Revision Surgery Following Operations for Lumbar Stenosis

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Background: For carefully selected patients with lumbar stenosis, decompression surgery is more efficacious than nonoperative treatment. However, some patients undergo repeat surgery, often because of complications, the failure to achieve solid fusion following arthrodesis procedures, or persistent symptoms. We assessed the probability of repeat surgery following operations for the treatment of lumbar stenosis and examined its association with patient age, comorbidity, previous surgery, and the type of surgical procedure.

Methods: We performed a retrospective cohort analysis of Medicare claims. The index operation was performed in 2004 ($n = 31,543$), with follow-up obtained through 2008. Operations were grouped by complexity as decompression alone, simple arthrodesis (one or two disc levels and a single surgical approach), or complex arthrodesis (more than two disc levels or combined anterior and posterior approach). Reoperation rates were calculated for each follow-up year, and the time to reoperation was analyzed with proportional hazards models.

Results: The probability of repeat surgery fell with increasing patient age or comorbidity. Aside from age, the strongest predictor was previous lumbar surgery: at four years the reoperation rate was 17.2% among patients who had had lumbar surgery prior to the index operation, compared with 10.6% among those with no prior surgery ($p < 0.001$). At one year, the reoperation rate for patients who had been managed with decompression alone was slightly higher than that for patients who had been managed with simple arthrodesis, but by four years the rates for these two groups were identical (10.7%) and were lower than the rate for patients who had been managed with complex arthrodesis (13.5%) ($p < 0.001$). This difference persisted after adjusting for demographic and clinical features (hazard ratio for complex arthrodesis versus decompression 1.56, 95% confidence interval, 1.26 to 1.92). A device-related complication was reported at the time of 29.2% of reoperations following an initial arthrodesis procedure.

Conclusions: The likelihood of repeat surgery for spinal stenosis declined with increasing age and comorbidity, perhaps because of concern for greater risks. The strongest clinical predictor of repeat surgery was a lumbar spine operation prior to the index operation. Arthrodeses were not significantly associated with lower rates of repeat surgery after the first postoperative year, and patients who had had complex arthrodeses had the highest rate of reoperations.

Level of Evidence: Therapeutic Level III. See Instructions for Authors for a complete description of levels of evidence.

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A commentary by Alan B.C. Dang, MD, and Steven R. Garfin, MD, is linked to the online version of this article at jbjs.org.

Randomized trials have demonstrated greater efficacy of decompression surgery as compared with nonoperative treatment for carefully selected patients with lumbar spinal stenosis¹⁻³. However, some patients have recurrent symptoms, and some undergo repeat surgery. In the Spine Patient Outcomes Research Trial (SPORT) for spinal stenosis, 8% of patients who underwent an operation had another operation within two years, and 13% had another operation within four years^{2,3}. In the Maine Lumbar Spine Study, 23% of patients had repeat surgery by ten years⁴. To assess delayed or infrequent outcomes such as reoperations, observational studies of large patient populations are often needed to supplement randomized trials.

The reasons for repeat surgery vary, but repeat surgery is generally an undesired event. Early reoperations are often performed because of technical errors or postoperative complications⁵. Later reoperations may be performed because of the failure to achieve osseous fusion after attempted arthrodesis, complications resulting from surgical implants, progressive degenerative changes such as adjacent segment disease, or persistent pain.

Some patients with these problems do not undergo repeat surgery, so reoperations may represent a subset of patients with unfavorable outcomes or progressive disease.

Repeat surgery for the treatment of lumbar stenosis is associated, on the average, with lower effectiveness and greater complications as compared with initial surgery⁶⁻⁸. Furthermore, the complications of repeat surgery may be greater among elderly patients with spinal stenosis than among younger patients with intervertebral disc disease. Uncertainty persists regarding the indications for adding arthrodesis surgery to decompression for the treatment of spinal stenosis^{9,10}, and there are wide geographic variations in the rates of lumbar arthrodesis¹¹.

The probability of another operation may vary with patient characteristics, the type of surgery, and other factors, yet few data are available to provide individualized estimates. We therefore analyzed Medicare claims data to assess the probability of repeat surgery following the surgical treatment of spinal stenosis, to determine whether the likelihood of repeat surgery is affected by age and comorbidity, and to determine whether the likelihood of repeat surgery is affected by previous spinal surgery and by the nature of the index operation.

Materials and Methods

Data Source

Data were obtained from the Medicare Provider Analysis and Review (MedPAR) database for the years 1999 to 2008. This database includes all Medicare hospital claims and uses procedure codes from the *International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)*. We restricted analysis to Medicare patients in the Old-Age and Survivors Insurance program, excluding those whose eligibility was based on Social Security Disability Income or end-stage renal disease. We also excluded patients who were enrolled in a health maintenance organization because such patients may not have complete claims data for individual episodes of care. This exclusion is often used in studies of Medicare data^{12,13}.

Patient Selection

We identified patients with an age of sixty-eight years or more who had a primary diagnosis of lumbar stenosis (ICD-9-CM diagnosis codes 724.02 and 721.42). This age criterion provided at least three years of prior Medicare eligibility for most patients, allowing for the identification of recent prior spine surgery. We

then identified patients who had any combination of lumbar discectomy, laminectomy, arthrodesis, or repeat surgery. We defined the index operation as the first lumbar spine operation for an individual that had been performed in 2004, allowing at least four years of follow-up for all patients. We required that either the diagnosis codes or the procedure codes specified the lumbar region. We excluded patients if any diagnosis at the index hospitalization indicated cancer, vehicular accident, spinal infection, inflammatory spondyloarthropathies, vertebral fractures or dislocations, or cervical or thoracic spine procedures. We also excluded sixteen patients with "add-on" arthrodesis level codes without a primary arthrodesis code. In a sensitivity analysis, we examined patients for whom lumbar stenosis was coded as either a primary or a secondary diagnosis.

Categorizing Surgical Procedures

We defined three broad categories of surgery: decompression, simple arthrodesis, and complex arthrodesis. Decompression included any procedure involving discectomy or laminectomy without arthrodesis. A simple arthrodesis was a procedure that was coded only for anterior arthrodesis techniques or only for transverse process or posterior arthrodesis techniques and that involved only one or two disc levels (arthrodesis involving two or three vertebrae, code 81.62) or an unreported number of disc levels. A complex arthrodesis was a procedure that was coded as 360° spine arthrodesis with a single incision (code 81.61), any combination of anterior arthrodesis with either transverse process or posterior arthrodesis techniques, or any arthrodesis involving more than two disc levels.

Measures of Comorbidity

We modified a comorbidity index developed by Quan and colleagues¹⁴. Our modification removed codes that might represent postoperative complications rather than preoperative comorbid conditions (for example, acute myocardial infarction) if recorded at the time of the index hospitalization. However, the full Quan index was used to search diagnoses from any hospitalization in the year prior to the index hospitalization. Thus, our modified score included comorbid conditions that had been coded during previous hospitalizations and selected conditions that were identified during the index hospitalization. In addition to this comorbidity index, we counted the number of hospitalizations in the year prior to index hospitalization as a crude measure of overall disease burden (excluding previous hospitalizations for spine surgery).

Previous Spine Surgery

We identified patients with lumbar surgery prior to the index operation in two ways. First, we identified ICD-9 diagnosis or procedure codes indicating previous surgery. Second, we searched hospital claims for three prior years to identify lumbar spine procedures. Excluding patients under age sixty-eight ensured that nearly all had three years of prior Medicare eligibility. For those with more than three years of eligibility, we searched only three prior years.

Reoperations After the Index Procedure

With the same procedure codes that we used for selecting patients, we identified lumbar spine operations following discharge after the index operation. We counted only the first recurrence of lumbar surgery. We use the term "repeat surgery" or "reoperation" to indicate any of these subsequent operations, although the nature of the surgery may have been different from the index operation, and we cannot know whether it involved the same spinal levels. We tabulated diagnosis and procedure codes recorded at these reoperations.

Statistical Methods

Comparisons among groups used chi-square statistics; all significance tests were two-sided, with an alpha of 0.05. Likelihood of reoperation was analyzed both as the percentage of patients with repeat surgery at each year of follow-up (for easy communication) and as a continuous variable (days to reoperation) in proportional hazards models. The time to reoperation was calculated as the number of days from the index hospital discharge to admission for the first lumbar spine reoperation. Multivariate analyses focused on reoperation risks for the three broad classes of surgery performed at the time of the index operation.

We used proportional hazards models to examine the cumulative probability of reoperation, adjusted for age, age-squared, sex, race, comorbidity score, previous hospitalization, lumbar surgery prior to the index operation, and presence of coexisting scoliosis or spondylolisthesis. We assessed the model with hazard plots and tests of Schoenfeld residuals.

We found that the proportionality assumption was violated. As previously described¹⁵, this was because the risk of early reoperation was lower following arthrodesis than it was following decompression, but, after the first year, the risk of reoperation following arthrodesis rose quickly and exceeded that following decompression surgery. We therefore included a time-varying coefficient to examine the probability of reoperation in each year of follow-up. The final model was confirmed using the Cox-Snell residuals plot for goodness of fit. We examined the same model for the subgroup of patients with no concurrent diagnosis of scoliosis or spondylolisthesis.

In addition to the cumulative probability of reoperation, we examined the instantaneous probability as it varied over time. The instantaneous probability is the likelihood of a future reoperation at a given time, assuming the patient has reached that time without a reoperation.

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Results

Patient and Procedure Characteristics

There were 31,543 eligible patients with an age of sixty-eight years or more who underwent an index operation because of primary diagnosis of spinal stenosis during 2004. The mean age (and standard deviation) was 76.0 ± 5.2 years, 55.8% of the patients were women, 93.9% were white, 3.5% were black, and 2.6% were other races (Table I). Among these patients, 5084 (16.1%) had a secondary diagnosis of spondylolisthesis, 1540 (4.9%) had a secondary diagnosis of scoliosis, and 1947 (6.2%) had had previous lumbar surgery. Among the index operations, 23,055 (73.1%) involved decompression alone, 5329 (16.9%) were simple arthrodeses, and 3159 (10.0%) were complex arthrodeses (Table I). There were 3461 repeat operations within four years of follow-up (reoperation rate, 11.0%).

Probability of Repeat Surgery by Patient Characteristics

The probability of a second operation decreased with increasing age (Table I). The probability of reoperation within four years was 14.2% for patients with an age of seventy years or less, compared with 7.0% for patients with an age of eighty years or more ($p < 0.001$).

Because the mix of surgical procedures could confound the association of reoperations with age, we examined mean patient ages for the three classes of procedures. The mean ages were similar (76.2 years for patients managed with decompression, 75.5 years for patients managed with simple arthrodesis, and 75.0 years for patients managed with complex arthrodesis). The differences were significant ($p < 0.001$) but were clinically trivial. Reoperations declined with increasing age even after adjusting for the type of surgery, previous surgery, previous hospitalization, scoliosis, spondylolisthesis, comorbidity, gender, and race.

Similarly, the probability of repeat surgery generally declined with increasing comorbidity. The four-year reoperation rate was 11.0% for patients with no recorded comorbidity, compared with 8.7% for those with the highest comorbidity ($p < 0.001$). Reoperations were more likely among whites (11.1% at four years) than among blacks (8.5%) ($p = 0.04$) but not Asians (13.1%). Reoperation rates were similar for men and women, even after adjustment in a proportional hazards model.

Probability of Repeat Surgery by Procedure Characteristics

The likelihood of repeat surgery was higher among patients who had had previous lumbar spine surgery at the time of the index operation (17.2% at four years) than among those with no evidence of prior surgery (10.6% at four years) ($p < 0.001$). For patients with a lumbar spine operation prior to the index procedure, the “reoperation” in our analysis constituted a second revision. In proportional hazards models adjusting for demographic characteristics, comorbidity, and type of index operation, the hazard ratio for previous spine surgery was 1.58 (95% CI, 1.41 to 1.76) ($p < 0.001$). Previous lumbar spine surgery was the strongest risk factor for repeat surgery. Patients with a secondary diagnosis of spondylolisthesis had a lower one or two-year reoperation rate than those with no spondylolisthesis (for example, 3.6% versus 4.2% at one year; $p = 0.038$), but the rates were the same at four years (11.0% for each) (Table I).

The one-year reoperation rate for the patients who had been managed with decompression alone was significantly higher than that for patients managed with simple arthrodesis ($p < 0.001$) but was nearly the same as that for patients who had been managed with complex arthrodesis (Tables I and II). However, after the first year, the reoperation rate was higher for the complex arthrodesis group and, at four years, the cumulative probability of reoperation was significantly higher for the complex arthrodesis group (13.5%) than for the other two groups (10.7% for both the decompression group and the simple arthrodesis group) ($p < 0.001$). Differences in reoperation rates according to the number of additional levels of arthrodesis were small and were not significant (except at four years, when a higher rate of reoperation was noted among patients who had had arthrodesis involving four vertebrae or more) (Table I).

Time-to-an-event analysis more clearly revealed the complex relationship between the type of surgery and the probability of repeat operation. Both the simple and complex arthrodesis groups had a lower cumulative probability of reoperation than the decompression group during the first year but had accelerating rates thereafter (Fig. 1). By two years, the cumulative risk in the complex arthrodesis group exceeded that in the decompression group and, by four years, a similar cross-over occurred for the simple arthrodesis group.

The instantaneous probability of reoperation was higher for the decompression group over the first year but was lower than that for either of the arthrodesis groups by two years (Fig. 2). In other words, after two years, the probability of having another operation was higher for patients managed with arthrodeses

TABLE I Probability of Repeat Surgery According to Patient Characteristics and Duration of Follow-up (N = 31,543)

Category	Total No. of Patients	No. of Patients with Reoperation				
		Within 1 Year	Within 2 Years	Within 3 Years	Within 4 Years	Any Reoperation, All Years of Follow-up
Overall	31,543	1303 (4.1%)	2252 (7.1%)	2938 (9.3%)	3461 (11.0%)	3681 (11.7%)
Age						
68 to 70 yr	5279	249 (4.7%)*	458 (8.7%)*	617 (11.7%)*	750 (14.2%)*	819 (15.5%)*
71 to 74 yr	8476	393 (4.6%)	681 (8.0%)	919 (10.8%)	1094 (12.9%)	1162 (13.7%)
75 to 79 yr	9833	401 (4.1%)	711 (7.2%)	911 (9.3%)	1064 (10.8%)	1127 (11.5%)
≥80 yr	7955	260 (3.3%)	402 (5.1%)	491 (6.2%)	553 (7.0%)	573 (7.2%)
Sex						
Male	13,955	586 (4.2%)	983 (7.0%)	1273 (9.1%)	1502 (10.8%)	1601 (11.5%)
Female	17,588	717 (4.1%)	1269 (7.2%)	1665 (9.5%)	1959 (11.1%)	2080 (11.8%)
Race/ethnicity						
White	29,608	1243 (4.2%)*	2150 (7.3%)*	2798 (9.5%)*	3291 (11.1%)*	3498 (11.8%)*
Black	1104	29 (2.6%)	48 (4.3%)	77 (7.0%)	94 (8.5%)	101 (9.1%)
Asian	168	10 (6.0%)	17 (10.1%)	20 (11.9%)	22 (13.1%)	24 (14.3%)
Other/unknown	663	21 (3.2%)	37 (5.6%)	43 (6.5%)	54 (8.1%)	58 (8.7%)
Quan comorbidity index						
0	15,602	636 (4.1%)	1094 (7.0%)*	1452 (9.3%)*	1716 (11.0%)*	1821 (11.7%)*
1	8994	407 (4.5%)	714 (7.9%)	912 (10.1%)	1072 (11.9%)	1145 (12.7%)
2	3764	135 (3.6%)	243 (6.5%)	323 (8.6%)	385 (10.2%)	415 (11.0%)
3	1680	62 (3.7%)	107 (6.4%)	134 (8.0%)	158 (9.4%)	162 (9.6%)
4	753	28 (3.7%)	44 (5.8%)	59 (7.8%)	65 (8.6%)	68 (9.0%)
≥5	750	35 (4.7%)	50 (6.7%)	58 (7.7%)	65 (8.7%)	70 (9.3%)
Diabetes						
No	24,809	1034 (4.2%)	1778 (7.2%)	2317 (9.3%)	2741 (11.0%)	2910 (11.7%)
Yes	6734	269 (4.0%)	474 (7.0%)	621 (9.2%)	720 (10.7%)	771 (11.4%)
Chronic pulmonary disease						
No	25,713	1088 (4.2%)	1841 (7.2%)	2420 (9.4%)	2844 (11.1%)*	3030 (11.8%)*
Yes	5830	215 (3.7%)	411 (7.0%)	518 (8.9%)	617 (10.6%)	651 (11.2%)
Previous lumbar surgery						
No	29,596	1180 (4.0%)*	2031 (6.9%)*	2649 (9.0%)*	3126 (10.6%)*	3322 (11.2%)*
Yes	1947	123 (6.3%)	221 (11.4%)	289 (14.8%)	335 (17.2%)	359 (18.4%)
Hospitalizations in previous year						
0	23,892	965 (4.0%)	1683 (7.0%)	2216 (9.3%)*	2611 (10.9%)	2786 (11.7%)
1	4813	210 (4.4%)	359 (7.5%)	465 (9.7%)	549 (11.4%)	583 (12.1%)
2	1772	71 (4.0%)	127 (7.2%)	162 (9.1%)	191 (10.8%)	201 (11.3%)
3+	1066	57 (5.3%)	83 (7.8%)	95 (8.9%)	110 (10.3%)	111 (10.4%)
Scoliosis						
No	30,003	1229 (4.1%)	2133 (7.1%)	2784 (9.3%)	3276 (10.9%)	3487 (11.6%)
Yes	1540	74 (4.8%)	119 (7.7%)	154 (10.0%)	185 (12.0%)	194 (12.6%)
Spondylolisthesis						
No	26,459	1120 (4.2%)*	1912 (7.2%)*	2474 (9.4%)	2900 (11.0%)	3074 (11.6%)
Yes	5084	183 (3.6%)	340 (6.7%)	464 (9.1%)	561 (11.0%)	607 (11.9%)
Index operation						
Decompression	23,055	988 (4.3%)*	1659 (7.2%)*	2127 (9.2%)*	2466 (10.7%)*	2603 (11.3%)*
Simple arthrodesis	5329	181 (3.4%)	342 (6.4%)	455 (8.5%)	568 (10.7%)	617 (11.6%)
Complex arthrodesis	3159	134 (4.2%)	251 (7.9%)	356 (11.3%)	427 (13.5%)	461 (14.6%)

TABLE I (Continued)

Category	Total No. of Patients	No. of Patients with Reoperation				
		Within 1 Year	Within 2 Years	Within 3 Years	Within 4 Years	Any Reoperation, All Years of Follow-up
Number of fused vertebrae						
None	23,911	1012 (4.2%)	1710 (7.2%)	2193 (9.2%)	2560 (10.7%)*	2705 (11.3%)*
2 or 3	6066	221 (3.6%)	421 (6.9%)	575 (9.5%)	695 (11.5%)	753 (12.4%)
4+	1566	70 (4.5%)	121 (7.7%)	170 (10.9%)	206 (13.2%)	223 (14.2%)
*Significant difference between levels of the same variable (p < 0.05).						

*Significant difference between levels of the same variable ($p < 0.05$).

than for those managed with decompression alone, and the highest probability was for patients managed with complex arthrodeses.

When only the patients without secondary diagnoses of spondylolisthesis or scoliosis were considered ($n = 25,241$), the same patterns of reoperations were observed (Table II). For example, when the complex arthrodesis group was compared with the decompression group, the adjusted hazard ratio for reoperation was 0.85 in the first year, 1.06 in the second year, and 1.41 in the fourth year or later (Table II). The cumulative probability of reoperation following complex arthrodesis remained higher beyond three years even when we further excluded patients who had had surgery prior to the index operation, although the difference was only marginally significant (hazard ratio, 1.35) ($p = 0.067$).

When considering patients with any diagnosis of lumbar stenosis (primary or secondary) ($n = 37,287$), all results were qualitatively the same, and conclusions were unchanged.

Diagnoses and Procedures at Time of First Reoperation

At the time of the first reoperation, the most common procedure was an arthrodesis or repeat arthrodesis (52.5%). Decompression without arthrodesis was performed at the time of 43.6% of reoperations, and removal of an implanted device

(without decompression or arthrodesis) was performed at the time of 3.6% of reoperations. Primary diagnoses at the time of reoperation included stenosis (34.9%), disc displacement or sciatica (21.5%), disc degeneration (16.8%), spondylolisthesis (9.7%), device complication (6.5%), scoliosis (2.7%), post-laminectomy syndrome (2.9%), surgical complications (1.3%), and synovial cyst (1.2%). The remaining 2.5% of reoperations included thirty-nine different primary diagnoses, all representing $<0.5\%$.

Device-related complications were reported at the time of 29.2% (315) of 1078 reoperations following an initial arthrodesis, although most were listed as secondary diagnoses. These included mechanical complications, removal, breakage, dislocation, infection or inflammatory reaction, and others. Device-related complications were more frequent in the complex arthrodesis group than in the simple arthrodesis group (34.9% compared with 25.0% respectively; $p = 0.001$). An ICD-9 code labeled “arthrodesis status,” implying concern about possible pseudarthrosis, was a secondary diagnosis at the time of 24.0% of reoperations following an arthrodesis. Overall, a device-related complication or arthrodesis status was recorded at the time of 47.5% of reoperations following an index arthrodesis, with more following complex than simple arthrodeses (53.4% compared with 43.1%, respectively, $p < 0.001$).

TABLE II Multivariate Models for Reoperation Following Initial Surgery for Spinal Stenosis*

Follow-up Interval	All Patients (N = 31,543)†		Excluding Patients with Spondylolisthesis or Scoliosis (N = 25,241)		Excluding Patients with Spondylolisthesis, Scoliosis, or Previous Surgery (N = 23,726)	
	Simple Fusion	Complex Fusion	Simple Fusion	Complex Fusion	Simple Fusion	Complex Fusion
1 yr	0.81 (0.72 to 0.91)	0.86 (0.72 to 1.03)	0.88 (0.76 to 1.02)	0.85 (0.67 to 1.08)	0.90 (0.77 to 1.07)	0.88 (0.67 to 1.15)
2 yr	0.92 (0.82 to 1.06)	1.14 (0.94 to 1.38)‡	0.98 (0.84 to 1.15)	1.06 (0.82 to 1.37)	1.04 (0.87 to 1.25)	1.16 (0.87 to 1.55)
3 yr	1.05 (0.92 to 1.21)	1.47 (1.19 to 1.81)‡	1.09 (0.91 to 1.30)	1.30 (0.97 to 1.73)	1.10 (0.91 to 1.34)	1.30 (0.94 to 1.81)
≥4 yr	1.09 (0.95 to 1.24)	1.56 (1.26 to 1.92)‡	1.13 (0.95 to 1.35)	1.41 (1.07 to 1.87)‡	1.12 (0.93 to 1.36)	1.35 (0.98 to 1.86)

*The values are given as hazard ratios (and 95% confidence intervals) from proportional hazards models. All models are adjusted for age and age-squared, sex, race, Quan comorbidity index (six levels), previous lumbar surgery, previous nonlumbar hospitalizations (four levels), spondylolisthesis, and scoliosis. Hazard ratios are relative to decompression alone as the referent and are modeled with use of a time-varying coefficient for each year of follow-up. †Seven patients with missing time data and sixty-nine patients whose “readmission” date was the same as the index date were excluded from the survival model. ‡Significance at the 0.05 level between complex and simple fusion.

Fig. 1

Line graph showing the cumulative probability of reoperation following lumbar surgery for spinal stenosis among Medicare beneficiaries with an index operation in 2004.

Fig. 2

Line graph showing instantaneous risk of reoperation following lumbar surgery for spinal stenosis among Medicare beneficiaries according to the type of index operation.

Discussion

The probability of repeat surgery for lumbar stenosis increased steadily during follow-up, reaching 11.0% at four years. This is slightly lower than the 13% rate observed in the SPORT³. Rates of repeat surgery declined with increasing patient age or comorbidity, perhaps reflecting concern about increased risks in these circumstances. This may help explain the lower rates of reoperation than in the SPORT, in which the mean age was ten years younger than in the present study. The rate of repeat surgery was higher among patients who had had

lumbar spine surgery prior to the index operation than among those with no previous lumbar spine surgery. In fact, prior surgery was the strongest clinical predictor of revision surgery.

It is unclear why reoperation rates were lower among black patients than among whites. It is conceivable that blacks have more successful index procedures (for example, if bone density differs). However, lower reoperation rates may also result from socioeconomic factors, such as less availability of supplemental insurance, greater out-of-pocket costs, and factors related to doctor-patient communication and trust.

After the first year of follow-up, the probability of repeat surgery was not lower among those who had an arthrodesis than among those who had a decompression alone. The instantaneous probability of reoperation was higher for the decompression group over the first year but was lower than those for both arthrodesis groups thereafter. The lower rate of revisions in the first year following arthrodesis may reflect the time for bone healing to occur and reluctance to consider an arthrodesis unsuccessful earlier than one year of follow-up.

At no time after the first year was the reoperation rate lower among those having complex arthrodeses as compared with simple arthrodeses. At four years, complex arthrodeses were associated with the highest probability of repeat surgery. Although the increase in the cumulative probability of repeat surgery was modest, it was significant after two years overall and after four years for patients without coexisting spondylolisthesis or scoliosis. Thus, there was no evidence to support a lower rate of reoperation with more complex surgery beyond one year of surveillance. Previous studies^{15,16} similarly demonstrated no reduction in reoperation rates following arthrodeses as compared with decompression alone in the absence of spondylolisthesis.

Our study had important strengths. It included all Medicare patients having surgery for spinal stenosis who met inclusion criteria, not selected patients, centers, or surgeons. Data on repeat hospitalizations and surgery were complete because patients had consistent insurance coverage and revisions performed in hospitals other than the original hospital were captured.

An important limitation of our observational study is potential confounding by indication, a problem avoided in randomized trials. Perhaps patients selected for arthrodeses, and especially complex arthrodeses, had more severe disease despite adjustments for demographic characteristics, comorbidity, previous surgery, and coexisting spondylolisthesis or scoliosis. However, wide geographic variations in surgery rates (especially arthrodesis)¹¹, studies of variability in surgical decision-making^{9,10}, and an increase in use of complex arthrodesis procedures⁸ suggest that the choice of procedure depends on surgeon preferences as well as patient characteristics. Surgeons vary substantially in terms of their decisions to perform surgery, to include an arthrodesis, or to use surgical implants, even for similar patients^{9,10}. Thus, the differences in reoperations may at least partly result from procedure choices as well as patient characteristics. If patients with more complex surgery had more complex disease, the index procedure did not lower their risk of reoperation to the same level as that for patients having decompression alone.

Another limitation is that diagnoses and procedures may be miscoded, although the data are used for billing and are subject to audit. Comparisons with medical records suggest that surgical procedures and spine operations in particular are generally coded accurately¹⁷⁻¹⁹, although the ICD-9 system lacks detail²⁰. Information regarding implants is limited. Surgeons have differing definitions of spine instability, and ICD-9 diagnosis codes do not represent this concept well. If surgical complexity was underestimated by ICD-9 codes²⁰, patients with

complex surgery would have been misclassified into less complex categories, blurring distinctions among categories, and producing conservative estimates of group differences. We know little about the accuracy of coding specifically for device complications or arthrodesis status.

Our ability to capture surgery prior to the index operation was imperfect, and previous surgery may be undercoded in billing claims²¹. This was our rationale for examining three previous years of claims to identify prior surgery, rather than relying solely on coding at the index operation. Examining previous claims data added substantially to the number of previous operations identified. Even so, we have likely missed some distant past operations. Furthermore, we have not distinguished one from multiple prior operations. To the extent that we have misclassified patients regarding prior surgery, it would tend to make the two groups (prior surgery versus no prior surgery) appear more similar than they really are and to “dilute” the differences. Thus, the observed difference in reoperation rates may be a conservative estimate.

Our results suggest a need for further studies of revision lumbar surgery. In particular, we need a better understanding of why patients with one revision (surgery prior to our index operation) are more likely to undergo yet further revision than patients having first-time surgery. We also need to clarify indications for arthrodesis in spinal stenosis because, in this observational cohort, arthrodesis was not associated with a lower risk of revision surgery (after one year) than decompression alone. Further research is needed to assess pain relief and functional improvement following initial surgery as compared with revision surgery. Finally, these results suggest that in evaluating new procedures and devices, more than two years of surveillance may be appropriate as the relative cumulative probabilities of reoperation continued to change even after two years. ■

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