Published in final edited form as:
JAMA. 2010 April 7; 303(13): 1259–1265. doi:10.1001/jama.2010.338.

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

Richard A. Deyo, MD, MPH, **Sohail K. Mirza, MD, MPH**, **Brook I. Martin, MPH**, **William Kreuter, MPA**, **David C. Goodman, MD, MS**, and **Jeffrey G. Jarvik, MD, MPH**
From the Departments of Family Medicine and Medicine, Oregon Health and Science University, and the Kaiser Permanente Center for Health Research, Portland, OR (Dr. Deyo); the Department of Orthopaedics, Dartmouth Medical School; Hanover, NH (Dr. Mirza, Mr. Martin); the Department of Health Services (Mr. Kreuter), and the Departments of Radiology and Neurological Surgery (Dr. Jarvik), University of Washington, Seattle, WA; Center for Health Policy Research at the Dartmouth Institute for Health Policy and Clinical Practice, Lebanon, NH (Dr. Goodman)

Abstract

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 non-operative treatment, but surgeons often recommend more invasive fusion procedures. Comorbidity is common in elderly patients, so benefits and risks must be carefully weighed in the choice of surgical procedure.

Objective—Examine trends in use of different types of stenosis operations and the association of complications and resource use with surgical complexity.

Contact information: Richard A. Deyo MD, MPH, Department of Family Medicine, Mail Code FM, Oregon Health and Science University, 3181 SW Sam Jackson Park Road, Portland, OR 972329, Telephone: 503-494-1694, Fax: 503-494-2746, deyor@ohsu.edu.

Author contributions:
Study Concept and design; analysis and interpretation of data: Deyo, Martin, Kreuter, Jarvik, Mirza, Goodman
Drafting of the manuscript: Deyo, Mirza
Critical revision of the manuscript for important intellectual content: Deyo, Martin, Kreuter, Jarvik, Mirza
Obtained funding; Deyo, Mirza
Administrative and technical support: Martin, Jarvik, Goodman
Access to data: Dr. Jarvik, Mr. Kreuter and Mr. Martin had full access to the data through 2006.
Dr. Mirza and Dr. Goodman had full access to all years of data.

The views and opinions expressed are those of the authors and not necessarily those of the NIH, Oregon Health and Science University, the University of Washington, or Dartmouth College

Disclosures: Dr. Deyo receives honoraria from the non-profit Foundation for Informed Medical Decision Making and from the Robert Wood Johnson Foundation. He holds an endowed chair at Oregon Health and Science University made possible by a gift from Kaiser Permanente. Prior to August 2008, Dr. Deyo and Dr. Mirza's research program benefitted from a gift to the University of Washington from Surgical Dynamics, which was acquired by Stryker Corporation over 5 years ago. Mr. Martin and Mr. Kreuter received partial salary support from this source. Dr. Goodman reports current research funding support from the following sources: Robert Wood Johnson Foundation, Health Resources and Services Administration, the National Institute on Aging (PO1 AG19783), National Cancer Institute, and Wellpoint Foundation. He reports receiving consulting fees from the Vermont Department of Banking, Insurance, Securities and Health Care Administration. He reports speaking fees from: Baystate Medical Center, World Congress, Brigham and Women's Hospital, ESRI Inc, Mt Sinai Hospital, NY,Rutgers University, Midwestern University Arizona College of Osteopathic Medicine, American Medical Association, AMERIGROUP Inc., Alliance for Academic Internal Medicine, New Hampshire American College of Physicians, Connecticut Children's Hospital, Iowa Health Business Alliance, OCS, Inc, Illinois Hospital Association, Richard Stockton College of New Jersey, Health Action Council, Cleveland OH, Texas Medical Association, National Hospice Workgroup, National Association of Health Data Organizations, St. Peters University Hospital, New Brunswick, NJ, Massachusetts Hospital Association.

Role of the Sponsor in the
Design and conduct of the study: none
Collection, management, analysis, and interpretation of the data: none
Preparation, review, or approval of the manuscript: none

Design, Setting, and Patients—Retrospective cohort analysis of Medicare claims for 2002–2007, focusing on 2007 to assess complications and resource use in U.S. 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 (one or two disc levels, single surgical approach) or complex fusion (more than 2 disc 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 to decompression alone was 2.95 (95% 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 $80,888 compared to $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.

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, clinical findings, and the patient's clinical course.

Surgery for spinal stenosis was the fastest-growing type of lumbar surgery in the U.S from 1980 to 2000.[13,14] Randomized trials indicate that for severely affected patients, decompression without fusion offers greater efficacy than non-surgical 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 permit more individualized decision-making. We therefore studied the Medicare population (adults aged 65 and older, 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) healthcare 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 (HMO). The latter are often excluded from Medicare data analyses as 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 and 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 discectomy, laminectomy, or fusion. 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.

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 one or two disc levels (corresponding to the ICD code for fusion involving 2 or 3 vertebrae). Complex fusions involved 360-degree spine fusion by single incision (during years this code was available); any combination of anterior with either transverse process or posterior fusion techniques; or any fusion of more than two disc 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 and older, so that most would have a full prior 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 post-operative 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 impact 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; non-healing 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.

Healthcare utilization

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 two 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 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 dollars.

Proportions of patients with complications, rehospitalizations, or nursing home discharge among subgroups were compared using chi-square analyses for bivariate analyses, and logistic regression for multivariate analyses. In regressions, these events were modeled as a function of age, race, gender, 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 datasets.[22] All significance tests were 2-sided, with an alpha of 0.05. 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 $1.65 billion (2009 dollars). Over the years 2002–2007, the number of operations and the rate per 100,000 beneficiaries declined slightly (Figure 1). 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 1). 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 aged 66 years and older for 11 months, included 32,152 patients with a mean age of 75.0 years; 54% were women. Among these stenosis patients, 5,915 (18.4%) had a secondary diagnosis of spondylolisthesis and 1,652 (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 non-white patients than among Whites (Table 2). Wound complications were not significantly associated with demographic factors.

Major medical complications and mortality rose with increasing comorbidity ($p<0.05$). For example, major medical complications occurred in 5.3% of patients with a comorbidity score of 3 or greater compared to 2.5% among those with a score of zero. (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 strongly associated with wound complications (4.6% vs 1.0% among those without prior surgery, $p<0.05$). The type of index procedure was associated with major medical complications, wound complications, rehospitalization, and mortality. For example, complex fusion operations were associated with a 5.2% rate of major medical complications compared to 2.1% for decompression alone, and a 30-day mortality of 0.6% versus 0.3% for decompression (all $p<0.05$, 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 7,561 index operations. Complication estimates were similar and conclusions were unchanged. The most common accompanying diagnoses were spondylolisthesis, scoliosis, and herniated or degenerative disc disease.

In multivariate analyses, we focused on the association of surgical procedure with outcomes, adjusting for age, gender, 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% CI 2.50, 3.49) for life-threatening complications, compared to 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 gender. 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 ($80,888) over 3 times those for decompressions alone ($23,724, Table 4).

Discharges to a skilled nursing facility rose with increasing age, comorbidity, and previous hospitalizations. Among patients aged 80 and 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 among 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 utilization 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).

DISCUSSION

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 healthcare utilization, 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 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 non-surgical care for stenosis alone focused overwhelmingly on decompression without fusion.[5,6] Some trials for lumbar stenosis suggest equivalent efficacy for decompression alone versus 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 to 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 post-operative 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, 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 Further, the complications we examined are more consistently coded than minor complications.[18] The

NIH-PA Author Manuscript

NIH-PA Author Manuscript

specificity of claims data for complications is high (unlikely to be coded without a real complication), though 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. Nonetheless, studies report substantial variability in surgical decision-making, even for similar patients.[1–3] Further, 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.

Acknowledgments

Supported by NIH/NIAMS Grant # 1R01AR054912-01A2 and NIH/NIA Grant #1RC1AG036268-01.

REFERENCES

1. Weinstein JN, Lurie JD, Olson PR, Bronner KK, Fisher ES. United States trends and regional variations in lumbar spine surgery: 1992–2003. Spine 2006;31:2707–2714. [PubMed: 17077740]
2. Irwin ZN, Hilibrand A, Gustavel M, et al. Variation in surgical decision making for degenerative spinal disorders. Part I: lumbar spine. Spine 2005;30:2208–2213. [PubMed: 16205348]
3. Katz JN, Lipson SJ, Lew RA, et al. Lumbar laminectomy alone or with instrumented or noninstrumented arthrodesis in degenerative lumbar spinal stenosis. Patient selection, costs, and surgical outcomes. Spine 1997;22:1123–1131. [PubMed: 9160471]
4. Fritzell P, Hagg O, Wessbert P, Nordwall A. and the Swedish Lumbar Spine Study Group. 2001 Volvo Award winner in clinical studies: lumbar fusion versus nonsurgical treatment of chronic low back pain: a multicenter randomized controlled trial from the Swedish Lumbar Spine Study Group. Spine 2001;26:2521–2532. [PubMed: 11725230]
5. Weinstein JN, Tosteson TD, Lurie JD, et al. Surgical versus nonsurgical therapy for lumbar spinal stenosis. N Engl J Med 2008;358:794–810. [PubMed: 18287602]
6. Malmivaara A, Slatis P, Heliovaara M, et al. for the Finnish Lumbar Spinal Research group. Surgical or nonoperative treatment for lumbar spinal stenosis? A randomized controlled trial. Spine 2007;32:1–8. [PubMed: 17202885]
7. Grob D, Humke T, Dvorak J. Degenerative lumbar spinal stenosis. Decompression with and without arthrodesis. J Bone Joint Surg Am 1995;77:1036–1041. [PubMed: 7608225]
8. Fischgrund JS, Mackay M, Herkowitz HN, et al. 1997 Volvo Award winner in clinical studies. Degenerative lumbar spondylolisthesis with spinal stenosis: a prospective, randomized study comparing decompressive laminectomy and arthrodesis with and without spinal instrumentation. Spine 1997;22:2807–2812. [PubMed: 9431616]
9. Moller H, Hedlund R. Instrumented and noninstrumented posterolateral fusion in adult spondylolisthesis – a prospective randomized study: part 2. Spine 2000;25:1716–1721. [PubMed: 10870149]
10. Bjarke, Christensen F.; Stender, Hansen E.; Laursen, M.; Thomsen, K.; Bulnger, CE. Long-term functional outcome of pedicle screw instrumentation as a support for posterolateral spinal fusion: randomized clinical study with a 5-year follow-up. Spine 2002;27:1269–1277. [PubMed: 12065973]

11. Ciol MA, Deyo RA, Howell E, Kreif S. An assessment of surgery for spinal stenosis: time trends, geographic variations, complications, and reoperations. J Am Geriatr Soc 1996;44:285–290. [PubMed: 8600197]
12. Fritzell P, Hagg O, Nordwall A. Complications in lumbar fusion surgery for chronic low back pain: comparison of three surgical techniques used in a prospective randomized study. A report from the Swedish Lumbar Spine Study Group. Eur Spine J 2003;12:178–189. [PubMed: 12709856]
13. Taylor VM, Deyo RA, Cherkin DC, Kreuter W. Low back pain hospitalization: recent United States trends and regional variations. Spine 1994;19:1207–1213. [PubMed: 8073311]
14. Deyo RA, Gray DT, Kreuter W, Mirza S, Martin BI. United States trends in lumbar fusion surgery for degenerative conditions. Spine 2005;30:1441–1445. [PubMed: 15959375]
15. Chou R, Helfand M. Challenges in systematic reviews that assess treatment harms. Ann Intern Med 2005;142:1090–1099. [PubMed: 15968034]
16. Schermerhorn ML, O'Malley AJ, Jhaveri A, Cotterill P, Pomposelli F, Landon EE. Endovascular vs. open repair of abdominal aortic aneurysms in the Medicare population. N Engl J Med 2008;358:464–474. [PubMed: 18234751]
17. Jencks SF, Williams MV, Coleman EA. Rehospitalizations among patients in the Medicare fee-for-service program. N Engl J Med 2009;360:1418–1428. [PubMed: 19339721]
18. Lawthers AG, McCarthy E, Davis RB, Teterson LE, Palmer RH, Iezzoni LI. Identification of In-hospital complications from claims data: is it valid? Medical Care 2000;38:785–795. [PubMed: 10929991]
19. Quan H, Sundararajan V, Halfon P, et al. Coding algorithms for defining comorbidities in ICD-9-CM and ICD-10 administrative data. Medical Care 2005;43:1130–1139. [PubMed: 16224307]
20. Deyo RA, Cherkin DC, Ciol MA. Adapting a clinical comorbidity index for use with ICD-9-CM administrative databases. J Clin Epidemiol 1992;45(6):613–619. [PubMed: 1607900]
21. Buntin MB, Zaslavsky AM. Too much ado about two-part models and transformation? Comparing methods of modeling Medicare expenditures. J Health Econ 2004;23:525–542. [PubMed: 15120469]
22. Lumley T, Diehr P, Emerson S, Chen L. The importance of the normality assumption in large public health data sets. Annu Rev Public Health 2002;23:151–169. [PubMed: 11910059]
23. Glick, HA.; Doshi, JA.; Sonnad, SS.; Polsky, D. Economic evaluation of clinical trials. New York: Oxford University Press; 2007.
24. Duan N. Smearing estimate: a nonparametric retransformation method. J Am Stat Assoc 1983;78:605–610.
25. Deyo RA, Mirza SK. Trends and variations in the use of spine surgery. Clin Orthop Rel Res 2006;443:139–146.
26. Deyo RA, Nachemson A, Mirza SK. Spinal fusion surgery – the case for restraint. N Engl J Med 2004;350:722–726. [PubMed: 14960750]
27. Herkowitz HN, Kurz LT. Degenerative lumbar spondylolisthesis with spinal stenosis: a prospective study comparing decompression with decompression and intertransverse process arthrodesis. J Bone Joint Surg Am 1991;73:802–808. [PubMed: 2071615]
28. Deyo RA, Ciol MA, Cherkin DC, Loeser JD, Bigos SJ. Lumbar spinal fusion: a cohort study of complications, reoperations, and resource use in the Medicare population. Spine 1993;18:1463–1470. [PubMed: 8235817]
29. Thomsen K, Christensen FB, Eiskjaer SP, Hansen ES, Fruensgaard S, Bunger CE. 1997 Volvo Award winner in clinical studies. The effect of pedicle screw instrumentation on functional outcome and fusion rates in posterolateral lumbar spinal fusion: a prospective randomized clinical study. Spine 1997;22:2813–2822. [PubMed: 9431617]
30. Abdu WA, Lurie JD, Spratt KF, et al. Degenerative spondylolisthesis: does fusion method influence outcome? Four-year results of the Spine Patient Outcomes Research Trial. Spine. 2009 Sept 14; [epub ahead of print].
31. Mirza SK, Deyo RA, Heagerty PJ, Konodi MA, Lee L, Turner J, Goodkin R. Development of an index to characterize the "invasiveness" of spine surgery: validation by comparison to blood loss and operative time. Spine 2008;33:2651–2661. [PubMed: 18981957]

32. Carreon LY, Puno RM, Dimar JR, Glassman SD, Johnson JR. Perioperative complications of posterior lumbar decompression and arthrodesis in older adults. J Bone Joint Surg 2003:2089–2092. 85-A. [PubMed: 14630835]

33. Glassman SD, Carreon LY, Dimar JR, Campbell MJ, Puno RM, Johnson JR. clinical outcomes in older patients after posterolateral lumbar fusion. Spine J 2007;7:547–551. [PubMed: 17905316]

34. Esses SI, Sachs BL, Dreyzin V. Complications associated with the technique of pedicle screw fixation. A selected survey of ABS members. Spine 1993;18:2231–2239. [PubMed: 8278838]

35. Cherkin DC, Deyo RA. Nonsurgical hospitalization for low-back pain: is it necessary? Spine 1993;18:1728–1735. [PubMed: 8235855]

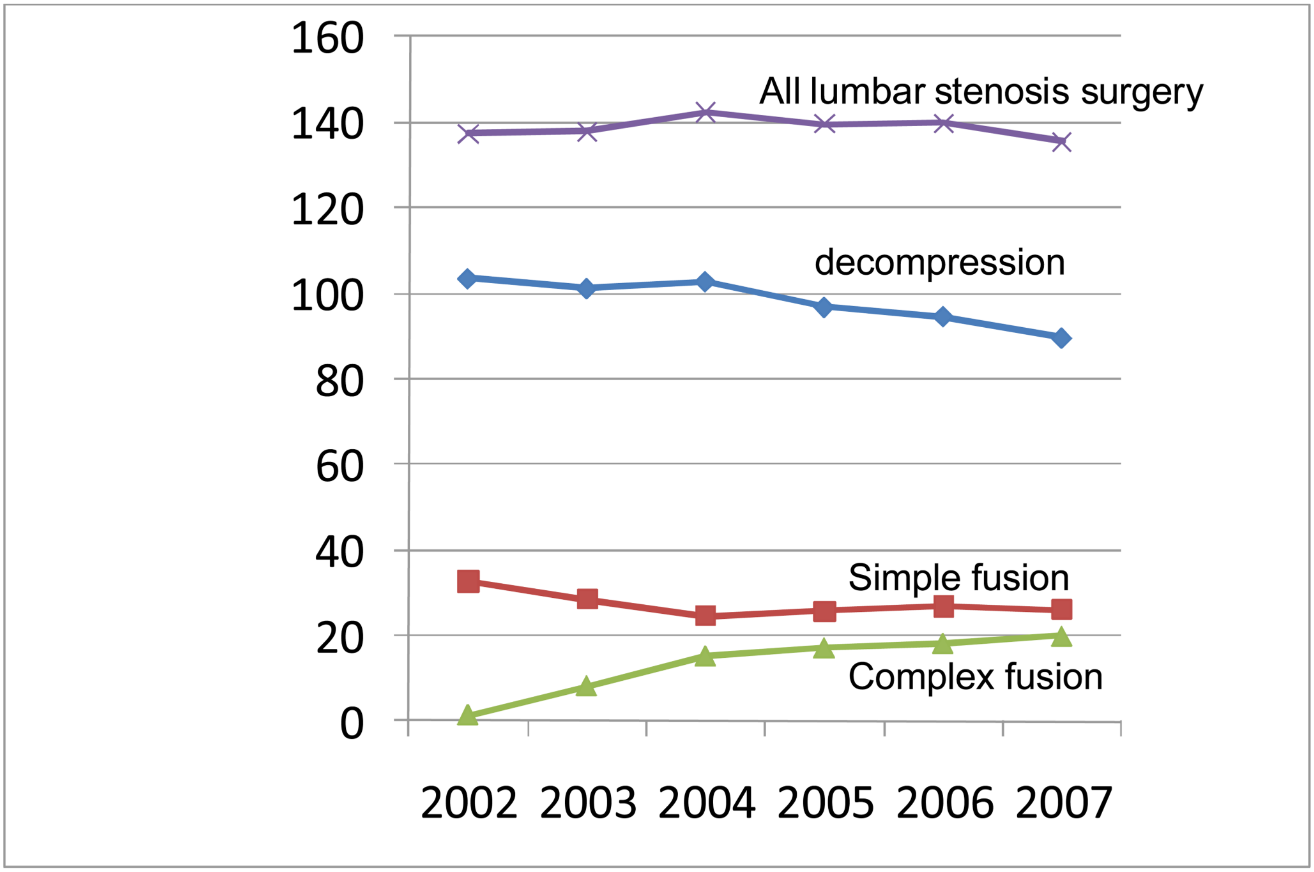

Figure 1.
Rates of surgical procedures for lumbar stenosis per 100,000 Medicare beneficiaries aged 65 and older, age and sex adjusted by the direct method to the 2002 population.*
*Excludes patients enrolled under Social Security Disability Income, End Stage Renal Disease, or Health Maintenance Organizations.

NIH-PA Author Manuscript
NIH-PA Author Manuscript

Table1

Type of surgical procedure performed according to combinations of diagnoses. In all cases, spinal stenosis was coded as the primary diagnosis.

Diagnoses	n	Decompression alone	Simple fusion	Complex fusion	All fusions
Stenosis alone (no spondylolisthesis or scoliosis)	25,060	19,699	3,027	2,335 (44% of fusions for this diagnosis)	5,362 (21% of all operations for this diagnosis)
Stenosis plus spondylolisthesis	5,915	1,216	2,793	1,906 (41% of fusions for this diagnosis)	4,699 (79% of all operations for this diagnosis)
Stenosis plus scoliosis	1,652	678	441	533 (55% of fusions for this diagnosis)	974 (59% of all operations for this diagnosis)
Stenosis plus either spondylolisthesis or scoliosis (or both)	7,092*	1,775	3,056	2,261 (43% of fusions for this diagnosis)	5,317 (75% of all operations for this diagnosis)

* 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

Table 2

Major medical complications, wound complications, and mortality following surgery for lumbar spinal stenosis, patients aged 66 years or older, 2007

		n	Cardiopulmonary complications or stroke,n (percent)	Wound complication, n (percent)	Mortality 30-days, n (percent)
Overall		32,152	984 (3.1%)	398 (1.2%)	128 (0.4%)
Age Category	66–70	8,554	215 (2.5)*	98 (1.1)	27 (0.3)*
	71–74	7,383	208 (2.8)	87 (1.2)	22 (0.3)
	75–79	8,667	286 (3.3)	120 (1.4)	32 (0.4)
	80+	7,548	275 (3.6)	93 (1.2)	47 (0.6)
Sex	Female	17,243	512 (3.0)	219 (1.3)	56 (0.3)*
	Male	14,909	472 (3.2)	179 (1.2)	72 (0.5)
Race/ Ethnicity	White	30,182	913 (3.0)*	374 (1.2)	116 (0.4)*
	Non-White	1970	71 (3.6)	24 (1.2)	12 (0.6)
Quan Comorbidity Score	0	16,631	412 (2.5)*	199 (1.2)*	43 (0.3)*
	1	9,731	304 (3.1)	111 (1.1)	36 (0.4)
	2	3,432	138 (4.0)	45 (1.3)	23 (0.7)
	3 or more	2,358	125 (5.3)	43 (1.8)	26 (1.1)
Chronic Pulmonary disease	Yes	5,525	272 (4.9)*	77 (1.4)	35 (0.6)*
	No	26,627	712 (2.7)	321 (1.2)	93 (0.3)
Previous spine surgery	Yes	2,196	87 (4.0)*	101 (4.6)*	--**
	No	29,956	897 (3.0)	297 (1.0)	121 (0.4)
Non-lumbar Hospitalizations in previous year	0	24,597	700 (2.8)*	288 (1.2)*	82 (0.3)*
	1	4,836	164 (3.4)	63 (1.3)	19 (0.4)
	2	1,689	68 (4.0)	22 (1.3)	13 (0.8)
	3 or more	1030	52 (5.0)	25 (2.4)	14 (1.4)
Type of surgical procedure	Decompression	21,474	458 (2.1)*	196 (0.9)*	72 (0.3)*
	Simple fusion	6,082	285 (4.7)	100 (1.6)	28 (0.5)
	Complex fusion	4,596	241 (5.2)	102 (2.2)	28 (0.6)
Number of disc levels fused	None or unknown	21,960	508 (2.3)*	216 (1.0)*	77 (0.4)*
	1–2	8,386	356 (4.2)	133 (1.6)	31 (0.4)

NIH-PA Author Manuscript
NIH-PA Author Manuscript

	n	Cardiopulmonary complications or stroke,n (percent)	Wound complication, n (percent)	Mortality 30-days, n (percent)
3 or more	1,806	120 (6.6)	49 (2.7)	20 (1.1)

* Differences among subgroups significant, $p<0.05$

** Suppressed for cell count less than 10

Table 3

Complications and health care utilization as a function of type of surgical procedure. 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. All odds ratios use decompression alone as the reference category. All differences from decompression are statistically significant*

Outcome	Simple fusion	Complex fusion
In-hospital cardiopulmonary or stroke complications, O.R. (95% CI)	2.64 (2.24, 3.11)	2.98 (2.51, 3.54)
Mortality within 30 days O.R. (95% CI)	1.93 (1.21, 3.08)	2.56 (1.61, 4.09)
Either of the above (“life-threatening complications”), O.R. (95% CI)	2.60 (2.21, 3.05)	2.95 (2.50, 3.49)
Wound complications, O.R. (95% CI)	1.59 (1.22, 2.08)	2.02 (1.54, 2.64) †
Length of stay, days: adjusted mean (95% CI)#	4.30 (3.62, 5.24)	4.61 (3.96, 5.59) †
Hospital charges, adjusted mean (95% CI)#	$58,511 (56,087, 64,987)	$80,888 (78,256, 87,422)†
Nursing home discharge, O.R. (95% CI)	2.70 (2.47, 2.95)	2.83 (2.57, 3.12)
Rehospitalization (any cause) within 30 days, O.R. (95% CI)	1.59 (1.44, 1.77)	1.94 (1.74, 2.17) †

*Length of stay and total mean charges are adjusted estimates based on least squares regressions; all other presented as Odds Ratios (OR) using logistic regression.

†Significant difference between complex and simple fusion (p<.05).

#Reference group (decompression) mean for length of stay=2.73 days (CI 2.00, 3.68); reference group (decompression) mean for hospital charges= $23,724 (CI 21,745, 29,656)

Table 4

Measures of health care utilization related to surgery for lumbar spinal stenosis, patients aged 66 years or older, 2007

		n	Mean Length of stay, days(SE)	Mean hospital charges, $ (SE)	Nursing home discharges, n (percent)	Rehospitalization (any cause) within 30 days, n (percent)
Overall		32,152	3.3 (0.02)	$38,476 (123)	4,236 (13.2)	2,936 (9.1)
Age	66–70	8,554	3.0 (0.03)*	40,735 (437)*	566 (6.6)*	627 (7.3)*
	71–74	7,383	3.2 (0.03)	39,443 (444)	709 (9.6)	601 (8.1)
	75–79	8,667	3.3 (0.03)	37,991 (388)	1,258 (14.5)	820 (9.5)
	80+	7,548	3.6 (0.04)	35,526 (382)	1,703 (22.6)	888 (11.8)
Sex	Female	17,243	3.5 (0.02)*	40,446 (295)*	2,848 (16.5)*	1,643 (9.5)*
	Male	14,909	3.1 (0.02)	36,196 (288)	1,388 (9.3)	1,293 (8.7)
Race	White	30,182	3.3 (0.02)*	38,524 (213)*	3,958 (13.1)*	2,754 (9.1)
	Non-white	1,970	3.8 (0.07)	44,992 (909)	278 (14.1)	182 (9.2)
Quan comorbidity score	0	16,631	3.1 (0.02)*	37,885 (292)*	1,859 (11.2)*	1,263 (7.6)*
	1	9,731	3.3 (0.03)	38,552 (361)	1,341 (13.8)	896 (9.2)
	2	3,432	3.7 (0.05)	39,446 (648)	547 (16.0)	405 (11.8)
	3+	2,358	4.1 (0.07)	40,912 (805)	489 (20.7)	372 (15.8)
Previous Spine surgery	Yes	2,196	4.1 (0.07)*	59,309 (1,073)*	3,957 (12.7)	258 (11.7)*
	No	29,956	3.2 (0.02)	36,949 (206)	279 (13.2)	2,678 (8.9)
Hospital stays in previous year (not for spine)	0	24,597	3.2 (0.02)*	38,008 (235)*	2,897 (11.8)*	1,926 (7.8)*
	1	4,836	3.5 (0.04)	39,055 (513)	696 (14.4)	542 (11.2)
	2	1,689	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)*	2,063 (9.6)*	1,667 (7.8)*
	Simple fusion	6,082	4.3 (0.04)	58,511 (506)	1,258 (20.7)	673 (11.1)
	Complex fusion	4,596	4.6 (0.4)	80,888 (753)	915 (19.9)	596 (13.0)
Number of Disc levels fused	None or unknown	21,960	2.8 (0.02)*	25,026 (158)*	2,180 (9.9)*	1,738 (7.9)*
	1–2	8,386	4.2 (0.03)	63,506 (429)	1,612 (19.2)	910 (10.9)

	n	Mean Length of stay, days(SE)	Mean hospital charges, $ (SE)	Nursing home discharges, n (percent)	Rehospitalization (any cause) within 30 days, n (percent)
3 or more	1,806	5.2 (0.08)	85,793 (1,384)	4,44 (24.6)	288 (15.9)

*Differences among subgroups significant at $p<0.05$