

Lumbar Spine Fusion in the Treatment of Degenerative Conditions: Current Indications and Recommendations

Harry N. Herkowitz, MD, and Kanwaldeep S. Sidhu, MD

Abstract

The role of arthrodesis in the treatment of degenerative disorders of the lumbar spine is controversial. Most patients with these conditions can be successfully treated nonoperatively. Lumbar fusion, with or without instrumentation, is associated with more complications, especially in the elderly population. Therefore, the potential benefits to be obtained by means of arthrodesis must be measured against the risks. Arthrodesis is indicated as an adjunct to decompression for patients with spinal stenosis associated with degenerative or iatrogenic spondylolisthesis and in the treatment of progressive degenerative lumbar scoliosis and iatrogenic instability resulting from extensive decompression. The occurrence of two or more episodes of disk herniation at the same segment is a relative indication for arthrodesis. In patients with incapacitating nonradicular back pain, arthrodesis should be a consideration only after failure of a trial of nonoperative treatment lasting more than 12 months and after secondary gain issues (e.g., workmen's compensation) have been adequately resolved. Arthrodesis has a poor success rate when used to treat back pain associated with multilevel disk degeneration seen on magnetic resonance images.

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The number of patients seen by orthopaedic surgeons for degenerative conditions of the lumbar spine is increasing. With increased longevity of the population, it is estimated that 4% of the population will undergo a lumbar spine operation in their lifetime. In addition, "degenerative disk disease" is diagnosed in a large proportion of disabled industrial workers with chronic back pain. The lumbar spine continues to be the site of the most expensive industrial injuries,¹ and lumbar spine disorders are the most common cause of disability in adults younger than 45 years of age.²

Degenerative conditions affecting the lumbar spine include disk herniation, degenerative spondylolisthesis, spinal stenosis, degener-

ative scoliosis, and degenerative disk disease. Most patients with these conditions are treated successfully by nonoperative means. However, a significant percentage will undergo surgical treatment that involves decompression and/or lumbar fusion.

Spinal fusion is considered the standard treatment of progressive spinal deformities, such as scoliosis, and instability resulting from trauma. Its use in many degenerative conditions of the lumbar spine, however, remains controversial.

In this review we shall attempt to define the role of spinal fusion as an adjunct to the treatment of the following degenerative conditions of the lumbar spine: disk herniation, degenerative spondylolisthesis,

degenerative lumbar scoliosis, and spinal stenosis. The role of spinal fusion in treating diskogenic pain due to other causes will be discussed only briefly. The role of provocative testing (diskography) and the significance of "black-disk disease" (as visualized on magnetic resonance [MR] imaging) remain controversial. A complete discussion of the pros and cons of spinal arthrodesis in treating degenerative disk disease is beyond the scope of this article. We have also limited discussion of the role of instrumentation as an adjunct to lumbar fusion because an article on this topic will appear in a forthcoming issue of this journal.

Epidemiology and Socioeconomic Impact of Low Back Pain

The lifetime incidence of low back pain in the general population is estimated to be 60% to 80%.³ At any

Dr. Herkowitz is Chairman, Department of Orthopaedic Surgery, William Beaumont Hospital, Royal Oak, Mich. Dr. Sidhu is a Spine Fellow in the Department of Orthopaedic Surgery, William Beaumont Hospital.

Reprint requests: Dr. Herkowitz, Department of Orthopaedic Surgery, William Beaumont Hospital, Suite 604, 3535 West 13 Mile Road, Royal Oak, MI 48073-6769.

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given point in time, 15% to 20% of the population state that they are having symptoms of low back pain. Low back pain accounted for 15 million office visits in 1990, ranking it the fifth most common reason for all physician visits.⁴

The rate of back surgery in the United States is at least 40% higher than that in any other country and is more than five times the rates in England and Scotland.⁵ The lifetime prevalence of lumbar spine surgery has been reported to be between 1% and 3%.³ The annual incidence of lumbar spine surgery in the United States is approximately 165 operations per 100,000 persons.⁶ The most common indication for lumbar spine surgery is excision of a herniated disk (122 operations per 100,000 persons). Lumbar fusion ranks as the second most common lumbar spine procedure (25 lumbar fusions per 100,000 persons).⁶ Between 1988 and 1990, more than 62,000 lumbar fusions were performed annually in the United States, with a failure rate of 20% to 40%.⁷

Frymoyer and Cats-Baril³ analyzed the direct and indirect costs of low back pain in 1990. The estimated direct costs (hospital, therapy, physicians, surgery, and medication) exceeded \$24 billion. The indirect costs related to lost productivity were estimated to exceed \$27 billion. Thus, the total cost of low back disorders may exceed \$50 billion annually. Clearly, the socioeconomic impact of low back disorders is indeed tremendous. Given the costs, a key question is, "How effective is spinal surgery?"

Outcomes After Lumbar Fusion

Turner et al⁷ performed a meta-analysis of patient outcomes after lumbar fusion. Only those studies in the literature with more than 30

patients and a follow-up period longer than 1 year were included. The diagnoses included only degenerative conditions, such as disk herniation, internal disk derangement, degenerative scoliosis, segmental instability, pseudarthrosis, failed back surgery syndrome, spondylolisthesis, and spinal stenosis; thus, data from both primary operations and revision surgeries were included. The authors found on average a 68% satisfactory outcome after lumbar fusion. The results in terms of back pain relief were rated as good or excellent by 61% of the patients and poor or fair by 35%. The complication rates related to lumbar fusions were as follows: mortality, 0.2%; deep infection, 1.5%; deep venous thrombosis, 3.7%; pulmonary embolus, 2.2%; neural injury, 2.8%; donor-site complications, 10.8%; and instrumentation failure, 7.3%.

Turner et al concluded that their analysis "did not support the superiority of any fusion procedure over others for clinical outcome." Their study supported the necessity of further prospective randomized controlled trials. In addition, their meta-analysis data confirmed that lumbar fusion is associated with a definite complication rate and that, therefore, the risk-benefit ratio must be considered carefully before performing spinal arthrodesis as an adjunct after decompressive lumbar surgery or as a primary procedure for low back pain.

The reasons for failure of lumbar fusion operations include improper diagnosis, poor patient selection, psychosocial factors, incorrect indications, inadequate surgical technique, and complications inherent to the surgical procedure. Of these, we believe that patient selection remains the single most important factor in minimizing the risk of failure.

Criteria for Lumbar Instability

Instability may be present preoperatively or may be iatrogenic, as a result of intraoperative alterations due to resection of the facets or pars interarticularis or due to radical disruption of the intervertebral disk.

Meta-analysis of the literature regarding lumbar fusions has revealed that a significant percentage of such procedures (more than 30%) are performed because of a diagnosis of segmental instability.⁷ The term "instability" as it applies to the lumbar spine, however, remains poorly defined. White and Panjabi⁸ define clinical instability of the spine as "loss of the ability of the spine under physiologic loads to maintain its pattern of displacement so that there is no initial or additional neurologic deficit, no major deformity, and no incapacitating pain."

Unfortunately, most criteria either are not reproducible or are too complex to be practical in daily practice. Normal values for anterior and posterior translation from L1 to L5 are 8% and 9%, respectively.^{9,10} At the lumbosacral junction, these values are 6% and 9%, respectively.⁹ Currently, the accepted standard for hypermobility or instability is more than 4 mm of translation (Fig. 1) and/or more than 10 degrees of angular motion between adjacent endplates on lateral flexion/extension radiographs when compared with the adjacent proximal and distal levels.¹¹ On the anteroposterior (AP) view, spinous process and facet malalignment may suggest segmental instability.

Degenerative spondylolisthesis with back pain may represent true segmental instability.¹² Curve progression or lateral listhesis in degenerative lumbar scoliosis may imply relative instability, which may worsen after a posterior decompression. Excessive segmental or junc-

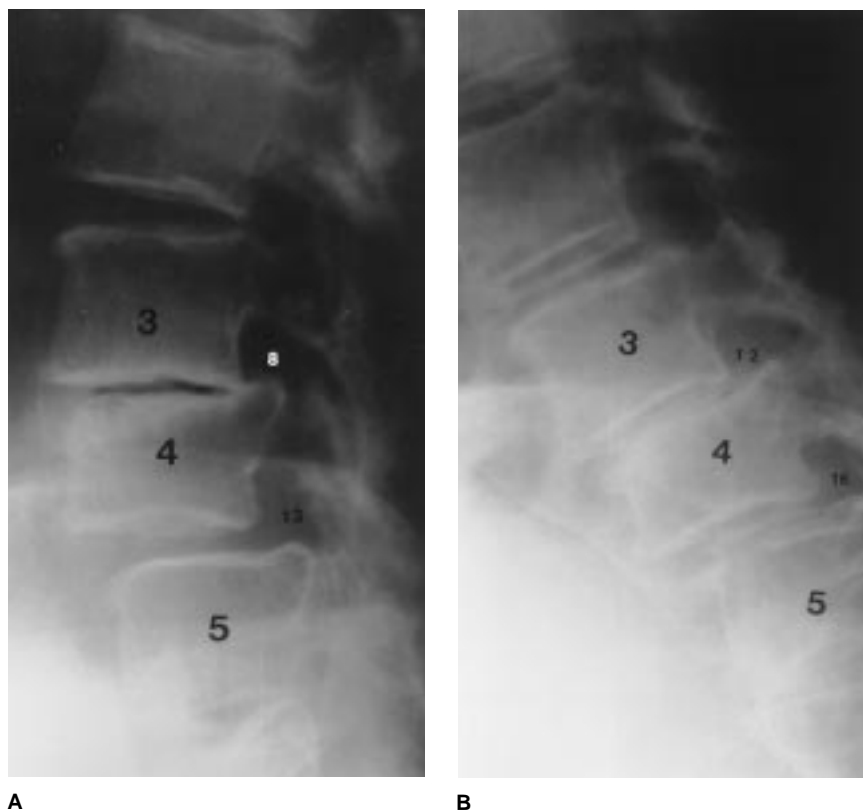


Fig. 1 Lateral lumbar radiographs depicting dynamic instability due to spondylolisthesis at L3-4 and L4-5. **A**, In extension, the anterior translation measures 8 and 13 mm, respectively. **B**, In flexion, the anterior translation measures 12 mm and 16 mm, respectively.

tional kyphosis may be an indicator of segmental instability at that motion segment.

Intraoperative structural alterations that may lead to instability include the following:

(1) Excessive removal of the facet joints: Patients who would not necessarily meet the criteria for arthrodesis preoperatively may become candidates for concomitant arthrodesis intraoperatively if excessive facetectomy is required for adequate decompression. The contribution of lumbar facet joints to stability of a motion segment has been studied by Abumi et al.¹³ Their biomechanical analysis of cadaveric specimens subjected to cyclical loading after progressive facetectomies revealed that more

than 50% resection of each facet joint at the same level leads to unacceptable segmental instability. Therefore, when a facetectomy of 50% or more is performed, posterolateral arthrodesis should be strongly considered.

(2) Disk excision: The incidence of simultaneous disk herniation and spinal stenosis is reported as 5% to 25%. Most disk herniations that occur in this group represent extrusions or free fragments of disk at the level of the foramen. Simple removal of these disk fragments at the time of decompressive laminectomy is sufficient. "Radical" disk excision involves the removal of as much of the disk material and endplates as possible. This destabilizes the anterior column after the posterior column

has been compromised by the decompressive laminectomy and may lead to iatrogenic spondylolisthesis. Therefore, if a radical discectomy is considered necessary, a concomitant posterolateral arthrodesis is often considered.

A second or third disk herniation at the same motion segment may be considered by some as evidence of instability at that particular interspace, even without radiologic confirmation.

Role of Lumbar Fusion in Various Degenerative Conditions

Primary Disk Herniation

The literature does not support performing a lumbar fusion in patients who undergo primary disk excision for radicular symptoms. Patients suffering from radicular symptoms due to disk herniation will experience successful pain relief after disk excision alone in approximately 90% of cases.¹¹ A failure rate of less than 10% after primary disk excision assumes appropriate patient selection and surgical indications. The latter include positive findings on physical examination, correlating findings on imaging studies, and an absence of major psychosocial dysfunction. The standard surgical treatment involves a limited exposure and excision of only the loose or extruded disk fragment. The incidence of recurrent disk herniation is estimated to be 8% to 10%; that of significant postoperative back pain, 10% to 15%.¹¹

Patients with long-standing back pain and acute onset of radiculopathy due to disk herniation pose a challenge for the spine surgeon. No prospective studies have supported performing a lumbar fusion in association with disk excision in this patient population. In a retrospective review of the data on 250 patients, Rish¹⁴

found no significant clinical difference between patients treated with discectomy alone and those treated with discectomy and fusion. Vaughan et al¹⁵ retrospectively reviewed the data on patients with L4-5 disk herniation treated with disk excision with or without simultaneous L4-5 fusion. This study, with an average follow-up of 7.3 years, demonstrated better clinical results in the fusion group, with a lower reoperation rate and a lower rate of recurrent disk herniation. The investigators speculated that the increased mobility of the L4-5 segment predisposed this motion segment to increased risk of late instability after discectomy. However, they did not find an increased incidence of recurrent disk herniation at the L4-5 interspace compared with the L5-S1 interspace after disk excision alone. Therefore, we do not recommend a primary arthrodesis following L4-5 discectomy. Prospective randomized trials must be done before arthrodesis can be recommended as the standard surgical procedure for the first L4-5 discectomy.

Patients with minor lower-extremity symptoms and predominant long-standing complaints of back pain are probably best treated with standard conservative measures—nonsteroidal anti-inflammatory medication, brief rest followed by aerobic conditioning, and appropriate physical or psychological therapy. In the absence of instability, patients with radiculopathy and back pain who are surgical candidates should undergo primary discectomy only.

If instability is present preoperatively, consideration should be given to performing a simultaneous fusion. Similarly, if instability is created intraoperatively, arthrodesis should be considered in order to stabilize the affected motion segment.

Recurrent Disk Herniation

Recurrent disk herniation may present as radiculopathy alone or as radiculopathy associated with back pain. Recurrence at a different level should be treated by the same surgical methods employed for a primary disk herniation. Most patients with recurring sciatica after primary disk herniation have symptoms that can be attributed to the same side and anatomic level.¹¹ These symptoms may be due to a true recurrent disk herniation at the same level or to epidural scar formation. Patients with symptoms due to epidural fibrosis are best treated by nonsurgical means.

The management of recurrent radiculopathy without significant back pain that is associated with recurrent disk herniation may be different at L4-5 than at L5-S1. The L5-S1 segment of the spine is inherently stable due to the restraining effect of the ligamentous lumbosacral attachments and its recessed location within the pelvis. Therefore, recurrent disk herniation at this level can be treated by discectomy alone. Because of the absence of these mechanical restraints at L4-5, the incidence of recurrent disk herniation at this interspace is higher.^{11,15} Intertransverse-process fusion at this level may be considered as an adjunct at the time of repeat surgery in order to decrease the failure rate.

Patients with radiculopathy and significant back pain associated with recurrent disk herniation present a difficult diagnostic challenge. The etiology of radiculopathy can usually be confirmed by imaging studies. The cause of back pain, however, remains controversial. Is the back pain due to instability? Is it diskogenic or due to black-disk disease, consistent with disk dehydration as seen on MR imaging? The evaluation of the back-pain component in such patients should

follow the algorithm described in the section on degenerative disk disease.

In the presence of instability or hypermobility, patients with significant back pain and recurrent disk herniation may be considered for fusion in association with discectomy if a new operation is considered. In cases of a first recurrence, the rate of anticipated relief of radiculopathy and reduction of back pain should approach 75%.¹¹

Recurrent disk herniation at the same motion segment is considered by some to be a clear indication for concomitant fusion at the time of repeat surgery. This opinion, however, is not supported by prospective randomized trials.

Spinal Stenosis

Most patients with clinical symptoms consistent with spinal stenosis will respond to nonoperative measures. However, if nonoperative treatment fails to relieve symptoms, decompression remains the basis of surgical treatment, with a success rate reported to be 75% to 90%.¹⁶

The issue of concomitant spinal arthrodesis at the time of decompression in this patient population remains controversial. The debate centers on the definition of spinal stability and its assessment both preoperatively and intraoperatively after decompression. Preoperative instability may be judged on the basis of the presence of any of the following factors, as determined radiologically: (1) degenerative spondylolisthesis or lateral listhesis, (2) flexible or progressive degenerative scoliosis or kyphosis, or (3) recurrent spinal stenosis at the same segment. Instability after decompression may be considered a potential risk in the presence of (1) excessive removal of facet joints, (2) radical disk excision, (3) removal of a pars interarticularis, or (4) a pars fracture.

Degenerative Spondylolisthesis

Degenerative spondylolisthesis (Fig. 2) is an acquired condition, postulated to be caused by chronic disk degeneration accompanied by or causing segmental and rotational instability. It occurs more frequently in the black and female populations and is rare before age 35.¹⁷ The most common level of involvement is L4-5, followed by L3-4 and L5-S1. The displacement rarely progresses to more than 30% of the vertebral body width.

The view that fusion should be an adjunct after decompression for degenerative spondylolisthesis appears to be approaching consensus. Several prospective randomized studies have now demonstrated significantly better results in patients undergoing concomitant arthrodesis.¹⁷⁻²⁰

Herkowitz and Kurz¹⁸ published a prospective study that compared decompressive laminectomy alone and decompressive laminectomy

with intertransverse arthrodesis in 50 patients with single-level spinal stenosis associated with degenerative spondylolisthesis. Patients who underwent simultaneous arthrodesis were statistically significantly better with respect to relief of pain in the back and lower limbs, as evidenced by the fact that 96% had "satisfactory" results, compared with 44% of the patients who did not undergo fusion ($P = 0.0001$). Progression of the slip occurred in 28% of the group who underwent fusion, compared with 96% of the patients who underwent only decompression. Poor results in the latter group of patients were associated with a significant postoperative increase in vertebral motion at the operative level and progression of the listhesis.

Several articles published since that study have supported the addition of arthrodesis when the stenotic segment is associated with a degenerative spondylolisthesis.^{17,19,20} Patients who undergo decompression

without arthrodesis have a 10% to 65% chance of further progression of the slip.

In addition, increased bone regrowth at the site of decompression has a greater chance of occurring when decompression is performed without arthrodesis.^{16,19} The issue of increased bone regrowth causing recurrent stenosis was looked at in a retrospective review of the data on 40 patients (average follow-up, 8.6 years).¹⁹ Patients who underwent decompression without arthrodesis had more bone regrowth and significantly poorer clinical outcome than patients who also underwent arthrodesis.

Bolesta and Bohlman²⁰ compared the results of decompression alone with those of decompression and fusion in the treatment of degenerative spondylolisthesis with spinal stenosis. The 18 patients who underwent decompression and fusion had less back and leg pain, less postoper-

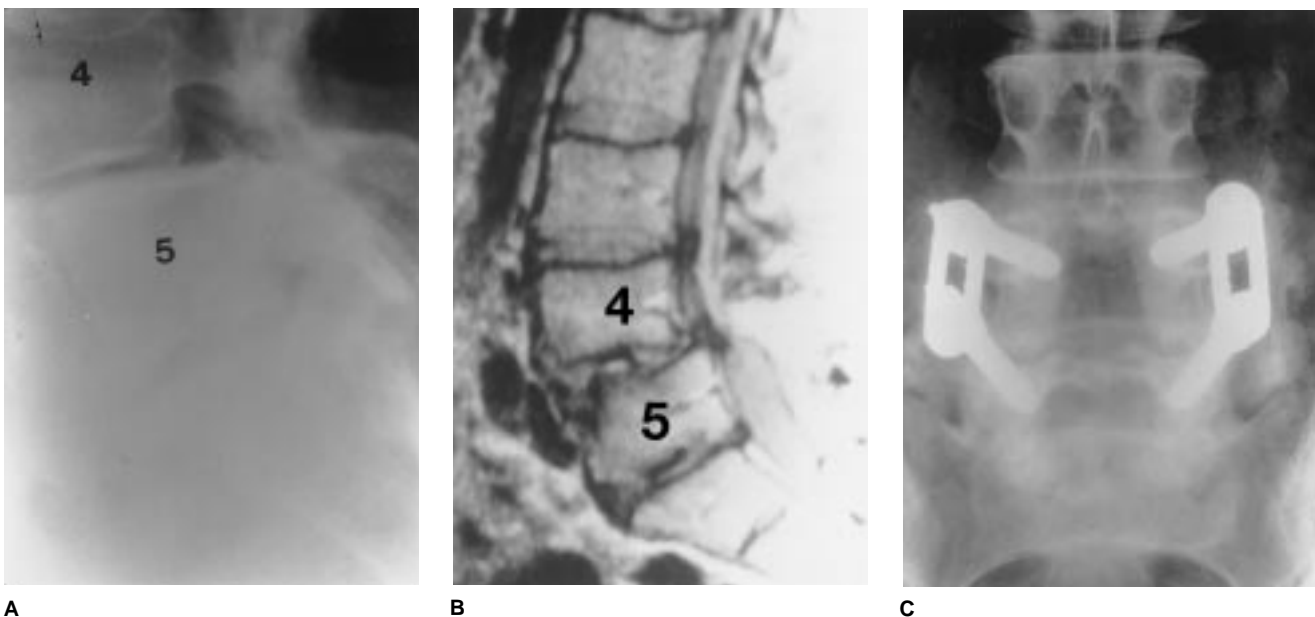


Fig. 2 Images of a patient with grade 2 degenerative spondylolisthesis at L4-5. **A**, Lateral lumbar radiograph. **B**, Sagittal MR image demonstrates stenosis at L4-5 due to the spondylolisthesis. **C**, Postoperative AP lumbar radiograph depicts the midline L4-5 decompression and the solid arthrodesis at L4-5 with instrumentation.

ative slippage, and significantly better clinical results than the 24 patients who underwent decompression alone. Not only does arthrodesis prevent progression of spondylolisthesis, it also confers stability to the decompressed segment, which by itself may prevent the recurrence of back and leg pain.

Meta-analysis of the literature by Mardjetko et al¹⁷ revealed a satisfactory outcome in 69% of patients with degenerative spondylolisthesis who underwent decompression without fusion, compared with 90% in patients who underwent a concomitant arthrodesis. This difference was statistically significant ($P<0.0001$).

In summary, the literature lends strong support to the addition of a posterolateral arthrodesis to decompressive lumbar surgery in patients who have stenosis as well as preexisting degenerative spondylolisthesis or isthmic spondylolisthesis (Fig. 3).

The indications for fusion in the presence of degenerative or isthmic spondylolisthesis without stenosis or symptoms of neurogenic claudication are not as definite. Relative indications for arthrodesis include pain unresponsive to nonoperative measures and progression of the slip. Before surgical treatment of this condition, it is imperative that the clinical, radiologic, and psychological studies indicate as accurately as possible the site of the spondylolisthesis that is causing the back pain.

Degenerative Scoliosis

Degenerative scoliosis typically occurs after age 60 and is secondary to disk degeneration and loss of facet-joint stability. The magnitude of the degenerative lumbar curve is usually less than 40 degrees. A coexisting lateral listhesis may be present near the apex (Fig. 4). Symptoms are usually caused by spinal stenosis

associated with compression of the nerve roots in the concavity of the curve or traction on the nerve roots in the convexity of the curve.

In the absence of curve progression or symptoms of spinal stenosis, fusion for back pain alone is rarely indicated in the elderly population. Over 80% of these patients will respond favorably to nonoperative measures. The morbidity associated with a long-segment lumbar fusion with or without instrumentation is significant and must be balanced against a 50% to 75% chance of improvement in their back pain.

Relative indications include curve progression and sagittal and/or coronal imbalance with unremitting back pain. Osteopenia presents unique problems when spinal instrumentation is being considered. As mentioned earlier, *de novo* degenerative curves rarely progress more than 40 degrees.

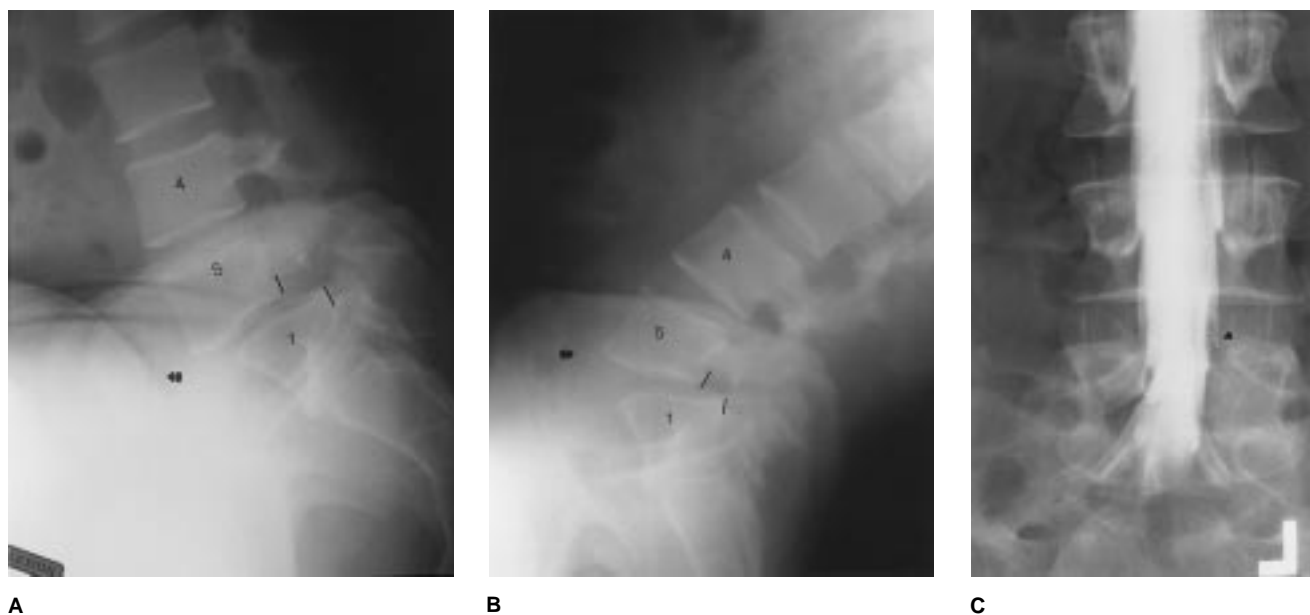


Fig. 3 Images of a patient with L5-S1 spondylolisthesis. Lateral lumbar radiographs depict isthmic spondylolisthesis with dynamic translation of L5 on S1 with flexion (A) and extension (B) (arrows indicate direction of movement; bars indicate limits of translation on flexion/extension). C, AP lumbar myelogram depicts the cutoff of the left L5 root (arrowhead), which correlates with the patient's symptoms of left leg radiculopathy.



Fig. 4 AP lumbar radiograph depicts degenerative lumbar scoliosis with an associated lateral listhesis of L1 on L2. Arrows indicate direction of bending on this side-bending film; bars indicate extent of lateral listhesis (12 mm).

With progressive disk degeneration and osteophyte formation, there is a decrease in curve flexibility that leads to stiffening of the spine. This may decrease the likelihood of significant curve progression.

The role of arthrodesis after decompression of a stenotic segment in patients with coexisting idiopathic or degenerative scoliosis is controversial. Clearly, not all patients in this category who undergo decompression need a concomitant fusion. The following six factors need to be considered in deciding who should undergo simultaneous fusion¹⁶:

Curve Flexibility

If more than 50% curve correction (as measured on supine forced side-bending films) has been achieved, a decompressive laminectomy alone may increase the risk of curve progression.

Curve Progression

A documented preoperative history of curve progression carries with it an increased likelihood of continued or accelerated progression after decompression.

Radiculopathy

If the patient has scoliosis with predominant radiculopathy within the concavity of the curve, a decompressive laminectomy with partial facetectomy may not be sufficient to decompress the nerve root in the concavity. This is because the nerve root may be compressed between the adjacent pedicles. The use of instrumentation with distraction of the adjacent pedicles on the concavity and neutralization or compression along the convexity may be necessary to reduce pedicular kinking and unload the compression on the nerve root.

Loss of Lumbar Lordosis

Loss of lumbar lordosis places the patient in sagittal imbalance. The presence of sagittal alignment can be confirmed on a standing lateral radiograph that includes the entire spine. On such a radiograph, a plumb line drawn inferiorly from the odontoid should normally pass through the posterior half of the L5 vertebral body. Most patients with sagittal imbalance will have loss of lumbar lordosis ("flat-back" deformity), such that the plumb line will lie anterior to L5. A flat-back deformity or relative lumbar kyphosis by itself may cause increasing back pain and can lead to impaired ability to stand upright. Therefore, improving the sagittal alignment through segmental instrumentation and fusion with or without osteotomy should be considered at the time of decompressive surgery. Coronal-plane imbalance must also be considered but is less common in degenerative scoliosis.

Fixed Lateral Listhesis

Fixed lateral listhesis within the degenerative curve by itself may represent a static degenerative process. However, if motion of the hypermobile segment is demonstrated on side-bending films, then instability is suggested. Because decompression of this segment may result in further decompensation of the curve and increased lateral listhesis, a concomitant arthrodesis should be considered. The addition of instrumentation with arthrodesis may facilitate curve correction and may lower the pseudarthrosis rate. In most cases, posterior segmental fixation is adequate (Fig. 5). Long fusions to the sacrum with distal sacral or pelvic fixation alone have a high failure rate and may necessitate anterior fusion in some cases.

Extent of Intraoperative Decompression

As mentioned earlier, a radical discectomy or excessive resection of the facet joints or the pars interarticularis may result in iatrogenic instability at the operated segment. Therefore, that segment should be fused.

The magnitude of the curve by itself is not an indication for arthrodesis. If none of the six factors is present, decompression alone is sufficient. When fusion is indicated, it is not necessary to fuse the entire length of the degenerative curve. The curve will often ascend into the lower portion of the thoracic spine and down to the sacrum. Such long fusions are unnecessary in elderly patients and may, in fact, contribute to significant morbidity. The fusion should end at a disk space that appears to be horizontal with neutral rotation. It should restore the sagittal alignment and include the decompressed spinal segments.

Simmons and Simmons²¹ reported their findings in a retrospec-

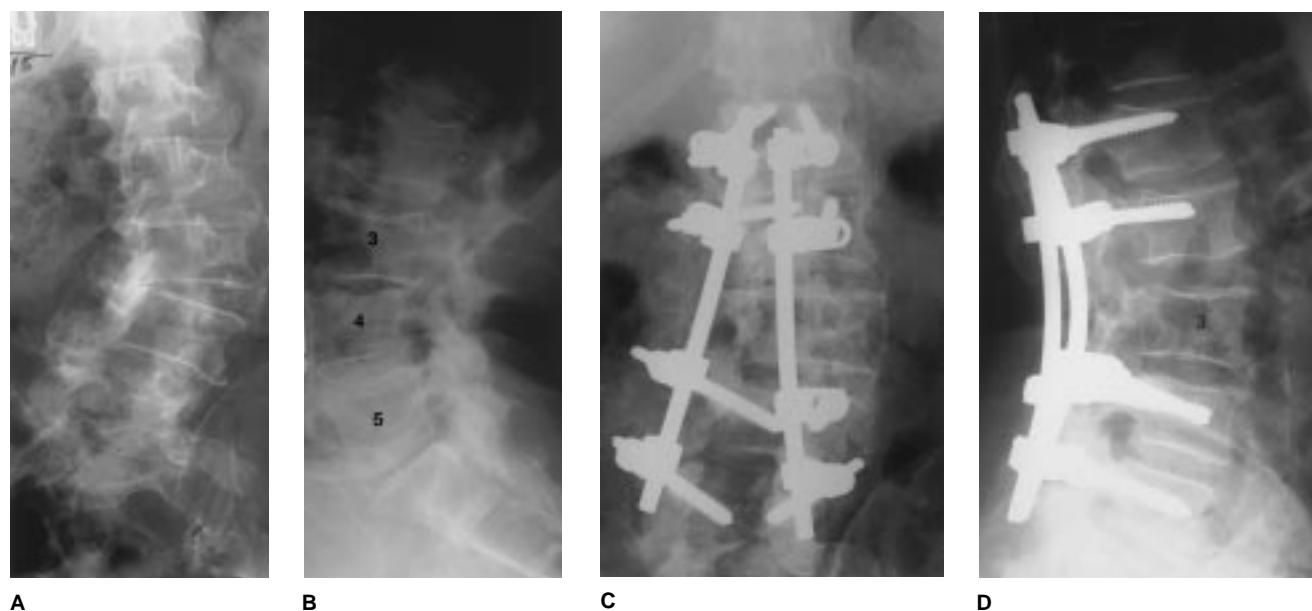


Fig. 5 A, AP radiograph depicts degenerative lumbar scoliosis. B, Lateral radiograph of the degenerative lumbar curve. C, Postoperative AP radiograph shows the midline decompression and arthrodesis of the lumbar scoliosis with instrumentation. D, Postoperative lateral radiograph depicts the pedicle-screw instrumentation from L1 to L5. The sagittal contour of the lumbar spine is well maintained.

tive series of 40 patients with degenerative lumbar scoliosis and stenosis treated with decompression and fusion. Segmental pedicle-screw fixation was used as an adjunct in all patients, 88% of whom had significant back pain in addition to symptoms of neurogenic claudication. At follow-up, which averaged 3.5 years, 93% of the patients had mild or no pain. There were no serious complications, pseudarthroses, or instrumentation failures. The mean curve correction was 50%. "Indirect" decompression was achieved by means of segmental adjustments at the involved levels. Similar results were reported by Marchesi and Aebi²² in 27 patients treated for adult lumbar scoliosis with the use of pedicle screws.

Recurrent Spinal Stenosis at the Same Segment

Patients who require a second decompressive laminectomy at the same segment should be considered

for a concomitant fusion. Repeat decompression usually necessitates a more extensive facetectomy, accompanied by additional bone removal, to facilitate adequate decompression of the lateral recesses. Sacrificing more than 50% of each facet joint may render that motion segment unstable. Similarly, iatrogenic spondylolisthesis in combination with recurrent stenosis is an indication for fusion because additional instability will be created with the second decompression. If translational instability is present on preoperative flexion/extension lateral radiographs, a concomitant arthrodesis is recommended.

Patients in whom stenosis develops proximal to a previous posterior fusion require only decompression unless excessive resection of the facet joints occurs at the time of surgery. The most common pattern is L3-4 stenosis proximal to a previous L4-S1 posterior fusion.

Degenerative Disk Disease

The use of spinal arthrodesis to treat chronic back pain associated with disk degeneration alone is controversial. It may be indicated only rarely, in patients with normal psychological profiles who do not have multilevel disk degeneration and for whom long-term conservative treatment has failed. Provocative testing (diskography) may have a role in appropriate patient selection. However, the value of diskography as a diagnostic modality on which surgical decisions should be based remains controversial. No prospective randomized trials have shown arthrodesis to be superior to nonoperative therapy for the treatment of chronic lower back pain associated with multilevel disk degeneration.

Chronic back pain associated with degenerative disk disease is one of the most common diagnoses in lumbar degenerative disorders. Every year, thousands of patients undergo fusion for this "disease."

However, the pathophysiologic mechanisms by which disk degeneration causes back pain remain unknown or are controversial at best. The diagnostic modality of choice for disk degeneration is MR imaging. On T2-weighted images, a normal hydrated disk should appear white. Because a dehydrated or degenerated disk appears dark on T2-weighted images (Fig. 6), the term "black-disk disease" has become popular. However, cadaver studies and MR imaging studies of asymptomatic persons have shown that disk degeneration or dehydration represents a normal physiologic process of aging, rather than a disease. If disk degeneration were a disease, then one would have to assume that everyone would get it with age, but the condition is most often asymptomatic. Thus, the disease process, if there is one, is poorly defined.

This, however, is not to imply that disk degeneration is always a benign

process. That would be akin to saying that since hip degeneration is a physiologic process, it should always be treated conservatively. Arthrodesis across a degenerated segment by posterolateral fusion is postulated to be therapeutic because it limits motion across that segment. This assumes that the disk is sensitive to painful stimuli and that a solid fusion decreases the input to pain-receptive structures. Proponents of anterior or posterior interbody fusion believe the disk itself to be the cause of pain and therefore attempt a cure by complete discectomy and arthrodesis involving the anterior column.

The difficulty lies in determining whether a degenerated disk is the true source of back pain. Is the back pain from the disk itself or is it related to the facets? Does degeneration of adjacent segments cause referred pain in other areas of the back? Which disk is the source of pain when there is multilevel disk

degeneration, as visualized on MR imaging? Despite several unanswered questions, surgical treatment remains prevalent because it is thought that there is a high rate of failure following conservative treatment for chronic lower back pain. There are, however, no studies to confirm this belief.

Poor patient selection is the most common cause of failure in lumbar spine surgery. Psychological testing and consultation with a neuropsychologist or psychiatrist should be considered in patients in whom hysteria, depression, psychosis, or hypochondriasis is suspected. The ability of a psychological test to predict successful surgical outcome remains controversial. Workmen's compensation and secondary gain issues must also be considered prior to surgical treatment.

A thorough analysis of the pros and cons of diskography and the indications for spinal arthrodesis as treatment of diskogenic back pain is

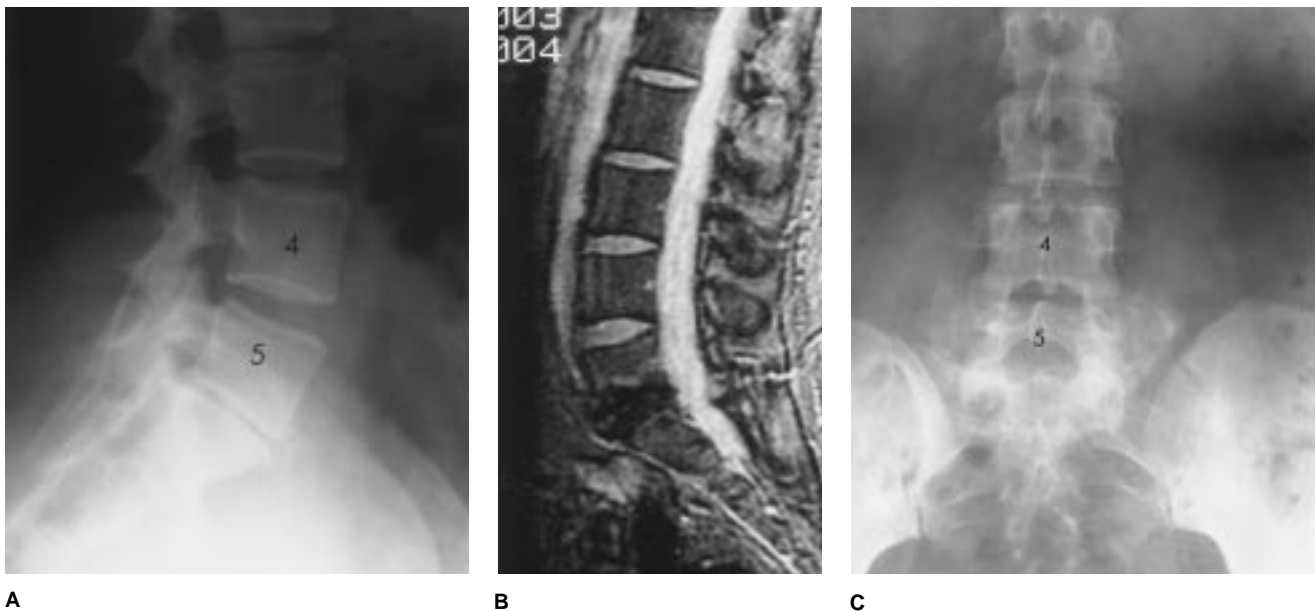


Fig. 6 Images of a patient with disk degeneration. **A**, Lateral lumbar radiograph depicts the loss of disk height at the L5-S1 interspace. **B**, Sagittal MR image depicts a "black disk" at L5-S1. **C**, Postoperative AP lumbar radiograph shows a solid arthrodesis at L5-S1.

beyond the scope of this article. In brief, the indications for spinal arthrodesis for treatment of diskogenic back pain are very limited. The following surgical indications should be considered²³: (1) unremitting pain and disability for more than 1 year; (2) failure of a trial of aggressive physical conditioning and conservative treatment lasting more than 4 months; (3) MR imaging findings consistent with advanced disk degeneration, preferably at a single level; and (4) normal findings from a psychiatric evaluation.

The reported success rates of arthrodesis for "diskogenic pain" range from 50% to 80% in properly selected patients. However, patient selection and a thorough preoperative discussion of expectations significantly influence the outcome of surgical treatment. Randomized prospective studies are needed to evaluate the role of spinal fusion in the treatment of diskogenic pain.

Techniques of Lumbar Fusion

The usual techniques fall into four categories: (1) posterolateral intertransverse-process fusion, (2) posterior lumbar interbody fusion (PLIF), (3) anterior lumbar interbody fusion, and (4) combined anterior-posterior (global, or 360-degree) fusion.

Posterolateral Intertransverse-Process Fusion

Bilateral posterolateral intertransverse-process fusion of the spine is the most frequently employed technique of arthrodesis in the lumbar spine. The major advantages of this technique include (1) the high probability of obtaining a solid fusion; (2) the ability to perform fusion in the absence of posterior elements (facets and laminae); (3) prevention of iatrogenic spinal stenosis by avoiding placement of bone graft along the

midline; and (4) low risk of injury to neural elements.

The pseudarthrosis rate after posterolateral fusion is reported to range from 5% to 25%.²⁴ For a single-level primary fusion, a 5% to 10% pseudarthrosis rate is usual. The rate of pseudarthrosis increases with the number of levels being fused and also with revision surgery. There appears to be some evidence in the recent literature that spinal instrumentation may lower the rate of pseudarthrosis.²⁵ Instrumentation may help restore the sagittal contour in a patient with flat-back deformity after a previous failed lumbar surgery (Fig. 7).

Posterior Lumbar Interbody Fusion

Posterior lumbar interbody fusion was introduced by Cloward in 1945. The technique involves a wide posterior decompression and complete disk excision by retraction of the dural sleeve and nerve roots. Bone graft is placed anteriorly between the vertebral bodies. The pseudarthrosis rate is reported to range from 6% to 27%.²⁴ Since the original description, several modifications of the original technique have been described.

The proponents of PLIF suggest the following advantages of the technique: (1) Total disk excision is possible, which they believe is important in patients with "diskogenic pain." (2) Disk height can be restored with an anterior bone graft. (3) There is a biomechanical advantage in having the site of arthrodesis under compression along the anterior column. (4) Nerve-root decompression is achieved. (5) Spinal alignment is restored, which is particularly important in patients with spondylolisthesis.

Disadvantages of PLIF include the following: (1) A wide posterior decompression is necessary. (2) There is a risk of canal compromise

from posterior extrusion of the graft. (3) There is a risk of injury to nerve roots and postoperative epidural fibrosis due to wide decompression and significant retraction of the neural elements during the procedure. (4) Destabilization of the anterior column (radical discectomy) and posterior column (radical decompression) can occur. (5) The pseudarthrosis rate is similar to that for other fusion techniques. It is postulated that the addition of posterior instrumentation reduces the rate of graft dislodgment and pseudarthrosis with PLIF.

We believe that this technique has a limited role, if any, in primary lumbar fusions. It does not offer a lower rate of pseudarthrosis or lesser complications compared with standard posterolateral intertransverse-process fusion. It may have a limited role in revision surgery, where standard intertransverse-process fusion is associated with a higher pseudarthrosis rate. In this situation, PLIF may facilitate a combined anterior-posterior fusion through a single approach. It may, with the addition of instrumentation, lower the pseudarthrosis rate in revision surgery.

Anterior Lumbar Interbody Fusion

This technique involves an anterior approach to the lumbar spine with complete excision of the disk and insertion of bone graft between the decorticated endplates of the contiguous vertebral bodies. The approach is usually retroperitoneal for access to the lumbar vertebrae and transperitoneal for the L5-S1 interspace.

This technique is often used in patients who have had multiple failed surgical procedures posteriorly, prior posterior infection, or rigid lumbar scoliosis. The majority of the studies report pseudarthrosis rates ranging from 20% to 30%.²⁴

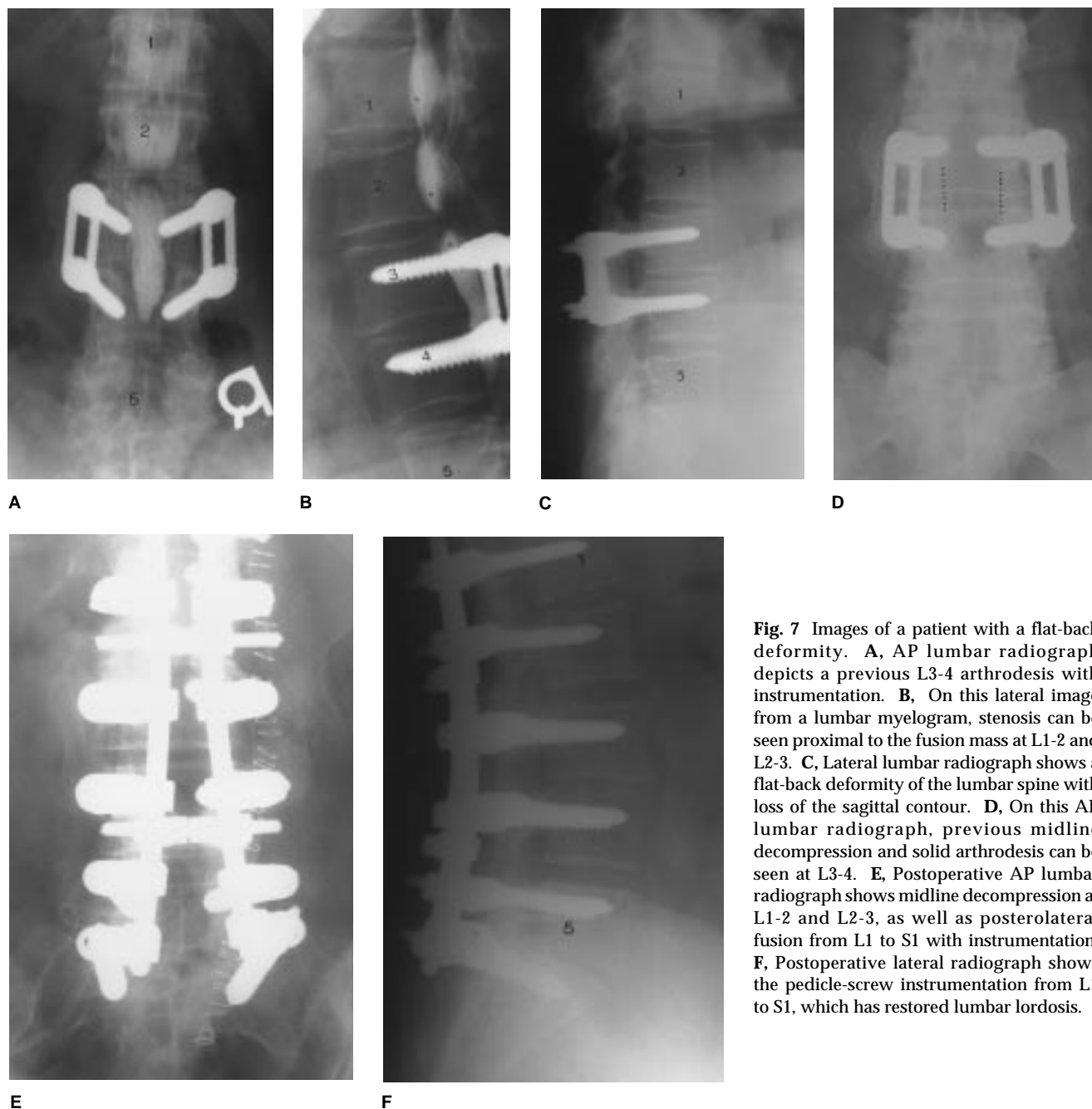


Fig. 7 Images of a patient with a flat-back deformity. **A**, AP lumbar radiograph depicts a previous L3-4 arthrodesis with instrumentation. **B**, On this lateral image from a lumbar myelogram, stenosis can be seen proximal to the fusion mass at L1-2 and L2-3. **C**, Lateral lumbar radiograph shows a flat-back deformity of the lumbar spine with loss of the sagittal contour. **D**, On this AP lumbar radiograph, previous midline decompression and solid arthrodesis can be seen at L3-4. **E**, Postoperative AP lumbar radiograph shows midline decompression at L1-2 and L2-3, as well as posterolateral fusion from L1 to S1 with instrumentation. **F**, Postoperative lateral radiograph shows the pedicle-screw instrumentation from L1 to S1, which has restored lumbar lordosis.

The accepted fusion rates for one- and two-level anterior interbody fusion are 85% and 70%, respectively.²⁴

Proponents of this technique have advocated its use as primary treatment of "diskogenic pain." If the

disk itself is believed to be the primary source of the pain, a posterolateral fusion without disk excision may not relieve the symptoms. In addition, some motion may persist anteriorly along the disk space despite a solid posterior fusion.

Prospective studies comparing anterior interbody fusion and posterolateral fusion are necessary before this technique can be advocated as a procedure of choice in this setting.

We believe that for degenerative conditions of the lumbar spine, ante-

rior interbody fusion is useful as a salvage procedure only. In revision surgery there may be extensive scar formation posteriorly, along with extensive loss of bone elements (transverse processes and/or facets), which would make standard posterolateral intertransverse-process fusion techniques inadequate. In such a situation, anterior interbody fusion may provide a virgin site for spinal arthrodesis, with the advantage that the bone graft is placed under compressive axial loads along the anterior column, which may help lower the pseudarthrosis rate in revision surgery.

Combined Anterior-Posterior (Global) Fusion

This technique combines the two approaches of anterior interbody fusion and posterolateral intertransverse-process fusion. Proponents of global fusion report a high fusion rate (greater than 90%) for one- or two-level fusions. Retrospective studies report clinical success rates in treating diskogenic pain in the range of 75% to 85%.

A lower pseudarthrosis rate should be expected with global fusions than with other techniques. However, a successful fusion does not always correlate with excellent clinical results, nor does the literature support performing global

fusion for diskogenic back pain when there is multilevel disk degeneration. With nonradicular back pain and multilevel disk degeneration, the efficacy of fusion itself is in question, regardless of the technique employed. Therefore, in primary operations, combined anterior-posterior fusion for degenerative disorders of the lumbar spine is rarely indicated. The added morbidity of combining the two approaches is not justified when compared with the morbidity associated with standard posterolateral fusion techniques.

Global fusions should be reserved for the following situations: (1) rigid scoliosis for which significant correction is desired, (2) flat-back deformity or significant coronal imbalance that cannot be corrected with posterior procedures alone, (3) long fusions to the sacrum, or (4) multiple failures of previous surgical procedures. In the last two situations, global fusions may decrease the pseudarthrosis rate.

Summary

The role of lumbar fusion for treatment of degenerative disorders of the lumbar spine is controversial. Lumbar fusion with or without instrumentation is associated with complications, especially in elderly

patients. These complications may be related to instrumentation, bone-graft harvest site, and longer operative times. Therefore, the benefits to be obtained with arthrodesis must outweigh the risks.

The literature strongly supports arthrodesis for patients undergoing decompression for spinal stenosis associated with degenerative or iatrogenic spondylolisthesis or progressive degenerative scoliosis. Patients who undergo extensive decompression intraoperatively (with an increased risk of later instability) should undergo concomitant arthrodesis. The occurrence of two or more episodes of disk herniation at the same segment is a relative indication for arthrodesis. In patients with incapacitating nonradicular back pain, arthrodesis should be a consideration only after failure of a trial of conservative treatment lasting more than 12 months and after secondary gain issues (e.g., workmen's compensation) have been adequately resolved. Arthrodesis has a poor success rate when used to treat diskogenic back pain with multilevel disk degeneration (as visualized with MR imaging).

The role of lumbar fusion and/or instrumentation will ultimately be decided on the basis of prospective randomized trials.

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