First described by Harms and Rolinger in 1982, TLIF has become extensively used in the treatment of degenerative spine disease. The advantages of the transforaminal approach have been extensively de-

Described in the spine literature. Cloward’s PLIF procedure improved on the ALIF by permitting the performance of circumferential arthrodesis through a single surgical approach. However, the PLIF procedure involves placement of bilateral interbody spacers while the dura mater is retracted medially. Notable advantages of the TLIF procedure include the following: circumferential fusion through a unilateral, posterior approach; less retraction of the thecal

perforative surgical complications of transforaminal lumbar interbody fusion: a single-center experience

Clinical article

Matthew J. Tormenti, M.D., Matthew B. Maserati, M.D., Christopher M. Bonfield, M.D., Peter C. Gerszten, M.D., M.P.H., John J. Moossy, M.D., Adam S. Kanter, M.D., Richard M. Spiro, M.D., and David O. Okonkwo, M.D., Ph.D.

Department of Neurological Surgery, University of Pittsburgh Medical Center, Presbyterian Hospital, Pittsburgh, Pennsylvania

Object. Since its original description in 1982, transforaminal lumbar interbody fusion (TLIF) has grown in popularity as a means for achieving circumferential fusion. The authors sought to define the perioperative complication rates of the TLIF procedure at a large academic medical center.

Methods. For all eligible patients from a consecutive series of 531 TLIF procedures, the institution’s complication database and the medical record were reviewed to identify complications. Medical, nonprocedure-related complications such as myocardial infarction and pulmonary embolism were excluded due to inconsistency in the recording of these complications in the database. Rates were calculated for each type of complication, and subgroup analysis was performed to investigate the effect of previous lumbar surgery, and of multilevel versus single-level interbody fusion on complication rates. Odds ratios were calculated and evaluated using chi-square analysis.

Results. Five hundred thirty-one patients underwent a TLIF procedure during the study period. Two hundred forty-four patients (46%) had undergone a previous lumbar operation. Interbody fusion was performed at 1 level in 317 patients, at 2 levels in 188 patients, at 3 levels in 24 patients, and at 4 levels in 2 patients. One hundred thirty-five patients (25.4%) had at least one procedure-related complication. The most common complications were durotomy (14.3% of patients) and infection (3.8% of patients). Symptomatic screw misplacement (2.1% of patients) and interbody cage migration (1.8% of patients) were less common complications. The overall complication rate was greater in those patients who had undergone a previous operation (OR 1.75, 95% CI 1.18–2.59; p < 0.01) and in those who had multilevel surgery (OR 1.54, 95% CI 1.04–2.28; p = 0.03), and the incidence of durotomy was higher in patients who had a previous operation (OR 1.75, 95% CI 1.07–2.87; p = 0.03). These differences were statistically significant. Durotomy also occurred more frequently in patients who had multilevel interbody fusion (OR 1.49, 95% CI 0.92–2.43; p = 0.13). A trend toward higher infection rates in those patients who underwent multilevel interbody fusion was observed (OR 1.5, 95% CI 0.62–3.68; p = 0.49), but this was not statistically significant. Infection rates did not differ between revision and first-time surgeries.

Conclusions. Transforaminal lumbar interbody fusion has gained widespread popularity as a procedure for achieving arthrodesis in the lumbar spine. Complications occurred more often in patients undergoing revision surgery or multilevel interbody fusion. Durotomy and infection were the most common complications in this series.

DOI: 10.3171/2011.9.SPINE11373

Key words • transforaminal lumbar interbody fusion • complication • durotomy • infection
Perioperative complications related to TLIF

Data Collection

A retrospective review was performed to identify all patients who underwent the TLIF procedure at the University of Pittsburgh Medical Center Presbyterian Hospital (Pittsburgh, Pennsylvania) between March 2005 and June 2009. Patients were identified by querying departmental billing records for the Current Procedural Terminology code for lumbar interbody arthrodesis. The operative report was then reviewed for each patient to confirm that the individual underwent transfemoral graft insertion rather than traditional PLIF or ALIF, which were performed contemporaneously during the early TLIF experience at our hospital. Eligibility for this study was predicated on transforaminal graft placement. The same individuals who reviewed the medical records (M.J.T., M.B.M., and C.M.B.) determined eligibility. This process yielded 531 consecutive patients. The electronic medical record for each patient was reviewed and recorded, including patient demographic data, the number of levels fused, history of lumbar surgery, disposition at discharge, and need for further surgery. We hypothesized that the most common complications would be durotomy and infection. We sought to determine whether revision surgery or multilevel operations would result in higher complication rates. Complications and their management were identified by querying a prospectively maintained departmental complication database for each of the 531 patients, and confirmed during retrospective review of each patient’s electronic medical record.

Whereas surgical, procedure-related complications such as durotomy, wound infection, and neurological deficit are rigorously documented in the database, perioperative medical complications such as myocardial infarction and pulmonary embolism are inconsistently recorded and were therefore not included in this analysis. Surgical complications have been reliably recorded in this database for more than 20 years, in compliance with quality control requirements of our institution. Treatment failures—including pseudarthrosis—were not included in this analysis of perioperative complications.

Methods

Patient Characteristics

Five hundred thirty-one patients underwent TLIF performed by 1 of 7 surgeons during a 51-month period between March 2005 and June 2009. Indications for the procedure included degenerative instability, degenerative and isthmic spondylolisthesis, adult idiopathic and degenerative scoliosis, pseudarthrosis, adjacent-segment disease,
and failed previous decompressive spine surgery (Table 1). The mean and median age of the patients was 50 years (range 19–86 years). There were 288 (54.2%) women and 243 (45.8%) men. Two hundred forty-four patients (46%) had undergone a previous lumbar operation (Table 2). Interbody fusion was performed at 1 level in 317 patients (60%), at 2 levels in 188 patients (35%), at 3 levels in 24 patients (5%), and at 4 levels in 2 patients (< 1%).

Summary of Complications

One hundred thirty-five patients (25.4%) of the cohort had at least a single procedure-related complication (Table 3). The most common complications encountered were durotomy (76 patients, 14.3%) and infection (20 patients, 3.8%).

Durotomy. This complication occurred in 76 patients (14.3%). Forty-four (57.9%) of these patients had undergone previous lumbar surgery at the operative level. Thirty-seven (48.7%) of these patients underwent multilevel interbody fusion. Three patients (3.9%) required a repeat operation for a persistent CSF leak. One patient experienced new-onset trigeminal neuropathy, presumably secondary to intracranial hypotension, which was successfully managed with oral medications. One patient had severe headaches that led to a CT scan, which revealed a small cerebellar hemorrhage. This hemorrhage was observed with serial imaging and no further intervention was needed.

Infection. Twenty patients (3.8%) developed a wound infection. Nine (45%) of these patients had had a previous lumbar operation, and 10 patients (50%) had multilevel surgery. All patients were treated with intravenous antibiotics. Nineteen patients (95%) underwent irrigation and debridement of the infected wound. In 2 (10%) of these patients, the pedicle screw/rod instrumentation was removed due to poor bone purchase, but the interbody cages were left in place.

Other Complications. Twenty-seven patients (5.1%) had a complication other than a durotomy or an infection; the majority of these complications were implant related. Eleven patients (2.1%) had symptomatic misplaced pedicle screws, all of which were eventually removed and replaced without incident. Migration of an interbody spacer occurred in 10 patients (1.9%). All but one of these patients underwent surgery for removal and replacement of the cage. One patient underwent decompression at the wrong level. This was recognized intraoperatively, the interbody fusion was performed at the correct (adjacent) level, and the posterior instrumented fusion was extended to include the inadvertently decompressed level.

Two additional patients had a neurological complication not related to instrumentation. One patient experienced temporary saddle anesthesia, consistent with a partial cauda equina syndrome, which ultimately resolved. A second patient experienced unilateral ulnar neuropathy, which was self-limited and presumably related to intraoperative positioning. One patient who was prone for 5 hours during surgery suffered a facial pressure ulcer despite the use of standard facial padding. This was treated with topical antibiotics and healed without further complication.

Violation of the retroperitoneal space occurred in 2 patients. In 1 patient, this error was realized intraoperatively, and a postoperative CT angiogram—obtained immediately following closure—revealed no evidence of retroperitoneal vascular injury. In the other patient, entry into the retroperitoneum was not recognized intraoperatively. The patient became tachycardic and hypotensive in the recovery room, prompting a CT angiogram. This revealed an iliac artery pseudoaneurysm, which was treated with endovascular stent placement.

Previous Lumbar Surgery

Two hundred forty-four patients (46%) had undergone previous lumbar surgery (Table 2). At least 1 complication occurred in 76 (31.1%) of these patients, compared with 59 (20.6%) of the 287 patients undergoing their first lumbar surgery (OR 1.75, 95% CI 1.18–2.59; p < 0.01). Durotomy occurred in 44 (18%) of the revision operations, compared with 32 (11.1%) of the first-time operations (OR 1.75, 95% CI 1.18–2.59; p = 0.03). Infection occurred in 9 (3.7%) of the revision operations, and in 11 (3.8%) of the first-time operations (OR 0.96—no difference). These results are summarized in Table 4.

### Table 2: Previous operations in 244 patients who later underwent TLIF procedures

<table>
<thead>
<tr>
<th>Previous Procedure</th>
<th>No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>discectomy</td>
<td>96 (39.3)</td>
</tr>
<tr>
<td>laminectomy</td>
<td>76 (31.1)</td>
</tr>
<tr>
<td>fusion (noninstrumented or instrumented)</td>
<td>72 (29.5)</td>
</tr>
</tbody>
</table>

### Table 3: Complications in 531 patients who underwent TLIF procedures

<table>
<thead>
<tr>
<th>Complication</th>
<th>No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>durotomy</td>
<td>76 (14.3)*</td>
</tr>
<tr>
<td>infection</td>
<td>20 (3.8)</td>
</tr>
<tr>
<td>screw misplacement</td>
<td>11 (2.1)</td>
</tr>
<tr>
<td>cage migration</td>
<td>10 (1.9)</td>
</tr>
<tr>
<td>retroperitoneal injury</td>
<td>2 (0.4)</td>
</tr>
<tr>
<td>neurological deficit</td>
<td>2 (0.4)</td>
</tr>
<tr>
<td>facial pressure ulcer</td>
<td>1 (0.2)</td>
</tr>
<tr>
<td>wrong-level surgery</td>
<td>1 (0.2)</td>
</tr>
</tbody>
</table>

* Three patients required repeat operation for a persistent CSF leak.
**Perioperative complications related to TLIF**

**Table 4: Subgroup analysis in patients who underwent TLIF procedures**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Prior Op</th>
<th>No Prior Op</th>
<th>Multilevel TLIF</th>
<th>Single-Level TLIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>no. of patients</td>
<td>244</td>
<td>287</td>
<td>214</td>
<td>317</td>
</tr>
<tr>
<td>no. of overall complications (%)</td>
<td>76 (31.1)</td>
<td>59 (20.6)</td>
<td>65 (30.4)</td>
<td>70 (22.1)</td>
</tr>
<tr>
<td>OR</td>
<td>1.75†</td>
<td>1.54†</td>
<td></td>
<td></td>
</tr>
<tr>
<td>95% CI; p value</td>
<td>1.18–2.59; &lt;0.01</td>
<td>1.04–2.28; 0.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>no. w/ durotomy (%)</td>
<td>44 (18.0)</td>
<td>32 (11.1)</td>
<td>37 (17.3)</td>
<td>39 (12.3)</td>
</tr>
<tr>
<td>OR</td>
<td>1.75†</td>
<td></td>
<td></td>
<td>1.49</td>
</tr>
<tr>
<td>95% CI; p value</td>
<td>1.07–2.87; 0.03</td>
<td></td>
<td>0.92–2.43; 0.13</td>
<td></td>
</tr>
<tr>
<td>no. w/ infection (%)</td>
<td>9 (3.7)</td>
<td>11 (3.8)</td>
<td>10 (4.7)</td>
<td>10 (3.2)</td>
</tr>
<tr>
<td>OR</td>
<td></td>
<td>0.96</td>
<td></td>
<td>1.50</td>
</tr>
<tr>
<td>95% CI; p value</td>
<td></td>
<td>not relevant</td>
<td>0.62–3.68; 0.49</td>
<td></td>
</tr>
</tbody>
</table>

* The p values were calculated using the 2-tailed Fisher exact probability test.
† Statistically significant.

**Multilevel Surgery**

Two hundred fourteen patients (40.3%) underwent interbody fusion at more than one level. A complication occurred in 65 (30.4%) of the patients with multilevel surgeries, compared with 70 (22.1%) of the 317 patients who underwent single-level interbody fusion (OR 1.54, 95% CI 1.04–2.28; p = 0.03). Durotomy occurred in 37 (17.3%) of the multilevel operations, compared with 39 (12.3%) of the single-level operations (OR 1.49, 95% CI 0.92–2.43; p = 0.13). Infection occurred in 10 (4.7%) of the multilevel operations, and in 10 (3.2%) of the single-level surgeries (OR 1.50, 95% CI 0.62–3.68; p = 0.49). These results are summarized in Table 4.

**Discussion**

The TLIF procedure allows for the achievement of circumferential arthrodesis in the lumbar spine via a single-stage, posterior approach. A radical discectomy and interbody fusion are performed via a unilateral oblique trajectory that minimizes the need for retraction of the neural elements. Since its introduction by Harms and Rolinger in 1982, the TLIF procedure has gained increasing popularity, although not unique to TLIF—must be considered in the planning and execution of these surgeries.

We have reported our complications after 531 consecutive cases of TLIF performed by 7 surgeons at a single hospital over more than 4 years. This represents the largest TLIF series to date. For comparison, a PubMed query for "transforaminal lumbar interbody fusion" yielded 13 series reporting complications after open TLIF, ranging in study size from 13 to 119 patients.

We sought to determine whether revision surgery and multilevel surgery are associated with a higher rate of complications due to the greater degree of technical difficulty, longer operating times, and greater blood loss typically encountered in these cases. The overall complication rate was 1.75 times higher for patients undergoing revision surgery, and 1.5 times higher for patients undergoing multilevel fusion. These differences were statistically significant.

**Complication Types and Rates**

**Durotomy.** Our 14% durotomy rate is generally in line with those reported in the literature. Together, the prior published series identified 32 cases of durotomy in 668 patients, excluding study patients who had PLIF, ALIF, or minimally invasive TLIF. Rates of durotomy ranged from 0% to 19.6% in individual series, with a weighted mean of 4.6%. We suspect that several factors contributed to our increased incidence of durotomy, most notably the high rate of revision surgery in our series (46%). This is slightly higher than the weighted mean of the previous studies (33.6%). Furthermore, we defined a durotomy as any inadvertent transgression—however small—of the lumbar dura mater, even when no CSF egress occurred. Finally, our patient population is typical of tertiary care spine referral centers in that “complex” patients—including older patients and those with more advanced degenerative disease, in whom dural manipulation during decompression and interbody fusion is often more difficult—are disproportionately represented. The rate of persistent CSF leak in this study was 0.6%, or 3.9% of durotomies. A durotomy was 1.75 times more likely to occur during revision surgery and 1.5 times more likely to occur during multilevel fusion, although the latter difference did not reach statistical significance.

Although there is variability in the management of durotomy by individual surgeons, a general protocol is typically followed. An attempt is made intraoperatively to perform primary closure. In a large majority of cases, this is possible. In the rare event that watertight dural closure is not feasible, attempts at muscle reinforcement or patch grafting are undertaken. Fibrin glue is used universally following primary closure or grafting. Watertight fascial closure is then performed, with some surgeons choosing...
to oversew the fascia to further reinforce the closure. Skin closure consists of running nylon suture. The decision to leave a surgical site drain in place is dependent on the surgeon, and is made on a case-by-case basis.

Infection. Development of infection after spine surgery is a serious, costly, and often life-altering complication, frequently necessitating additional surgery and long-term antibiotic therapy. Infection is also a common cause of decreased patient satisfaction. Our 3.8% infection rate is consistent with rates in the available TLIF literature (Table 5). It is also similar to rates of infection reported after traditional PLIF, which range from 0% to 2.9%,12,16,31 and after the posterior portion of traditional anterior-posterior procedures, which range from 0% to 11.3%.9,14,33,36

Infection status was not related to previous lumbar surgery or multilevel surgery. We observed no difference in the rate of infection between revision and first-time operations. Infection was 1.5 times more common in multilevel surgeries, but this difference was not statistically significant. Patient-related factors such as obesity, diabetes mellitus, or nutritional status may have been more important in leading to infection than the type of surgery.30 Infection rates in the 3 series with 100 or more patients ranged from 2% to 4.5%. Several of these studies attempted to correlate postoperative infection to preoperative or intraoperative factors, such as a history of smoking or the number of treated levels, but did not find statistically significant differences.

Screw Misplacement. This is a well-known complication of transpedicular instrumentation. A recent meta-analysis placed the accuracy of pedicle screw insertion at 95.1% and 90.3% with and without stereotactic image guidance, respectively.17 Not all misplaced screws result in symptoms, however, and so the true incidence of screw misplacement is most likely underestimated, because CT or MR imaging studies are usually only obtained in clinical practice if a patient is symptomatic. Accurate pedicle screw placement has been correlated with surgeon experience.30 At our institution, at least 50% of all pedicle screws are placed by neurosurgical residents of varying experience.

Symptomatic nerve root impingement by errant pedicle screws is well described and is reported to occur in approximately 1%–3% of cases.7,8,18,20,28,35 In these cases, patients typically report intense radicular pain in the distribution of the offending screw. A CT scan will often confirm the offending pedicle breach. Removal of the offending screw results in symptom improvement in most cases, although symptoms may persist.

In the current series it was not possible to estimate the accuracy of transpedicular instrumentation due to the inconsistency with which postoperative CT scans were obtained. Eleven patients (2.1%) presented with worsening postoperative pain as a result of nerve root impingement by a pedicle screw. All screws were removed and revised. In 1 patient, radicular pain persisted following screw removal. This patient underwent placement of a spinal cord stimulator 15 months after the index surgery. The spinal cord stimulator was successful in significantly reducing this patient’s pain.

Cage Migration. Migration of the intervertebral cage—typically dorsally—is an uncommon but potentially serious complication, placing the adjacent neural elements at risk, and in some cases heralding nonunion. The phenomenon has been described in the literature previously.3,22,32 Aoki and colleagues recently reported on 3 patients with interbody cages that had migrated posteriorly. Of these, only 1 patient had symptomatic neural compression caused by the extruded cage; the other 2 cases of cage migration—which were not associated with symptoms—were found on routine follow-up imaging and observed.

Ten patients (1.9%) in this series had posterior migration of an interbody cage. Nine of these 10 patients un-
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derwent surgery for removal and replacement of the cage. The average time to presentation was 1 month (range 2 weeks–15 months). Seven of these patients presented with new radicular pain or numbness in a distribution consistent with the radiographic findings of cage migration. One patient presented with a migrated cage in the setting of discitis and osteomyelitis, presumably due to implant loosening at the cage/bone interface as a result of endplate erosion. Another patient presented 15 months after her initial surgery with persistent low-back pain. Cage migration was documented on subsequent imaging studies, and although she denied radiculopathy, pseudarthrosis was suspected and—during a subsequent surgery to address adjacent-level degeneration—the patient underwent removal of the extruded cage and replacement with a larger spacer. In 1 patient, cage migration was found incidentally on lumbar radiographs obtained after a ground-level fall 3 months postsurgery. Because this patient was asymptomatic and the radiographs exhibited evidence of early fusion, the individual was discharged with routine clinical and radiographic follow-up. He remained asymptomatic at the latest follow-up 32 months after surgery.

Retroperitoneal Injury. Injury to retroperitoneal structures is a rare but known complication of posterior lumbar surgery. In the upper lumbar spine, the vessels at risk for injury are the distal aorta and inferior vena cava, whereas lower lumbar surgery places the iliac vessels at risk. Vascular injury may result from overly aggressive use of the rongeur during discectomy, or from penetration by an errant pedicle screw. Early recognition of injury and the availability of open and endovascular surgeons are essential for the avoidance of catastrophic blood loss. Two patients in our series suffered retroperitoneal violation during performance of the interbody fusion. In 1 patient, a cage had broken through the anterior longitudinal ligament and entered the retroperitoneal space. A CT angiogram was obtained and failed to identify any vascular injury. After discussion with the patient, the decision was made to observe the cage with serial imaging. In the other patient, an iliac artery pseudoaneurysm—believed to have occurred as a result of overly aggressive discectomy—was identified, and the patient underwent endovascular repair without further sequelae.

Wrong-Level Surgery. The reported incidence of wrong-level surgery in the lumbar spine ranges from 0.03% to 0.04%, Although adherence to the preoperative time-out process, review of relevant radiographs, and intraoperative localization have helped decrease rates of wrong-level and wrong-side surgery, wrong-level surgery is not preventable in all cases. One patient (0.2%) in our series underwent laminectomy and partial medial facetectomy at an unintended level before the improper localization was realized; TLIF was performed as planned at the level below, and the PLIF was extended rostrally by 1 segment to include the incorrectly decompressed level.

Study Limitations

A weakness of our study is the retrospective fashion in which the complications were reviewed. Due to this fact, it is possible that an underestimation of complications may have occurred. In addition, complications may be affected more by patient-related factors such as comorbidities than by the choice of operation. Another weakness of the study is that comorbidities are not reliably documented in our medical records and, thus, medical comorbidities could not be included in the analysis.

Conclusions

Transforaminal lumbar interbody fusion was associated with an overall 25.4% perioperative surgical complication rate in this large series. The perioperative surgical complication rate of TLIF was significantly higher in revision surgery and multilevel cases.

Disclosure

Dr. Gerszten is a consultant for Zimmer Spine. Dr. Kanter is a consultant for Lianx, Inc., and NuVasive, Inc.

Author contributions to the study and manuscript preparation include the following. Conception and design: Okonkwo, Tormenti, Maserati, Bonfield, Kanter. Acquisition of data: all authors. Analysis and interpretation of data: Tormenti, Maserati, Bonfield, Kanter. Drafting the article: Tormenti, Maserati, Bonfield. 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: Okonkwo. Statistical analysis: Maserati. Study supervision: Spiro.

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Manuscript submitted April 18, 2011.
Accepted September 12, 2011.

Portions of this work were presented as a plenary session talk at the annual meeting of the American Association of Neurological Surgeons in Philadelphia, Pennsylvania, on May 3, 2010.

Please include this information when citing this paper: published online October 14, 2011; DOI: 10.3171/2011.9.SPINE11373.

Address correspondence to: David O. Okonkwo, M.D., Ph.D., Department of Neurological Surgery, University of Pittsburgh Medical Center, 200 Lothrop Street, Suite B-400, Pittsburgh, Pennsylvania 15213. email: okonkwo@upmc.edu.