■ SPINE

# National trends in revision spinal fusion in the USA

## PATIENT CHARACTERISTICS AND COMPLICATIONS

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**Using the United States Nationwide Inpatient Sample, we identified national trends in revision spinal fusion along with a comprehensive comparison of comorbidities, inpatient complications and surgical factors of revision spinal fusion compared to primary spinal fusion.**

**In 2009, there were 410 158 primary spinal fusion discharges and 22 128 revision spinal fusion discharges. Between 2002 and 2009, primary fusion increased at a higher rate compared with revision fusion (56.4% *vs* 51.0%; p < 0.001). In 2009, the mean length of stay and hospital charges were higher for revision fusion discharges than for primary fusion discharges (4.2 days *vs* 3.8 days, p < 0.001; USD $91 909 *vs*. $87 161, p < 0.001). In 2009, recombinant human bone morphogenetic protein (BMP) was used more in revision fusion than in primary fusion (39.6% *vs* 27.6%, p < 0.001), whereas interbody devices were used less in revision fusion (41.8% *vs* 56.6%, p < 0.001).**

**In the multivariable logistic regression model for all spinal fusions, depression (odds ratio (OR) 1.53, p < 0.001), psychotic disorders (OR 1.49, p < 0.001), deficiency anaemias (OR 1.35, p < 0.001) and smoking (OR 1.10, p = 0.006) had a greater chance of occurrence in revision spinal fusion discharges than in primary fusion discharges, adjusting for other variables. In terms of complications, after adjusting for all significant comorbidities, this study found that dural tears (OR 1.41; p < 0.001) and surgical site infections (OR 3.40; p < 0.001) had a greater chance of occurrence in revision spinal fusion discharges than in primary fusion discharges (p < 0.001). A p-value < 0.01 was considered significant in all final analyses.**

**Cite this article: *Bone Joint J* 2014;96-B:807–16.**

The number of spinal fusions performed in the USA each year is increasing.[1-10] Between 1998 and 2008 the national rate per 100 000 people for primary cervical, thoracic and lumbar fusions rose by 90%, 61% and 141%, respectively.[1] This rise could result in more patients needing revision spinal surgery, which potentially increases patient morbidity and overall healthcare costs.

Patients need revision of a primary fusion for various reasons, including the failure of bony fusion, complications related to their surgical implants, progressive degenerative change in the spine, and persistent pain.[11] The failure rates for cervical, thoracic and lumbar fusion have previously been reported, but the figures vary because of differences in technique, instrumentation and graft use. The failure rate of cervical fusion is between 0% and 50%,[12-19] with a 2.1% revision rate for anterior cervical discectomy and fusion.[20] The failure rate of thoracic fusion failure rates is 18%[21] and that of lumbar fusion, between 9% and 36%.[22-27] Factors found to be associated with pseudarthrosis and an increased risk of revision are age; primary fusion of multiple levels;[21] pre-operative emotional status[28]; patient behaviour, including smoking[29-31]; workers' compensation[28]; systemic disease processes affecting bone healing[32-35]; and the use of medication (NSAIDS and steroids).[36, 37]

Advances in spinal surgery, including instrumentation, minimally invasive surgical techniques, and new bone grafting options have helped to ensure the success of spinal fusion.[38-40] For example, the use of bone morphogenetic protein (BMP) has lowered the revision rate of lumbar fusion[41] although related complications have been reported.[42-44] Revision fusion surgery may also be associated with more peri-operative complications, including delayed wound healing and a higher rate of dural tears.[45-48]

Epidemiological studies which examine national trends in primary spinal fusion have been performed;[1,5] however, analyses of trends in revision spinal fusion surgery are lacking. The purpose of this study was threefold: 1) to

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doi:10.1302/0301-620X.96B6.31149 $2.00

*Bone Joint J* 2014;96-B:807–16.
*Received 18 December 2012; Accepted after revision 21 February 2014*

**Table I.** Six most common primary diagnoses for cervical, thoracic and lumbar revision fusion

| | % | ICD-9-CM* | ICD-9 Description |
|---|---|---|---|
| Revision cervical fusion | | | |
| 1 | 46.40 | 996.49 | Mechanical complication of internal orthopaedic device, implant, and graft |
| 2 | 8.2 | 996.78 | Other complications due to other internal orthopaedic device, implant, and graft |
| 3 | 7.7 | 721.0 | Cervical spondylosis without myelopathy |
| 4 | 6.8 | 722.0 | Displacement of cervical intervertebral disc without myelopathy |
| 5 | 5.3 | 723.0 | Spinal stenosis in cervical region |
| 6 | 4.1 | 722.4 | Degeneration of cervical intervertebral disc |
| Revision thoracic fusion | | | |
| 1 | 46.7 | 996.49 | Mechanical complication of internal orthopaedic device, implant, and graft |
| 2 | 4.1 | 737.10 | Kyphosis (acquired) (postural) |
| 3 | 3.9 | 996.78 | Other complications due to other internal orthopaedic device, implant, and graft |
| 4 | 3.2 | 737.30 | Kyphoscoliosis and scoliosis |
| 5 | 2.9 | 737.19 | Other kyphosis (acquired) |
| 6 | 2.4 | 724.01 | Spinal stenosis, thoracic region |
| Revision lumbar fusion | | | |
| 1 | 39.60 | 996.49 | Mechanical complication of internal orthopaedic device, implant, and graft |
| 2 | 10.40 | 996.78 | Other complications due to other internal orthopaedic device, implant, and graft |
| 3 | 9.60 | 724.02 | Spinal stenosis, lumbar region |
| 4 | 8.10 | 722.52 | Degeneration of lumbar or lumbosacral intervertebral disc |
| 5 | 5.90 | 722.83 | Post-laminectomy syndrome, lumbar region |
| 6 | 5.20 | 721.3 | Lumbosacral spondylosis without myelopathy |

* ICD-9, international classification of diseases, ninth revision

present national trends in revision spinal fusion surgery in the USA; 2) to compare patient characteristics, comorbidities, inpatient complications and surgical factors of revision spinal fusion discharges to primary spinal fusion discharges; and 3) to describe the most common primary diagnoses for revision spinal fusion discharges.

We hypothesised that revision fusions have increased at a lower rate than primary fusions, but that revision fusions are associated with a higher burden of comorbidity and complications, with greater hospital charges.

## Materials and Methods

Data for this study were obtained from the Nationwide Inpatient Sample (NIS), a dataset from the Healthcare Cost and Utilization Project (HCUP) created by the Agency of Healthcare Research and Quality (AHRQ). The NIS is the largest all-payer inpatient care database in the USA and contains data on inpatient discharges from 1050 hospitals located in 44 States, which approximates to a 20% stratified sample of US hospitals. To calculate national estimates using the NIS, discharge weights supplied by the AHRQ were applied (further information regarding weighted estimates can be found at: http: //www.hcupus.ahrq.gov/tech_assist/nationalestimates/508_course/508course.htm).

**Study design.** Using the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes, discharges were identified and separated into two groups for analysis: (1) primary spinal fusion (ICD9: 81.00-81.08) and (2) revision spinal fusion (ICD9: 81.30-81.39, 'revision fusion'). In this study, the category 'spinal fusion' refers to cervical, thoracic and lumbar fusions collectively, unless specifically stated. In 2009 patient characteristics, comorbidities and hospital characteristics were compared for both primary and revision fusions. All comorbidities were identified using the AHRQ comorbidity software, modelled on the Elixhauser algorithm[49] except for smoking, which was identified using ICD9 305.1 'tobacco use disorder'. The following inpatient complications were studied: inpatient mortality; surgical site infection (SSI); dural tears and wound dehiscence. Primary diagnoses for revision cervical, thoracic and lumbar fusions are presented in Table I.

Institutional review board approval was deemed unnecessary for this study, as the data were gathered from a publicly available national dataset, not linked to protected health information.

**Statistical analysis**. Between 2002 and 2009, the estimated frequency of discharges of patients with a principal procedure of primary and revision spinal fusion was identified. Sampling weights provided by the NIS dataset were used to produce national estimates for all hospital admissions in the USA. Utilisation rates per 100 000 US individuals were calculated by dividing weighted discharges by the US census yearly population estimates.[50] For comparison of temporal rates between 2002 and 2009, a mixed design ANOVA (GLM, general linear model) was used to compare slopes (regression coefficients) of primary fusions to revision fusions (factor 'revision fusion') over time (factor 'time', years 2002 to 2009) with an interaction of 'refusion × time'.

In 2009, statistical comparisons of data for primary and revision fusion were presented using means and standard deviations (SD) for continuous variables and frequencies and percentages for dichotomous variables. Patient characteristics, medical comorbidities and inpatient complications were coded '1' for presence and '0' for absence. Revision fusion discharges in the study were coded as '1' and

**Table II**. Univariable analyses of patient characteristics and comorbidities for primary and revision spinal fusion in 2009 (PVD, peripheral vascular disorder; CHF, congestive heart failure; d/o, disorder; dz, disease; comps, complications; w/o, without; mets, metastasis; RA/CVD, rheumatoid arthritis/collagen vascular disease; DM diabetes mellitis)

| Patient characteristics | | Primary spinal fusion (%) | Revision spinal fusion (%) | Unadjusted odds ratio (95% CI) | p-value |
|---|---|---|---|---|---|
| Age ≥ 65 | | 112 890 (*27.5*) | 5843 (*26.4*) | 0.94 (0.88 to 1.01) | 0.092 |
| Female | | 220 053 (*53.7*) | 12 293 (*55.6*) | 1.08 (1.01 to 1.14) | 0.018 |
| Comorbidities | | | | | |
| Behavioural | Smoking* | 110 403 (*26.9*) | 6872 (*31.1*) | 1.23 (1.15 to 1.31) | < 0.001 |
| | Alcohol abuse | 6336 (*1.5*) | 319 (*1.4*) | 0.94 (0.73 to 1.20) | 0.600 |
| | Drug abuse | 4373 (*1.1*) | 334 (*1.5*) | 1.45 (1.13 to 1.86) | 0.003 |
| Neuropsych. | Depression* | 52 658 (*12.8*) | 4176 (*18.9*) | 1.58 (1.46 to 1.71) | < 0.001 |
| | Psychotic d/o* | 10 180 (*2.5*) | 850 (*3.8*) | 1.57 (1.33 to 1.84) | < 0.001 |
| | Neurological d/o* | 16 104 (*3.9*) | 1041 (*4.7*) | 1.21 (1.05 to 1.40) | 0.009 |
| Cardiovascular | Hypertension | 188 998 (*46.1*) | 10 609 (*48.0*) | 1.08 (1.01 to 1.14) | 0.019 |
| | PVD | 7628 (*1.9*) | 462 (*2.1*) | 1.13 (0.91 to 1.39) | 0.275 |
| | CHF | 6601 (*1.6*) | 331 (*1.5*) | 0.95 (0.74 to 1.21) | 0.653 |
| | Valvular dz | 10 101 (*2.5*) | 600 (*2.7*) | 1.10 (0.92 to 1.33) | 0.305 |
| Respiratory | Chronic lung dz* | 60 333 (*14.7*) | 3682 (*16.6*) | 1.16 (1.07 to 1.26) | < 0.001 |
| | Pulmonary circ. D/o | 2469 (*0.6*) | 182 (*0.8*) | 1.36 (0.97 to 1.91) | 0.090 |
| Gastrointestinal | Peptic ulcer dz | 86.7 (*0.02*) | 5 (*0.02*) | 1.09 (0.15 to 8.19) | 0.931 |
| | Liver dz | 3855 (*0.9*) | 206 (*0.9*) | 1.01 (0.74 to 1.39) | 0.928 |
| Renal | Renal failure | 8010 (*2.0*) | 410 (*1.9*) | 0.95 (0.76 to 1.19) | 0.634 |
| | Electrolytes d/o* | 30 303 (*7.4*) | 1967 (*8.9*) | 1.21 (1.09 to 1.35) | < 0.001 |
| Endocrine | Dm, uncomplicated | 59 377 (*14.5*) | 3206 (*14.5*) | 1.00 (0.92 to 1.09) | 0.958 |
| | Dm, w/ comps | 6109 (*1.5*) | 363 (*1.6*) | 1.11 (0.88 to 1.41) | 0.375 |
| | Obesity | 44 452 (*10.8*) | 2569 (*11.6*) | 1.09 (0.99 to 1.20) | 0.084 |
| | Hypothyroidism | 38 320 (*9.3*) | 2252 (*10.2*) | 1.09 (0.99 to 1.21) | 0.085 |
| Haematological | Deficiency anaemia* | 32 722 (*8.0*) | 2438 (*11.0*) | 1.43 (1.29 to 1.57) | < 0.001 |
| | Coagulopathy | 6 551 (*1.6*) | 461 (*2.1*) | 1.32 (1.07 to 1.63) | 0.011 |
| | Chronic blood loss* | 3015 (*0.7*) | 224 (*1.0*) | 1.38 (1.01 to 1.87) | 0.042 |
| Neoplastic | Metastatic cancer* | 2368 (*0.6*) | 54 (*0.2*) | 0.429 (0.24 to 0.78) | 0.006 |
| | Lymphoma | 1094 (*0.3*) | 41 (*0.2*) | 0.68 (0.33 to 1.37) | 0.279 |
| | Tumour w/o mets* | 1730 (*0.4*) | 31 (*0.1*) | 0.32 (0.14 to 0.724) | 0.006 |
| Other | Ra/CVD | 11 767 (*2.9*) | 697 (*3.2*) | 1.10 (0.92 to 1.31) | 0.297 |
| | Weight loss | 3412 (*0.8*) | 194 (*0.9*) | 1.06 (0.77 to 1.47) | 0.719 |
| | Paralysis | 9215 (*2.3*) | 445 (*2.0*) | 0.89 (0.72 to 1.10) | 0.279 |

* significant at p < 0.05.

primary fusion discharges were coded as ‘0’. Means were compared using two-sample *t*-tests and proportions were compared using chi-squared tests for primary fusion *versus* revision fusion discharges. Unadjusted OR (OR) and 95% confidence intervals (CI) are presented.

Associations among multiple variables were evaluated via multivariable logistic regression techniques. Different factors were tested for association to revision fusion relative to primary fusion discharges, adjusting for patient comorbidities. Binary variables included in the final model for spinal fusion, cervical fusion, thoracic fusion and lumbar fusion were: age ≥ 65; gender; smoking status and comorbidities, which were identified with a univariable p-value < 0.05 (Table II). The final models were presented with adjusted ORs and 95% CIs. It is important to note that the ORs presented in the final multivariable analysis are relative to primary fusions. For example, the OR in the multivariable analysis for depression was 1.53, meaning that depression was 1.53 times more likely to be present in revision fusion discharges than in primary fusions. Because small clinical differences can become statistically significant in large databases such as the NIS, and because of multiple testing, p < 0.01 was considered significant in all final analyses. Statistical analyses were performed using SAS (SAS version 9.1. SAS, Inc., Cary, North Carolina). No order of the association or ‘prediction’ is asserted.

## Results

**Trends in revision spinal fusion in the USA (2002-2009)**. Between 2002 and 2009, the rate of spinal revision fusion discharges increased at a significantly lower rate than primary spinal fusion discharges. Spinal revision fusion increased by 41.6%, from 5.1 to 7.2 per 100 000 adults, whereas primary fusions increased by 46.6%, from 91.1 to 133.6 per 100 000 (p < 0.001) (Table III) (Fig. 1). For patients ≥ 65 years the revision fusion rate increased by 128.3%, from 6.5 in 2002 to 14.8 per 100 000 adults (≥ 65 years) in 2009 (p < 0.01), and the primary fusion rate increased by only 105%, from 139.2 to 285.3 per 100 000 adults (≥ 65 years) (p < 0.001). By contrast, in patients < 65 years the revision fusion rate increased by only 24.3%, from 4.9 in 2002 to 6.1 per 100 000 adults (< 65) in 2009 (p < 0.01), while the

**Table III**. US national estimates for trends of primary and revision spinal fusion discharges between 2002 and 2009

| | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | % Increase |
|---|---|---|---|---|---|---|---|---|---|
| **Primary spinal fusion** | | | | | | | | | |
| n | 262 204 | 278 945 | 277 226 | 311 244 | 326 222 | 334 854 | 393 616 | 410 158 | *56.4* |
| Rate per 100 000 US | 91.11 | 96.08 | 94.60 | 105.24 | 109.25 | 111.03 | 129.32 | 133.60 | *46.6* |
| Spinal revision fusion | | | | | | | | | |
| n | 14 654 | 13 886 | 14 589 | 16 385 | 16 805 | 15 487 | 19 134 | 22 128 | *51.0* |
| Rate per 100 000 | 5.09 | 4.78 | 4.98 | 5.54 | 5.63 | 5.14 | 6.29 | 7.21 | *41.6* |
| % of all fusions | *5.3* | *4.7* | *5.0* | *5.0* | *4.9* | *4.4* | *4.6* | *5.1* | |
| **Primary cervical fusion** | | | | | | | | | |
| n | 117 141 | 129 828 | 124 885 | 133 599 | 139 008 | 142 719 | 157 966 | 163 110 | *39.2* |
| Rate per 100 000 | 40.70 | 44.72 | 42.62 | 45.17 | 46.55 | 47.32 | 51.90 | 53.13 | *30.5* |
| **Cervical Revision fusion** | | | | | | | | | |
| n | 3840 | 3788 | 4013 | 4147 | 4359 | 4173 | 5316 | 5715 | *48.8* |
| Rate per 100 000 | 1.33 | 1.30 | 1.37 | 1.40 | 1.46 | 1.38 | 1.75 | 1.86 | *39.5* |
| % of all cervical fusions | *3.2* | *2.8* | *3.1* | *3.0* | *3.0* | *2.8* | *3.3* | *3.4* | |
| **Primary thoracic fusion** | | | | | | | | | |
| n | 15 888 | 16 013 | 18 391 | 22 518 | 19 857 | 20 232 | 24 003 | 25 463 | *60.3* |
| Rate per 100 000 | 5.52 | 5.52 | 6.28 | 7.61 | 6.65 | 6.71 | 7.89 | 8.29 | *50.4* |
| **Thoracic revision fusion** | | | | | | | | | |
| n | 999 | 1038 | 1135 | 1368 | 1433 | 1351 | 1656 | 1903 | *90.5* |
| Rate per 100 000 | 0.35 | 0.36 | 0.39 | 0.46 | 0.48 | 0.45 | 0.54 | 0.62 | *78.6* |
| % of all thoracic fusions | *5.9* | *6.1* | *5.8* | *5.7* | *6.7* | *6.3* | *6.5* | *7.0* | |
| **Primary lumbar fusion** | | | | | | | | | |
| n | 128 636 | 132 678 | 133 574 | 154 770 | 166 912 | 171 419 | 210 407 | 220 240 | *71.2* |
| Rate per 100 000 | 44.70 | 45.70 | 45.58 | 52.33 | 55.90 | 56.84 | 69.13 | 71.74 | *60.5* |
| **Lumbar revision fusion** | | | | | | | | | |
| n | 9380 | 8775 | 9195 | 10 662 | 10 785 | 9843 | 11 937 | 14 281 | *52.2* |
| Rate per 100 000 | 3.26 | 3.02 | 3.14 | 3.61 | 3.61 | 3.26 | 3.92 | 4.65 | *42.7* |
| % of all lumbar fusions | *6.8* | *6.2* | *6.4* | *6.4* | *6.1* | *5.4* | *5.4* | *6.1* | |

N indicates the national weighted estimate; rate per 100 000 is the use rate per 100 000 US population based on US census yearly estimates; % of fusions is the percentage of all fusions that were revisions, for cervical, thoracic and lumbar spine; the % represents % of each respective group. Further information on the methodology for creating national weighted estimates using the NIS can be found at http://www.hcup-us.ahrq.gov/tech_assist/nationalestimates/508_course/508course.htm.

primary fusion rate increased by 31.8%, from 84.3 to 111.2 per 100 000 adults (< 65) (p < 0.001). Between 2002 and 2009, cervical, thoracic and lumbar revision fusions increased at variable rates, which were not significantly different when the slopes of increase were compared (Fig. 2). Revision fusion of the cervical spine increased by 39.5%, from 1.3 to 1.9 per 100 000 adults, that of the thoracic spine increased by 78.6%, from 0.35 to 0.62 per 100 00 adults: revision fusion of the lumbar spine increased by 42.7%, from 3.3 to 4.7 (cervical *vs* thoracic p = 0.08; cervical *vs* lumbar p = 0.09; thoracic *vs* lumbar p = 0.02)

**Patient and hospital characteristics in 2009**. Patient and hospital characteristics for primary and revision spinal fusion discharges in 2009 are shown in Table IV. In 2009 there were 410 158 discharges with a principal procedure of primary spinal fusion, and 22 128 discharges with a principal procedure of spinal revision fusion. Mean age was not significantly different between the two discharge groups, at 54.7 and 54.8 years respectively (p = 0.54). Length of hospital stay (LOS) and the mean total hospital charges were significantly higher for revision fusion discharges than for primary fusion discharges (4.2 days *vs* 3.8 days; p < 0.001; $91 909 *vs* $87 161, p < 0.001). While these differences were statistically significant, there may only be marginal differences clinically. There was a slightly higher percentage of women in revision fusion discharges, but this was not significant (55.6% *vs* 53.7%, p = 0.02). Geographically, there was a greater number of primary and revision spinal fusion discharges in the South region of the USA compared to the West, Midwest and Northeast regions. These regions were defined by the U.S. Census

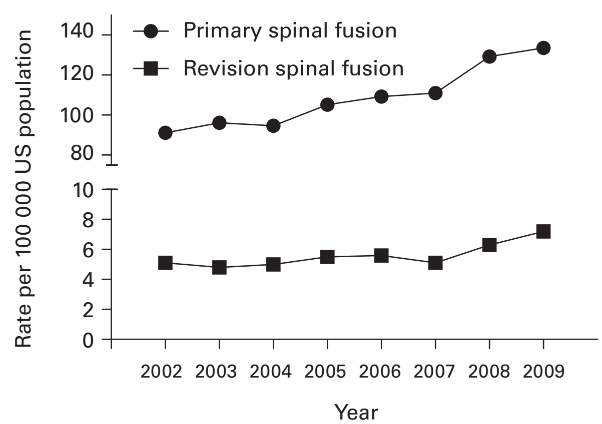


Fig. 1

Trends in the national rate of primary and revision spinal fusion between 2002 and 2009 per 100 000 US population.

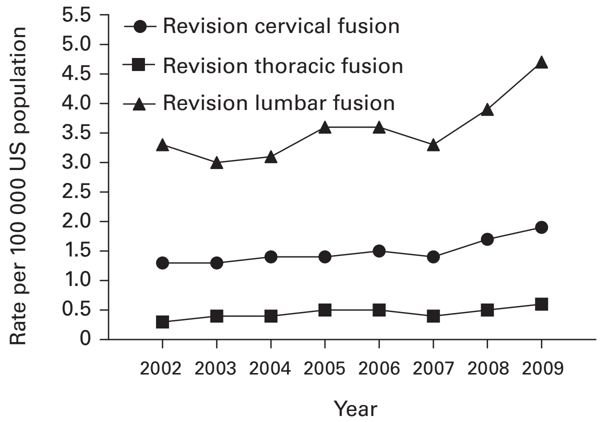


Fig. 2

Trends in the national rate of revision cervical fusion, revision thoracic fusion and revision lumbar fusion between 2002 and 2009 per 100 000 US population.

**Table IV.** Patient and hospital characteristics for primary and revision spinal fusion discharges in 2009

| | Spinal fusion (n = 432 286) (SD) | | | Cervical fusion (n = 16 8825) (SD) | | | Thoracic fusion (n = 27 366) (SD) | | | Lumbar fusion (n = 234 521) (SD) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Primary spinal fusion** | **Revision spinal fusion** | **p-value** | **Primary spinal fusion** | **Revision spinal fusion** | **p-value** | **Primary spinal fusion** | **Revision spinal fusion** | **p-value** | **Primary spinal fusion** | **Revision spinal fusion** | **p-value** |
| N (%) | 410158 (94.9) | 22128 (5.1) | | 163110 (96.6) | 5715 (3.4) | | 25463 (93.0) | 1903 (7.0) | | 220240 (93.9) | 14281 (6.1) | |
| Mean Age | 54.7 (SD 25.1) | 54.8 (SD 13.9) | 0.544 | 53.7 (SD 12.7) | 51.8 (SD 11.5) | < 0.001 | 43.2 (SD 23.6) | 54.5 (SD 18.9) | < 0.001 | 56.7 (SD 14.7) | 56.1 (SD 13.8) | 0.019 |
| Age ≥ 65 (%) | 112 890 (27.5) | 5843 (26.4) | 0.092 | 33 209 (20.4) | 838 (14.7) | < 0.001 | 5812 (22.8) | 674 (35.43) | < 0.001 | 73 547 (33.4) | 4264 (29.9) | < 0.001 |
| LOS (days) | 3.8 (SD 2.4) | 4.2 (SD 4.3) | < 0.001 | 2.7 (SD 4.9) | 3.1 (SD 3.6) | 0.015 | 8.3 (SD 8.2) | 6.8 (SD 6.5) | 0.004 | 4.0 (SD 3.2) | 4.2 (SD 3.9) | 0.003 |
| Total Charges ($) | 87 161 (SD 76 009) | 91 909 (SD 77 535) | <0.001 | 59 361 (SD 60 230) | 64 430 (SD 58 042) | 0.006 | 173 487 (SD 129 657) | 149 993 (SD 121 129) | 0.007 | 97 842 (SD 67 176) | 95 294 (SD 71 404) | 0.0529 |
| Chronic conditions | 3.8 (SD 2.4) | 3.9 (SD 2.6) | 0.278 | 3.6 (SD 2.3) | 3.5 (SD 2.5) | 0.372 | 4.0 (SD 2.0) | 4.6 (SD 2.7) | < 0.001 | 4.0 (SD 2.4) | 3.9 (SD 2.6) | 0.136 |
| Gender | | | | | | | | | | | | |
| Male (%) | 189 937 (46.3) | 9830 (44.4) | 0.018 | 79 956 (49.0) | 2366 (41.4) | < 0.001 | 11 163 (43.8) | 754 (39.7) | 0.148 | 98 210 (44.6) | 6613 (46.3) | 0.077 |
| Female (%) | 220 054 (53.7) | 12 293 (55.6) | | 83 130 (51.0) | 3348 (58.6) | | 14 252 (56.0) | 1148 (60.4) | | 121 935 (55.4) | 7663 (53.7) | |
| Payer Type | | | | | | | | | | | | |
| Medicare (%) | 129 277 (31.5) | 7824 (35.4) | < 0.001 | 42 777 (26.2) | 1451 (25.4) | < 0.001 | 6433 (25.3) | 777 (40.9) | < 0.001 | 79 652 (36.2) | 5507 (38.6) | < 0.001 |
| Medicaid (%) | 23463 (5.7) | 1241 (5.6) | | 9711 (6.0) | 445 (7.8) | | 3620 (14.2) | 121 (6.4) | | 10 051 (4.6) | 660 (4.6) | |
| P.I. (%) | 206 354 (50.3) | 9632 (43.6) | | 89 683 (55.0) | 2902 (50.8) | | 12 993 (51.0) | 837 (44.0) | | 103 045 (46.8) | 5810 (40.7) | |
| Other (%) | 50 047 (12.5) | 3385 (15.3) | | 20 940 (12.8) | 902 (15.8) | | 2374 (9.3) | 128 (6.7) | | 27 491 (12.5) | 2279 (16.0) | |
| Median Income | | | | | | | | | | | | |
| $1-47,999 (%) | 195 997 (45.7) | 9823 (48.9) | < 0.001 | 36 140 (22.2) | 1080 (18.9) | 0.234 | 5222 (20.5) | 339 (17.8) | 0.127 | 48 582 (22.1) | 2711 (19.0) | < 0.001 |
| $48,000 + (%) | 204 748 (51.1) | 11 696 (54.4) | | 122 854 (75.3) | 4488 (78.5) | | 19 694 (77.3) | 1519 (79.8) | | 166 936 (75.5) | 11 153 (78.1) | |
| Regions | | | | | | | | | | | | |
| Northeast (%) | 62 664 (15.3) | 3705 (16.7) | 0.067 | 25 210 (15.5) | 1014 (17.7) | 0.134 | 3351 (13.2) | 232 (12.2) | 0.698 | 34 017 (15.5) | 2438 (17.1) | 0.130 |
| Midwest (%) | 87 633 (21.4) | 4711 (21.3) | | 31 830 (19.5) | 1151 (20.1) | | 6314 (24.8) | 511 (26.9) | | 49 166 (22.3) | 3019 (21.1) | |
| South (%) | 180 149 (43.9) | 9442 (42.7) | | 74 556 (45.7) | 2513 (44.0) | | 9107 (35.8) | 697 (36.7) | | 95 757 (43.5) | 6096 (42.7) | |
| West (%) | 79 713 (19.4) | 4270 (19.3) | | 31 514 (19.3) | 1037 (18.1) | | 6690 (26.7) | 463 (24.3) | | 41 300 (18.8) | 2728 (19.1) | |

In payer types, ''Other" includes self charge and no charge recipients; Median household income is defined through patient zip code; Data for regions and payer types are shown as column percentage and frequency in parenthesis; P.I., private insurance.

Bureau. This may be due to regional population differences, which were not adjusted for.

**Patient characteristics and comorbidities**. The univariable analysis of patient characteristics and comorbidities associated with revision spinal fusion compared to primary fusion are presented in Table II. Comorbidities that were present at significantly higher rates in revision fusion discharges were: depression; smoking; drug abuse; psychotic disorders; neurological disorders; chronic pulmonary disease; deficiency anaemias; and fluid and electrolyte disorders. Factors with a low prevalence that were less associated with revision fusion and were more commonly present in primary fusion discharges were metastatic cancer and solid tumour without metastasis.

**Factors related to surgery**. Factors related to surgery for revision spinal fusion discharges compared to primary fusion discharges in 2009 are shown in Table V (Fig. 3). BMP was used in 39.6% of revision fusion discharges but in only 27.6% of primary fusions (unadjusted OR 1.73; 95% CI 1.62 to 1.84; $p < 0.001$). Autogenous bone graft was used in 40.6% of revision fusion procedures and 37.1% of primary fusions (unadjusted OR 1.15; 95% CI 1.08 to 1.22; $p < 0.001$). Fusion of more than four levels was carried out in 27.1% of revision fusion discharges but

**Table V.** Univariable analyses of surgical related factors for patients who had a revision fusion compared to a primary fusion in 2009. Values are given as number of discharges with percentages in parentheses

| | Primary spinal fusion (%) | Revision spinal fusion (%) | Unadjusted odds ratio (95% CI) | p-value |
|---|---|---|---|---|
| **Spinal fusion** | | | | |
| Autogenous bone graft | 152 226 (*37.1*) | 8981 (*40.6*) | 1.15 (1.08 to 1.22) | < 0.001 |
| BMP* | 113 121 (*27.6*) | 8753 (*39.6*) | 1.73 (1.62 to 1.84) | < 0.001 |
| Interbody device | 232 320 (*56.6*) | 9240 (*41.8*) | 0.55 (0.52 to 0.59) | < 0.001 |
| ≥ 4 levels fused | 73 952 (*18.0*) | 5998 (*27.1*) | 1.70 (1.58 to 1.82) | < 0.001 |
| **Cervical fusion** | | | | |
| Autogenous bone graft | 39 836 (*24.4*) | 1964 (*34.4*) | 1.64 (1.44 to 1.85) | < 0.001 |
| BMP | 16 320 (*10.0*) | 1281 (*22.4*) | 2.60 (2.25 to 3.0) | < 0.001 |
| Interbody device | 86 339 (*52.9*) | 2461 (*43.1*) | 0.67 (0.60 to 0.76) | < 0.001 |
| ≥ 4 levels fused | 28 953 (*17.8*) | 1434 (*25.1*) | 1.56 (1.36 to 1.79) | < 0.001 |
| **Thoracic fusion** | | | | |
| Autogenous bone graft | 10 460 (*41.1*) | 769 (*40.4*) | 0.96 (0.78 to 1.19) | 0.707 |
| BMP | 6857 (*26.9*) | 931 (*48.9*) | 2.60 (2.10 to 3.21) | < 0.001 |
| Interbody device | 7675 (*30.1*) | 378 (*19.9*) | 0.58 (0.44 to 0.75) | < 0.001 |
| ≥ 4 levels fused | 18 167 (*71.4*) | 1303 (*68.5*) | 0.88 (0.70 to 1.10) | 0.271 |
| **Lumbar fusion** | | | | |
| Autogenous bone graft | 101 546 (*46.1*) | 6207 (*43.5*) | 0.89 (0.82 to 0.96) | 0.002 |
| BMP | 89 784 (*40.8*) | 6462 (*45.3*) | 1.21 (1.12 to 1.31) | < 0.001 |
| Interbody device | 137 655 (*62.5*) | 6356 (*44.5*) | 0.49 (0.45 to 0.52) | < 0.001 |
| ≥ 4 levels fused | 25 580 (*12.1*) | 3224 (*22.6*) | 2.13 (1.94 to 2.34) | < 0.001 |

* BMP, bone morphogenetic protein

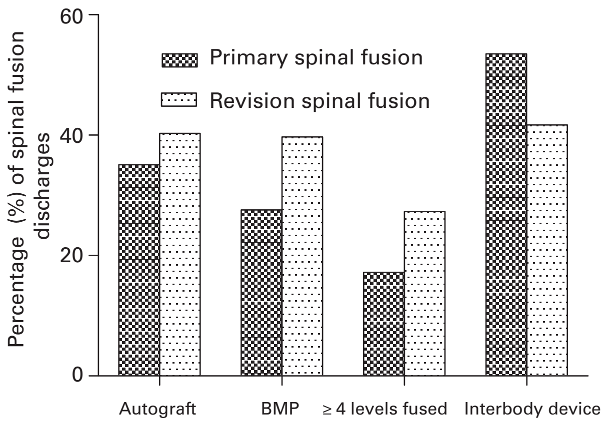


Fig. 3

Graph showing percentage of spinal fusion discharges that (1) used autogenous bone, (2) used recombinant human bone morphogenetic protein (BMP), (3) had four or more levels fused and (4) used an interbody device.

in only 18.0% of primary fusions (unadjusted OR 1.70; 95% CI 1.58 to 1.82; p < 0.001). By contrast, interbody devices were used less in revision fusion procedures, with a usage rate of 41.8% compared to 56.6% in primary fusions (unadjusted OR 0.55; 95% CI 0.52 to 0.59; p < 0.001). In the thoracic spine, the use of BMP and fusion of four or more levels did not differ between primary and revision discharges.

**Multivariable logistic regression analysis.** A multivariable logistic regression model was used to adjust for interrelationships among variables (Table VI; Figs 4 and 5). In the analysis of all spinal fusions combined (Table VI), after adjusting for other variables, depression (OR 1.53; 95% CI 1.41 to 1.66, p < 0.001), psychotic disorders (OR 1.49; 95% CI 1.26 to 1.75, p < 0.001), deficiency anaemias (OR 1.35; 95% CI 1.22 to 1.49, p < 0.001) and smoking (OR 1.10; 95% CI 1.03 to 1.18, p = 0.006) had a significantly greater odds of occurrence in revision spinal fusion discharges. By contrast, there was a lower odds of occurrence of metastatic cancer (OR 0.39; 95% CI 0.21 to 0.71; p = 0.002) and tumour without metastasis (OR 0.32; 95% CI 0.14 to 0.71; p = 0.005). Of note, there were also lower odds of occurrence of patients aged ≥ 65 (OR 0.93; 95% CI 0.86 to 0.99; p = 0.033) in revision fusion discharges, but this did not meet significance at p < 0.01. With regard to complications (Fig. 5), dural tears (OR 1.41; 95% CI 1.19 to 1.67, p < 0.001) and SSI (OR 3.40; 95% CI 2.44 to 4.74; p < 0.001) had greater odds of occurrence in revision fusion discharges, after adjusting for other variables. The odds of wound dehiscence (OR 2.30; 95% CI 1.19 to 4.42; p = 0.013) were also higher in revision fusion discharges, but were not significant at p < 0.01. Notably, the odds of inpatient mortality were lower in revision fusion discharges (OR 0.31, 95% CI 0.10 to 0.99, p = 0.0471) than for primary fusion discharges, but were not significant at the 1% level of significance.

After adjusting for all variables, the final multivariable logistic analyses comparing revision cervical fusion and primary cervical fusion (Table VI) identified female gender (OR 1.28; p < 0.001), depression (OR 1.73; p < 0.001) and drug abuse (OR 1.86, p = 0.006) to have a greater odds of occurrence in revision fusion discharges. By contrast, there was a lower odds of occurrence of patients aged ≥ 65 years in revision fusion discharges (OR 0.70; p < 0.001). For complications, SSI (OR 4.88; p < 0.001) had almost five times greater odds of occurrence in revision cervical fusion

**Table VI**. Factors that were independently associated with revision spinal fusion compared with primary spinal fusion, after adjusting for other variables in 2009 (multivariable logistic regression). Age ≥ 65, smoking and female gender were included in all models and are only presented here if significant

| | | Adjusted odds ratio (95% CI) | p-value |
|---|---|---|---|
| **Spinal revision fusion** | | | |
| Revision cervical fusion | | | 0.033 |
| 1 | 46.40 | 1.10 (1.03 to 1.18) | 0.006 |
| 2 | 8.2 | 1.53 (1.41 to 1.66) | < 0.001 |
| 3 | 7.7 | 1.49 (1.26 to 1.75) | < 0.001 |
| 4 | 6.8 | 1.35 (1.22 to 1.49) | < 0.001 |
| 5 | 5.3 | 0.39 (0.21 to 0.71) | 0.002 |
| 6 | 4.1 | 0.32 (0.14 to 0.71) | 0.005 |
| Complications | Dural tear | 1.41 (1.19 to 1.67) | < 0.001 |
| | Wound dehiscence* | 2.30 (1.19 to 4.42) | 0.013 |
| | Surgical site infection | 3.40 (2.44 to 4.74) | < 0.001 |
| **Cervical revision fusion** | | | |
| Patient characteristics | Age ≥ 65 | 0.70 (0.59 to 0.82) | < 0.001 |
| | Female gender | 1.28 (1.13 to 1.45) | < 0.001 |
| Comorbidities | Depression | 1.73 (1.49 to 2.01) | < 0.001 |
| | Drug abuse | 1.86 (1.19 to 2.90) | 0.006 |
| Complications | Surgical site infection | 4.88 (2.27 to 10.49) | < 0.001 |
| **Thoracic revision fusion** | | | |
| Patient characteristics | Age ≥ 65 | 1.50 (1.16 to 1.92) | 0.002 |
| Comorbidities | Depression | 1.81 (1.37 to 2.41) | < 0.001 |
| | Hypertension | 1.46 (1.14 to 1.88) | 0.003 |
| | Hypothyroidism* | 1.46 (1.04 to 2.03) | 0.027 |
| | Metastatic cancer | 0.27 (0.12 to 0.61) | 0.002 |
| | Tumour w/o mets* | 0.12 (0.02 to 0.85) | 0.034 |
| Complications | Surgical site infection | 3.57 (1.56 to 8.20) | 0.003 |
| **Lumbar revision fusion** | | | |
| Patient characteristics | Age ≥ 65 | 0.86 (0.79 to 0.93) | 0.003 |
| | Female gender | 0.90 (0.83 to 0.97) | 0.008 |
| Comorbidities | Depression | 1.40 (1.26 to 1.54) | < 0.001 |
| | Psychotic disorder | 1.57 (1.29 to 1.92) | < 0.001 |
| | Deficiency anaemia | 1.27 (1.13 to 1.43) | < 0.001 |
| | Smoking* | 1.10 (1.01 to 1.20) | 0.024 |
| Complications | Surgical site infection | 2.81 (1.86 to 4.26) | < 0.001 |

95% CI, 95% confidence intervals; w/o, without; 'mets', metastasis. Results significant at $p < 0.01$
* results that approached but did not meet significance at $p < 0.01$

discharges than in primary cervical fusions, after adjusting for other variables.

In the final multivariable logistic analysis for thoracic fusion, after adjusting for all variables, age ≥ 65 (OR 1.50; p = 0.002), depression (OR 1.81; p < 0.001) and hypertension (OR 1.46; p = 0.003) had a greater odds of occurrence in revision fusion discharges. By contrast, metastatic cancer (OR 0.27; p = 0.002) had lower odds of occurrence in revision fusion discharges. SSI had nearly four times greater odds of occurrence in revision thoracic fusion (OR 3.57; p < 0.003), after adjusting for other variables.

In the final multivariable logistic analysis for lumbar fusion, after adjusting for all variables, depression (OR 1.40; 95% CI 1.26 to 1.54; p = 0.003), psychotic disorders (OR 1.57; p < 0.001) and deficiency anaemias (OR 1.27; p < 0.001) had greater odds of occurrence in revision lumbar fusion discharges. Smoking (OR 1.10; p = 0.0243) had a greater odds of occurrence in revision fusion discharges, but this was not significant at p < 0.01. By contrast, female gender (OR 0.90; p = 0.008) and age ≥ 65 (OR 0.86; p = 0.003) had a lower odds of occurrence in revision fusion discharges. SSI (OR 2.81; p < 0.001) had a almost three times greater odds of occurrence in lumbar revision fusions, after adjusting for other variables.

**Primary diagnoses for revision fusion**. The six most common primary diagnoses coded for spinal revision fusion discharges are presented in Table I. For revision cervical, thoracic and lumbar fusions, the most common primary

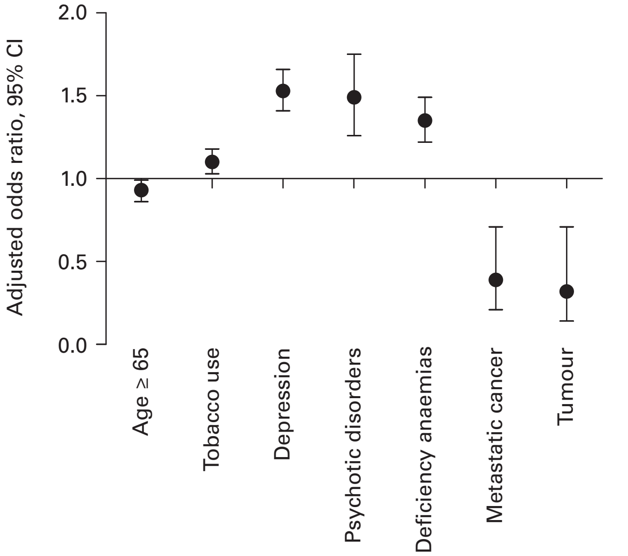


Fig. 4

Graph showing adjusted odds ratios (95% confidence intervals) for factors with a higher odds of occurrence in revision spinal fusion discharges compared to primary spinal fusion discharges (including cervical, thoracic, lumbar together), after adjusting for other variables.

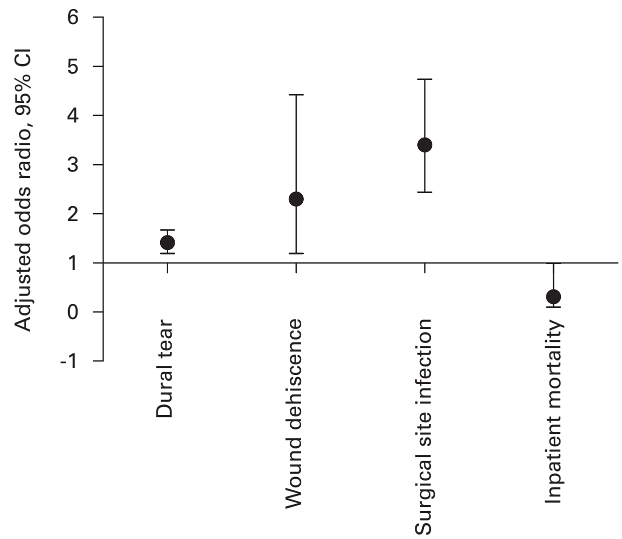


Fig. 5

Graph showing adjusted odds ratios (95% confidence intervals) for complications with a higher odds of occurrence in revision spinal fusion discharges compared to primary spinal fusion discharges, after adjusting for other variables.

diagnosis code was 'mechanical complication of internal orthopaedic device, implant, and graft' (ICD9: 996.49). This was the primary diagnosis code in 46.4% of revision cervical fusions, 46.7% of revision thoracic fusions and 39.6% of revision lumbar fusions.

## Discussion

The primary goal of this study was to assess national trends in revision spinal fusion surgery. The results show that between 2002 and 2009 revision spinal fusion discharges increased at a slower rate than primary fusions. Given rising healthcare costs nationally, reducing revision rates is an important step towards cost savings and better patient care. The lower rate of increase in revision spinal fusion overall may be due to many factors, including the development of more advanced instrumentation, improved bone grafting options and an increased number of adequately trained spine specialists. When the data are stratified by age, the primary and revision fusion rates increased in those aged ≥ 65 years between 2002 and 2009. The increased revision fusion rate in patients ≥ 65 may be partially due to advances in spinal surgery which allow surgeons to lower their threshold for revision, but it may also simply be related to the increased rate of primary fusion in the elderly. There may also be some boundary effect, as patients undergoing revision may have moved into the ≥ 65 years category, whereas their primary fusion was carried out before the age of 65. When analysing trends for the individual spinal regions, revision fusion of the cervical and thoracic spine increased faster than primary fusion between 2002 and 2009: revision lumbar fusion increased at a lower rate than primary lumbar fusion over that same period. Considering the fact that spinal fusion reportedly has higher rate of complications than other types of spinal surgery,[51-53] further research in the rising trend of spinal fusion is warranted.

A secondary aim of this study was to compare patient characteristics, comorbidities and inpatient complications between primary and revision fusion discharges. For all spinal fusions collectively, depression, psychotic disorders, smoking and deficiency anaemias were more common in revision fusion discharges than in primary discharges, after adjusting for all other variables. As these variables were more common in patients undergoing revision spinal fusion, these characteristics are important factors for surgeons when evaluating their patients for primary surgery. However, given the nature of the NIS dataset, we were unable to assess whether these characteristics were present before the primary surgery or developed afterwards. In the literature, smoking[54] and depression have clearly been associated with poorer outcomes after primary and revision spinal operations.[55, 56]

The mean age for patients undergoing primary or revision spinal fusion was generally similar, except for thoracic fusion discharges, where revision patients were significantly older. The mean length of hospital stay and mean total hospital charges were significantly higher for revision fusion discharges collectively. The higher hospital charges associated with revision fusion may be attributed to the greater complexity of the procedure, the involvement of multiple levels and a higher rate of BMP use, which is consistent with the literature.[57]

When analysing factors related to surgery for spinal fusion, we found that revision fusion had a significantly higher rate of BMP use than did primary fusion and was used in 31.5% of all spinal fusions nationally in 2006.[58] We also found that fusion of four or more levels occurred at a higher rate in revision spinal fusion discharges than in primary fusion, making for a more complex procedure. Revision fusion had a significantly lower use of interbody devices than did primary fusion.

In terms of complications, after adjusting for all significant comorbidities we found that dural tears and SSI had greater odds of occurrence in revision spinal fusion discharges than in primary fusion discharges. The increased rate of dural tears and SSI with revision fusion discharges is consistent with previous studies,[45-48,59] which have shown that there was a relative risk of 2.2 for dural tears in revision fusions.[60] The lower inpatient mortality in revision discharges is also consistent with a study which found mortality to be twice as high in primary spinal fusion cases compared to revision cases.[61]

There are weaknesses in the use of these datasets, which include a reliance on the accuracy of ICD-9-CM codes for identifying spinal fusion cases and identifying different patient diagnoses (comorbidities). It is important to note that the use of extremely large administrative databases such as the NIS may, at times, lead to small non-significant clinical differences becoming statistically significant. However, to address this matter, a lower cut-off of $p < 0.01$ was used for significance in all of the final analyses. Also, given that the unit of observation in the NIS is a discharge and not an individual, a single patient cannot be followed over time through multiple admissions to assess risk factors for revision fusion, outcome and revision rate. The NIS provides a yearly snapshot of discharge-based national administrative data. There is no information available about a patient's primary surgery when analysing a revision fusion discharge. For example, if a revision fusion discharge is coded with a diagnosis of depression, we know that depression and revision fusion existed together at discharge for that patient but it is not possible to assess whether that depression existed before their primary surgery or developed afterwards. This ignorance of diagnostic codes also applies to certain inpatient complications that are studied, and limits the interpretation of results from logistic models of these data. Thus, results from our multivariable logistic regression analysis in this study were used to identify independent associations among all these variables comparing revision spinal fusion to primary fusion. Patient characteristics and complications that were found to be more highly associated with revision fusion discharges should not be interpreted as predictors of revision spinal fusion. Despite these limitations, the NIS has been used in previous studies of spinal surgery in the USA,[1,62-64] and it has been shown to match the Medicare claims (National Hospital Discharge Survey).[64,65]

## Supplementary material

One table providing information about ICD-9-CM diagnosis and three tables which present univariable patient characteristics for cervical, thoracic and lumbar fusion separately, are available alongside the electronic version of this article on our website www.bjj.boneandjoint.org.uk

S. Rajaee is the first author, H. Bae is the corresponding and last author.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

This article was primary edited by S Hughes and first proof edited by A. C Ross

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