A minimally invasive approach for posterior lumbar interbody fusion

ANTHONY A. SALERNI, M.D.
Lakes Region General Hospital, Laconia, New Hampshire

Object. Despite the technical innovations that posterior approaches for lumbar fusion have undergone, the goal of a significant reduction in the extent of dissection has remained elusive. Because extensive muscular dissection is related to both acute and chronic pain, a reproducible minimally invasive posterior approach to lumbar interbody fusion would have significant clinical value. The technical aspects of a minimally invasive approach to posterior lumbar interbody fusion ($\mu$PLIF) with fixation involving tools developed for videoscopic discectomy will be described.

Methods. The technical description of this $\mu$PLIF procedure is based on experience gained in the first 38 cases. Outcomes categorized using a modified Macnab criteria are reported for 13 patients in whom 1 year or more of follow-up data were available.

All procedures were completed. The section of anulus fibrosus that was exposed provided access for a thorough discectomy and endplate preparation. Outcome in 11 of the 13 patients in whom outcome data were available was excellent or good. Six of these patients returned to work between 3 and 12 weeks postoperatively. Two patients suffered complications related to insertion of the interbody device.

Conclusions. This procedure involves a reproducible technique that results in a construct that is radiographically identical to that which could be expected from any standard open procedure. The minimized muscular dissection results in a tremendous improvement in postoperative mobility. All complications in this series were related to the placement of femoral cortical allograft implants. The use of a modified cement restrictor should eliminate the risk of interbody device placement.

KEY WORDS • posterior lumbar interbody fusion • minimally invasive • interbody fusion

Cloward first described PLIF at the 1947 meeting of the Hawaiian Medical Society (Coward RB, unpublished data). He published his first series in 1953. Although Cloward had good success and limited complications, the procedure did not flourish. Except for sporadic cases performed by Cloward, Lin and his associates, along with a small cadre of his followers, the procedure would languish for the next 50 years. It was because of Lin’s continued efforts that curiosity in the procedure was kept alive. It was not until after live telecasts of surgery in 1977 and again in 1983, however, that wide-ranging interest began (Lin PM, unpublished data). By the end of the 1980s, this interest rapidly grew into a movement. The result was a vindication of Cloward’s earlier vision. During the last decade, a paradigm shift has silently occurred, culminating in the fact that today lumbar spinal fusion in most areas is synonymous with lumbar interbody fusion.

Posterior lumbar interbody fusion and its variations are labor intensive, and the anatomy encountered during this approach generates significant technical demands. The obligatory extensive dissection produces significant pain, which in some cases can become chronic. At the very least, this is a leading factor resulting in extended hospital stays and inflated costs. In the last century the major thrust of the scientific endeavor concerned the achievement of reliably high fusion rates. Whereas this labor has been successful, the significant problem of surgery-induced pain has shared in little of this success. In fact, the resultant routine use of pedicle screw fixation has only served to intensify this problem.

Methods that serve to reduce these problems would be beneficial. An ideal procedure would minimize dissection and pain, allow neural decompression, reestablish the disc space with interbody fusion, lend itself to the application of internal fixation, and have complications that are both acceptable in nature and frequency. A technique for a minimally invasive PLIF is described that brings us closer to these goals.

CLINICAL MATERIAL AND METHODS

Patient Population

Between March 2001 and July 2002, 38 patients chose to undergo lumbar fusion involving the minimal-access procedure that is the focus of this report. All patients presenting with the sole complaint of low-back pain had undergone conservative therapy for more than 1 year. In those with significant neural compression and/or significant radicular symptoms at least 6 months of conservative management had failed to resolve symptoms. In the absence of gross spinal instability, the correlation of back

Abbreviations used in this paper: DSH = disc space height; $\mu$PLIF = minimally invasive posterior lumbar interbody fusion.
pain to the operative level was made anatomically by magnetic resonance imaging and functionally by discography in all patients presenting solely with back pain. There were 26 men and 12 women whose mean age was 43 years. Twenty-four patients underwent single-level fusions and 14 had two-level fusions.

Surgical Technique

The patient is placed in the prone position on a C-arm-compatible operating table. Slight flexion can facilitate discectomy, but the capacity to establish lordosis prior to fusion must remain available. After positioning, preparing, and draping, a line is drawn to mark the parasagittal plane 4 to 9 cm off midline on the side of the radicular symptoms. This is significantly more lateral than that described for a microendoscopic discectomy. A spinal needle is passed on this line under fluoroscopic guidance to the appropriate facet joint. A METRx System operating tube (Medtronic Sofamor Danek, Memphis, TN) is centered over this spinal needle, and the skin is marked again where the tube edges intersect with the parasagittal line. This demarcates the maximum cephalocaudal dimensions needed for the skin incision. The incision made for harvesting of the iliac crest graft can always be used for approaches to the L5–S1 disc and frequently may be used for L4–5 fusions. Electrocautery is taken through the subcutaneous fat, and the dorsal fascia is incised longitudinally. A K-wire is then fluoroscopically placed on the lateral aspect of the facet joint. Dilators are passed over this, followed by the 18- or 20-mm operating METRx System tube, which is subsequently secured to the table. The remaining thin layer of muscle is cauterized and removed to allow definition of the osseous anatomy. The tube is moved about so that all soft tissue over the facet and laminae, from pedicle to pedicle, is removed. Most of the bone is removed using a high-speed drill. The little that remains may be trimmed using Kerrison ronguers. The ligamentum flavum and the anterior and medial aspect of the joint capsule are left intact so as not to disturb the underlying epidural veins prematurely. This is important because control of epidural bleeding before completing the bone work can be extremely difficult. These soft tissues also serve as a barrier to protect neural structures during bone resection. Complete excision of both articular processes, along with a modest laminotomy, allows visualization of the exiting nerve root as well as the lateral aspect of the dural sac (Fig. 1). Through this perspective, approximately 10 mm of the annulus fibrosus is accessible without the need for any retraction of the neural elements.

The presence of osteophytes and the natural shape of the disc always limit access into the disc via a standard anulotomy. This impediment to complete disc removal is countered by using Kerrison ronguers or small osteotomes to open the posterior entrance to the disc space (Fig. 2). Although seemingly a trivial point, if this maneuver is not performed, thorough disc excision and endplate preparation may not be possible. After this modification of the anulotomy, the surgeon may proceed with the discectomy, relying heavily on curettage to prepare the endplates as far across midline as possible. Endplate preparation is essential, but perforation must be avoided. After discectomy, calibrated distractors are inserted into the disc space to determine the size of the implant needed to reestablish DSH.

Cortical shims were used initially, but because of inherent technical shortcomings of this material, modified cement restrictors are now used (Fig. 3). Prior to implant insertion, graft material is tightly packed toward the contralateral side and as far anterior as possible. Attention must also be given to the packing of disc space on the side ipsilateral to that of the dissection. After the disc space is full of graft material, the implant is inserted. The modified anulotomy allows for the spacer to advance and distract more easily as it is tamped along its oblique trajectory across the disc space. The angle of this trajectory should be as close to 45° as possible. Although it is the skin incision that determines this angle, the anatomical characteristics of the iliac crest will often dictate where the skin incision shall be made.
incision may not be made (Fig. 4). If initial engagement of the spacer into the disc is at all questionable, an osteotome or a box chisel can be used to widen the posterior opening into the disc space. To prevent damage to the endplate, chiseling deeper than a few millimeters should be avoided. After countersinking the spacer by at least 5 mm, more bone graft is packed into the device. The result is a disc space that is fully packed with cancellous autograft and whose height is maintained by the packed cement restrictor (Fig. 5). The nerve roots and dura mater are inspected for loose or otherwise offending pieces of graft material. After withdrawal of the operating tube, pedicle screws are inserted percutaneously as previously described.\(^3\) The wounds are closed in layered fashion after application of the segmental fixation (Fig. 6).

**RESULTS**

In all patients presenting for PLIF the procedures were completed. Thorough discectomy and endplate preparation proceeded with relative simplicity. Restructuring of the disc space and its complete packing with cancellous autograft proved to be straightforward. Improvements in DSH achieved intraoperatively were maintained in all patients throughout the study period (Fig. 7). Although there were no dissection-related complications, one patient suffered a nerve root injury during the insertion of a piece of autologous femur that was to be used as an interbody device. The injury occurred when the inserter failed, fracturing the implant. This failure prompted the shift to the use of the specially modified interbody device shown in Fig. 3. The complete control offered by its design should minimize the chance that this problem will recur.

Outcome was analyzed in the 13 cases in which 1-year follow-up data were gathered. Outcome was determined by applying a modified Macnab criteria.\(^8\) This system requires each patient to be assigned to one of four categories, each of which is defined by the description of residual pain and the capacity for employment. To analyze the data numerically, each of these categories was assigned a value from 1 (poorest grade) to four (best grade) (Table 1).

The mean Macnab grade for the group was 3. A grade of 4 was assigned to eight cases and a grade of 3 to three cases. One patient was in the poorest outcome group. This patient had sustained two severe back injuries including an osteoporotic compression fracture at T-8. He also had a metabolic bone disorder. Furthermore, he had been undergoing narcotic analgesic therapy for 3 years prior to surgery and he was receiving long-term disability payments. There was no evidence that the poor outcome in this patient was related to the surgical procedure. In the patients with grade 3 and 4 outcomes, the rate of return to work was impressive. Six patients did so between 3 and 12 weeks postoperatively. There were three who returned to work between 12 and 24 weeks. The three patients in the good outcome group who did not return to work were either retired or had been receiving long-term disability and/or supplemental social security payments prior to and after surgery.

**DISCUSSION**

There are significant and unavoidable problems that
negatively affect the overall success rate of lumbar interbody fusion performed by any of the current standard methods. When conducting posterior or modified posterior procedures, postoperative pain significantly increases the disability. This occurs at the very least in the short term, and for some it can become chronic.

Interbody constructs, whether they are autograft, allograft, metallic, or some combination, serve a dual purpose. The relationship of their two functions is both facilitatory and inhibitory to the fusion process. Because fusion is not instantaneous, all interbody constructs must be able to resist some load for at least some period of time. This creates a bioengineering dilemma because the osteoconductive-inductive material that best facilitates fusion is prone to collapse under compressive loads. Alternatively, the materials that best resist the loads encountered in a lumbar disc space either do not fuse or do not readily fuse. Consequently, the properties of the material used to fashion interbody constructs must be balanced. Although the material that is used to maintain DSH protects the material that facilitates fusion from excessive loads, it does so at the expense of the fusion process. Simple calculations show that commercially available cortical allograft struts can easily occupy 40% or more of the surface area available for fusion. An ideal construct would partially shield the osteoconductive-inductive material from the extreme loads of the disc space but occupy only a minimal percentage of the surface area of the endplate. Because pedicle screws are certainly capable of bearing load, the load-
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TABLE 1
Modified Macnab criteria

<table>
<thead>
<tr>
<th>Result</th>
<th>Grade</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>excellent</td>
<td>4</td>
<td>no pain; no restriction of mobility; return to normal work &amp; activity</td>
</tr>
<tr>
<td>good</td>
<td>3</td>
<td>occasional radiculopathy; relief of presenting symptoms; return to modified work</td>
</tr>
<tr>
<td>fair</td>
<td>2</td>
<td>some improved functional capacity; still handicapped &amp; unemployed</td>
</tr>
<tr>
<td>poor</td>
<td>1</td>
<td>continued symptoms of nerve root involvement; additional operative intervention needed at the index level irrespective of postop duration</td>
</tr>
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The trajectory of the approach minimizes the concerns about retraction or protection of neurological structures. With regard to fusion, it is possible to improve and maintain DSH by placing obliquely oriented devices. Large amounts of cancellous autograft can be packed into the disc space. Nevertheless, care must be taken when packing the area that resides contralateral to the interbody device. Adequate filling can be assured only if it is packed prior to insertion of the implant. Once the implant is placed in its central position, the dural sac will hinder the packing of graft into this space. Another significant pitfall relates to the neuroanatomy: a direct lateral takeoff of the exiting nerve root or a conjoined nerve root would make this procedure impossible. Although the chance of encountering this variant anatomy cannot be eliminated, careful review of the magnetic resonance imaging study should alert the surgeon to this potential during preoperative planning.

Posterior lumbar interbody fusion and fixation results in excellent fusion rates. Optimal results can only be expected, however, if the basic principles of osteosynthesis, as reiterated by Lin,9 are respected. It is clear that the casual placement of bone, dowels, struts, or cages into a disc space does not ensure fusion. Even though exposure is limited when performing this modification of the PLIF, disc removal and endplate preparation must be thorough and meticulous. It is only by way of this thorough preparation, followed by the complete packing of the disc space with bone graft, that optimal fusion rates can be expected.6

It is technically feasible to accomplish near-total dissection, reestablish the DSH, and perform interbody fusion via a 20-mm-long, posterolaterally made incision. Lumbar decompression and fixation can also be achieved. Operative time is comparable with that of standard open approaches. Consequently, it is reasonable to expect comparable fusion rates. If this proves to be the case, then minimally invasive PLIF will offer significant advantages.

Because of the presence of anatomical or pathological obstacles, it seems that the greatest risk of minimally invasive spine surgery is failure to achieve the primary objective. Prompt recognition of the conditions that could preclude its completion is important because it allows the surgeon to abort the PLIF early on and convert to a more traditional approach. This risk seems warranted because the tremendous reduction in operatively induced pain should significantly improve the cost/benefit ratio of lumbar fusion.

To date, the author has performed PLIF in 40 patients. At this point, the instrumentation is in the developing stages, and the capacity for major restructuring of the disc space is limited. Consequently, preserved DSH should be a relative contraindication for minimally invasive PLIF. As the instrumentation is refined and, in particular, if the promise of bone morphogenetic proteins is realized, technical demands should ease, and minimally invasive approaches should increase in dominance.

References