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ADJACENT SEGMENT DEGENERATION IN THE LUMBAR SPINE

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Background: A primary concern after posterior lumbar spine arthrodesis is the potential for adjacent segment degeneration cephalad or caudad to the fusion segment. There is controversy regarding the subsequent degeneration of adjacent segments, and we are aware of no long-term studies that have analyzed both cephalad and caudad degeneration following posterior arthrodesis. A retrospective investigation was performed to determine the rates of degeneration and survival of the motion segments adjacent to the site of a posterior lumbar fusion.

Methods: Two hundred and fifteen patients who had undergone posterior lumbar arthrodesis were included in this study. The study group included 126 female patients and eighty-nine male patients. The average duration of follow-up was 6.7 years. Radiographs were analyzed with regard to arthritic degeneration at the adjacent levels both preoperatively and at the time of the last follow-up visit. Disc spaces were graded on a 4-point arthritic degeneration scale. Correlation analysis was used to determine the contribution of independent variables to the rate of degeneration. Survivorship analysis was performed to describe the degeneration of the adjacent motion segments.

Results: Fifty-nine (27.4%) of the 215 patients had evidence of degeneration at the adjacent levels and elected to have an additional decompression (fifteen patients) or arthrodesis (forty-four patients). Kaplan-Meier analysis predicted a disease-free survival rate of 83.5% (95% confidence interval, 77.5% to 89.5%) at five years and of 63.9% (95% confidence interval, 54.0% to 73.8%) at ten years after the index operation. Although there was a trend toward progression of the arthritic grade at the adjacent disc levels, there was no significant correlation, with the numbers available, between the preoperative arthritic grade and the need for additional surgery.

Conclusions: The rate of symptomatic degeneration at an adjacent segment warranting either decompression or arthrodesis was predicted to be 16.5% at five years and 36.1% at ten years. There appeared to be no correlation with the length of fusion or the preoperative arthritic degeneration of the adjacent segment.

Level of Evidence: Prognostic study, Level IV (case series). See Instructions to Authors for a complete description of levels of evidence.

The prevalence of lumbar arthrodesis has continued to increase because of the emergence of newer techniques of spinal instrumentation and improved imaging modalities that allow for accurate recognition of spinal abnormalities. The levels involved in the arthrodesis typically are degenerative or unstable, and the ultimate goals are to provide relief of symptoms and to restore stability. Retrospective studies on scoliosis as well as longitudinal studies on lumbar fusion have suggested that lower lumbar fusions predispose patients to problems in the adjacent motion segments[1-14]. Additionally, evidence of increased motion of cephalad adjacent segments and increased disc compression at adjacent motion segments has been well described in cadaveric studies[15-17].

Although adjacent segment degeneration in the lumbar and lumbosacral spine has been examined extensively in previous biomechanical and clinical studies, we are aware of no study that has specifically addressed the rate of degeneration of adjacent segments. In addition, previous studies have not demonstrated an association between radiographic evidence of degeneration of adjacent segments and the long-term clinical outcome of posterior lumbar fusion. Radiographic signs of degeneration of disc spaces adjacent to the site of a lumbar fusion may reflect the natural history of lumbar spondylosis and may only be meaningful when they are associated with clinical symptoms of radiculopathy, discogenic pain, or stenosis referable to that level[18].

The objectives of the present study were to estimate the incidence, prevalence, and rate of degeneration of the adjacent segments in the lumbar spine following posterior lumbar arthrodesis, both radiographically and symptomatically, and to determine which lumbar segments are at the greatest risk for new symptoms. We also assessed whether multiple-level fu-

sion is a risk factor for adjacent segment disease and analyzed the correlation between radiographic degeneration and findings warranting additional operative intervention. Finally, we examined and analyzed the independent demographic and surgical factors that were associated with clinical outcomes.

Materials and Methods

Between April 1983 and August 1994, 215 patients who had had a posterior lumbar arthrodesis were evaluated. The hospital records, office charts, and radiographs were reviewed and analyzed by an independent observer (G.G.) to determine demographic characteristics, symptoms, preoperative and postoperative diagnoses, and patient function at each follow-up visit. One hundred and sixty-five of the 215 patients had had a posterior lumbar intertransverse process arthrodesis that had been performed by the senior author (E.G.D.) at a single institution for the treatment of degenerative disease of the lumbar spine during this time-period. None of these patients had an acute fracture or dislocation, had been managed for a neoplasm, or were scheduled to have an additional anterior surgical procedure.

The remaining fifty patients had had either a previous posterior lumbar arthrodesis at an outside institution or a remote arthrodesis that had been performed by the senior author before 1983. These patients were included in the survivorship analysis and were valuable for providing long-term data points for the evaluation of disease-free survivorship based on the date of the index procedure. Such patients were only included in the study if they had had radiographic evidence of a healed lumbar fusion after the index arthrodesis. Patients were not included in the radiographic analysis if preoperative radiographs from the time of the index arthrodesis were not available. This subgroup included twenty-nine female patients and twenty-one male patients. The average age of these fifty patients at the time of the index procedure was 41.9 years, and the average duration of follow-up was 13.2 years. Thirty of these fifty patients had a subsequent procedure at segments adjacent to the site of the index fusion; specifically, twenty-seven patients had an arthrodesis and three had a decompression.

The indications for the index posterior lumbar arthrodesis included (1) progressive spondylolisthesis, (2) degenera-tive or iatrogenic spondylolisthesis in patients undergoing decompression for the treatment of spinal stenosis, (3) progressive lumbar scoliosis, (4) iatrogenic instability resulting from an extensive decompression, (5) the occurrence of two or more episodes of disc herniation at the same level, and (6) incapacitating nonradicular back pain after the failure of nonoperative treatment. The arthrodesis was performed at all levels associated with clinical signs and symptoms and at which neural element compression was demonstrated on neuroradiographic images. The diagnosis of adjacent segment disease was based on the presence of instability, radiculopathy, or spinal stenosis that was symptomatic enough for the patient to elect revision surgery. The criteria for arthrodesis as opposed to decompression at an adjacent segment were the same as those previously listed for the index arthrodesis.

All patients returned for regular postoperative visits that involved a radiographic assessment and an examination by the senior author. The persistence of symptoms, work status, functional status, the use of pain medication, and the findings of a complete neurological examination were documented. The outcome at each follow-up visit was rated as excellent, good, fair, or poor on the basis of a modified function scale (Table I)[14,19]. The category that was assigned was determined on the basis of the worst outcome parameter.

The study group included 126 female patients and eighty-nine male patients. The average age of the patients at the time of the index procedure was fifty years (range, thirteen to eighty-five years). All 215 patients had a clinical visit with documentation of function at least one year after the index procedure. The average duration of follow-up was 6.7 years (range, one to forty-one years). One hundred and seventy-eight patients had at least two years of follow-up (average, 7.7 years). One hundred and ten arthrodeses (51%) were performed with instrumentation, and 105 (49%) were performed without instrumentation. Ninety-eight patients had a single-level arthrodesis. One hundred and seventeen patients had a multiple-level arthrodesis; specifically, seven patients had a five-level arthrodesis, eighteen had a four-level arthrodesis, eighteen had a three-level arthrodesis, and seventy-four had a two-level arthrodesis. Six of the seven five-level arthrodeses were from the thoracic spine to the L5 vertebra.

Standard biplanar anteroposterior, lateral, flexion, and

TABLE I Criteria for the Assessment of Clinical Outcome[14,19]				
Outcome	Pain	Medication	Activity	Work Status
Excellent	None except for occasional back pain	None	Normal	Normal
Good	Markedly improved, occasional pain	Occasional use of pain medication	Minimal functional limitations	Return to work, although not at the same job activity
Fair	Some improvement	Frequent use of pain medication	Restricted	Limited
Poor	No change in symptoms or a worsening of the patient's condition	Oral use of narcotics	Incapacitated	Disabled

Grade	Disc-Space Narrowing	Osteophytes	End Plate Sclerosis
TABLE II University of California at Los Angeles Grading Scale for Intervertebral Space Degeneration*			
I	–	–	–
II	+	–	–
III	±	+	–
IV	±	±	+

*The assigned grade was based on the most severe radiographic finding that was evident on plain radiographs. These categories are mutually exclusive when used for grading. Patients were rated on the basis of the worst category satisfied. + = present, – = absent, and ± = either present or absent. An equivalent point scale was assigned to each segment based on the severity of the grade (i.e., Grade I was assigned 1 point).

extension radiographs of the lumbosacral spine from the preoperative visit as well as from the last postoperative visit were reviewed for each patient. Lateral radiographs demonstrating neutral, flexion, and extension views were measured for anteroposterior translation and intervertebral disc height at each lumbar segment. Objective intervertebral disc heights were measured with use of published methods[20]. The degenerative grade at each lumbar disc level was rated at the time of the index procedure and again at the time of the last radiographic follow-up visit. These measurements were performed independently by two of the authors (G.G. and J.C.W.). The amount of lumbar degeneration was classified, according to the University of California at Los Angeles grading scale, as no disease (Grade I), mild disease (Grade II), moderate disease (Grade III), or severe disease (Grade IV) (Table II)[5]. Radiographic evidence of instability was defined, on the basis of published standards, as >4 mm of translation or >10° of angular motion between adjacent end plates on lateral flexion and extension radiographs when compared with the adjacent cephalad and caudad levels[21].

Statistical Analysis

The incidence and prevalence of surgical intervention for adjacent segment disease were calculated for each year, and a Kaplan-Meier survivorship curve with 95% confidence intervals was constructed. Incidence was defined as the percentage of patients who had not had revision surgery at the start of a given year and had had subsequent development of new disease that was treated surgically during that year. Prevalence was defined as the overall percentage of patients who had surgery at an adjacent segment during a given time-period.

Where applicable, two cephalad and two caudad lumbar motion segments adjacent to the fusion were considered at risk for new disease. The prevalence of symptomatic adjacent segment disease was calculated by dividing the number of cases of new disease at that segment by the total number of segments at risk for disease.

A Cox proportional-hazards model was used to determine the independent variables that contributed to the rate of adjacent segment degeneration. Independent variables included age at the time of the index procedure, gender, preop-
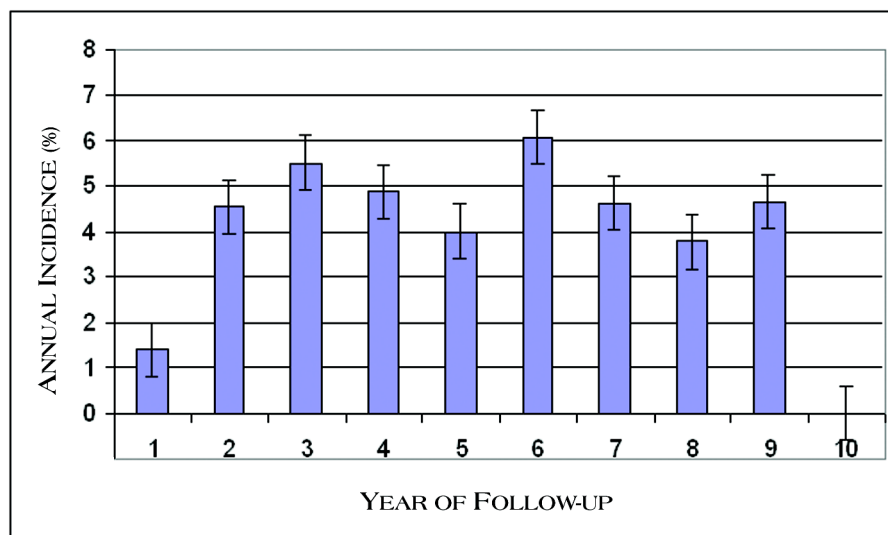

Fig. 1

Histogram showing the annual incidence of new-onset disease per year of follow-up. The I-bars indicate the standard error for each year of follow-up.

TABLE III Relative Risk of New Disease Developing at an Adjacent Vertebral Level						
	Vertebral Level					
	T12-L1	L1-L2	L2-L3	L3-L4	L4-L5	L5-S1
Total no. of discs at risk	26	52	134	116	78	97
No. of discs with new disease	4	5	11	17	17	7
Prevalence *(%)*	15.4	9.6	8.2	14.7	21.8	7.2
Relative risk	Intermediate	Intermediate	Low	Intermediate	High	Low

erative diagnosis, the length of the fusion instrumentation, and the length of time between the index procedure and the last follow-up visit. The Fisher exact test was used to compare the preexisting disc degeneration at adjacent levels with the development of adjacent segment disease. The level of significance was set at $p < 0.05$.

Results

Fifty-nine (27.4%) of the 215 patients had adjacent segment disease that was symptomatic enough for them to elect to have a surgical procedure at the adjacent level. Forty-four of these fifty-nine patients had a decompression and arthrodesis, and fifteen had a decompression only. Postoperatively, new disease at an adjacent level developed at a relatively constant rate of 3.9% per year (95% confidence interval, 2.8% to 5.1%; range, 0% to 6.1%) (Fig. 1).

Kaplan-Meier survivorship analysis was performed in order to assess the rate of disease-free survival for the entire series of patients and to take into account patients who had been lost to follow-up (Fig. 2). The estimated rate of disease-free survival was 83.5% (95% confidence interval, 77.5% to 89.5%) at five years after the index operation and 63.9% (95% confidence interval, 54.0% to 73.8%) at ten years after the index operation. This finding suggests that 16.5% of all patients who have had a posterior lumbar fusion will have new disease warranting a second procedure at an adjacent level within the first five years after the index procedure and that 36.1% will have new disease within the first ten years after the index procedure.

There were significant differences among the various motion segments with regard to the relative risk of adjacent segment disease ($p < 0.001$) (Table III). The relative risk of
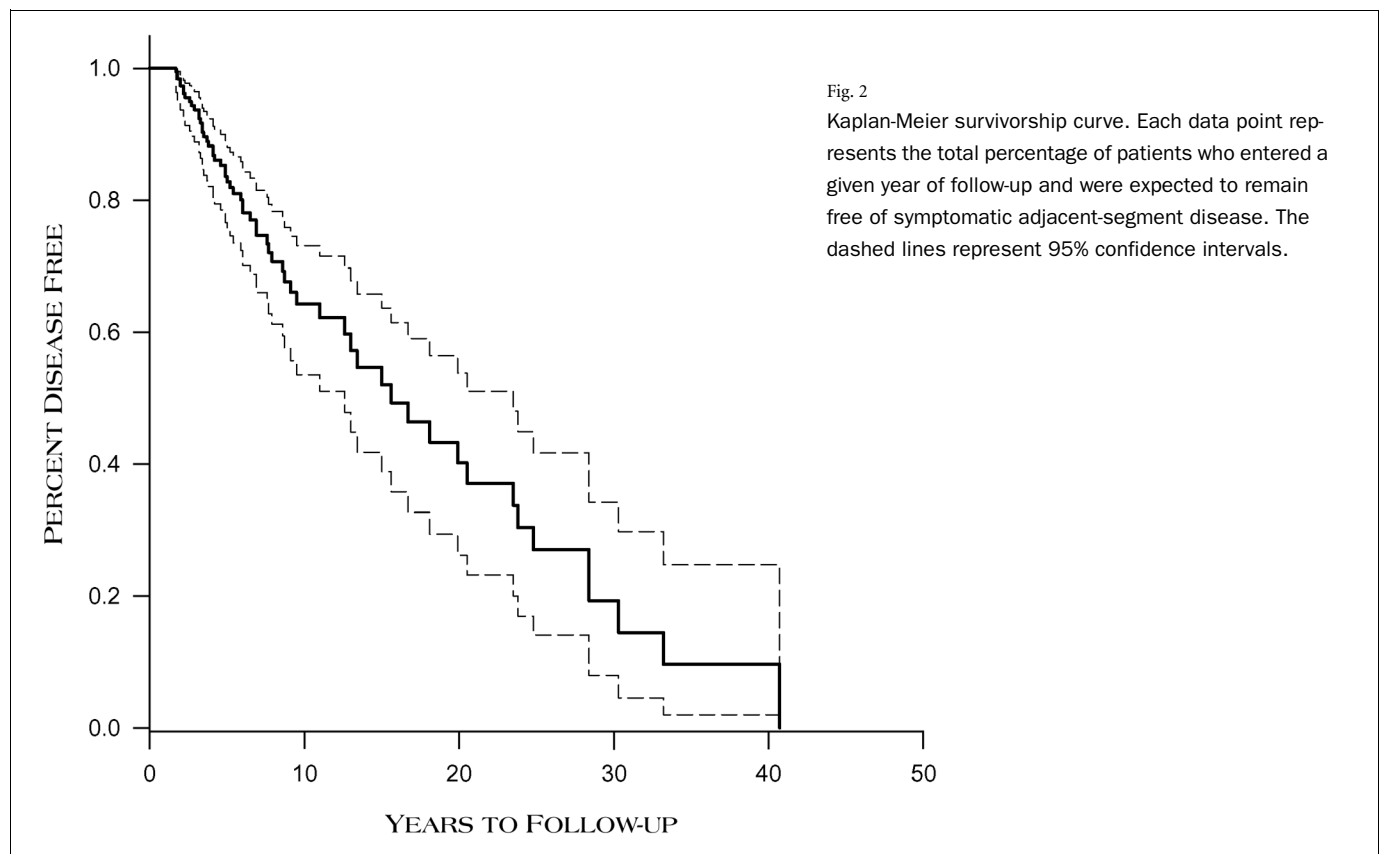

Fig. 2
Kaplan-Meier survivorship curve. Each data point represents the total percentage of patients who entered a given year of follow-up and were expected to remain free of symptomatic adjacent-segment disease. The dashed lines represent 95% confidence intervals.

TABLE IV Progression of Arthritic Grade of Intervertebral Disc Degeneration			
	Mean Arthritic Grade		P Value*
	Preoperative	Postoperative	
Cephalad adjacent segment	1.67	2.19	<0.001
Cephalad to cephalad adjacent segment	1.49	1.84	<0.001
Caudad adjacent segment	2.29	2.81	<0.001
Caudad to caudad adjacent segment	2.03	1.62	<0.012
*Wilcoxon signed-rank test. The p values indicate the significance of the difference between preoperative and postoperative degeneration. Comparisons were made at the cephalad and caudad levels, both immediately adjacent to the fusion and adjacent to the adjacent segment.			

new-onset disease at the L2-L3 interspace was 2.7 times lower than that at the L4-L5 level, which had the highest prevalence. The L5-S1 interspace had a relatively low risk of subsequent degeneration, with a prevalence of 7.2%.

The 122 patients who did not have additional surgical intervention at an adjacent segment and who had at least two years of follow-up were evaluated with use of established criteria for outcome[14,19]. The average duration of follow-up (and standard error) from the time of the index procedure was 6.5 ± 4.8 years (range, 2.0 to 38.1 years). Fourteen of these 122 patients had an excellent outcome, forty-two had a good outcome, forty-nine had a fair outcome, and seventeen had a poor outcome at the last follow-up visit.

On the basis of the data in Table II, each grade was assigned a numeric point value. The average radiographic score for adjacent segment disease this 4-point scale was 1.81 points preoperatively and 2.24 points postoperatively. There was significant degeneration at all levels when the most recent radiographs were compared with the preoperative radiographs (Table IV).

Cox regression analysis showed no significant correlation between adjacent segment disease and diagnosis (p = 0.34), age at the time of surgery (p = 0.13), gender (p = 0.92), or instrumentation (p = 0.47), with the numbers available. The Fisher exact test showed a trend but no significant correlation between preexisting radiographic degeneration and adjacent segment disease (p = 0.115). Contrary to our hypothesis, segments that were adjacent to a single-level fusion had a three times higher risk for the development of disease than did those that were adjacent to a multiple-level fusion (Cox proportional hazards model, 3.4; 95% confidence interval, 1.83 to 6.23; p < 0.001).

Discussion

The continued degeneration of motion segments adjacent to lumbar spinal fusions is a potential concern for both patients and surgeons and accounts for a substantial percentage of revision spine surgery. Although the development of adjacent segment degeneration can be considered part of the normal aging and degenerative process, this phenomenon appears to be at least partly influenced by the altered stresses that arise as a consequence of lumbar fusion[15,17,18,22].

There have been many clinical studies, ranging in size from forty-five to 312 patients, that have described accelerated degeneration of lumbar segments adjacent to the site of a previous arthrodesis[2,7,9-14]. Those studies have detailed disc-space narrowing and spondylolisthesis in the adjacent segments after lumbar or, more commonly, lumbosacral fusion. The reported prevalence of degeneration at the adjacent segments has ranged from 5% to 43%[3,7,11]. However, the prevalence of lumbar surgery performed for the treatment of this degeneration has been much lower (range, 2% to 15%). The majority of subsequent operations have involved neural decompression rather than cephalad extension of the fusion. The disparity in these data can be explained by variability in the duration of follow-up and inconsistency in the definition of adjacent segment disease in the various studies.

In addition, biomechanical studies have supported the increased prevalence of degenerative disease adjacent to the fusion[15-17]. The authors of those studies postulated that increased stress or hypermobility at the adjacent segment was a possible etiology of adjacent segment degeneration. Lee and Langrana showed that there is increased stress at the adjacent facet joints of L3-L4 and L4-L5 after lumbosacral arthrodesis[16]. Quinnell and Stockdale specifically addressed the influence of a single lumbar floating arthrodesis on the rest of the lumbar spine and concluded that the disc cephalad to the fusion is unaffected in terms of its external dimensions whereas the discs caudad to the fusion exhibit a change in their loading characteristics[17]. More recently, Axelsson et al., in an in vitro model, assessed adjacent segments with use of roentgen stereophotogrammetric analysis and found relative hypermobility in the juxtafused segment[23]. The findings of those biomechanical studies suggest that lumbar fusions produce adverse consequences on the adjacent motion segments.

In the present study, the rate of surgical intervention for adjacent segment disease was 3.9% per year during the first ten years following primary posterior lumbar arthrodesis. Kaplan-Meier survivorship analysis predicted that, at ten years, 36.1% of the patients would have sufficient disease to warrant additional surgical intervention. We believe that our model accurately describes the risk of symptomatic adjacent segment degeneration because it takes into account patients who had died and those who had been lost to follow-up.

We hypothesized that, after a multiple-level fusion, more motion would be transferred to the adjacent segments, thus

leading to a more rapid onset of disc degeneration and new disease at the adjacent levels. Contrary to that hypothesis, patients who had a multiple-level fusion were significantly less likely to have symptomatic adjacent segment disease than those who had a single-level fusion (p < 0.001). This finding may be explained by the fact that a patient who has a single-level fusion has more levels at risk than a patient who has a long fusion segment. For example, a patient who has a fusion at L3-L4 has four levels at risk for adjacent segment degeneration, whereas a patient who has instrumentation from the thoracic spine to L5 has only one level at risk for disease.

Our radiographic data showed a large amount of inconsistency when the intervertebral disc height was measured quantitatively. This finding was concordant with the findings of other investigators who have attempted to measure intervertebral disc height objectively but have found that it is impossible to do so unless one carefully controls the tube-target-film relationship, uses optimum radiographic techniques that include osseous landmarks, and compensates for radiographic magnification[20,23]. Therefore, we developed a modified arthritis-grading scale to grade disc degeneration qualitatively (Table II).

The radiographic findings of the present study did show a significant progression of the arthritic grade of the adjacent segment. However, the clinical importance of this radiographic progression is undetermined. It is expected that arthritic degeneration of a motion segment will progress with time, regardless of whether or not the motion segment is adjacent to a fused segment. The radiographic findings of the present study suggest that there is no predictable way to determine which segments will degenerate in the future. Although symptomatic degeneration is multifactorial, it may be less likely to occur in arthritic segments than in mobile segments without arthritis.

Our study had several important limitations. The first limitation is that the study was a retrospective review of a heterogeneous patient population. Although a multivariate regression analysis was performed to assess the contributions of independent variables such as age, gender, instrumentation, and preoperative diagnosis, a more homogenous population might have provided a stronger correlation between independent variables and adjacent segment disease.

Another limitation of our study is that it lacked a control group for comparison. A matched population of patients with spondylosis who refused operative intervention would provide the most ideal control group if they were available for long-term follow-up. We would then be able to assess the degenerative changes in the adjacent segments without the influence of a juxtaposed fusion. Instead, we have assumed that the adjacent segment disease is a direct result of the surgical fusion.

The greatest limitation of our study is that reoperation was used as the end point for survivorship analysis. This definition did not consider patients with adjacent segment degeneration who might have benefited from surgical intervention but did not have an operation because of unknown reasons such as comorbidities or other unresolved variables. Pain is a complex matter that involves psychosocial factors, which are likely to be more important than physical factors. Of the patients who do choose surgery, it is never known how they would fare without it. With this in mind, the survivorship data presented in the present study most likely overestimated the percentage of disease-free survival.

The present study offers insight into the natural history of a lumbar fusion and estimates the rate of adjacent segment degeneration at five and ten years after posterior lumbar arthrodesis. Our clinical findings did not support a relationship between preoperative arthritic degeneration, the use of instrumentation, or the length of fusion and subsequent degeneration of adjacent motion segments. Although one cannot discern the contribution of fusion apart from natural history, our data provide important information regarding adjacent segment disease. The present study should provide useful information for both the patient and the clinician and should guide future research regarding adjacent segment disease. ∎

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