Correction of lumbar coronal plane deformity using unilateral cage placement

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The authors describe a surgical technique for the correction of symptomatic degenerative lumbar scoliosis. Using a single, unilateral, interbody cage placed on the concave side of the coronal deformity, combined with a dorsal decompression and instrumented posterolateral fusion, this technique has resulted in excellent curve correction, fusion results, and clinical outcomes in a series of 4 patients. Each of these patients presented with intractable, axial low-back pain and symptomatic unilateral nerve root compression on the concave side of a lumbar scoliotic deformity. The management is described in detail. (DOI: 10.3171/2009.12.FOCUS09283)

Key Words • degenerative lumbar scoliosis • interbody cage • spinal deformity

Lumbar scoliosis is increasingly recognized as a cause of debility in the adult population.3,8,17,20,22,25 In contrast to thoracic scoliosis, in which the deformity itself is often the cause of concern for the patient, in lumbar scoliosis, the most frequent presenting complaint is radicular pain caused by nerve root compression.22 The causes of lumbar scoliotic deformities can be categorized as idiopathic, degenerative, or iatrogenic due to factors following prior unsuccessful spinal surgery.1,17 In each of these categories, there is a coronal curvature of the lumbar spine that is frequently associated with an oblique angulation and/or rotation of the involved VBs.7,11,18,19,22 Degenerative lumbar scoliosis is the result of a progressive, coupled, asymmetrical degeneration of the intervertebral discs and facet joint complexes.8,20 Additionally, both an asymmetrical collapse of the VBs and lateral listhesis may occur, which further increases the degree of coronal plane deformity.23 This phenomenon is most commonly observed as a focal deformity, involving only 1 or 2 motion segments, and occurs in the midportion of the lumbar spine.21 In the lumbar spine, the resulting scoliotic deformity has a concave curve that leads to a relative narrowing of the ipsilateral neural foramen, and a convex curve that opens the corresponding contralateral neural foramen.8,13 Clinical symptoms of lumbar scoliosis most frequently result from bony compression—by either bone, disc, or both—of the ipsilateral nerve root on the concave side. Additionally, severe disc space collapse, which is frequently observed on the concave side of the deformity, may lead to a bone/nerve root/bone phenomenon at the neural foramen, with resulting intractable radicular pain that is unresponsive to any attempts at nonsurgical therapy. Furthermore, it is not uncommon for a translational deformity to occur where the L-2 or L-3 vertebra is translated laterally with respect to the adjacent vertebrae, further compounding the degree of nerve root compression.23

The surgical goals in the treatment of lumbar scoliosis are neural decompression, reduction of the coronal plane deformity, maintenance of sagittal balance, and mechanical stabilization of the spine.2,3,8,12,16,24,25 In this report, we describe a modification of our usual surgical technique of posterior lumbar interbody fusion,9 which has been found useful for treating patients with lumbar scoliosis resulting in ipsilateral, symptomatic, nerve root compression.

Methods

Four female patients, age 33–71 years (mean age 55 years), who presented to our institution with complaints of axial low-back pain and intractable unilateral radicular pain, were found to have lumbar scoliotic deformities. All patients harbored a left-convex lumbar scoliosis, with two patients having a double-curve thoracolumbar type of deformity. Coronal plane deformities were measured according to the Cobb method, using the maximally angulated end-vertebrae of the coronal curve. The magnitude of the lumbar scoliotic deformity varied from 22–36°.
This is performed bilaterally, using curettes, pituitary rongeurs, and paddle-shaped disc “shavers,” which allows virtually all of the disc material to be removed from the disc space. This process alone helps to gain some degree of coronal plane correction. After the discectomy is completed, attention is directed toward the placement of the structural interbody strut graft. We routinely use a lordotic-shaped carbon fiber cage, which is filled with morcelized autologous bone graft. A distractor is placed between the pedicle screws on the concave side of the coronal deformity. With distraction between these screws, the cage is impacted into the disc space. Following impaction to the appropriate depth, the distractors are released, the VBs recoil, and the unilateral cage serves to maintain the coronal curve correction that has been achieved. The contralateral disc space on the convexity is then addressed. Generous amounts of autologous fusion substrate bone are packed into the disc space on the convex side, extending from the anterior annulus fibrosis back to the posterior annular defect. In this manner, a very significant amount of bone graft can be compacted into the intervertebral space.

After the index coronally deformed segment has been treated, the remainder of the procedure is carried out in the usual fashion. Prior to securing the rods to the pedicle screws, a compressive force is applied to the screws, bilaterally, at the index level; however, the force applied is greater on the convex side. This allows for a further degree of coronal curve correction. Importantly, by providing dorsal compression, the posterior column is effectively shortened and lumbar lordosis is maintained. The remainder of the construct is secured and a layered wound closure, over 2 suction drains, is performed.

Postoperatively, plain radiographs are obtained in the recovery room on the day of surgery. A CT scan is obtained on the third postoperative day. Serial neurological examinations are performed throughout the hospital stay. Routine follow-up includes clinical examinations with plain radiographs at 6 weeks, 3 and 6 months, and 1 and 2 years. The degree of deformity correction is initially assessed on the postoperative CT scan and compared with the preoperative imaging studies. The final amount of curve correction is determined from the most recent plain radiographs where Cobb angles are determined for both coronal and sagittal alignment on 36-inch standing anteroposterior and lateral films.

Results

Data regarding preoperative coronal plane deformity, and the levels included in this determination for each patient, are provided in Table 2. The levels treated with unilateral interbody cages for coronal plane deformity reduction, as well as the spinal levels that were treated with an instrumented posterolateral fusion, are summarized in Table 2. In one patient, unilateral interbody cages were placed at 2 adjacent spinal levels. In another patient, bilateral interbody cages were placed at separate spinal levels, in addition to the single unilateral interbody cage. Postoperative values are reported from the most recent plain radiographic measurements. The duration of clinical and

with a mean of 29.9°. In each case, imaging studies demonstrated significant narrowing of the neural foramen and disc spaces on the concave side of the curve. On the contralateral convex side, the neural foramina were enlarged, and the disc spaces were of normal height. Dynamic lateral bending radiography demonstrated that the lumbar scoliotic curves were rigid in all 4 patients. Flexion and extension radiographs revealed unstable lumbar degenerative spondylolisthesis in 3 patients. Prolonged attempts at conservative therapy had been undertaken in each of these patients without success. All patients were smokers and were referred to smoking-cessation programs during preoperative evaluation. Surgery was performed only after preoperative smoking abstinence was achieved. Details of the patients are presented in Table 1.

In addition to obtaining a detailed history and physical examination, a full medical evaluation was conducted in each case prior to surgical treatment. Furthermore, DEXA scans with a bone densitometer (QDR-2000, Hologic Inc.) were obtained in each patient. We determined T-scores (comparison with normal 30-year-old women) for the lumbar spine in each case (T-score range −3.2 to −1.75). Smoking status was also recorded, and the number of years of follow-up was noted. Table 2 summarizes the surgical treatment with each patient without success. All patients were smokers and were referred to smoking-cessation programs during preoperative evaluation. Surgery was performed only after preoperative smoking abstinence was achieved. Details of the patients are presented in Table 1.

Surgical Technique

The surgical technique for each case was identical at the level of maximal coronal curvature. At the index coronally deformed segment(s) a dorsal osseous decompression was performed that included removal of the spinous process, bilateral laminae, bilateral pars interarticularii, bilateral inferior zygapophyseal facet joints, and the medial and superior aspects of the subjacent superior facet joints. This degree of bone resection allows for the involved nerve roots to be completely decompressed in addition to a dorsal release of the coronal deformity and passive deformity correction. At this point, pedicle screws are placed above and below the involved segment. In addition, if more levels need to be treated, the pedicle screws are placed at these levels as well.

Once the pedicle screws are in position, and intraoperative fluoroscopy has confirmed their appropriate placement, then the bone graft is harvested. Autologous bone graft is obtained from the iliac crest and combined with the additional local bone graft which was obtained during the dorsal bony decompression. All soft tissue is removed from the bone prior to mixing the local bone with the iliac crest autograft.

An aggressive discectomy is performed at the index level where the coronal correction is to be performed.

| TABLE 1: Summary of demographic data in 4 patients who underwent unilateral interbody cage placement |
|---------------------------------|--------|--------|--------|--------|
| Factor                          | Case 1 | Case 2 | Case 3 | Case 4 |
| age (yrs), sex                  | 71, F  | 61, F  | 33, F  | 53, F  |
| T-score                         | −3.2   | +1.5   | −2.9   | +1.6   |
| smoking status                  | yes    | yes    | yes    | yes    |
| yrs of follow-up                | 2      | 1.75   | 2.5    | 2      |

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Table 2: Summary of pre- and postoperative data*

<table>
<thead>
<tr>
<th>Factor</th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>unilat cage level(s)</td>
<td>rt L2–3</td>
<td>rt L2–3</td>
<td>rt L1–2, L2–3</td>
<td>rt L2–3</td>
</tr>
<tr>
<td>bilat cage level(s)</td>
<td>NA</td>
<td>L3–4, L4–5</td>
<td>NA</td>
<td>NA</td>
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<tr>
<td>fusion levels</td>
<td>L2–S1</td>
<td>L2–5</td>
<td>T11–S1</td>
<td>T11–L4</td>
</tr>
<tr>
<td>reference levels for Cobb angle</td>
<td>L2–5</td>
<td>L2–3</td>
<td>T12–L4</td>
<td>L1–4</td>
</tr>
<tr>
<td>preop coronal curve (Cobb angle in °)</td>
<td>22.3</td>
<td>35</td>
<td>35.9</td>
<td>26.5</td>
</tr>
<tr>
<td>postop coronal curve (°)</td>
<td>10.4</td>
<td>2.1</td>
<td>24.7</td>
<td>11.1</td>
</tr>
<tr>
<td>coronal curve correction (%)</td>
<td>11.9 (53)</td>
<td>32.9 (94)</td>
<td>11.2 (31)</td>
<td>15.4 (58)</td>
</tr>
<tr>
<td>preop global sagittal alignment (cm)</td>
<td>+4.5</td>
<td>+2.5</td>
<td>+2.5</td>
<td>–2</td>
</tr>
<tr>
<td>postop global sagittal alignment (cm)</td>
<td>+5</td>
<td>+2</td>
<td>+1.9</td>
<td>–1.8</td>
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<tr>
<td>fusion achieved</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

* NA = not applied.

radiographic follow-up ranged from 1.75 to 2.5 years. The mean duration of both clinical and radiographic follow-up was 25 months. Representative pre- and postoperative radiographs are shown in Figs. 1 and 2.

A successful radiographic spinal fusion was definitively documented in each case. One patient with a long fusion construct (T10–L5), in whom a pseudarthrosis developed and focal kyphosis occurred at the rostral extreme of the construct (T10–L11), required revision surgery and rostral extension of the fusion to the T-5 level. The mean correction of coronal plane deformity achieved with this technique was 17.9° over the involved segments. The magnitude of scoliosis correction varied from 94 to 31%. Importantly, no loss of sagittal plane balance occurred as a result of the coronal curve correction procedure. The global sagittal balance was preserved in all cases. The mean preoperative global sagittal alignment was +1.9 cm, and the mean postoperative global sagittal alignment was +1.8 cm. Based on Odom criteria, we determined that clinical outcomes were excellent in 3 patients and good in 1 patient. All 4 patients responded that they would undergo the same procedure again provided that the same postoperative result was achieved.

Discussion

With an increase in the aging population, there has been an increasing awareness of degenerative spinal deformity as a cause of significant morbidity.3,4,8,17,20–22,25 In the lumbar spine, scoliotic deformities will often be associated with a degree of VB angulation as well as a rotational deformity. Furthermore, unlike thoracic spinal deformity in which cosmetic concerns are prevalent, in lumbar degenerative scoliotic deformity the presenting complaint leading to treatment is most often a combination of axial and radicular pain.8,11,13,20,21

When patients present with lumbar radiculopathy, it is important to perform a detailed clinical and radiographic evaluation. Accordingly, this assessment should routinely include plain radiographs of the lumbar spine to investigate for, and quantify the degree of, any lumbar scoliotic deformity that may be present. Although herniated intervertebral discs and/or spinal stenosis are more frequent causes of lumbar radiculopathy, a careful and

![Fig. 1. Case 4. Left and Right: Preoperative anterolateral and lateral 36-inch standing radiographs demonstrating a 26° left-convex lumbar scoliotic deformity with a degenerative listhesis of L2–3 and an asymmetrical collapse of the right L-2 and L-3 VBs.](image-url)
systematic review of the radiographic studies will demonstrate that a significant proportion of these patients also harbor a concomitant lumbar spinal deformity. It is important to determine whether radicular symptoms are related to the spinal deformity, spinal stenosis, herniated discs, or a combination thereof, to formulate an effective treatment plan and achieve satisfactory clinical results.

Previously, the technique we had used for patients with lumbar scoliosis requiring spinal fusions was to place bilateral cages into the involved intervertebral disc space. In this manner, the nerve roots were able to be well decompressed and the lumbar lordosis was maintained or improved in most cases; however, the degree of coronal plane deformity did not change appreciably. The modified surgical technique has allowed us to achieve substantial curve corrections while also providing a thorough decompression of the involved nerve roots.

It is important to note that an aggressive bony decompression and disc removal not only provide an excellent decompression of the neural elements, but also serve as a deformity-release maneuver. When combined with proper surgical positioning, with the patient’s hips fully extended on a radiolucent operating table, a substantial degree of passive curve correction can be achieved by removing aggressive bony and disc material, and thus less corrective mechanical force needs to be applied to the construct to produce a satisfactory degree of deformity correction. To lessen the incidence of failure of the bone-implant interface or fracture, it is necessary to minimize the corrective mechanical forces on constructs in patients with low BMD. Furthermore, in patients with low BMD, the use of carbon fiber cages, which have a similar modulus of elasticity to that of the adjacent bone, may serve to lessen the incidence of cage subsidence.

By placing a single cage on the concave side of the deformed segment and by applying asymmetrical dorsal compressive forces to the stabilizing construct, we have been able to achieve excellent coronal curve correction. The selective application of relatively increased compressive forces on the convex side of the curve allows for an additional coronal plane curve correction and applies a compressive force on the interbody graft material in the disc space proper. At the same time, this technique allows a very generous quantity of bone graft to be packed into the convex side of the intervertebral disc space. The application of bilateral compressive forces also shortens the posterior column, which is pivotal in the maintenance or improvement of lumbar lordosis and global sagittal balance.

All 4 patients in this series were smokers and 2 pa-
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tients had significantly decreased BMD shown on DEXA
evaluation. Despite the presence of these significant risk
factors for nonunion, the packing of generous amounts of
bone into the intervertebral disc space, in addition to bi-
lateral posterolateral autograft fusions over the transverse
processes, has led to successful circumferential arthrodes-
is of the coronally deformed segments in all 4 cases. In
one patient, in whom a pseudarthrosis developed at the
rostral-most extent of the fusion construct, requiring
a revision surgery, the pseudarthrosis occurred at spinal
segments that were not involved with the coronal plane
deformity and were treated with an instrumented poste-
rolateral fusion rather than circumferential stabilization and fusion.

Conclusions
The preliminary results with this minor technical
improvement have been gratifying. In all 4 patients we
documented excellent improvements in coronal plane alignment, noted no instance of deterioration in sagittal balance, and observed solid circumferential fusions at the levels of the coronal deformity. In addition, the clinical outcomes have been uniformly positive. In candidates for lumbar spinal fusion surgeries who also possess focal coronal curvatures, consideration and im-
plementation of unilateral intervertebral cage placement
has produced excellent overall results in our preliminary experience.

Disclosure
DuPuy Spine and Biomet Spine provide support of non-
study-related clinical or research efforts overseen by Dr. Heary.
Conception and design: RF Heary. Acquisition of data: both authors.
Analysis and interpretation of data: both authors. Drafting the article:
both authors. Critically revising the article: both authors. Reviewed
final version of the manuscript and approved it for submission: RF
Heary.

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