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Indications for fusion following decompression for lumbar spinal stenosis

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Degenerative lumbar spinal stenosis is a common condition affecting middle-aged and elderly people. Significant controversy exists concerning the appropriate indications for fusion following decompressive surgery. The purpose of this report is to compare the clinical outcomes of patients who were and were not treated with fusion following decompressive laminectomy for spinal stenosis and to identify whether fusion was beneficial. The authors conclude that patients in whom concomitant fusion procedures were performed fared better than patients who were treated by means of decompression alone when evidence of radiological instability existed preoperatively.

Key Words * lumbar spinal stenosis * laminectomy * fusion * indication

The decision to perform fusion following decompression for degenerative lumbar spinal stenosis has been studied by many authors.[14,16,30,52,69] Unfortunately, no clear consensus has been reached to determine which patients are most likely to benefit from a concomitant lumbar fusion. Patient satisfaction following lumbar decompression alone ranges from 59 to 96%, with early surgical failures resulting from inadequate decompression and preoperative lumbar instability.[2,4,8,12,21,22,26,29,31,34,65] Late recurrence of back or leg problems may also result from acquired spinal instability.

The goal of this study was to analyze clinical outcomes in patients treated with and without fusion following lumbar decompression to determine which patients benefited most. The ability to identify predictive factors for successful surgery with fusion would improve overall clinical results and decrease both early and late failures caused by persistent or acquired spinal instability.

CLINICAL MATERIAL AND METHODS

Between January 1, 1986, and June 30, 1988, 178 consecutive patients at the Mayo Clinic underwent decompressive lumbar laminectomy for degenerative lumbar stenosis and form the basis for this study. This retrospective work has been previously reported by Fox, et al.[16] One hundred twenty-four patients (70%) participated in this study, which required completion of a detailed questionnaire and standing anteroposterior, lateral, and flexion-extension lumbar spine radiographs.

All medical and surgical records including pre- and postoperative radiographs were reviewed. Questionnaires completed by patients compared their preoperative and postoperative symptoms, including their abilities to walk and perform common daily activities. In addition, the presence or absence of back and leg pain, numbness, and weakness before and after surgery were addressed. All radiographs were reviewed specifically for the preoperative presence or development of spondylolisthesis after surgical decompression. Patient-reported outcomes were then correlated with investigator-determined evidence for postoperative radiological spinal instability.

Patient Characteristics

There were 65 men and 59 women with an average age of 67.5 years (range 34-83 years). The mean follow-up period was 5.8 years (range 4.6-6.8 years). Preoperative back pain was present in 87% of patients whereas leg pain(s) was present in 94%. Pseudoclaudication was reported by 83% of patients.

Radiological Characteristics

Table 1 summarizes the preoperative level, direction, and magnitude of subluxation in the patients studied. Notably, 60 patients (48%) had anterior subluxation of 3 mm or more, 23 (19%) had retrospondylolisthesis, and 42 (34%) had some degree of lateral spondylolisthesis. Pre- and postoperative disc heights, lateral lumbar curvatures, facet angles, anterior osteophytes or traction spurs, and relative sagittal angulation measurements were also recorded.

TABLE 1 PREOPERATIVE LEVEL, DIRECTION, AND MAGNITUDE OF SUBLUXATION IN 124 PATIENTS WITH LUMBAR SPINAL STENOSIS					
Subluxation (mm)	No. of Affected Levels				
	L1-2	L2-3	L3-4	L4-5	L5-S1
anterior					
3-5	1	0	9	21	3
6-10	0	0	2	23	2
11-15	0	0	0	6	0
>16	0	0	0	1	1
posterior					
3-5	0	4	10	7	5
6-10	0	0	0	1	0
11-15	0	0	0	0	0
>16	0	0	0	0	0
lateral					
3-5	0	2	15	30	4
6-10	0	2	4	1	0
11-15	0	0	0	0	0
>16	0	0	0	0	0

All 124 patients underwent postmyelographic computerized tomography (CT) scanning and all had anteroposterior canal diameters measuring 12 mm or less. In addition, there were 14 patients with disc herniations located on the same side as their preoperative leg pain that were deemed significant enough to remove at surgery.

Surgical Characteristics

Ninety-two patients (74%) underwent lumbar decompression alone, and 32 patients (26%) underwent

concomitant posterolateral fusion. The fusions were performed with autogenous iliac crest bone graft alone (15 patients) or with the adjunctive use of Isola instrumentation (17 patients)(Acromed Corp., Cleveland, OH). Fusions were performed at one level in 18 patients, two levels in seven patients, and three levels in six patients; one four-level fusion was performed. The most common level fused was L4-5 in 29 of 32 patients, followed by L5-S1 in 14 patients, L3-4 in seven patients, and L2-3 in two patients. All patients wore a custom-fitted lumbosacral spinal orthosis for 3 months following surgery.

The decision to fuse was based on several factors. The most common reason was significant preoperative low-back pain associated with preoperative spondylolisthesis and dynamic instability observed on flexion-extension radiographs in 18 patients. Fusion was performed in an additional 10 patients who required an extensive decompression across a minimally degenerated L4-5 disc space. Following aggressive canal decompression via bilateral inferior facetectomies, medial superior facetectomies, and bilateral foraminotomies, the spines in four patients were intraoperatively determined to be unstable and underwent concomitant fusions.

RESULTS

Patient-Reported Outcomes

Fifty-eight (47%) of 124 patients reported no back pain at follow up, whereas 46 patients (37%) were improved. Only seven patients (6%) reported worsened back pain. Seventy-five patients (60%) reported no leg pain and 26 (21%) reported improved leg pain, whereas six (5%) reported worse pain. Eighty-eight (71%) reported improved walking ability, whereas 107 (86%) claimed little or no need for help with their usual activities of daily living.

Overall Outcome in Patients With and Without Fusion

There was a reduced incidence of poor outcomes among those patients who underwent fusion. Ninety-one percent of those who underwent concomitant fusion procedures had good or fair outcomes compared with only 75% of those who underwent decompression alone. Table 2 summarizes patient-reported outcomes based on preoperative anterior subluxation, whether fusion was performed and what type, and whether postoperative progression of anterior subluxation had occurred.

TABLE 2 SUMMARY OF PATIENT-REPORTED OUTCOMES FOLLOWING DECOMPRESSION FOR LUMBAR SPINAL STENOSIS*					
Occurrence of Preop Slip (n.o. of patients)	Type of Fusion (n.o. of patients)	Postop Slip (n.o. of patients)	Outcome		
			Good	Fair	Poor
no preop slip (64)	none (62)	increased (20)	7	8	5
		no change (42)	22	5	15
	lat mass only (1)	increased (0)	0	0	0
		no change (1)	1	0	0
	Steffée plate (1)	increased (0)	0	0	0
		no change (1)	0	1	0
preop slip (60)	none (30)	increased (22)	12	7	3
		no change (8)	3	4	1
	lat mass only (15)	increased (8)	3	5	0
		no change (7)	4	2	1
	Steffée plate (15)	increased (2)	1	0	1
		no change (13)	7	6	0
* See Results section for description of outcomes.					

Patient outcome was graded as good if patients had no back or leg pain, unlimited walking ability, and the ability to perform daily activities unassisted; fair, if outcome improved back and/or leg pain but with some modification of performance of daily activities; and poor, if outcome was no improvement or worsening of preoperative symptoms, increased difficulty in walking and ability to perform daily activities, or continued, severe postoperative back pain. In this study, when all patients were considered postoperatively, 60 patients (48%) achieved good results, 38 patients (31%) experienced fair results, and 26 patients (21%) had poor results.

Comparison of the 26 poor-outcome patients with the other 98 good- and fair-outcome patients revealed no significant differences with respect to age, weight, height, preoperative back or leg symptoms, preoperative bladder or bowel function, preoperative walking ability, or performance of daily activities. The 26 patients with a poor outcome were slightly more likely to be male (16 men vs. 10 women) and to have preoperative retrospondylolisthesis (27% of those with preoperative retrospondylolisthesis experienced poor outcomes compared with only 2% of those without).

Incidence of Postoperative Subluxation

Anterior Subluxation. Anterior spondylolisthesis was present at 69 levels in 60 patients prior to surgery (Table 1). Progressive postoperative subluxation occurred in 32 of these patients. The mean vertebral slippage was 5.1 mm (range 2-13 mm). Twenty of 64 patients without preoperative anterior subluxation developed anterior slippage postoperatively (mean 7.8 mm, range 2-20 mm). For those with preoperative slippage, the incidence of further postoperative subluxation was one of one at L1-2, 10 of 11 at L3-4, 40 of 51 at L4-5, and one of six at L5-S1. Table 3 correlates the magnitude of preoperative anterior spondylolisthesis with the incidence of postoperative progression at L4-5, the most common site for progressive subluxation.

TABLE 3 MAGNITUDE OF PREOPERATIVE ANTERIOR SUBLUXATION AND THE INCIDENCE OF POSTOPERATIVE SPONDYLOLISTHESIS		
Preop Degree of L4-5 Slip (mm)	Postop Slip	
	W/O Fusion (%)	Fusion (%)
0-2 (73 patients)	14 of 71 (19.7)	0 of 2 (0)
3-5 (21 patients)	10 of 16 (62.5)	2 of 5 (40)
6-10 (23 patients)	4 of 6 (66.7)	7 of 17 (41.2)
11-15 (6 patients)	2 of 2 (100)	1 of 4 (25)
>16 (1 patient)	0	0 of 1 (0)
total	30 of 95 (31.6)	10 of 29 (34.5)

Posterior Subluxation. Table 1 summarizes the incidence and level of preoperative posterior spondylolisthesis. It was most common at the L3-4 and L4-5 levels (10 and eight patients each, respectively) and less common at the L2-3 and L5-S1 levels (four and five patients each, respectively). The incidence of progressive postoperative posterior subluxation was one of four at L2-3, three of 10 at L3-4, zero of eight at L45, and one of five at L5-S1. None of these patients underwent fusion. Of patients without preoperative retrospondylolisthesis, none developed it following decompressive surgery.

Lateral Subluxation. Seven (9%) of 82 patients without preoperative side-to-side or lateral subluxation developed lateral slippage following decompressive surgery, whereas six (14%) of 42 patients with

preoperative lateral slippage progressed at eight levels. The most common sites were the L4-5 and L3-4 (four and three patients, respectively), although the degree of preoperative slippage did not correlate with the risk for progression.

Lateral Lumbar Curvature and the Incidence of Progressive Anterior Subluxation

As the degree of preoperative lateral lumbar curvature increased, so did the patients risk for progression following decompression. However, only at lumbar curvatures greater than 21° did this become significant. The risk for postoperative anterior spondylolisthesis was less for those patients with preoperative lateral lumbar curvature than for those with normal curvatures.

Preoperative Disc Height and the Incidence of Progressive Anterior Subluxation

Data collected suggest that a normal or near-normal disc height at L-4 may predispose to an increased risk for postoperative subluxation when decompression spans this disc space. Conversely, a markedly narrowed disc height at L-3 predisposed to an increased incidence for subluxation at L3-4 following decompression across the L-3 disc space.

Preoperative Facet Angles and the Incidence of Progressive Anterior Subluxation

Facet angles were measured at L3-4 and L4-5 where postoperative subluxation most commonly occurred. Only the 23 patients who underwent laminectomy alone without violation of the facet joints and did not undergo fusion were analyzed. A review of facet angles for those in whom there was no slippage postoperatively at L3-4 revealed no significant difference in facet angle when compared with those who did. However, at L4-5, those in whom slippage occurred had a mean preoperative facet angle of 65.8° (nine patients), compared with a mean facet angle of 50.4° (14 patients) for those in whom there was no slippage at L4-5 postoperatively. These data suggest that more sagittally oriented facet joints at L4-5 may predispose to postoperative subluxation following decompression.

Radiological Comparison of Good-to-Fair Outcomes With Poor Outcomes

Comparison of preoperative radiographic imaging revealed no differences between these groups with respect to disc heights, facet angles, or scoliosis. The number of levels decompressed and the extent of bone removal did not influence outcome. Notably, the presence of preoperative anterior spondylolisthesis or lateral vertebral slippage did not influence outcome. Furthermore, increased postoperative anterior subluxation did not influence outcome: 45% of patients with good or fair outcomes had increased postoperative subluxation compared with 35% of those experiencing a poor outcome.

Current radiographic analysis of the 26 poor-outcome patients included standing flexion-extension lumbar radiographs and either CT myelography or magnetic resonance imaging. Seventeen patients had no change in their preoperative alignment. Two patients with fusions had pseudarthroses, and of the 15 without fusion, one patient was found to have had an inadequate surgical decompression, and arachnoiditis was found in two patients. Nine patients, one of whom underwent fusion, had increased postoperative subluxation.

Number of Levels Decompressed and Progressive Anterior Slippage

Patients undergoing a one-level decompression had a 13% chance of progressive anterior subluxation following surgery. This compares to a fourfold increase in patients undergoing a two- or three-level decompression (53% and 59%, respectively). There were too few patients to evaluate four- and five-level

decompressions.

Extent of Decompression and Progressive Anterior Subluxation

The extent of bone decompression determined the incidence of postoperative progression of anterior spondylolisthesis. Patients with no preoperative slippage underwent more extensive bone decompression and had a higher incidence of postoperative progressive subluxation. Patients with preoperative slippage had a significantly greater chance of progressive subluxation when compared with those in whom there was no preoperative slippage. These findings are summarized in Table 4.

TABLE 4 EXTENT OF DECOMPRESSION CORRELATED WITH THE INCIDENCE OF PROGRESSIVE ANTERIOR SUBLUXATION FOLLOWING LUMBAR DECOMPRESSION FOR SPINAL STENOSIS (PATIENTS WITH FUSIONS EXCLUDED)				
	Type of Surgery			
	Lami- nectomy	Laminectomy Bilat Medial Facetectomy	Laminectomy Unilat Total Facetectomy	Laminectomy Bilat Total Facetectomy
no. of patients	23	49	16	4
w/ preop anterior slip	7	17	5	2
increased slip (%)	4 (57)	13 (76)	4 (80)	2 (100)
w/o preop anterior slip	16	32	11	2
increased slip (%)	4 (25)	10 (31)	4 (36)	1 (50)

DISCUSSION

Anatomical Basis for Instability

Adams and Hutton[1] performed laboratory studies in cadavers and found the percentage strength contribution by various structures within the lumbar spine in sagittal translation to be intact facet capsules (39%), intact disc and ligament (29%), supraspinous and interspinous ligaments (19%), and ligamentum flavum (13%). Cusick, et al.,[7] also demonstrated the importance of the posterior supporting structures. It is not surprising then that performing an extensive lumbar decompression results in a greater likelihood of anterior spondylolisthesis postoperatively. In the current study, 73% of patients with preoperative anterior spondylolisthesis experienced progressive subluxation following surgery. This compares with 31% of patients with slippage following surgery who did not have preexisting spondylolisthesis.

The degree of preoperative slippage did not correlate with the likelihood or the degree of postoperative progression. However, as seen in Table 4, the greater the disruption of normal anatomical structures, the greater the likelihood of progressive spondylolisthesis postoperatively. There were no data from our study to suggest that preoperative retrospondylolisthesis or lateral spondylolisthesis significantly contributed to radiologically confirmed progression of spondylolisthesis postoperatively or to a poor clinical outcome.

Results from biomechanical studies would also suggest that preservation of an intact lumbar disc and annular ligament would be important to help prevent spinal instability following surgery. However, our data suggested that disc excision at surgery does not routinely lead to subluxation. In fact, only three of 14 patients in whom discs were removed at surgery in addition to their decompressions experienced

progressive anterior spondylolisthesis following surgery. In these patients, relatively healthy discs at L-4 and L-5 were removed compared with the relatively degenerated discs in the other 11 patients. This would suggest that the intervertebral disc does become stiffer and more stabilizing as disc height narrows due to degeneration. Hopp and Tsou[32] found no incidence of progressive subluxation after lumbar decompression associated with discectomy, but this has been disputed by Tuite, et al.[64]

Other anatomical considerations that may lead to a more unstable lumbar spine following decompressive laminectomy include the presence of a minimally degenerated L-4 disc or a markedly narrowed L-3 disc, especially in the presence of minimal anterior column osteophytes.[17,32,34,42,45,60,68] Furthermore, sagittally oriented facet joints at L4-5[23,56] and lateral lumbar curvature[28,58,62] preoperatively were associated with a greater risk for postoperative radiographically confirmed instability.

A minimally degenerated L-4 disc increased the risk for postoperative subluxation. This confirms work reported by Lombardi, et al.,[45] suggesting that preserved disc space heights tended to lead to increased incidence of subluxation following decompressive surgery. Some authors have proposed that a narrowed, degenerative disc is more likely to lead to increased slippage postoperatively,[32,42,52] and this seemed to be true at the L-3 disc level. Severely degenerated and narrowed disc spaces are generally regarded as stabilizing and resist subluxation.[56] We did not find improved outcomes in patients with greater disc space narrowing following surgery as noted by Johnsson and colleagues.[35] Tuite, et al.,[63] suggested that an abnormal disc space angle may be a better radiological marker to predict outcomes than disc space heights.

Sagittally oriented facet joints at L4-5 (mean facet angle 65.8°) tended to allow greater slippage following decompression. Additionally, review of preoperative facet joint morphology suggested that patients with slippage following surgery had less coronally oriented facet joint surface ventrally, and this was likely to be removed at the time of medial facetectomy. This confirms works by Robertson, et al.,[56] and Grobler, et al.,[23] all of whom found that assessment of residual facet joint morphology following decompression may be more important in predicting slippage after surgery rather than the absolute amount of joint removed.

Other Factors Influencing Spinal Instability

A patient's gender may influence the likelihood of postoperative spinal instability.[28,34,56,61,64] Men were found to have a greater incidence of postoperative slippage if they had normal alignment preoperatively (male/female 1.6:1). Conversely, women were more likely to show radiological progression when preexisting spondylolisthesis was present (female/male 1.7:1).

Other factors not found to be associated with increased likelihood of postoperative spinal instability included age,[35,59,68] height, weight, retro- or lateral spondylolisthesis,[32,51] presence of anterior osteophytes,[46] or a low intercrestal line.[15] Relative sagittal angulation measurements were not found to be predictive for postoperative instability. Significant preoperative back pain and difficulty performing activities of daily living also did not correlate well with the development of postoperative spinal instability.[16,49,50]

Radiological Criteria for Spinal Instability

Controversy has always existed regarding the association of lumbar spondylolisthesis and low-back pain. Equally controversial is whether spondylolisthesis signifies an unstable spine condition and if flexion-extension radiographs truly detect instability.[9,10,18,53,54,66] The absolute determination of

spinal instability and secondary back pain may be made prior to an operation but they may also develop iatrogenically following an extensive lumbar decompression for stenosis. Therefore, the ability to detect spinal instability can be difficult before, during, and after surgery.

Knutsson[40] originally described degenerative discogenic pain and reported that narrowing of the intervertebral disc space, reactive changes in the adjacent vertebral bodies, vacuum disc phenomenon, spondylolisthesis (anterior or retrograde), and abnormal motion on flexion-extension radiographs of 3 mm or more were all indicative of lumbar instability. Traction spurs as described by Macnab[47] are also believed to be abnormal and suggest lumbar instability. Posner et al.,[55] and White and Panjabi[67] have developed a radiological checklist for the diagnosis of lumbar instability, but it does not correlate clinical symptoms.[28]

In general, the static presence of anterior spondylolisthesis greater than 3 to 4 mm or dynamic sagittal plane translation greater than 3 to 4 mm is suggestive of radiological lumbar instability.[18] It is not known whether retro- and lateral spondylolisthesis have equal connotations, or if the many other radiological signs described previously indicate an unstable spine condition. The presence of these radiological findings in association with a clinically symptomatic patient is the clearest indication of lumbar instability.[9,20,33,63]

An additional test not used in this study but which may prove helpful is lumbar discography. Discography determines the sensitivity of the disc to a mechanical or chemical stimulus and correlates sensitivity with images of internal anatomy to determine if the disc is the source of the patient's clinical pain. Nuclear degeneration likely results in progressive destruction of the nucleus pulposus. If this affects the innervated outer one-third of the disc space, or the annulus, then back and/or extremity pain may develop in the absence of nerve root irritation or radiculopathy.[6,24,48] In patients with spondylolisthesis, traction and additional stresses placed on the subluxated motion segment annular fibers are postulated to be a source of back pain.

If lumbar discography could indeed predict whether a disc was the source of a patient's pain, then fusion would be the gold standard of operation. The main problem, then, is what causes back pain in patients with lumbar stenosis. Generally these patients are older and have significant degenerative changes within both their discs and facet joints. Additionally, deconditioning from leg problems can lead to pain from injuries to the soft tissues of the back. To sort out these causes useful procedures include a careful history and physical examination, flexion-extension radiographs, and magnetic resonance imaging or CT scanning, followed by diagnostic discography or facet injections. Unfortunately, many patients have more than one source for their pain, making this process more difficult to interpret.[13,18,25,27,39,50]

Clinical Criteria for Lumbar Instability. Historically, recurrent, usually acute episodes of low-back pain produced by mechanical stresses of diminishing magnitude suggest clinical instability.[39] The supine position provides more relief than sitting. Patients with associated degenerative central or foraminal lumbar stenosis may also experience pseudoclaudication or leg pain with activity. Neurological examination is generally normal. Back pain is most likely due to disc degeneration, annular tears, and osteoarthritic changes within the facet joint as proposed by Kirkaldy-Willis and Farfan,[39] as well as others.[28,50] Postoperative low-back pain may persist or result from altered stresses on these same structures or may be due to a wide variety of psychosocial causes.[27] External bracing or immobilization has been used by some authors to determine the potential effects of fusion.[11,18,25]

In our study, 23 of 26 patients with poor outcomes had persistent complaints of low-back pain, which

could be related to radiological evidence of spinal instability in 11 patients. Other causes likely included degenerative disc disease, painful facet arthropathies, excessive stresses placed on remaining spine-supporting structures following decompression, or other anatomical or physiological factors. Interestingly, Rosenberg[57] noted that back symptoms presumed to be due to instability after decompression diminished with time. His patients generally were able to adapt functionally to their back symptoms, and later fusion was rarely necessary. Katz, et al.,[37] found that patients bothered predominantly by back pain preoperatively were significantly less satisfied with the results of surgery for degenerative lumbar stenosis.

In summary, the more extensive the decompression, the greater the likelihood for progressive spondylolisthesis, with greater than a twofold chance (73% vs. 31%) if spondylolisthesis exists preoperatively. Therefore, it seems intuitive then that the fewer normal anatomical structures violated, the less chance there is for postoperative instability. However, the primary goal for this surgery remains decompression of the neural elements. If destabilization is necessary to achieve this goal, then fusion may be required.

Benefits and Long-Term Complications of Fusions After Decompression for Degenerative Lumbar Spinal Stenosis

Benefits. Several authors have reported that patients with preoperative spondylolisthesis and stenosis who undergo decompression and fusion experience better outcomes than those in whom a decompression alone is performed.[14,16,30,36,42] Caputy and Luessenhop[4] predicted that 15% of patients would benefit from concomitant fusions following decompression based on a retrospective analysis of their surgical failures related to progressive radiologically demonstrated subluxation.

Long-Term Complications. The long-term effects on adjacent spinal levels are not well understood, but accelerated degeneration above and below areas of fusion are generally found.[19,41,44] Subsequent acquired spinal stenosis or recurrence of stenosis at previously operated levels could contribute to late failures following lumbar decompressive surgery.[3,4,61] New lumbar instability above or below a previous fusion would also account for late failures. Katz, et al.,[38] reported a 17% reoperation rate within 4 years for postoperative lumbar instability or stenosis following decompressive surgery. Caputy and Luessenhop[4] predicted that stenosis and spinal instability could affect as many as 50% of patients within 10 to 15 years postsurgery. In our current study, three (2%) of our 124 patients developed new symptomatic spinal stenosis at an adjacent unoperated level within 5 years of surgery, whereas no patient developed instability adjacent to a fusion, after an average follow-up period of 5.8 years. Lehmann, et al.,[44] reported that 45% of patients demonstrated segmental instability at an adjacent level following lumbar fusions without decompressions, after an average 33-year follow up. This was associated with significant stenosis in approximately one-third of cases.

Additional Surgery

We found seven patients who initially achieved good outcomes but developed recurrent symptoms between 2 and 4 years postoperatively due to progressive subluxation and spinal instability. This suggests that patients may initially adapt to decompression, but repeated stresses on remaining supporting structures and continued degenerative processes can cause destabilization of the spine with resultant pain or neurological symptoms.[5,38,43] Four of these patients underwent fusion procedures, with good or fair outcomes in three.

Of the 26 patients with poor outcomes after initial surgery, only three had additional surgery. One patient underwent further decompression, and two underwent fusion. All three experienced fair outcomes. Additional surgery was not performed in the remaining 23 patients, and therefore it is unknown whether a fusion procedure would benefit these patients.

CONCLUSIONS

Based on this retrospective review and a review of the literature, we have drawn the following conclusions.

- 1) Adequate neural decompression should be the primary goal of surgery for patients with degenerative lumbar stenosis. The extent of bone removal should be dictated by clinical and radiological findings.
- 2) Radiologically demonstrated instability, as judged by postoperative flexion-extension studies, shows a high incidence of progressive spondylolisthesis in all patients after surgery, but is greatest in those with preoperative spondylolisthesis. Notably, however, radiologically demonstrated progression does not necessarily correlate with a poor outcome, particularly in patients with preexisting spondylolisthesis.
- 3) Radiological factors predictive of progressive anterior spondylolisthesis include preoperative anterior spondylolisthesis, abnormal motion on dynamic radiographs, decompression across a minimally degenerated L-4 or markedly degenerated L-3 disc space, CT scans demonstrating sagittally oriented facet joints, or when a radical decompression greater than one level is performed. Patients with these preoperative findings or who are deemed to have an unstable spine following decompression should be considered candidates for fusion.
- 4) As a group, patients who underwent fusion procedures fared better when compared with those who did not. However, fusion procedures may not necessarily improve outcomes in patients without radiological and/or clinical evidence for spinal instability. Notably, the patients at greatest risk for a poor outcome were those without preoperative spondylolisthesis who did not undergo fusion or develop radiologically confirmed instability postoperatively. In general, all patients with preoperative anterior spondylolisthesis of 5 mm or more or with movement of 4 mm or more on flexion-extension radiographs are considered for fusion. These patients must have back pain and be younger than 70 years of age. Prospective, randomized, controlled trials will need to be performed to determine unequivocally the indications for lumbar fusion in patients undergoing decompression for stenosis.

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