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Use of Bone Morphogenetic Proteins in Spinal Fusion Surgery for Older Adults with Lumbar Stenosis: Trends, Complications, Repeat Surgery, and Charges

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Abstract

Study Design—Retrospective cohort study of Medicare claims.

Objective—Examine trends and patterns in the use of bone morphogenetic proteins (BMP) in surgery for lumbar stenosis; compare complications, reoperation rates, and charges for patients undergoing lumbar fusion with and without BMP.

Summary of Background Data—Small randomized trials have demonstrated higher rates of solid fusion with BMP than with allograft bone alone, with few complications, and in some studies, reduced rates of revision surgery. However, complication and reoperation rates from large population-based cohorts in routine care are unavailable.

Methods—We identified patients with a primary diagnosis of lumbar stenosis who had fusion surgery in 2003 or 2004 (n=16,822). We identified factors associated with BMP use; major medical complications during the index hospitalization, rates of rehospitalization within 30 days, and rates of reoperation within 4 years of follow-up (through 2008).

Results—Use of BMP increased rapidly, from 5.5% of fusion cases in 2003 to 28.1% of fusion cases in 2008. BMP use was greater among patients with previous surgery and among those having complex fusion procedures (combined anterior and posterior approach, or greater than 2 disc levels). Major medical complications, wound complications, and 30-day rehospitalization rates were nearly identical with or without BMP. Reoperation rates were also very similar, even after stratifying by previous surgery or surgical complexity, and after adjusting for demographic and clinical features. On average, adjusted hospital charges for operations involving BMP were about \$15,000 greater than hospital charges for fusions without BMP, though reimbursement under Medicare's Diagnosis-Related Group (DRG) system averaged only about \$850 greater. Significantly fewer patients receiving BMP were discharged to a skilled nursing facility (15.9% vs. 19.0%, $p<0.001$).

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Conclusion—In this older population having fusion surgery for lumbar stenosis, uptake of BMP was rapid, and greatest among patients with prior surgery or having complex fusion procedures. BMP appeared safe in the perioperative period, with no increase in major medical complications. Use of BMP was associated with greater hospital charges but fewer nursing home discharges, and was not associated with reduced likelihood of reoperation.

Keywords

bone morphogenetic protein; spinal stenosis; lumbar fusion; reoperations

Bone morphogenetic proteins (BMP) were approved for use in spine surgery by the U.S. Food and Drug Administration (FDA) late in 2002. Two BMP products are approved in the U.S., both for use in conjunction with lumbar fusion surgery. These products were developed with the goals of increasing the likelihood of solid bone fusion and decreasing the need for iliac crest bone autograft in lumbar fusion procedures. By improving the likelihood of solid fusion, use of BMP might also reduce the need for subsequent revision surgery.

Randomized controlled trials (RCTs) have suggested that, compared to fusion procedures without BMP, these products increase the likelihood of solid fusion.^{1–5} A smaller number of trials has examined the probability of repeat surgery, and suggests that repeat surgery is decreased with the use of BMP.^{3–6} However, these trials have been small, and other studies have yielded conflicting results.^{1,7} A meta-analysis favored BMP, but the difference in reoperation rates was not statistically significant.⁸

Most studies have included relatively few older adults, who are most likely to have surgery for spinal stenosis. However, a recent report noted that solid fusion rates – with or without BMP – were lower among adults over age 65 than among younger adults. The authors attributed this to weakened osteoinductive capacity in elderly patients.⁹

Several important questions remain regarding the use of BMPs. Patterns of use have not been well characterized. It is unclear, for example, whether BMP is being reserved for complex fusions, such as those involving multiple levels or revision operations, or is used more generally in less complex procedures, as well. There has been little surveillance since its introduction to assess the impact on reoperation rates in routine practice, outside the tightly controlled conditions of randomized trials.

We therefore undertook an assessment of BMP use among Medicare patients undergoing surgery for spinal stenosis. Our goals were to:

1. Examine trends in the use of BMP for this population
2. Compare patients undergoing fusion with and without BMP to determine if there are differences in previous surgery, type of procedure performed, patient demographics, or comorbidity
3. Examine hospital charges for surgery with and without BMP
4. Examine rates of complications and of repeat surgery following fusion procedures with and without BMP, adjusting for any differences in patient demographic characteristics, procedural details, or comorbid medical conditions.

METHODS

Data Source

We used the Medicare Provider Analysis and Review (MedPAR) database for the years 2002–2008 to examine trends in the use of BMP. This database includes all Medicare hospital claims and uses surgical procedure codes from the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM). We restricted analysis to Medicare beneficiaries who were eligible through the Old Age and Survivors Insurance program, excluding those receiving Social Security Disability Income or having end-stage renal disease. We excluded patients enrolled in a health maintenance organization at the time of the index visit, because patients with prepaid insurance may not have complete claims data. This exclusion is common in studies of Medicare utilization.^{10,11}

Data on mortality were obtained from another file maintained by the Centers for Medicare and Medicaid Services. These files have unique patient identifiers, allowing linkage of data from multiple files and identification of repeat hospitalizations. Institutional Review Boards at the University of XX and the XX Health and Science University approved the project.

Categorizing Surgical Procedures

We defined 2 categories of spine surgery, labeled simple fusion or complex fusion. A simple fusion included codes only for anterior fusion techniques or only for transverse process or posterior fusion techniques and involved only one or two disc levels (2 or 3 vertebrae) or an unreported number of disc levels. Complex fusions were those coded as 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 involving more than two disc levels. We did not examine off-label use of BMP in the cervical spine.

Trends in use of BMP

To examine trends in the use of BMP, we selected patients aged 65 years and older with a primary diagnosis of lumbar stenosis (98.2% of cases) or “spondylogenic compression of lumbar spinal cord” (1.8% of cases). We then identified those having any code for spinal fusion or refusion. We excluded patients if any diagnosis in the surgical hospitalization indicated cancer, vehicular accident, spinal infection, inflammatory spondyloarthropathies, vertebral fractures or dislocations, or cervical or thoracic spine procedures.

Characteristics of patients receiving BMP

To compare patients having fusions with or without BMP, we restricted analysis to patients having an index fusion operation in the years 2003 and 2004. An index operation was an individual's first operation that met eligibility criteria. This provided a minimum of 4 years of to track reoperations for all patients. ICD procedure code 84.52 identified patients who received BMP. We further required that patients be aged 68 years or greater, providing 3 years of prior Medicare eligibility for most patients, to help identify any lumbar surgery prior to the index visit, and comorbid conditions. In a sensitivity analysis, we examined whether choosing patients aged 66 and over, with just one year to “look back,” affected the conclusions.

Complications

Complications in three categories were considered: major medical complications, wound complications, and mortality. Major medical complications included procedure codes for cardiopulmonary resuscitation, and for endotracheal intubation and mechanical ventilation. They included the 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 the likelihood that they would be consistently coded, in contrast to minor complications.^{12,13}

Wound complications included diagnosis codes for 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. Only complications coded during the index hospitalization were included.

Using date of death, we calculated mortality within 30 days of hospital discharge (including patients who died in hospital).

Healthcare utilization

MedPAR includes hospital charges, but not professional fees. We examined both hospital charges and actual Medicare reimbursements. Charges and reimbursements were adjusted to 2004 dollars using the medical component of the Consumer Price Index. 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,¹¹ suggesting complications, poor discharge planning, inadequate outpatient follow-up, or other problems.

Reoperations after the index procedure

For analysis purposes, we counted only the first reoccurrence of lumbar surgery following the index operation. We used the term “repeat surgery” or “reoperation” to indicate any subsequent operation, even though 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 at these reoperations.

Previous spine surgery

We identified patients who had had lumbar surgery prior to the index operation in two ways. First, we identified ICD-9-CM codes that indicated previous surgery, such as postlaminectomy syndrome, aftercare involving an internal fixation device, refusion, reopening of a laminectomy site, and removal of a device from bone. Second, we searched hospitalizations in the previous 3 years to identify previous lumbar spine procedures. This was our primary analysis, though we also examined the results including younger subjects (age 66 or greater) with just 1 previous year to “look back”.

Measures of Comorbidity

We modified the comorbidity index of Quan and colleagues,¹⁴ updating our adaptation of the Charlson index.¹⁵ We removed Quan index codes that could represent postoperative complications when recorded at the index hospitalization. Examples included codes for congestive heart failure, acute myocardial infarction, acute stroke, and renal dialysis. However, we used the full Quan index to search for comorbid conditions on any hospitalization during the year prior to the index hospitalization. Thus, our modified score included conditions coded in previous hospitalizations and the index hospitalization. For analysis, we dichotomized the Quan comorbidity score as any or none. In addition, we calculated the number of hospitalizations in the year prior to the index hospitalization, as a crude measure of overall disease burden (excluding previous hospitalizations for spine surgery).

Statistical Analysis

Trends in use of BMP were examined both as numbers of procedures involving BMP in each year, and as a percentage of all fusion operations each year.

Complications, mortality, reoperations and charges were compared between patients operated with and without BMP using chi-square analyses for categorical variables and t-tests for charges. Because use of BMP was more common among patients with previous spine surgery and among those having complex fusion procedures, we also examined patient outcomes stratified by these features.

To adjust for possible confounding, we also compared these outcomes in multivariate regression models. In these regressions, the probability of a complication or reoperation was modeled as a function of BMP use, along with age, race, gender, comorbidity, previous spine surgery, previous hospitalizations without spine surgery, presence of spondylolisthesis, presence of scoliosis, and complexity of the fusion procedure. In multivariate models for charges or reimbursements, we included an interaction term between BMP use and surgical complexity, because the association between BMP and charges or reimbursements differed with surgical complexity.

To study reoperations, we also used time-to-an-event statistical methods (“survival” analysis), with the event being a second lumbar operation. We focused on the cumulative probability of reoperation for procedures performed with and without BMP. Time to reoperation was calculated as days between hospital discharge for the index operation and the date of admission for the first subsequent lumbar operation. We used Cox proportional hazards regression to adjust for age group, gender, race, comorbidity score, previous hospitalization, lumbar surgery prior to the index operation, simple vs. complex fusion, presence of spondylolisthesis and presence of scoliosis. We assessed the model with hazard plots and tests of Schoenfeld residuals, and the proportionality assumption was met. Visually, however, the survival curves suggested a cross-over of reoperation probabilities between 1 and 2 years of follow-up, so we also analyzed the data with a time-varying covariate to estimate hazard ratios before and after 1 year of follow-up.

RESULTS

Trends in use of BMP

Use of BMP increased rapidly after its introduction in 2002. In our Medicare sample, only 39 cases of its use were recorded in 2002, but there were 588 cases in 2003, the first full year of availability. By 2008, this figure had increased to 3,585 cases (Figure 1a). As a percent of all fusion operations, BMP use increased from 5.5% in 2003 to 28.1% in 2008 (Figure 1b).

Characteristics of patients having surgery with and without BMP

Patients having fusion surgery with or without BMP had similar ages (74.9 years and 75.3 years, respectively), a difference that was statistically significant, but clinically trivial. There were no significant gender or race differences between the groups (Table 1). The group receiving BMP was more likely to have had previous spine surgery than those who did not receive BMP (21.5% vs. 14.4%, $p<0.001$), and those receiving BMP were more likely to have a complex fusion procedure at the index operation (40.5% vs. 28.6%, $p<0.001$) (Table 1). Nonetheless, a majority of BMP use (59.5%) was for simple fusions, and 78.5% was in patients with no evidence of previous surgery. Almost half the BMP use (48.6%) was for patients with neither previous surgery nor complex fusions.

Similar proportions of fusions performed with and without BMP had secondary diagnoses of spondylolisthesis or scoliosis. The groups with and without BMP had no significant differences in comorbidity score, recorded diagnoses of diabetes or smoking, or number of hospitalizations in the past year (Table 1). In summary, the groups were similar in demographic characteristics and comorbidity, but those receiving BMP were more likely to have had previous spine surgery, and were more likely to be undergoing complex fusion procedures.

Complications

There were no statistically significant or clinically relevant differences in perioperative complication rates between the groups with and without BMP (Table 2). This was true for major medical complications, wound complications, 30-day mortality, and rehospitalizations within 30 days. In logistic regression models adjusting for age, sex, race, comorbidity score, previous hospitalizations without spine surgery, previous spine surgery, previous hospitalizations, simple or complex fusion, and presence of spondylolisthesis or scoliosis, all differences between the BMP and no-BMP groups remained small and non-significant. Our definitions of “simple” and “complex” fusions incorporated a dichotomous indication of number of levels fused, but as a sensitivity analysis, we also performed regressions including all the ICD-9 indicators of number of levels fused (2–3 vertebrae, 4–8 vertebrae; ≥ 9 vertebrae). This had little effect on the regression results, significance, or conclusions. As expected, fusion complexity and number of levels fused were highly collinear.

Reoperations

The probability of repeat surgery was nearly identical for the 2 groups. For patients who received BMP, the rate of repeat surgery was 2.7% at one year and 6.3% at 2 years, compared with 2.9% and 6.0% for the group without BMP. At 4 years, the reoperation rates were 10.8% for fusions with BMP and 10.5% for those without (Table 2).

Because any advantage of BMP in reducing reoperation rates might only be apparent among patients with previous spine surgery or those with complex fusion procedures, we examined these subgroups in stratified analyses. Among patients with previous surgery, the percentage with reoperations at one year was slightly lower with BMP, but the difference was not statistically significant. By 2 years, the differences were even smaller and remained nonsignificant, and this remained true at 4 years (Table 3). Similarly, when we separately examined simple vs. complex fusions, the differences in reoperations up to 4 years were clinically trivial and statistically non-significant (Table 3). There was no trend favoring BMP. All of the results for complications and reoperations changed only trivially (by less than 1%) when we included patients aged 66 and older, rather than 68 and older.

In proportional hazards models, adjusted for age, sex, race, comorbidity score, previous hospitalizations without spine surgery, previous spine surgery, simple vs. complex fusion, presence of spondylolisthesis and presence of scoliosis, curves for the cumulative probability of reoperation for fusions with and without BMP were very similar through 4 years of follow-up (Figure 2). The hazard ratio for fusions with BMP vs. those without was 0.96 (95% CI 0.83, 1.12; $p=0.629$). When a time-varying covariate was added, the reoperation rate during the first year was non-significantly lower with BMP (HR 0.83; 95% CI 0.61, 1.12), and after the first year it was non-significantly higher (HR 1.02; 95% CI 0.85, 1.22). As with complications, adding number of levels fused to the model had little effect, because the definition of complex fusion incorporated an indicator of levels fused.

To assess reasons for reoperation, we examined diagnosis and procedure codes at the time of reoperation. The proportion with “arthrodesis status” coded, implying concern about

possible pseudarthrosis, was nearly identical (24.6% vs. 21.5% for reoperations following surgery with and without BMP respectively, $p=0.34$). The same was true for device complications (25.1% vs. 24.8% for reoperations following surgery with and without BMP, respectively $p = 0.91$).

Healthcare Utilization

For these operations in 2003 and 2004, average hospital charges for fusions without BMP were \$48,130, and for those with BMP they were \$63,929 (Table 2). In a linear regression model adjusted for age, sex, race, comorbidity score, previous lumbar surgery, simple or complex fusion, and presence of spondylolisthesis or scoliosis, these figures changed modestly. The adjusted estimate for fusion with BMP was \$62,779 (95% CI 60,921 – 64,637), significantly greater than charges without BMP (\$47,199; 95% CI 46,665, 47,737) ($p<0.001$). Thus, operations involving BMP incurred on average \$15,580 higher charges than operations without, a relative increment of 33.0%. However, actual Medicare reimbursements under the DRG prospective payment system were much lower, and the difference smaller. The adjusted reimbursement for fusions with BMP was \$18,189, and reimbursement for fusions without BMP was \$17,345 ($p<0.001$).

Mean hospital stays for the two groups were identical at 4.9 days ($p = 0.75$). and the median stay was 4.0 days in both groups. Patients receiving BMP were significantly less likely to be discharged to a skilled nursing facility than those who did not receive BMP (15.9% vs. 19.0%, $p<0.001$)

DISCUSSION

Surgeons rapidly adopted BMP for fusion surgery in this older population, though evidence for its efficacy and safety in this age group was sparse. It was used in a greater proportion of revision operations than first-time surgery, and more in complex fusions than in simple fusions. Nonetheless, about half the use of BMP was not for these more involved procedures. Complication rates were nearly identical for procedures performed with or without BMP, supporting its short-term safety in the lumbar spine.

Rates of revision surgery were equivalent following surgery with or without BMP. This remained true even in stratified or multivariate analyses to adjust for surgical complexity or for previous lumbar surgery. The use of BMP was associated with \$15,000 greater average hospital charges than for fusion surgery without BMP, though the difference in actual reimbursement was much smaller (about \$850). Some of the charge difference may be related to factors other than BMP alone, but the difference persisted in models adjusting for previous surgery, simple or complex fusion, and coexisting scoliosis or spondylolisthesis. Patients receiving BMP were less likely to be discharged to a skilled nursing facility for unclear reasons. This could be a result of less donor site morbidity related to autograft harvesting, unmeasured differences between the BMP and non-BMP groups in this non-randomized comparison, or other factors. If the finding is robust, it could reduce the cost impact of BMP.

The results for reoperation superficially contradict the evidence from 2 small randomized trials that found a lower rate of reoperation after fusions with BMP. However, there may be several explanations for this disparity. First, use of new technology in routine care, outside the confines of randomized trials, is sometimes less effective or safe than trials suggest.^{16,17} This may occur because routine use includes patients with characteristics that were excluded from trials; because average clinicians are less expert than those involved in trials; or because of more patients and longer follow-up in routine care. Second, BMP may be less effective in elderly patients than in the younger patients who were the majority in clinical

trials. This might be a result of differences in bone density or osteoinductive capacity. Third, BMP may produce a higher rate of solid fusion, without necessarily reducing reoperation rates. This could occur if symptom improvement and solid fusion are only loosely related, as some studies have reported.^{18,19} These data do not allow a direct measure of solid fusion rates. Fourth, there is evidence that a large fraction of BMP use has been off-label,²⁰ and such use may be less effective than strictly on-label use. Our results may not apply to newer BMP preparations under review at the FDA.

These results suggest that BMP may add substantial cost to fusion procedures, with little improvement in subsequent reoperation rates. Some investigators have used the assumption of reduced reoperations in estimating a favorable cost-effectiveness of BMP, despite the added procedure cost.²¹ Our results question this assumption, and may be important in future cost-effectiveness calculations, at least among older adults having surgery for lumbar stenosis. However, reduced nursing home use could mitigate increased costs.

This study included nearly all Medicare patients having surgery primarily for spinal stenosis, and not selected patients, centers, or surgeons. The data are nearly complete for repeat surgery or hospitalization and for mortality. However, there are important limitations. First, diagnoses and procedures may not be accurately coded, although the data are used for billing and are subject to audit. We and others have found that surgical procedures, and spine operations in particular, appear to be generally coded accurately.²²⁻²⁴ Similarly, complications may not be consistently recorded, but surgical complications are more reliably coded in Medicare data than complications from medical therapy.^{13,14} Further, the major complications we examined are more consistently coded than minor complications.^{13,14} The detail in ICD-9-CM spine surgery codes is limited, and information on implants is incomplete.

Second, we have no data on pain, function, or symptomatic outcomes. At least one small study showed a difference in patient-reported outcomes between BMP and autograft populations.¹ Similarly, we cannot determine possible effects of BMP in reducing symptoms or complications from iliac crest bone graft donor sites, although the differences in discharge disposition between groups may be related to these factors. We also have no data on possible long-term complications of BMP, such as ectopic bone formation.

Third, there may be unmeasured differences between the two study populations. We used a well-established index of medical comorbidities, and examined recent hospitalizations as a marker of comorbid illness. We also stratified and adjusted for previous surgery and surgical complexity. However, surgeons may have identified other risk factors for pseudarthrosis or likelihood of additional surgery that were not recorded in the database. For instance, we cannot identify whether there was a higher rate of instrumentation in the autograft group, a potential confounding factor for revision surgery rates.⁸ Thus, it is possible that BMP had a beneficial effect in reducing reoperation rates of more complex patients (in ways we could not measure) to the same rate as that for less complex patients.

Finally, we have reported hospital charges and reimbursements, rather than actual resource costs. Despite adjustment for previous surgery, surgical complexity, measures of comorbidity, and the presence of deformity, the differences in charges between operations with and without BMP may have been influenced by unmeasured factors other than the cost of BMP alone. Further, we have not assessed post-hospital rehabilitation costs, which may differ for the groups with and without BMP.

Thus, our design provided excellent data on trends in BMP use and rates of revision surgery among patients who had fusion procedures with or without BMP. However, we could not fully determine the reasons for revision, describe patient reported outcomes, or determine if

there are subtle differences between the population receiving BMP and the population who did not.

Further study in this older population is justified, to better characterize the value of BMP in this context. Our findings suggest the value of studying effectiveness in routine care to complement evidence from randomized efficacy trials. They also suggest the importance of studying the effectiveness of new technology in the full range of patient demographics and indications in which it may be used.

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Figure 1.
Trends in the use of BMP for lumbar fusion in older adults having surgery for spinal stenosis, Medicare population

Figure 2.

Cumulative probability of a second operation for fusions performed with or without BMP. In a proportional hazards model adjusted for age, sex, race, comorbidity score, any previous non-surgical hospitalizations, previous spine surgery, simple vs. complex fusion, presence of spondylolisthesis and presence of scoliosis, the hazard ratio for BMP was 0.96 (95% CI 0.83, 1.12; $p=0.63$). When analyzed with a time-varying covariate, the HR for the first year was non-significantly lower with BMP (HR 0.825; 95% CI 0.61, 1.12), and after the first year it was non-significantly higher (HR 1.02; 95% CI 0.85, 1.22).

Baseline patient and procedure characteristics overall, and by use of BMP. Medicare patients aged 68 and older; first stenosis fusion operation in 2003 or 2004.

Table 1

Baseline Characteristic		n	No. (%) of patients			p-value *
			All patients n=16,822	Fusion with BMP n=1,703	Fusion without BMP n=15,119	
Mean Age, years			75.3 (4.8)	74.9 (4.7)	75.3 (4.9)	0.001
Gender	Female	11,000	11,000 (65.4)	1114 (65.4)	9886 (65.4)	0.98
	Male	5,822	5822 (34.6)	589 (34.6)	5233 (34.6)	
Race, %	White	15,760	15,760 (93.7)	1,582 (92.9)	14,179 (93.8)	0.27
	Black	643	643 (3.8)	77 (4.5)	566 (3.7)	
	Other/Unknown [†]	419	419 (2.5)	44 (2.6)	375 (2.5)	
	Yes	2,547	2,547 (15.1)	366 (21.5)	2,181 (14.4)	
Previous Spine surgery	Simple fusion	11,806	11,806 (70.2)	1014 (59.5)	10,792 (71.4)	<0.001
	Complex fusion	5,016	5,016 (29.8)	689 (40.5)	4,327 (28.6)	
Number of disc levels fused	Unknown	7,511	7,511 (44.7)	357 (21.0)	7,154 (47.3)	<0.001
	1-2	7,380	7,380 (43.9)	1,050 (61.7)	6,330 (41.9)	
	3 or more	1,931	1,931 (11.5)	296 (17.4)	1,635 (10.8)	
	Yes	7,535	7,535 (44.8)	721 (42.3)	6,814 (45.1)	
Spondylolisthesis	Yes	1,863	1,863 (11.1)	206 (12.1)	1,657 (11.0)	0.03
Scoliosis	Yes	3,420	3,420 (20.3)	366 (21.5)	3,054 (20.2)	0.16
Diabetes	Yes	831	831 (4.9)	87 (5.1)	744 (4.9)	0.21
Smoker	Yes	8,522	8,522 (50.7)	841 (49.4)	7,681 (50.8)	0.74
Quan Comorbidity score	0	8,300	8,300 (49.3)	862 (50.6)	7,438 (49.2)	0.27
Hospitalizations in previous year (not spine surgery)	1 or more	12,742	12,742 (76.0)	1,289 (75.7)	11,453 (75.6)	0.79
	0	2,507	2,507 (14.6)	253 (14.9)	2,254 (14.9)	
	1	1,010	1,010 (6.0)	99 (5.8)	911 (6.0)	
	2	312	312 (1.9)	39 (2.3)	273 (1.8)	
	3	134	134 (0.8)	13 (0.8)	121 (0.8)	
	4 or more	117	117 (0.7)	10 (0.6)	107 (0.7)	

* Comparing those with and without BMP

† Other races suppressed because they produced some cells with fewer than 10 persons each.

Table 2

Patient outcomes overall and according to use of BMP.

Outcome Measure	Overall (n= 16,822)	Fusion with BMP (n = 1,703)	Fusion without BMP (n = 15,119)	p-value *
Reoperation within 6 month, n (%)	207 (1.2)	21(1.2)	186(1.2)	0.992
Reoperation within 1 year, n (%)	489 (2.9)	46 (2.7)	443 (2.9)	0.594
Reoperation within 2 years, n (%)	1,019 (6.1)	107 (6.3)	912 (6.0)	0.681
Reoperation within 3 years, n (%)	1,444 (8.6)	157 (9.2)	1,287 (8.5)	0.324
Reoperation within 4 years, n (%)	1,771 (10.5)	183 (10.8)	1,588 (10.5)	0.757
Rehospitalization within 30 days (any cause), n (%)	2,060 (12.3)	205 (12.0)	1,855 (12.3)	0.782
Cardiac, pulmonary or stroke complications, n (%)	955 (5.7)	87 (5.1)	868 (5.7)	0.285
Wound complications, %	372 (2.2)	40 (2.4)	332 (2.2)	0.684
Death within 30 days, n (%)	133 (0.8)	15 (0.9)	118 (0.8)	0.656
Nursing home discharge n (%)	3,140 (18.7)	271 (15.9)	2,869 (19.0)	<0.001
Hospital charges, U.S. dollars (95% CI) (Observed) ^[1]	\$49,729 (\$13,931 – 109,877)	\$63,929 (\$20,174 – 131,733)	\$48,130 (\$13,642 – 106,866)	<0.001
Hospital charges, U.S. dollars (95% CI) (Adjusted) ^{[1][2]}	\$48,776 (\$48,262 – 49,290)	\$62,779 (\$60,921 – 64,637)	\$47,199 (\$46,665 – 47,737)	<0.001
Payment Amount, U.S. dollars (SE) (Observed) ^{[1][3]}	\$17,086 (\$10,475 – 27,858)	\$18,054 (\$11,108 – 28,412)	\$16,977 (\$10,437 – 27,800)	<0.001
Payment Amount, U.S. dollars (SE) (Adjusted) ^{[1][2][3]}	\$17,430 (\$17,325 – 17,536)	\$18,189 (\$17,884 – 18,495)	\$17,345 (\$17,232 – 17,458)	<0.001

* Comparing those with and without BMP

^[1]Charges and payments all reported in 2004 U.S. dollars. Payments in 2003 inflated to 2004 equivalents using the Consumer Price Index medical component.

^[2]Adjusted charges and payments estimated using an ordinary least squares regression model that include the following variables: BMP (yes/no), fusion complexity (simple or complex), BMP X surgical complexity (an interaction term), age, sex, race (white, black, other), comorbidity (any/none), previous surgery, previous hospitalization (yes/no), scoliosis (yes/no), spondylolisthesis (yes/no). To create the adjusted predictions we set all of the covariates at the sample means (except for BMP the interaction term) and then summarized within the BMP and no BMP groups.

^[3]Analysis of payment excludes 188 cases with zero dollar payments, for whom other coverage may have been in effect.

Table 3

Patient Characteristics and proportion of fusion procedures resulting in repeat surgery, stratified by the presence of prior lumbar surgery and the complexity of the fusion procedure.

	Previous surgery		Type of fusion	
	No (n = 14,275)	Yes (n = 2,547)	Simple (n = 11,806)	Complex (n = 5,016)
Age, mean (sd)	75.4 (4.9)	74.7 (4.6)	75.5 (4.9)	75.1 (4.7)
% Female	65.6	64.4	65.8	64.4
% White	93.5	94.9	93.9	93.2
% complex fusion	28.8	35.5	0	100
% previous surgery	--	--	13.9	18.0
% 3+ disc levels fused	11.1	13.9	0 (by definition)	38.5
% spondylolisthesis or scoliosis	55.8	35.3	53.3	51.3
% with comorbidity score of 1 or more	48.1	56.2	49.3	49.5
Repeat surgery, n (%)				
1 year	Without BMP	343/12,938 (2.7)	100/2,181 (4.6)	136/4,327 (3.1)
	With BMP	32/1,337 (2.4)	14/366 (3.8)	20/689 (2.9)
	p-value	0.58	0.52	0.74
2 years	Without BMP	726/12,938 (5.6)	186/2,181 (8.5)	282/4,327 (6.5)
	With BMP	77/1,337 (5.8)	30/366 (8.2)	45/689 (6.5)
	p-value	0.82	0.83	0.99
3 years	Without BMP	1,023/12,938 (7.9)	264/2,181 (12.1)	406/4,327 (9.4)
	With BMP	112/1,337 (8.4)	45/366 (12.3)	67/689 (9.7)
	p-value	0.55	0.92	0.78
4 years	Without BMP	1,263/12,938 (9.8)	325/2,181 (14.9)	496/4,327 (11.5)
	With BMP	130/1,337 (9.7)	53/366 (14.5)	82/689 (11.9)
	p-value	0.96	0.83	0.74