Lumbar Motion Segment Pathology Adjacent to Thoracolumbar, Lumbar, and Lumbosacral Fusions

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Study Design. Fifty-eight patients came to two spinal surgeons with abnormalities adjacent to a previously fused thoracic or lumbar spinal segment after they had been asymptomatic for more than 2 years. Radiographs, outcome analysis, analog pain evaluation, patient demographics, and medical indices were analyzed to evaluate risk factors for adjacent segment abnormality.

Objectives. Risk factors for adjacent segment breakdown and pathophysiology of adjacent segment breakdown were analyzed in this longitudinal study.

Summary of Background Data. Fifty-eight patients underwent a thoracolumbar, lumbar, or lumbosacral fusion with an average symptom-free period of 13.1 years before presentation with severe symptomatology necessitating further surgery at the adjacent segment.

Methods. Fifty-eight patients with adjacent segment abnormality were analyzed by outcome assessment questionnaire, pain, analog evaluation, radiographic studies, demographic factors, and sequential follow-up evaluation. Thirty-seven of these patients have been followed for more than 2 years after their adjacent segment surgery.

Results. Fifty-eight patients developed spinal stenosis, disc herniation, or instability at a segment adjacent to a previously asymptomatic fusion that was done an average of 13.1 years earlier. Segments adjacent to the adjacent segment itself were as likely to breakdown (58%). Thirty-seven patients were followed for more than 2 years, having outcomes defined as good or excellent in 70.3%. Seven of the 37 patients required an additional surgical procedure. Sagittal and coronal imbalances appeared to play a role in breakdown, although statistical significance was not evident.

Conclusions. This represents the largest series of adjacent segment breakdowns reported in the literature. The segment adjacent to the adjacent segment was almost as likely to breakdown. Sagittal and coronal alignment appeared to play a role in adjacent abnormality. Good outcomes are evident in 70% of cases. [Key words: adjacent segment, fusion, lumbar spine] Spine 1996;21:970-981.

The outcome of surgical fusion in the lumbosacral spine is varied and unpredictable. Analysis of the literature is mixed with good and poor results. The indications for spinal fusion are mixed in controversy and are not clearly definable. "Instability" of the lumbar spine has been a subject of many articles, although its definition and diagnosis vary from surgeon to surgeon.

The use of lumbar fusion is increasing rapidly, especially in the United States, and outcome data do not support this trend. Articles defining poor results are frequent, and prospective analysis of fusion is largely absent. Most surgeons believe that spinal fusion is a good procedure for the appropriate patient, and superior results have been reported. Certain categories of lumbar instability, such as spondylolisthesis, have improved results when fusion is included with decompression.

Anecdotally, surgeons believe that breakdown of the segment adjacent to a fused spinal motion segment can occur. The literature does not support this proposition. Previous biomechanical and clinical articles defining adjacent segment problems are lacking and consist largely of case reports. The largest series reported of adjacent segment breakdowns involved 18 patients described by Lee. Many long-term studies do not define the presence or absence of adjacent segment breakdown.

The purpose of the present study was to evaluate those patients with segmental abnormality adjacent to previously fused spinal segments.

Materials and Methods

Fifty-eight patients were seen and treated by two spinal surgeons for problems associated with adjacent segment disease and abnormality. All patients previously had undergone a spinal fusion procedure, and all patients were symptom-free with normal function for more than 2 years after their index operation. Before their index fusion surgery, patients had zero to three decompressive procedures. Diagnosis at the time of index procedure was herniated nucleus pulposus in 18 patients, spinal stenosis in 25 patients, spondylolisthesis in eight patients, spinal fracture in five patients, and kyphoscoliosis in 10 patients. Eight patients had combined diagnoses. The average patient age at the time of index procedure was 42.6...
Subject: Medical

### Table 1. Summary of Patients With Index Procedure, Index Diagnosis, and Symptom-Free Period

<table>
<thead>
<tr>
<th>Index Procedure</th>
<th>Number</th>
<th>Diagnosis (#)</th>
<th>Average Symptom-Free Period (yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L4-Sacrum fusion</td>
<td>20</td>
<td>Spondylolisthesis (6) Fracture (2) Herniated nucleus pulposus (4) Spinal stenosis (14)</td>
<td>13.0</td>
</tr>
<tr>
<td>Thoracolumbar fusion</td>
<td>11</td>
<td>Kyphoscoliosis (10) Fracture (1)</td>
<td>15.7</td>
</tr>
<tr>
<td>L5-Sacrum fusion</td>
<td>11</td>
<td>Herniated nucleus pulposus (11) Fracture (1)</td>
<td>16.6</td>
</tr>
<tr>
<td>Floating fusion</td>
<td>9</td>
<td>Spondylolisthesis (3) Fracture (1) Herniated nucleus pulposus (3) Spinal stenosis (5)</td>
<td>6.3</td>
</tr>
<tr>
<td>L3-Sacrum fusion</td>
<td>7</td>
<td>Fracture (1) Herniated nucleus pulposus (6) Spinal stenosis (6)</td>
<td>13.0</td>
</tr>
</tbody>
</table>

years, with a range of 12–75 years. There were 22 male and 36 female patients.

After a symptom-free period averaging 13.1 years, these patients came to one of two spinal surgeons complaining of severe back and leg pain. Extensive conservative modalities were exhausted on each, including exercise, therapy, medications, or injections. Secondary to persistent pain and problems, all 58 patients underwent a surgical procedure after appropriate studies and diagnoses were established. Visual analog scales (0–10) at the time of initial visit, preoperatively, and at follow-up evaluation were obtained. Before surgery, the average back pain score was 8.2, and the mean score for leg pain was 7.2. Functional assessment evaluation was done on all patients again before and after surgery. All patients were evaluated at follow up with measured outcomes. Thirty-seven have follow-up periods of 2 years or more.

The patients were grouped according to their index surgical procedure. Twenty patients underwent an L4–S1 fusion; 11 patients underwent an L5–S1 fusion; nine patients had a floating fusion not including the lumbosacral junction; seven patients had an L3–S1 fusion; and 11 patients had a thoracolumbar fusion for kyphoscoliosis. The numbers of patients, their fusion levels and index, and original diagnoses are included in Table 1.

After a lengthy symptom-free period, all patients presented with back and leg pain and marked functional limitations. Work-up before surgery included plain radiographs (anteroposterior and lateral), functional assessment questionnaire, magnetic resonance imaging or computed tomography (CT/MRI), and analog pain documentation. Radiographs were measured by Cobb method from superior to inferior aspect of the fused segment. Follow-up evaluations were done 3, 6, 9, 12, and 24 months after surgery and examined patient status, functional questionnaire, analog pain score, and radiographic evaluation.

Statistical analysis using Pearson’s Product Coefficient was done. Groupings by procedure group, outcome analysis, radiographic measures, and symptom-free period were analyzed and compared by analysis of variance.

### Results

After an extensive symptom-free period, three diagnostic categories were established in the 58 patients with adjacent segment abnormality based on the previously mentioned criteria: spinal stenosis, disc prolapse, and instability and listhesis (Table 2).

Spinal stenosis was the most common finding at follow-up presentation. Notably, the segment adjacent to the adjacent segment was almost as likely to breakdown as the adjacent segment itself, especially in the group of stenotic patients. In 36 of 58 cases, a surgical procedure was required at the segment adjacent to the fused segment.

#### L4-to-Sacrum Fusions

According to procedure, 20 L4–S1 fusions had an average symptom-free period from index procedure to adjacent segment surgery of 13.0 years. Spinal stenosis above the segment was the most common finding, occurring in 16 of the 20 patients. Twelve of the 20 had an abnormality above the adjacent vertebra. Spondylolisthesis and herniated nucleus pulposus each represented three cases (Figures 1–3). Radiographic analysis noting sagittal and coronal alignment were measured over the fused segments. The average scoliosis or lateral curvature represented 4.1°, whereas lordosis averaged 21.7°. There was no statistical correlation comparing radiographic measurement, 2-year outcome, and length of symptom-free period.

#### L5-to-Sacrum Fusions

Eleven patients had a L5–S1 fusion in their index procedure. Listhesis, disc prolapse, and stenosis were represented in three, two, and 11 patients, respectively. The average sagittal alignment in this group was 14.5° of lordosis, whereas the average coronal alignment was 1.2°. Lordosis less than 13° was associated with a shorter symptom-free period (3.8 years), although this was not statistically significant.

#### Floating Fusions

There were nine floating fusions in this group—this included patients that had isolated fusions at L2–L3 (1 patient), L3–L4 (2), L4–L5 (3), and L3–L5 (3; Figure 4). Because of differing levels, radiographic measurements are nonconclusive. Symptom-free period in this group averaged 6.3 years—considerably shorter than other groups.

### Table 2. Diagnostic Categories and Location of Abnormality After Prolonged Symptom-Free Period

<table>
<thead>
<tr>
<th>Adjacent Segment</th>
<th>Adjacent to Fused Segment</th>
</tr>
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<tbody>
<tr>
<td>Spinal stenosis</td>
<td>50</td>
</tr>
<tr>
<td>Disc prolapse</td>
<td>7</td>
</tr>
<tr>
<td>Instability and listhesis</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>4</td>
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<td></td>
<td>0</td>
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</table>
**L3-to-Sacrum Fusions**

The L3–S1 fusion is done rarely. The seven patients in this group had a symptom-free period averaging 13.0 years. At presentation, stenosis adjacent to the segment occurred in seven patients, disc herniation in one patient, and instability or spondylolisthesis in three patients. Average sagittal alignment in this group represented 20.2° lordosis, whereas anteroposterior alignment was 9.4°. There was no correlation between symptom-free period, sagittal angulation, and 2-year outcome.

**Thoracolumbar Fusions**

The most interesting group represented the patients with kyphoscoliosis (Figure 5). All 11 patients underwent a thoracolumbar fusion to L4 or below. Only patients fused to L4 presented into this group. Average sagittal and coronal angulations in this group represented 10° kyphosis and 39.8°, respectively. The symptom-free period averaged 15.7 years. Diagnosis at the time of salvage operation represented stenosis in 11 patients, and listhesis in two patients.

**2-Year Follow-Up Evaluation**

Thirty-seven of these patients have been followed more than 2 years; these fall into the following categories: L4–S1 fusion, 16; L5–S1 fusion, nine; floating fusion, five; L3–S1 fusion—one; and thoracolumbar fusion, six. Of these 37 patients, 14 patients underwent decompression and fusion procedure, whereas 23 underwent a decompression procedure only. Twenty-six are doing well and describe their functional outcome as good or excellent. The average follow-up back pain score and leg pain score in this group are 4.0 and 2.3. Seven of 37 patients have required a second operation. Three patients had a decompressive procedure ultimately requiring a fusion; two patients underwent a decompression and fusion procedure that had to be refused; and two patients had hardware removal.

The ultimate outcomes on the 2-year follow-up group represented an average back pain score of 4.0 and leg pain score of 2.3 at an average of 3.1 follow-up years. Patients rated their result as excellent in nine cases, good in 17 cases, fair in eight cases, and poor in two cases. Of this group, five have had to undergo a repeat surgical operation to repair a fusion or fuse a segment that had been simply decompressed. Angulation of the spine in sagittal and coronal planes did appear to reflect the outcome within groups. Statistical correlation grouping of outcome results with radio-
graphic angulation and length of symptom-free period were nonconclusive.

**Discussion**

The role of spinal fusion in the United States is under great scrutiny and criticism. Several factors contribute to this. In a meta-analysis of the literature, Turner et al. reviewed 47 articles defining outcomes after spinal fusion. There were no randomized trials, and the outcomes were variable. On the average, 68% of patients had a satisfactory outcome after fusion, but the range was wide. Individuals with previous surgery and patients involved in prospective trials appeared to fare worse than their counterparts. Despite this, the number of spinal fusions done grew an increasingly rapid rate from 1979 through 1990.

Because a paucity of literature supports the fusion procedure, its definable indications remain controversial. Underlying this is the true definition of lumbar instability. The nature of instability has been studied by Farfan, Kirkaldy-Willis, and Frymoyer et al. Listhesis or translation of one vertebral body on another is a contributor to instability, although the natural history of spondylolysis frequently is asymptomatic. Radiographic techniques help establish the diagnosis of instability. Flexion–extension and dynamic radiographs identify instability according to Dupuis et al., especially when translation is more than 5 mm. Farfan defined facet orientation as a contributor to intervertebral disc failure. Frymoyer et al. reported 96 patients undergoing midline spinal fusion more than 10 years earlier. He found the plain radiograph to be of little value in determining the source of pain after surgery. The only exception represented acquired spondylolysis that did appear to be associated directly with a poor clinical outcome. Although these studies are embellished in clinical literature, they do not fully clarify the pain process.

Throughout this milieu of uncertainty, studies do support fusion as a viable procedure in certain diagnostic entities. Frymoyer did a long-term follow-up study of spinal fusion, evaluating 312 patients. The average follow-up period was 13.7 years. One hundred forty-three of these patients underwent a fusion. Thirty percent of the fusions were deemed failures. He concluded that midline spinal fusion offered few benefits in the management of lumbar spine disease. Lehmann et
al in 1987 reported 62 patients of which 33 returned
for physical examination. The follow-up period was
long—33 years. They concluded that most patients
were satisfied with their results. Of the 62 patients con-
tacted, nine had to undergo an additional procedure.
Although fusion can be supported as a viable procedure,
diagnostic criteria and surgical indications obviously are
crucial in the resultant outcome. Consistent throughout
this literature is an absence of commentary describing
adjacent segment abnormality.

Anecdotally, most surgeons believe that breakdown
of the adjacent segment occurs. In the clinical setting,
the segment adjacent to a fused segment is a common
differential of diagnostic possibilities. Although predict-
able, the literature is largely nonsupportive. The previ-
ously mentioned studies have one significant common-
ality: they report no adjacent segment breakdown in
follow-up periods ranging from 2 to 33 years. Literature
focusing on adjacent segment analysis is absent. Anderson
in 1956 reported a case describing spondylolisthesis
after spinal fusion. In 1963, Harris and Wiley noted
six cases of acquired spondylolisthesis as a sequel to spine
fusion. Stenosis after anterior spinal fusion was noted by
Louw in 1986. Careful analysis was done from a
biomechanical and clinical standpoint by Lee. In a
laboratory study comparing bilateral lateral fusion, pos-
terior fusion, and anterior fusion, he concluded that
bilateral lateral fusion was the better method providing
good stabilization of the fused segment with lower stress
transmission to the adjacent unfused segments. In a
clinical study, Lee reported 18 patients in whom new
symptoms had developed at the segment adjacent to a
fusion. Patients had an average symptom-free interval
of 8.5 years. The initial fusions were scattered between
L5-S1, L4-S1, L3-S1, L2-S1, and L1-L4.

The present series represents the largest numerical
series of adjacent segment disease. Fifty-eight lumbar
fusions were symptom-free for an average period of
13.1 years (range, 2.6–40.0 years). The index proce-
dure was performed after zero to three previous proce-
dures, usually of a decompressive type. The diagnoses at
time of index procedure represented spondylolisthesis
(eight cases), spinal stenosis (25), herniated nucleus pul-
posus (18), and kyphoscoliosis (10).

After a lengthy symptom-free period, the patients
returned with severe back and leg pain. Average scores
Figure 3. A and B, A 31-year-old man had L5 fracture dislocation with cauda equina syndrome. C and D, After an 11-year symptom-free period, he returned with spinal stenosis and instability at L3-L4.
for back and leg pain were 8.2 and 7.0, respectively. Functional assessment revealed evidence of marked dysfunction in all cases. Frank neurologic signs including weakness or change in reflex were noted in 36 patients (62.1%).

Diagnostic patterns in the adjacent segment group revealed spinal stenosis in 50 patients, lysis in 13 patients, and herniated nucleus pulposus in seven patients with some in a combined category. Notably, the segment adjacent to the adjacent segment was almost as
likely to breakdown as the adjacent segment itself. There were 36 cases of the segment adjacent to the adjacent segment breaking down, with stenosis being

Figure 5. A 28-year-old woman had an anterior T12-L4 fusion with Dwyer cable. Segmental kyphosis is present (A). B and C, After 16 symptom-free years, she developed stenosis at L4-L5 and spondylolisthesis at L5-S1, necessitating additional successful surgery.

the most common diagnostic finding. After extensive conservative treatment, all 58 patients eventually underwent a surgical procedure, with 37 having been fol-
lowed for more than 2 years. Functional outcome re-
veals 26 patients with an excellent or good result, eight
with a fair result, and two with a poor result. Fourteen
patients underwent a fusion and decompression, and 23
underwent decompression alone. The fusion group had
successful outcomes in 11 of 14 patients (78.6%), and
the decompression group had successful outcomes in 15
of 23 (65.2%). Of this 2-year follow-up group, seven
have actually had another procedure—five a fusion, two
hardware removals.

Preoperative predictive factors, including radiographs,
were subdivided according to their index fusion pro-
dure. There were 20 L4–S1 fusions, 11 L5–S1 fusions,
seven L3–S1 fusions, and nine fusions that were floating
lumbar fusion of one type or another. Radiographic
measurements for each of these groups were noted.
There did appear to be a loss of overall sagittal align-
ment in this group. Although the numbers are not sta-
tistically significant, the overall relative kyphosis in the
spine was reduced compared with a normal population.
Statistical analysis comparing sagittal alignment with
time to development of symptomatology did not reveal
clear trends.

As a separate diagnostic entity, long thoracolumbar
fusions for scoliosis have similarities to the lumbosacral
dilemma described previously. Thoracolumbar fusions
for scoliosis are a commonly accepted procedure. The
literature surrounding their outcome is plentiful. Clin-
ical discussion surrounds adjacent segment disease, but
the literature again is deplete documenting this.

Cochran et al evaluated 100 patients from the Gothen-
burg Scoliosis Databank. These patients represented a
minimum follow-up period of 5 years, with radiographs
showing marginal alignment in the sagittal and coronal
plane. The overall clinical results were good. They be-
thought degenerative facet changes and disc space
towing occurred in 11 patients, all of whom had
osteo hook purchase in L4 or L5. Somewhat contrary to
this, Michel and Lalain studied 206 patients of an
original group of 493 undergoing surgery in the 1960s.
They followed the patients for at least 10 years, with the
average follow-up period being almost 14 years. Again,
the radiographs were disappointing, although the cli-
nical results were good, and only 20% of the patients
actually had back pain. Looking specifically at the seg-
ments below the fusion, they noted the vertebral bodies
to be elongated and trapezoidal, leading to a normal
average lordosis. A short kyphosis occurred when the
lower hook rested in L1 or L2. Therefore, the authors
believed the best level of lower hook placement was L3
or L4. Back pain was not increased with this lower hook
purchase level.

In the present series, 11 patients had breakdowns
below a previously fused kyphoscoliosis of the thoraco-
lumbar spine. All patients had significant symptomat-
ology including back pain and leg pain, and 58% had
neurologic dysfunction (either weakness or change in
neurologic examinations of a major degree). Several
commonalities occurred in our group. All of the symp-
tomatic patients had fusion to L4 or below, and there
was loss of sagittal and coronal alignment of a signifi-
cant degree. Notably, the bottom vertebrae of the fusion
was not balanced in this group and appeared to have a
significant sagittal or coronal malalignment (36° lateral
angulation, 10° kyphosis). Results after surgery in this
group are good. Of the 11 patients undergoing surgery,
seven have now been followed for more than 2 years. Four
had a simple decompression procedure, whereas
three had a decompression combined with a fusion.
Diagnoses at the time of follow-up procedure included
spondylothesis in two patients and spinal stenosis in
11 patients. The segment adjacent to the adjacent seg-
ment was involved in a significant number of cases—
eight of 11—and two required subsequent surgery: one
had a failed fusion and underwent a simultaneous an-
teroposterior fusion to stabilize, whereas one had a sim-
ple decompression procedure and, although she did well
initially, later developed problems and underwent a fusi-
on (Figure 6). Both patients have now been followed
for more than 2 years after their most recent procedure
and are doing very well.

From a clinical perspective, these 58 patients came to
the authors with significant back and lower extremity
pain. Exhaustive nonoperative measures were attempted
before surgical intervention. In patients with disc herni-
ation or spinal stenosis without instability, simple de-
compressive procedures were done. In patients with in-
stability, including lysisithesia or significant sagittal
or coronal malalignment, fusion was augmented to the
procedure process. Analysis of the diagnostic category
and analysis of the surgical procedure—decompression,
decompression with fusion, decompression with fusion ± instru-
mamentation all reveal no significant trend toward out-
come of these patient groups.

This series of 58 patients is the largest documented
series of abnormality adjacent to previous spinal fus-
ions. Data were collected on this group, and analysis
for risk of breakdown was ascertained. Unfortunately,
inherent limitations to this type of review exist and
make bold statements or generalities quite difficult.
Because the follow-up period of this group is long, most of
the lumbosacral fusions were done in a conventional
fashion—without instrumentation. The small number of
instrumented lumbosacral fusions, seven, had a shorter
time to adjacent segment breakdown than the nonin-
strumented group. Because instrumentation has only
been performed recently, this may not represent a true
phenomenon—rather, it may document only a selection
bias.

On evaluating these patients by index procedure, it is
interesting that those patients undergoing floating fu-
sion had a shorter time to breakdown compared with
the other symptomatic groups. The large percent of
these floating fusions did have instrumentation as an
adjunct to their original fusion. Sagittal and coronal alignment appeared to play a role in many of these individual cases. There were ten cases that had outcomes defined as fair or poor. Analysis of the two cases with poor results included one patient with pseudomeningocele noted at the time of surgery with persistent dural leak after surgery. Of the 58 patients, one other had a dural laceration at the time of surgery but had a
good clinical outcome. The other patient with poor results had persistent back and leg pain that was severe and incapacitating after surgery. There were no surgical complications noted in this particular case. There were no wound infections. Statistical correlation grouping outcome results with radiographic angulation, length of symptom-free period, index diagnostic category, or type of surgical procedure was nonconclusive.

The present study does not define the natural history of the fusion process and does not have a comparable control population. Attempts by the authors to retrieve natural history information on fusion patients has yielded retrieval rate of approximately 50%. This study documenting adjacent segment disease may only be documenting the natural history of a disease process that may have developed otherwise irrespective of the fusion. Although this is a large series, it is not large enough to answer important questions for clinicians comparing adjacent segment breakdown with use of instrumentation type of surgical intervention or specific numbers specifying sagittal or coronal limits of malalignment.

The present study represents the largest accumulation of adjacent segment breakdown problems in the literature. Although defining exact trends is difficult based on such a long, lengthy, and scattered population, certain generalities can be noted. These lead to the following conclusions: 1) after a lengthy symptom-free period, segments next to a fused segment can breakdown; 2) the segment next to the adjacent segment is almost as likely to breakdown as the adjacent segment itself, 3) fusion in addition to decompression of the adjacent segment is often necessary.

References

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