Changes in coronal and sagittal plane alignment following minimally invasive direct lateral interbody fusion for the treatment of degenerative lumbar disease in adults: a radiographic study

Clinical article

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Object. The lateral transpsoas approach for lumbar interbody fusion is a minimal access technique that has been used by some to treat lumbar degenerative conditions, including degenerative scoliosis. Few studies, however, have analyzed its effect on coronal and sagittal plane correction, and no study has compared changes in segmental, regional, and global coronal and sagittal alignment after this technique. The object of this study was to determine changes in sagittal and coronal plane alignment occurring after direct lateral interbody fusion (DLIF).

Methods. The authors performed a review of the radiographic records of 36 patients with lumbar degenerative disease treated with the DLIF technique. Thirty-five patients underwent supplemental posterior fixation to maintain correction. Preoperative and postoperative standing anteroposterior and lateral lumbar radiographs were obtained in all patients for measurement of segmental and regional coronal and sagittal Cobb angles. Standing anteroposterior and lateral 36-in radiographs were also obtained in 23 patients for measurement of global coronal (center sacral vertebral line) and sagittal (C-7 plumb line) balance.

Results. The mean coronal segmental Cobb angle was 4.5° preoperatively, and it was 1.5° postoperatively (p < 0.0001). The mean pre- and postoperative regional lumbar coronal Cobb angles were 7.6° and 3.6°, respectively (p = 0.0001). In 8 patients with degenerative scoliosis, the mean pre- and postoperative regional lumbar Cobb angles were 21.4° and 9.7°, respectively (p = 0.0004). The mean global coronal alignment was 19.1 mm preoperatively, and it was 12.5 mm postoperatively (p < 0.05). In the sagittal plane, the mean segmental Cobb angle measured −5.3° preoperatively and −8.2° postoperatively (p < 0.0001). The mean pre- and postoperative regional lumbar lordoses were 42.1° and 46.2°, respectively (p > 0.05). The mean global sagittal alignment was 41.5 mm preoperatively and 42.4 mm postoperatively (p = 0.7). The average clinical follow-up was 21 months in 21 patients. The mean pre- and postoperative visual analog scale scores were 7.7 and 2.9, respectively (p < 0.0001). The mean pre- and postoperative Oswestry Disability Indices were 43 and 21, respectively (p < 0.0001).

Conclusions. Direct lateral interbody fusion significantly improves segmental, regional, and global coronal plane alignment in patients with degenerative lumbar disease. Although DLIF increases the segmental sagittal Cobb angle at the level of instrumentation, it does not improve regional lumbar lordosis or global sagittal alignment.

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Key Words • degenerative lumbar disease • adult degenerative scoliosis • direct lateral interbody fusion • coronal alignment • sagittal alignment

MINIMALLY INVASIVE surgical technologies for the treatment of degenerative conditions of the adult lumbar spine continue to improve. These technologies have been reported by some to be associated with less tissue trauma, less blood loss, less postoperative pain, shorter hospital stays, and faster return to daily activities than traditional open approaches. 17 A relatively recent technological advancement in the field of minimally invasive spine surgery is the lateral transpsoas approach for lumbar interbody fusion. 16 This technique, which has been referred to as XLIF (NuVasive, Inc.) or DLIF (Medtronic Sofamor Danek), has been used by some in the surgical treatment of degenerative lumbar disease in adults, including degenerative scoliosis. 1,2,4,8,14,19,20 It has been reported to be effective in providing some correction of degenerative lumbar scoliosis with less blood loss and morbidity than traditional open procedures. 1,2,19,20

Abbreviations used in this paper: DLIF = direct lateral interbody fusion; XLIF = extreme lateral interbody fusion.
Spinal alignment following DLIF

Despite these reports of its potential usefulness in improving degenerative lumbar curvature, few studies have analyzed the changes in local and global spinal alignment that occur after this procedure. Those that have addressed this point have focused mainly on the ability of lateral transpsoas approaches to improve regional coronal Cobb angles.2,8,9,10,11 No study, however, has determined whether these improvements in regional coronal alignment result in significant changes in global coronal balance. Data with regard to changes in sagittal plane alignment after this technique are even scarcer. Dakwar et al.9 found that one-third of patients did not have correction of sagittal plane imbalance after XLIF. Nevertheless, precise measurements of changes in segmental, regional, and global sagittal alignment after the lateral transpsoas approach are lacking. Data on the ability of this technique to improve coronal and sagittal plane alignment will be important in determining its overall usefulness as a surgical tool for the correction of spinal imbalance resulting from degenerative lumbar disease. The purpose of this study was to analyze the effect of minimally invasive lumbar interbody fusion via the lateral transpsoas approach utilizing the DLIF technique on segmental, regional, and global coronal and sagittal plane alignment in patients with degenerative lumbar disease, including degenerative scoliosis.

Methods

Patient Population

Patient characteristics are given in Table 1. A total of 36 patients (9 men and 27 women) were included in this study. The mean patient age was 62 years (range 43–84 years). Diagnoses included lumbar spondylosis in 20 patients, degenerative scoliosis in 7, adjacent-segment degeneration in 5, spondylololisthesis in 3, and pseudarthrosis in 1.

Operative Data

Table 2 describes the operative details. The general technique of DLIF has been previously described. Briefly, the patient is positioned in the lateral decubitus position with the concave side of the lumbar coronal curve facing up. This facilitates access to the largest number of disc spaces with a relatively small incision. Blunt dissection is then used to access the disc spaces under fluoroscopic guidance. After discectomy, including contralateral anulus disruption, an appropriately sized poly-etheretherketone graft is inserted.

All DLIF grafts were packed with RhBMP-2 (recombinant human bone morphogenetic protein–2; InFuse, Medtronic Sofamor Danek) and had a total lordosis of 6°. Graft lengths ranged from 50 to 55 mm and heights from 10 to 12 mm. Grafts were targeted for positioning into the anterior one-third of the disc space.

Direct lumbar interbody fusion was performed across an average of 1.8 levels per patient from L1–2 to L4–5. A total of 66 levels were treated with DLIF in all patients. Supplemental percutaneous posterior fixation was performed in all but one patient to maintain correction. For maximum lordosis correction, compressive forces were applied across the pedicle screws prior to final rod tightening.

Radiographic Analysis

Preoperative and postoperative anteroposterior and lateral radiographs of the lumbar spine were obtained in all patients for measurement of segmental and regional coronal and sagittal Cobb angles. Postoperative radiographs were taken prior to discharge from the hospital. Cobb angles were measured electronically using Centricity workstations (General Electric HealthCare). Segmental Cobb angles were measured from the angle formed between the inferior endplate of the superior vertebral body and the superior endplate of the inferior vertebral body at the level of interest. Regional Cobb angles were measured from the angle formed between the superior endplate of the L-1 vertebral body and the superior endplate of the S-1 body (Fig. 1).

Preoperative and postoperative standing anteroposterior and lateral 36-in films were also obtained in 23 patients for measurement of global coronal (center sacral vertebral line–C-7 plumb line distance) and sagittal (C-7 plumb line–posterior superior aspect of S-1 distance) balance.

Data Analysis

Measurements were collected and analyzed using a Microsoft Excel database (Microsoft Corp.). Preoperative and postoperative measurements were compared using a paired Student t-test, and a p value of 0.05 was considered statistically significant.

Results

Clinical Data

The mean clinical follow-up was 21 months in 21 pa-

* Thirty-five patients underwent supplemental posterior fixation.

<table>
<thead>
<tr>
<th>Variable</th>
<th>No. of Patients</th>
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<td>male/female</td>
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patients. The mean pre- and postoperative visual analog scale scores were 7.7 and 2.9, respectively (p < 0.0001), and the mean pre- and postoperative Oswestry Disability Indices were 43 and 21, respectively (p < 0.0001).

**Coronal Plane Alignment**

Changes in coronal plane alignment after DLIF are given in Fig. 2. The mean coronal segmental Cobb angle was 4.5° preoperatively, and postoperatively it was 1.5° (p < 0.0001). The mean pre- and postoperative regional lumbar coronal Cobb angles were 7.6° and 3.6°, respectively (p = 0.0001). In 8 patients with degenerative scoliosis, the mean pre- and postoperative regional lumbar coronal Cobb angles were 21.4° and 9.7°, respectively (p = 0.0004) (Fig. 3). The mean global coronal alignment was 19.1 mm preoperatively, and postoperatively it was 12.5 mm (p < 0.05) (Fig. 2).

**Sagittal Plane Alignment**

In the sagittal plane, the mean segmental Cobb angle measured −5.3° preoperatively, and postoperatively it measured −8.2° (p < 0.0001) (Fig. 4). The mean pre- and postoperative regional lumbar lordosis was 42.1° and 46.2°, respectively (p > 0.05). The mean global sagittal alignment was 41.5 mm preoperatively, and postoperatively it was 42.4 mm (p = 0.7).

**Discussion**

The field of minimally invasive spine surgery has rapidly expanded since its inception in the early 1990s. Minimally invasive techniques have evolved beyond simple neural element decompression to involve more complex procedures, including spinal fusion. Minimally invasive spinal fusion in particular has been associated with decreased blood loss, decreased postoperative pain, and shorter hospital stays compared with traditional open procedures. Minimally invasive fusion techniques are being continually refined and allow the surgeon to gain access to both the anterior and posterior spinal columns with smaller incisions and less tissue disruption.
Spinal alignment following DLIF

One of the biggest technical challenges in the field of minimally invasive spinal fusion has been achieving access to the anterior lumbar disc space for anterior interbody fusion. Anterior minimally invasive procedures have traditionally been associated with an increased risk of complications and technical difficulties compared with open procedures. The direct lateral transpsoas approach represents one of the most recent minimally invasive techniques for access to the anterior lumbar disc space and allows for discectomy, release, and interbody fusion. It provides minimally invasive exposure of the lumbar disc space while avoiding the morbidities associated with traditional anterior lumbar interbody fusion procedures, including retrograde ejaculation and major vessel or ureteral injury. It has been used by some in the treatment of degenerative conditions of the adult lumbar spine with satisfactory results with regard to complications and fusion status.

Although minimally invasive surgical techniques, including the lateral transpsoas approach (XLIF or DLIF), have been found to be useful in achieving spinal fusion with less morbidity than traditional open procedures, the utility of these techniques in the treatment of spinal deformity is less well established. The goals of any surgical intervention for spinal deformity include alleviating radicular symptoms, halting deformity progression, and restoring spinal balance. By allowing for the release of the contralateral and ipsilateral anuli and providing access for the placement of an interbody graft across the entire length of the disc space, the direct lateral transpsoas approach has been considered to be a potentially useful minimally invasive technique for spinal deformity correction. Indeed, when combined with posterior fixation, it has been reported to be effective in providing some correction of degenerative lumbar scolicotic curves with less blood loss and morbidity than open procedures.

Nevertheless, the precise effect of lumbar interbody fusion via the direct lateral transpsoas approach on spinal alignment in the coronal and sagittal planes remains unknown. As the potential utility of any minimally invasive surgical approach for the treatment of spinal deformity depends on its ability to achieve correction in the sagittal and coronal planes, understanding the changes in sagittal and coronal plane alignment that occur after application of a particular technique is central in determining its role as a surgical tool for correcting abnormalities in spinal balance. Moreover, as restoration of normal sagittal plane balance has been found to be more closely associated with favorable patient outcomes than correction of coronal plane abnormalities, the effect of a minimally invasive technique on sagittal plane alignment may be an even more important determinant of its ultimate clinical utility than its ability to achieve coronal plane correction.

In this radiographic study we found that, in combination with posterior fixation, lumbar interbody fusion via the lateral transpsoas approach, specifically utilizing the DLIF technique, results in statistically significant improvements in segmental, regional, and global coronal plane alignment in patients with degenerative lumbar conditions, including degenerative scoliosis. However, although DLIF significantly increases the segmental sagittal Cobb angle at the level of instrumentation, it does not result in statistically significant improvements in regional lumbar lordosis or global sagittal alignment. This may be due to the fact that DLIF is performed in the lateral position and does not involve sectioning of the anterior longitudinal ligament, which may limit its utility in increasing lumbar lordosis or improving global sagittal balance, even when using maximally lordotic grafts. Although the transforaminal lumbar interbody fusion technique does not involve anterior longitudinal ligament sectioning and has been shown to provide improvement in lumbar lordosis after posterior pedicle screw-rod compression, transforaminal lumbar interbody fusion does involve a unilateral facetectomy, which can facilitate changes in segmental and regional lordosis that are not possible with DLIF. Additional factors that may affect the ability of DLIF to significantly alter sagittal plane alignment include hypertrophic facets in the degenerative spine, positioning of the DLIF graft in the anterior or posterior lumbar interbody space, and the fact that DLIF is most often performed in the mid lumbar spine, as opposed to L4–5 or L5–S1, which contribute most to lumbar lordosis. Also, we used grafts with a maximum lordosis of 6°. Newer grafts with a maximum lordosis of up to 12° have recently been developed that may allow for more significant changes in sagittal plane alignment. On the other hand, coronal plane correction by the DLIF technique is likely facilitated as a large graft extending across the entire length of the disc space is used and the ipsilateral and contralateral anuli are released.

Conclusions

The DLIF technique, then, seems to be a valuable surgical tool for the minimally invasive correction of coronal plane deformities in patients with adult lumbar degenerative conditions, including degenerative scoliosis. For sagittal plane abnormalities, however, increases in the segmental sagittal Cobb angle after DLIF do not translate into improvements in regional or global sagittal alignment. As such, DLIF alone may not be an appropriate strategy for addressing sagittal plane abnormalities, and it may be necessary to combine the DLIF technique with open posterior osteotomies in this setting. Ultimately, prospective clinical studies will be needed to determine the true efficacy of minimally invasive spinal deformity correction using direct lateral transpsoas lumbar interbody fusion.

Disclosure

Dr. Koski is a consultant for Medtronic. Dr. Moller received a teaching honorarium from Medtronic. Dr. Liu is a consultant for Medtronic and DePuy. Dr. Fessler receives support of non–study-related clinical or research efforts from Medtronic.

Author contributions to the study and manuscript preparation include the following. Conception and design: Acosta, Liu. Acquisition of data: Acosta, Slimack, Moller. Analysis and interpretation of data: Acosta, Slimack, Moller.
References


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