# Trends, Major Medical Complications, and Charges Associated With Surgery for Lumbar Spinal Stenosis in Older Adults

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**Context** In recent decades, the fastest growth in lumbar surgery occurred in older patients with spinal stenosis. Trials indicate that for selected patients, decompressive surgery offers an advantage over nonoperative treatment, but surgeons often recommend more invasive fusion procedures. Comorbidity is common in older patients, so benefits and risks must be carefully weighed in the choice of surgical procedure.

**Objective** To examine trends in use of different types of stenosis operations and the association of complications and resource use with surgical complexity.

**Design, Setting, and Patients** Retrospective cohort analysis of Medicare claims for 2002-2007, focusing on 2007 to assess complications and resource use in US hospitals. Operations for Medicare recipients undergoing surgery for lumbar stenosis (n=32 152 in the first 11 months of 2007) were grouped into 3 gradations of invasiveness: decompression alone, simple fusion (1 or 2 disk levels, single surgical approach), or complex fusion (more than 2 disk levels or combined anterior and posterior approach).

**Main Outcome Measures** Rates of the 3 types of surgery, major complications, postoperative mortality, and resource use.

**Results** Overall, surgical rates declined slightly from 2002-2007, but the rate of complex fusion procedures increased 15-fold, from 1.3 to 19.9 per 100 000 beneficiaries. Life-threatening complications increased with increasing surgical invasiveness, from 2.3% among patients having decompression alone to 5.6% among those having complex fusions. After adjustment for age, comorbidity, previous spine surgery, and other features, the odds ratio (OR) of life-threatening complications for complex fusion compared with decompression alone was 2.95 (95% confidence interval [CI], 2.50-3.49). A similar pattern was observed for rehospitalization within 30 days, which occurred for 7.8% of patients undergoing decompression and 13.0% having a complex fusion (adjusted OR, 1.94; 95% CI, 1.74-2.17). Adjusted mean hospital charges for complex fusion procedures were US $80 888 compared with US $23 724 for decompression alone.

**Conclusions** Among Medicare recipients, between 2002 and 2007, the frequency of complex fusion procedures for spinal stenosis increased while the frequency of decompression surgery and simple fusions decreased. In 2007, compared with decompression, simple fusion and complex fusion were associated with increased risk of major complications, 30-day mortality, and resource use.

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In planning spine operations, surgeons have wide discretion. For pain-related surgery, consensus on indications for specific procedures (eg, decompression alone or decompression plus fusion) is generally lacking[1-3] despite randomized trials for some condition and procedure combinations.[4-10] Furthermore, individual surgeon preferences may outweigh patient and disease characteristics in choosing procedures.[3] Such choices are important because greater invasiveness is associated with greater complications, health care use, and mortality[4,11,12] but generally similar clinical benefit.[7-10,12]

Risks of spine surgery are particularly important in older adults, for whom stenosis is the most common surgical indication. Symptomatic lumbar stenosis results from progressive degenerative changes in intervertebral joints and ligamentous structures, leading to spinal canal and neural foraminal narrowing. Diagnosis and treatment require complex judgments integrating data from imaging, clini-

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cal findings, and the patient's clinical course.

Surgery for spinal stenosis was the fastest-growing type of lumbar surgery in the United States from 1980 to 2000.[13,14] Randomized trials indicate that for severely affected patients, decompression without fusion offers greater efficacy than nonsurgical treatments.[5,6] However, assessment of therapeutic safety often requires observational data, because randomized trials may exclude high-risk patients, be too short to identify some risks, or be too small to detect uncommon events.[15]

Better information on surgical complications would help surgeons, referring physicians, and patients weigh benefits and risks and would permit more individualized decision making. We therefore studied the Medicare population (adults ≥65 years, who receive federal health insurance coverage) to better define (1) trends in the use of various surgical procedures for lumbar stenosis; (2) how complications vary as a function of age, comorbid conditions, previous surgery, and complexity of the surgical procedure; and (3) health care use associated with stenosis surgery, including hospital length of stay, hospital charges, rehospitalization, and postoperative nursing home care.

## METHODS

### Data Source

We used Part A claims (the Medicare Provider Analysis and Review, or MedPAR database) for the most recent available years (2002-2007) to examine trends in use of various surgical procedures. This database includes 100% of Medicare hospital claims, using surgical procedure codes from the *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*). We excluded beneficiaries receiving Social Security Disability Income, those with end-stage renal disease, or those enrolled in a health maintenance organization. The latter are often excluded from Medicare data analyses because detailed claims may not be available.[16,17]

These data files have unique patient identifiers that allow linkage among files and identification of repeat hospitalizations. Institutional review boards at the University of Washington, Oregon Health and Science University, and Dartmouth College approved the project.

### Trends in Surgical Procedures

To examine surgical trends, we selected patients aged 65 years or older with a primary diagnosis of lumbar spinal stenosis (98.2% of cases) or spondylogenic compression of lumbar spinal cord. We included those with a surgical procedure indicating any combination of diskectomy, laminectomy, or fusion. We excluded patients if any diagnosis at the index hospitalization indicated cancer, vehicular crash, spinal infection, inflammatory spondyloarthropathies, vertebral fractures or dislocations, or cervical or thoracic spine procedures. Race and ethnicity were determined by what was reported on Medicare claim files as submitted by hospitals.

### Categorizing Surgical Procedures

We defined 3 broad categories of spine surgery: decompression, simple fusion, or complex fusion. Decompression included any combination of discectomy and laminectomy without fusion. A simple fusion involved a single surgical approach (only codes for anterior fusion or only for transverse process or posterior fusion techniques), and involved only 1 or 2 disk levels (corresponding to the *ICD* code for fusion involving 2 or 3 vertebrae). Complex fusions involved 360° spine fusion by single incision (during the years this code was available); any combination of anterior with either transverse process or posterior fusion techniques; or any fusion of more than 2 disk levels. If the number of levels was not coded, cases were classified by approach only (single vs combined anterior and posterior approach).

### Complications

To study complications, we focused on January 1 to December 1, 2007, providing 30 days of postoperative observation for all patients. The index operation was the first operation meeting our eligibility requirements. We selected only patients aged 66 years or older, so that most would have had a full year of Medicare eligibility to identify recent previous spine surgery, hospitalizations, and comorbid conditions.

Complications in 3 categories were considered: major medical complications, wound complications, and mortality. These may be associated with any surgery and are not specific for lumbar spine surgery. Major medical complications included procedure codes for cardiopulmonary resuscitation or repeat postoperative endotracheal intubation and mechanical ventilation. They included diagnosis codes for cardiorespiratory arrest, acute myocardial infarction, respiratory failure, pulmonary embolism, bacterial pneumonia, aspiration pneumonia, pneumonia with unknown organism, and stroke, excluding late effects. These complications were chosen because of their major effect on health and more consistent coding, in contrast to minor complications.[18]

Wound complications included hemorrhage, hematoma, or seroma complicating a procedure; disruption of operation wound; nonhealing surgical wound; postoperative infection; and other infection. We also included patients with a procedure code for "excisional debridement of wound, infection or burn," or a diagnosis related group code for wound debridement and skin graft.

Mortality was determined from a file identifying date of death. We calculated mortality within 30 days of hospital discharge, including in-hospital death.

### Health Care Use

MedPAR includes length of hospital stay and hospital charges but not professional fees. The file also identifies discharges to a skilled nursing facility. We examined rehospitalizations within 30 days because short-term rehospitalizations are a target for quality improvement,[17] suggesting complications, poor discharge planning, inadequate outpatient follow-up, or other problems.

### Measures of Comorbidity

We modified the comorbidity index of Quan and colleagues.[19,20] We removed codes such as acute myocardial infarction or acute stroke that could represent postoperative complications when recorded at the index hospitalization. However, we used the full index to identify comorbid conditions in any hospitalization during the previous year. We also calculated number of hospitalizations in the year prior to the index hospitalization (excluding those for spine surgery), as a marker of overall disease burden.

### Previous Spine Surgery

We identified patients with previous lumbar surgery in 2 ways. First, we identified diagnosis or procedure codes suggesting previous surgery, such as postlaminectomy syndrome, or refusion. Second, we searched hospitalizations in the previous year to identify lumbar spine procedures.

### Statistical Analysis

Trends in use of surgical procedures were examined using both volume and rates of relevant procedures per 100 000 Medicare beneficiaries. Age and sex were adjusted by the direct method to the 2002 Medicare population. Charges were adjusted for inflation using the health care component of the consumer price index, adjusting to 2009 US dollars.

Proportions of patients with complications, rehospitalizations, or nursing home discharge among subgroups were compared using $\chi^2$ analyses for bivariate analyses and using logistic regression for multivariate analyses. In regressions, these events were modeled as a function of age, race, sex, comorbidity, previous spine surgery, secondary diagnoses of spondylolisthesis or scoliosis, and complexity of surgical procedure.

Length of stay and hospital charges were compared among subgroups with *t* tests or analysis of variance, then modeled in linear regressions. Regressions were performed using untransformed charges because mean estimates were similar to those of alternative approaches that better account for skewed data.[21-24] Means are often sufficient in large data sets.[22] All significance tests were 2-sided, with an $\alpha$ of .05, which we considered to be statistically significant. Statistical analysis was performed with Stata software, version 10 (StataCorp, College Station, Texas).

## RESULTS

### Surgical Trends

In 2007, there were 37 598 operations for a primary diagnosis of lumbar stenosis among patients meeting our criteria. The aggregate hospital bill was nearly US $1.65 billion (2009 dollars). Over the years 2002-2007, the number of operations and the rate per 100 000 beneficiaries decreased slightly (FIGURE). The adjusted rate of lumbar stenosis surgery per 100 000 Medicare beneficiaries was 137.4 in 2002 and 135.5 in 2007.

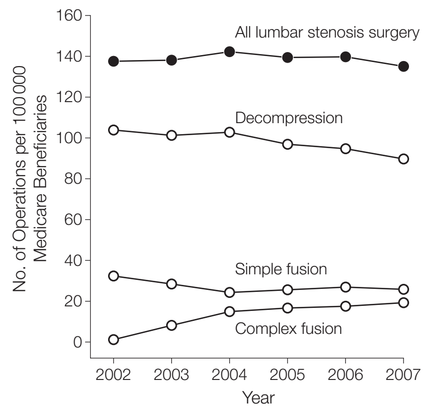
Rates of decompression surgery and simple fusions declined during these years. However, rates of complex fusion surgery increased from 1.3 per 100 000 (just under 1% of operations) to 19.9 per 100 000 (14.6% of operations), a 15-fold increase (Figure). Correspondingly, although the overall procedure rate fell 1.4%, aggregate hospital charges increased 40% (inflation adjusted).

### Complications

The 2007 study cohort, limited to index procedures among patients 66 years or older for 11 months, included 32 152 patients with a mean age of 75.0 years; 54% were women. Among these stenosis patients, 5915 (18.4%) had a secondary diagnosis of spondylolisthesis and 1652 (5.1%) had a secondary diagnosis of scoliosis. These secondary diagnoses increased the likelihood of a fusion procedure (TABLE 1). Patients with scoliosis had the highest percentage of complex fusion procedures. Although patients without spondylolisthesis or scoliosis were less likely to undergo fusion surgery, they accounted for 50% of such procedures.

Major medical complications were reported in 3.1% of patients overall, and wound complications in 1.2%. Mortality was 0.4% within 30 days of discharge. Major medical complications and mortality increased modestly with increasing age and were generally similar for men and women. Major complications and mortality were slightly higher among nonwhite patients than among whites (TABLE 2). Wound complications were not significantly associated with demographic factors.

**Figure.** Surgical Procedures for Lumbar Stenosis per 100 000 Medicare Beneficiaries 65 Years or Older




Adjusted for age and sex by the direct method to the 2002 population.

Major medical complications and mortality rose with increasing comorbidity ($P < .001$ for both). For example, major medical complications occurred in 5.3% of patients with a comorbidity score of 3 or greater compared with 2.5% among those with a score of 0 (Table 2). Complication rates were only modestly affected by comorbid diabetes, obesity, or chronic coronary disease. However, complications and mortality were substantially greater among patients with chronic lung diseases than those without. Hospitalizations in the previous year strongly predicted complications and mortality (Table 2).

Operative features were also associated with complications. Previous spine surgery was modestly associated with medical complications or mortality but was strongly associated with wound complications (4.6% vs 1.0% among those without prior surgery, $P < .001$). The type of index procedure was associated with major medical complica-

**Table 1.** Type of Surgical Procedure Performed According to Combinations of Diagnoses

| | No. of Patients | | | No. (%) of Patients | |
|---|---|---|---|---|---|
| Diagnoses | Total | Decompression Only | Simple Fusion | Complex Fusion[a] | All Fusions[b] |
| Stenosis alone, no spondylolisthesis or scoliosis | 25 060 | 19 699 | 3026 | 2335 (44) | 5362 (21) |
| Stenosis plus spondylolisthesis | 5915 | 1216 | 2793 | 1906 (41) | 4699 (79) |
| Stenosis plus scoliosis | 1652 | 678 | 441 | 533 (55) | 974 (59) |
| Stenosis plus either spondylolisthesis or scoliosis, or both | 7092[c] | 1775 | 3056 | 2261 (43) | 5317 (75) |

[a] The percentage is for the number of fusions for the particular diagnosis.
[b] The percentage is for the number of operations for the particular diagnosis.
[c] This total is less than the sum of patients with spondylolisthesis and patients with scoliosis because these diagnoses are not mutually exclusive, and some patients had both secondary diagnoses. In all cases, spinal stenosis was coded as the primary diagnosis.

**Table 2.** Major Medical Complications, Wound Complications, and Mortality Following Surgery for Lumbar Spinal Stenosis, Patients 66 Years or Older, 2007

| | | No. (%) of Patients | | |
|---|---|---|---|---|
| | No. of Patients | Cardiopulmonary Complications or Stroke | Wound Complication | Thirty-Day Mortality |
| Overall | 32 152 | 984 (3.1) | 398 (1.2) | 128 (0.4) |
| Age, y | | | | |
| 66-70 | 8554 | 215 (2.5)[a] | 98 (1.1) | 27 (0.3)[a] |
| 71-74 | 7383 | 208 (2.8) | 87 (1.2) | 22 (0.3) |
| 75-79 | 8667 | 286 (3.3) | 120 (1.4) | 32 (0.4) |
| ≥80 | 7548 | 275 (3.6) | 93 (1.2) | 47 (0.6) |
| Sex | | | | |
| Women | 17 243 | 512 (3.0) | 219 (1.3) | 56 (0.3)[a] |
| Men | 14 909 | 472 (3.2) | 179 (1.2) | 72 (0.5) |
| Race/ethnicity | | | | |
| White | 30 182 | 913 (3.0)[a] | 374 (1.2) | 116 (0.4)[a] |
| Nonwhite | 1970 | 71 (3.6) | 24 (1.2) | 12 (0.6) |
| Quan comorbidity score | | | | |
| 0 | 16 631 | 412 (2.5)[a] | 199 (1.2)[a] | 43 (0.3)[a] |
| 1 | 9731 | 304 (3.1) | 111 (1.1) | 36 (0.4) |
| 2 | 3432 | 138 (4.0) | 45 (1.3) | 23 (0.7) |
| ≥3 | 2358 | 125 (5.3) | 43 (1.8) | 26 (1.1) |
| Chronic pulmonary disease | | | | |
| Yes | 5525 | 272 (4.9)[a] | 77 (1.4) | 35 (0.6)[a] |
| No | 26 627 | 712 (2.7) | 321 (1.2) | 93 (0.3) |
| Previous spine surgery | | | | |
| Yes | 2196 | 87 (4.0)[a] | 101 (4.6)[a] | [b] |
| No | 29 956 | 897 (3.0) | 297 (1.0) | 121 (0.4) |
| Nonlumbar hospitalizations in previous year | | | | |
| 0 | 24 597 | 700 (2.8)[a] | 288 (1.2)[a] | 82 (0.3)[a] |
| 1 | 4836 | 164 (3.4) | 63 (1.3) | 19 (0.4) |
| 2 | 1689 | 68 (4.0) | 22 (1.3) | 13 (0.8) |
| ≥3 | 1030 | 52 (5.0) | 25 (2.4) | 14 (1.4) |
| Type of surgical procedure | | | | |
| Decompression | 21 474 | 458 (2.1)[a] | 196 (0.9)[a] | 72 (0.3)[a] |
| Simple fusion | 6082 | 285 (4.7) | 100 (1.6) | 28 (0.5) |
| Complex fusion | 4596 | 241 (5.2) | 102 (2.2) | 28 (0.6) |
| No. of disk levels fused | | | | |
| None or unknown | 21 960 | 508 (2.3)[a] | 216 (1.0)[a] | 77 (0.4)[a] |
| 1-2 | 8386 | 356 (4.2) | 133 (1.6) | 31 (0.4) |
| ≥3 | 1806 | 120 (6.6) | 49 (2.7) | 20 (1.1) |

[a] Differences among subgroups significant, $P < .05$.
[b] Suppressed for cell count of 10 or less.

tions, wound complications, rehospitalization, and mortality. For example, complex fusion operations were associated with a 5.2% rate of major medical complications compared with 2.1% for decompression alone, and a 30-day mortality of 0.6% vs 0.3% for decompression (all $P < .05$, Table 2). Results were similar considering only patients without spondylolisthesis or scoliosis.

In a sensitivity analysis, we considered patients with any diagnosis of stenosis (primary or secondary), adding 7561 index operations. Complication estimates were similar and conclusions were unchanged. The most common accompanying diagnoses were spondylolisthesis, scoliosis, and herniated or degenerative disk disease.

In multivariate analyses, we focused on the association of surgical procedure with outcomes, adjusting for age, sex, race, comorbidity, previous hospitalizations, spondylolisthesis, scoliosis, and previous back surgery. We combined major medical complications and 30-day mortality to represent life-threatening complications. Age, comorbidity, and previous hospitalizations remained independently associated with life-threatening complications. Complex fusion procedures had an odds ratio of 2.95 (95% confidence interval, 2.50-3.49) for life-threatening complications compared with decompression alone (TABLE 3). For wound complications, previous surgery and greater surgical complexity were the greatest risk factors after adjustment.

### Health Care Utilization

Length of hospitalization varied only modestly by age, race, or sex. However, it rose with increasing comorbidity or previous hospitalizations. Patients with previous lumbar surgery had almost a day longer hospitalization than those undergoing a first operation. Patients having a complex fusion had almost a 2-day longer stay than those having decompression alone (TABLE 4).

Mean hospital charges decreased with increasing age, perhaps reflecting less complex surgery in the oldest old. Charges increased modestly with increasing comorbidity and more substantially with previous hospitalizations. The greatest variation occurred with type of surgery. Complex fusion operations resulted in mean hospital charges (US $80 888) more than 3 times as those for decompressions alone (US $23 724, Table 4).

Discharges to a skilled nursing facility rose with increasing age, comorbidity, and previous hospitalizations. Among patients 80 years or older, more than 20% were discharged to a skilled nursing facility. Such discharges also rose with increasing surgical complexity. Approximately 20% of those having any fusion procedure were discharged to a skilled nursing facility, twice the percentage as those having decompression alone.

The likelihood of 30-day rehospitalization increased steadily with age, comorbidity, and previous hospitalizations. It also rose with increasing surgical complexity (Table 4). Charges and use patterns were similar among the subgroup with no scoliosis or spondylolisthesis or for those with any diagnosis of stenosis (primary or secondary)

In regression models, length of stay, hospital charges, nursing home discharge, and rehospitalization remained significantly associated with type of surgical procedure after adjustment for patient demographic and clinical characteristics (Table 3).

## COMMENT

Rates of surgery for lumbar stenosis declined slightly from 2002-2007, but use of more complex procedures increased substantially. More complex procedures were associated with greater complications, mortality, hospital charges, and other measures of health care use, even after adjustment for patient demographic and clinical characteristics. Age was less predictive than comorbidity or type of surgical procedure.

It is unclear why more complex operations are increasing. It seems implausible that the number of patients with the most complex spinal pathology increased 15-fold in just 6 years. The introduction and marketing of new surgical devices and the influence of key

**Table 3.** Complications and Health Care Use as a Function of Type of Surgical Procedure[a]

| | Odds Ratio (95% Confidence Interval) | |
|---|---|---|
| Outcome | Simple Fusion | Complex Fusion |
| In-hospital cardiopulmonary or stroke complications | 2.64 (2.24-3.11) | 2.98 (2.51-3.54) |
| Mortality within 30 days | 1.93 (1.21-3.08) | 2.56 (1.61-4.09) |
| Either of the above, "life-threatening complications" | 2.60 (2.21-3.05) | 2.95 (2.50-3.49) |
| Wound complications | 1.59 (1.22-2.08) | 2.02 (1.54-2.64)[b] |
| Length of stay, adjusted mean, d[c] | 4.30 (3.62-5.24) | 4.61 (3.96-5.59)[b] |
| Hospital charges, adjusted mean, US $[c] | 58 511 (56 087-64 987) | 80 888 (78 256-87 422)[b] |
| Nursing home discharge | 2.70 (2.47-2.95) | 2.83 (2.57-3.12) |
| Rehospitalization, any cause, within 30 days | 1.59 (1.44-1.77) | 1.94 (1.74-2.17)[b] |

[a] Odds ratios and adjusted means for measures of complications and health care use are adjusted for age group, sex, race, comorbidity score, number of hospitalizations in the previous year, presence of spondylolisthesis, presence of scoliosis, and previous lumbar surgery, and all odds ratios use decompression alone as the reference category. All differences from decompression are statistically significant. Length of stay and total mean charges are adjusted estimates based on least squares regressions; all others are presented as odds ratios using logistic regression.
[b] Significant difference between complex and simple fusion ($P < .05$).
[c] Reference group (decompression) mean for length of stay was 2.73 days (95 % confidence interval, 2.00-3.68); reference group (decompression) mean for hospital charges was US $23 724 (95% confidence interval, $21 745-$29 656).

**Table 4.** Measures of Health Care Use Related to Surgery for Lumbar Spinal Stenosis, Patients Aged 66 Years or Older, 2007

| | | Mean (SE) | | No. (%) of Patients | |
|---|---|---|---|---|---|
| | No. of Patients | Length of Stay, d | Hospital Charges, US $ | Nursing Home Discharges | Rehospitalization (Any Cause) Within 30 Days |
| Overall | 32 152 | 3.3 (0.02) | 38 476 (123) | 4236 (13.2) | 2936 (9.1) |
| Age, y | | | | | |
| 66-70 | 8554 | 3.0 (0.03)[a] | 40 735 (437)[a] | 566 (6.6)[a] | 627 (7.3)[a] |
| 71-74 | 7383 | 3.2 (0.03) | 39 443 (444) | 709 (9.6) | 601 (8.1) |
| 75-79 | 8667 | 3.3 (0.03) | 37 991 (388) | 1258 (14.5) | 820 (9.5) |
| ≥80 | 7548 | 3.6 (0.04) | 35 526 (382) | 1703 (22.6) | 888 (11.8) |
| Sex | | | | | |
| Women | 17 243 | 3.5 (0.02)[a] | 40 446 (295)[a] | 2848 (16.5)[a] | 1643 (9.5)[a] |
| Men | 14 909 | 3.1 (0.02) | 36 196 (288) | 1388 (9.3) | 1293 (8.7) |
| Race | | | | | |
| White | 30 182 | 3.3 (0.02)[a] | 38 524 (213)[a] | 3958 (13.1)[a] | 2754 (9.1) |
| Nonwhite | 1970 | 3.8 (0.07) | 44 992 (909) | 278 (14.1) | 182 (9.2) |
| Quan comorbidity score | | | | | |
| 0 | 16 631 | 3.1 (0.02)[a] | 37 885 (292)[a] | 1859 (11.2)[a] | 1263 (7.6)[a] |
| 1 | 9731 | 3.3 (0.03) | 38 552 (361) | 1341 (13.8) | 896 (9.2) |
| 2 | 3432 | 3.7 (0.05) | 39 446 (648) | 547 (16.0) | 405 (11.8) |
| ≥3 | 2358 | 4.1 (0.07) | 40 912 (805) | 489 (20.7) | 372 (15.8) |
| Previous spine surgery | | | | | |
| Yes | 2196 | 4.1 (0.07)[a] | 59 309 (1073)[a] | 3957 (12.7) | 258 (11.7)[a] |
| No | 29 956 | 3.2 (0.02) | 36 949 (206) | 279 (13.2) | 2678 (8.9) |
| Hospital stays in previous year, not for spine | | | | | |
| 0 | 24 597 | 3.2 (0.02)[a] | 38 008 (235)[a] | 2897 (11.8)[a] | 1926 (7.8)[a] |
| 1 | 4836 | 3.5 (0.04) | 39 055 (513) | 696 (14.4) | 542 (11.2) |
| 2 | 1689 | 3.8 (0.8) | 40 370 (973) | 350 (20.7) | 249 (14.7) |
| ≥3 | 1030 | 4.9 (0.15) | 43 820 (1403) | 293 (28.4) | 219 (21.3) |
| Type of surgical procedure | | | | | |
| Decompression | 21 474 | 2.7 (0.02) | 23 724 (129)[a] | 2063 (9.6)[a] | 1667 (7.8)[a] |
| Simple fusion | 6082 | 4.3 (0.04) | 58 511 (506) | 1258 (20.7) | 673 (11.1) |
| Complex fusion | 4596 | 4.6 (0.4) | 80 888 (753) | 915 (19.9) | 596 (13.0) |
| No. of disk levels fused | | | | | |
| None or unknown | 21 960 | 2.8 (0.02)[a] | 25 026 (158)[a] | 2180 (9.9)[a] | 1738 (7.9)[a] |
| 1-2 | 8386 | 4.2 (0.03) | 63 506 (429) | 1612 (19.2) | 910 (10.9) |
| ≥3 | 1806 | 5.2 (0.08) | 85 793 (1384) | 444 (24.6) | 288 (15.9) |

[a] Differences among subgroups significant at $P < .05$.

opinion leaders may stimulate more invasive surgery, even in the absence of new indications.[14] Surgeons may believe more aggressive intervention produces better outcomes. Improvements in surgical technique, anesthetic technique, and supportive care may make more invasive surgery feasible when risks formerly would have been prohibitive. Financial incentives to hospitals and surgeons for more complex procedures may play a role as may desires of surgeons to be local innovators.

Geographic variations in spine surgery rates are among the largest observed for surgical procedures, and variations in use of fusion surgery exceed those for decompression alone.[1,25] Such variations persist despite extensive research in this area, in part because of the difficulty of conducting randomized surgical trials. They suggest a poor consensus on indications for surgery or the choice of particular procedures. Studies among spine surgeons indicate substantial variability in decisions to operate, perform a fusion, or use surgical implants.[2,3] Our study shows clinically important consequences of these choices.

Evidence for greater efficacy of more complex procedures for lumbar stenosis is lacking.[26] For patients who also have spondylolisthesis or scoliosis, spinal fusion may improve outcomes over decompression alone.[8,27] However, trials establishing an advantage of surgery over nonsurgical care for stenosis alone focused overwhelmingly on decompression without fusion.[5,6] Some trials for lumbar stenosis suggest equivalent efficacy for decompression alone vs decompression and fusion in the absence of spondylolisthesis.[7]

It is not surprising that fusion procedures are associated with more complications than decompression alone. Compared with decompression, spine fusion requires more extensive dissection, decortication of bone, and longer operative time, and often involves placement of implants. This study confirms previous findings that fusion is associated with greater complications and postoperative mortality than decompression alone.[11,28]

For other indications, randomized trials suggest that fusion by a single approach with bone grafting alone, fusion with implants, and combined anterior and posterior fusion with implants have similar efficacy for improving pain and function.[4,12] For patients with stenosis and degenerative spondylolisthesis, fusions with and without implants have similar clinical outcomes.[8,29,30] However, more complex procedures are associated with more complications.[12,29,31] Complications also increase with more operated levels,[32] and with revision surgery.[7-10,33,34] Our data indicate that these patterns hold true for older patients with spinal stenosis.

Patient demographic and clinical characteristics are generally not matters of choice, but surgeons and patients control the choice of surgical procedure. In the absence of compelling data showing better pain relief or function with more complex surgery, our results may suggest using the least invasive procedure that accomplishes clinical goals. This contrasts with a competing theory that surgeons should correct every anatomic abnormality, hoping to avoid future symptoms. The theory behind this "prophylactic" approach remains unproven, and the risk of greater complications from more extensive surgery must be weighed against potential benefits. Thus, it may be prudent to consider whether decompression alone is sufficient; whether stabilizing structures such as facet joints or interspinous ligaments can be preserved; and if a fusion is planned, how much instrumentation and graft material supplementation is needed.

Our study has the advantage of including all Medicare patients having surgery for spinal stenosis, and not selected patients, centers, or surgeons. It includes nearly complete data on repeat hospitalizations and mortality. However, there are also limitations. Diagnoses and procedures may be miscoded, even though the data are used for billing and subject to audit. Furthermore, spine operations appear to be generally coded accurately.[35] Surgeons use varying definitions of spine instability, and *ICD-9* diagnosis codes may not represent this concept well. The level of detail in *ICD-9* spine surgery codes is limited, and information on use of implants is incomplete. Complications may not be consistently recorded, but surgical complications are more reliably coded in large databases than complications from medical therapy.[18] Furthermore, the complications we examined are more consistently coded than minor complications.[18] The specificity of claims data for complications is high (unlikely to be coded without a real complication), although sensitivity may be lower (some complications not coded). Thus, we are more likely to underestimate than overestimate complication rates.

Surgeons tailor operations to the nature, extent, and location of an individual's pathology, but claims data do not indicate severity or extent of anatomic changes, patient symptoms, or functional status. Nevertheless, studies report substantial variability in surgical decision making, even for similar patients.[1-3] Furthermore, accounting for coexisting spondylolisthesis or scoliosis did not alter our results.

Another limitation is that we have presented hospital charges rather than actual resource costs or reimbursements, which typically are substantially less than charges. The relationship between costs and charges is complex and varies by hospital and by type of service.

Among Medicare recipients, between 2002 and 2007, the frequency of complex fusion procedures for spinal stenosis increased, while the frequency of decompression surgery and simple fusions decreased. In 2007, compared with decompression, simple fusion and complex fusion were associated with increased risk of major complications, 30-day mortality, and resource use.

**Author Contributions:** Dr Deyo and Messrs Martin and Kreuter had full access to the data through 2006; Drs Mirza and Goodman had full access to the data for all years of the study. Drs Deyo, Mirza, and Goodman take responsibility for the integrity of the data; Drs Deyo and Mirza and Messrs Martin and Kreuter take responsibility for the accuracy of the data analysis.
*Study concept and design:* Deyo, Mirza, Martin, Jarvik.
*Acquisition of data:* Deyo, Mirza, Martin, Kreuter, Jarvik.

*Analysis and interpretation of data:* Deyo, Mirza, Martin, Goodman
*Drafting of the manuscript:* Deyo, Mirza
*Critical revision of the manuscript for important intellectual content:* Deyo, Mirza, Martin, Kreuter, Goodman, Jarvik.
*Statistical analysis:* Martin, Kreuter.
*Obtained funding:* Deyo, Mirza, Jarvik
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*Study supervision:* Deyo, Mirza

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