
<td>6</td>
<td>47, F</td>
<td>lt</td>
<td>T10–11</td>
<td>HNP</td>
<td>600</td>
<td>290</td>
<td>4</td>
<td>none</td>
</tr>
<tr>
<td>7</td>
<td>43, M</td>
<td>lt</td>
<td>T10–11</td>
<td>HNP</td>
<td>1500</td>
<td>271</td>
<td>3</td>
<td>none</td>
</tr>
<tr>
<td>8</td>
<td>41, F</td>
<td>rt</td>
<td>T7–8</td>
<td>HNP</td>
<td>300</td>
<td>240</td>
<td>7</td>
<td>none</td>
</tr>
<tr>
<td>9</td>
<td>34, F</td>
<td>rt</td>
<td>T9–10</td>
<td>HNP</td>
<td>100</td>
<td>276</td>
<td>3.2</td>
<td>none</td>
</tr>
<tr>
<td>10</td>
<td>38, M</td>
<td>lt</td>
<td>T9–10</td>
<td>trauma</td>
<td>250</td>
<td>214</td>
<td>14</td>
<td>none</td>
</tr>
<tr>
<td>11</td>
<td>58, M</td>
<td>rt</td>
<td>T6–7</td>
<td>HNP</td>
<td>300</td>
<td>415</td>
<td>5.2</td>
<td>none</td>
</tr>
<tr>
<td>12</td>
<td>40, M</td>
<td>rt</td>
<td>T9–10</td>
<td>HNP</td>
<td>100</td>
<td>349</td>
<td>3.1</td>
<td>none</td>
</tr>
<tr>
<td>13</td>
<td>51, F</td>
<td>lt</td>
<td>T12–L1</td>
<td>HNP</td>
<td>1700</td>
<td>396</td>
<td>14</td>
<td>chyle leak</td>
</tr>
<tr>
<td>14</td>
<td>17, F</td>
<td>rt</td>
<td>T7–8</td>
<td>trauma</td>
<td>150</td>
<td>154</td>
<td>8</td>
<td>pneumonia</td>
</tr>
<tr>
<td>15</td>
<td>21, M</td>
<td>lt</td>
<td>T12–L1</td>
<td>trauma</td>
<td>200</td>
<td>235</td>
<td>43</td>
<td>pneumonia</td>
</tr>
<tr>
<td>16</td>
<td>56, M</td>
<td>lt</td>
<td>T11–12</td>
<td>HNP</td>
<td>900</td>
<td>333</td>
<td>10.6</td>
<td>none</td>
</tr>
<tr>
<td>17</td>
<td>57, F</td>
<td>lt</td>
<td>T8–9</td>
<td>HNP</td>
<td>1500</td>
<td>469</td>
<td>3.3</td>
<td>CSF leak</td>
</tr>
<tr>
<td>18</td>
<td>49, F</td>
<td>rt</td>
<td>T6–7</td>
<td>HNP</td>
<td>400</td>
<td>517</td>
<td>3.4</td>
<td>none</td>
</tr>
<tr>
<td>19</td>
<td>17, F</td>
<td>lt</td>
<td>T10–11</td>
<td>trauma</td>
<td>200</td>
<td>236</td>
<td>14</td>
<td>pneumonia</td>
</tr>
<tr>
<td>20</td>
<td>69, F</td>
<td>lt</td>
<td>T11–12</td>
<td>trauma</td>
<td>200</td>
<td>282</td>
<td>3</td>
<td>none</td>
</tr>
<tr>
<td>21</td>
<td>70, M</td>
<td>rt</td>
<td>T11–12</td>
<td>infection</td>
<td>100</td>
<td>216</td>
<td>3</td>
<td>none</td>
</tr>
<tr>
<td>22</td>
<td>56, F</td>
<td>rt</td>
<td>T3–4</td>
<td>HNP</td>
<td>50</td>
<td>402</td>
<td>3.7</td>
<td>none</td>
</tr>
<tr>
<td>23</td>
<td>36, M</td>
<td>rt</td>
<td>T8–9</td>
<td>HNP</td>
<td>250</td>
<td>396</td>
<td>3.3</td>
<td>CSF leak</td>
</tr>
<tr>
<td>24</td>
<td>25, M</td>
<td>rt</td>
<td>T7–8</td>
<td>HNP</td>
<td>150</td>
<td>388</td>
<td>1.5</td>
<td>CSF leak; death due to massive pulmonary embolus</td>
</tr>
<tr>
<td>25</td>
<td>43, F</td>
<td>rt</td>
<td>T5–6</td>
<td>HNP</td>
<td>250</td>
<td>672</td>
<td>4</td>
<td>none</td>
</tr>
</tbody>
</table>

* HNP = herniated nucleus pulposus.
radiography at 6-month follow-up. In 1994, Currier et al.\textsuperscript{9} reported their case series of central or centrolateral disc herniation in 19 patients who underwent transthoracic discectomy and fusion, involving either autogenous rib graft or allograft. All patients were placed in thoracolumbosacral orthosis for 3 months postoperatively. Of the 17 patients available for follow-up, 12 had either excellent or good outcomes, with a 100% final fusion rate (1 patient had pseudarthrosis requiring posterior instrumentation).\textsuperscript{9} Despite the positive results with their technique, these authors suggested the use of arthodesis only if the decompression caused instability, such as when the decompression is extended to avoid compromising the collateral blood flow to the spinal cord in the neural foramina or to improve visualization. Anand and Regan\textsuperscript{3} have discussed their experience using an endoscopic technique for thoracic discectomy and fusion. In their series of 100 patients, 40 patients with axial back pain and concordant discography underwent fusion with either autogenous rib graft or a BAK cage. Among patients who presented with a predominant component of axial pain, the Oswestry Disability Index (ODI) and VAS back pain scores in those in the discectomy/fusion group were compared with those in discectomy-alone group. Both groups showed a significant reduction in ODI and VAS scores, but there was no significant difference between the 2 groups, which were not randomized.\textsuperscript{3} Our patients experienced similar long-term pain reduction (mean 24-month reduction 5.5 points). Furthermore, a significant portion of the reduction in VAS scores occurred early in our patients' postoperative course (mean 3-month reduction 4.25 points). This agrees with our clinical impression that these patients promptly return to work and to usual activities of daily living. In the absence of controlled studies, the decision to add a fusion to a thoracic discectomy relies on the surgeon's judgment of the clinical and intraoperative situation. Indeed, some authors advocate using the degree of back pain to guide operative decision making, stating that fusion should be reserved for patients presenting with a significant component of axial back pain.\textsuperscript{3,10,12,14} A fusion may also be the treatment of choice to arrest any further motion at the level of a myelopathic spinal cord. In summary, clinical outcomes in the studies by Otani et al.,\textsuperscript{14} Currier et al.\textsuperscript{9} and Anand and Regan,\textsuperscript{3} as well as in the present cases, suggest both the safety and efficacy of transthoracic discectomy and fusion; however, the superiority of discectomy and fusion over discectomy alone remains to be proven clinically.

At present, the MACS-TL system is the only screw/plate construct for the anterior thoracic spine that has been designed to be introduced using endoscopy. It is a modular system that uses polyaxial screws to allow the clamping element to be placed flat on the vertebral bodies and stabilized. The plate is ultimately inserted in the clamping element and secured with locking nuts. The entire construct is not only low profile but is designed with no sharp edges, the presence of which could be dangerous in the thoracic cavity. Although benefits and drawbacks to using a minimally invasive thoracoscopic approach have been described in detail in previous publications,\textsuperscript{2,7,8,11,13,15,16} there has been little discussion of the role of anterior screw/plate instrumentation to enhance fusion in the thoracic spine. In the current study, we performed 25 thoracoscopic and thoracoscopic-assisted discectomies using the MACS-TL plating system. All patients with follow-up reported a substantial and sustained clinical improvement postoperatively. Although the procedure is technically demanding with a steep learning curve, the plating system adds visual cues to the 2D image of an endoscopic approach because the initial placement of one of the posterior screws cranial and caudal to the disc space defines the working area and the location of the canal. In contrast to patients who undergo fusion without plate fixation, the patients in this cohort were mobilized without needing to wear a brace, which facilitates postoperative care and patient comfort. The patients reported a substantial and sustained clinical improvement postoperatively.

**Conclusions**

To date, this is the only report detailing the efficacy and safety of adding screw/plate instrumentation to thoracic fusion after discectomy. Although fusion techniques involving cage systems or structural allograft and autograft techniques have been used after discectomy in patients who present with axial pain, no study to date has reported on the use of a plate system, which may not only confer more immediate stability to a fused segment, thereby decreasing postoperative pain, but may also obviate the need for postoperative orthosis. Our study shows that thoracic discectomy and fusion with plate fixation via a minimally invasive approach can be achieved with postoperative clinical improvement and minimal morbidity. Further studies are necessary to evaluate the role of plate-assisted fusions after thoracoscopic discectomy.

**Disclosure**

Dr. Schmidt serves as a consultant for Aesculap. The remaining authors report no other conflicts of interest concerning the materials or methods used in this study or the findings specified in this paper. Author contributions to the study and manuscript preparation include the following. Conception and design: Schmidt, Apfelbaum. Acquisition of data: Bisson. Analysis and interpretation of data: Bisson. Drafting the article: Bisson. Critically revising the article: Schmidt, Jost, Apfelbaum. Reviewed final version of the manuscript and approved it for submission: all authors. Study supervision: Schmidt.

**Acknowledgments**

We thank Kristin Kraus, M.Sc., for editorial assistance in preparing this article and Kelly Johnson for assistance preparing the video and figures.

**References**


3. Anand N, Regan JJ: Video-assisted thoracoscopic surgery for thoracic disc disease: Classification and outcome study of 100

Manuscript submitted December 15, 2010. Accepted January 21, 2011. Supplemental online information:
Address correspondence to: Meic H. Schmidt, M.D., Department of Neurosurgery, University of Utah, 175 North Medical Drive East, Salt Lake City, Utah 84132. email: neuropub@hsc.utah.edu.