National in-hospital morbidity and mortality trends after lumbar fusion surgery between 1998 and 2008

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Increasing numbers of posterior lumbar fusions are being performed. The purpose of this study was to identify trends in demographics, mortality and major complications in patients undergoing primary posterior lumbar fusion. We assessed data collected for the Nationwide Inpatient Sample for each year between 1998 and 2008 and analysed trends in the number of lumbar fusions, mean patient age, comorbidity burden, length of hospital stay, discharge status, major peri-operative complications and mortality. An estimated 1 288 496 primary posterior lumbar fusion operations were performed between 1998 and 2008 in the United States. The total number of procedures, mean patient age and comorbidity burden increased over time. Hospital length of stay decreased, although the in-hospital mortality (adjusted and unadjusted for changes in length of hospital stay) remained stable. However, a significant increase was observed in peri-operative septic, pulmonary and cardiac complications. Although in-hospital mortality rates did not change over time in the setting of increases in mean patient age and comorbidity burden, some major peri-operative complications increased. These trends highlight the need for appropriate peri-operative services to optimise outcomes in an increasingly morbid and older population of patients undergoing lumbar fusion.

Materials and Methods

Data source. Nationwide Inpatient Sample (NIS) data files were analysed for this study. The NIS represents the largest all-payer inpatient database in the United States. Information on the design of the NIS is available on the internet. This study was exempt from review by the institutional review board, as the data used are sufficiently anonymised.

Selection of study sample and statistical methods. Data from 1998 to 2008 were accessed. Admissions for primary posterior lumbar fusion were identified using the International Classification of Diseases, 9th revision, Clinical Modification (ICD-9-CM) codes. The ICD-9 code 81.08 includes ‘lumbar and lumbosacral fusion, posterior technique’, ‘arthrodeseis of lumbar or lumbosacral region: posterior (interbody) technique’, ‘posteriorlateral technique’, ‘posterior lumbar interbody fusion (PLIF)’ and ‘transforaminal lumbar interbody fusion (TLIF)’. Linear trends in patient demographics, including mean age, comorbidity burden as indicated by the mean Deyo index and gender were analysed. The Deyo comorbidity index is a modification of the Charlson index and was developed to predict in-hospital outcomes based on a number of comorbidities.
when using administrative data, such as are used in this paper. In brief, a number of comorbidities, defined by their ICD-9 codes, are assigned a weight when present. The sum of these weights is converted to an overall score (the higher the score, the higher the chance of adverse outcomes). The Deyo index was originally validated in spinal patients, making it especially attractive for this study. Linear trends in discharge destination (routine versus non-routine, i.e. short- and long-term facilities and home health-care) were computed.

Pre-operative spinal diagnoses were tabulated and each entity was analysed over time. The diagnoses included degenerative disc disease, spinal stenosis, scoliosis, spondylolisthesis, trauma, tumour, multiple spine diagnoses (two or more) and other diagnoses. Rates of major complications were tabulated by identifying entries that listed ICD-9-CM codes consistent with post-operative cerebral infarction, sepsis, shock/cardiorespiratory arrest, acute myocardial infarction, cardiac complications (other than myocardial infarction), pneumonia and pulmonary embolism. In-hospital mortality rates were determined for each year. Morbidity and mortality rates were adjusted for changes in length of hospital stay by computing the number of events per 1000 inpatient days.

Statistical analysis. Weighted means and percentages were calculated and plotted for continuous and categorical variables, respectively. As the NIS represents only a stratified sample of approximately 20% of all annual hospitalisations in the United States, each actual entry in the database (unweighted data) is assigned a weight that allows for the extrapolation of that particular entry to generate a national estimate (weighted number). Different regression methods for trend analysis were used to characterise the linear association between the outcomes of time. In particular, Poisson regression, linear regression and logistic regression were applied to person–time data (i.e. in-hospital mortality per 1000 inpatient days), continuous data (i.e. mean age, mean comorbidity burden, mean length of stay) and binary data (i.e. incidences of spinal pathologies), respectively. Pearson’s correlation coefficient (r) was assessed to evaluate the association between the total number of lumbar fusion operations and time, and the association between the gender differences in proportions and time. The regression coefficient (β) associated with time, which illustrates the direction and the magnitude of the trend over time, is reported along with its p-value. A p-value < 0.05 was considered significant.

The linear trend analysis was performed using Stata version 11 (StataCorp, College Station, Texas) and other descriptive statistical analyses were performed using SAS version 9.2 (SAS Institute, Cary, North Carolina). In order to facilitate data analysis and to obtain consistent estimates of mean and variance parameters taking into account the complex survey data setting, SAS procedures SURVEYMEANS and SURVEYFREQ were used for descriptive analyses. SVYSET and SVY LINEARIZED from Stata procedures were used for linear trend analysis.

Results

A total of 1 288 496 primary posterior lumbar fusions were performed between 1998 and 2008, during which time the number of procedures performed per year increased almost threefold, to 182 981 in 2008 (r = 0.987, p < 0.0001) (Fig. 1). A similar increase was seen in the population growth-adjusted use. Use in the civilian population increased from 23 per 100 000 in 1998 to 60 per 100 000 in 2008 (r = 0.987, p < 0.0001) (Fig. 2). A significant increase in the mean age of the patients from 52.47 to 56.85 years (β = 0.496, p < 0.0001) and comorbidity burden from 0.32 to 0.55 was seen over time (β = 0.027, p < 0.0001) (Figs 3 and 4).

The mean length of stay decreased from 5.1 days in 1998 to 4.7 days in 2008 (β = -0.098, p < 0.0001) (Fig. 5).
percentage of routine discharges to the patients’ customary residence remained stable at around 70% during this time.

More women than men underwent lumbar fusion at any given time point. The gender gap increased over the period from 5% in 1998 to 13% in 2008 (Pearson’s correlation coefficient (between the gender differences in proportions and time) r = 0.91, p < 0.0001) (Fig. 6). The in-hospital mortality rates after primary posterior lumbar fusion per 1000 inpatient days decreased from 0.34 in 1998 to 0.30 in 2008, but this was not significant (β = -0.009, p = 0.584) (Fig. 7).

Table I gives a detailed analysis of linear trends in spinal pathology. Although the proportions of procedures addressing spinal stenosis and multiple spine diagnoses (≥ 2) each significantly increased over time (p < 0.0001), degenerative disc disease, scoliosis, spondylolisthesis, trauma, tumour and other diagnosis each decreased significantly (p < 0.0001).

The in-hospital complication rates after primary posterior lumbar fusion per 1000 inpatient days were also calculated. No significant changes in rates of peri-operative complications were observed for cerebral (β = 0.035, p = 0.051) and myocardial infarction (β = -0.007, p = 0.527); however, cardiac complications (other than myocardial infarction) (β = 0.059, p < 0.0001), pneumonia (β = 0.063, p < 0.0001), pulmonary embolism (β = 0.060, p < 0.0001), sepsis (β = 0.064, p < 0.0001) and shock cardiorespiratory arrest each increased significantly. Detailed analysis of the rates of peri-operative major complications linear trends adjusted per 1000 in-hospital days is given in Table II.
Discussion

We analysed nationally representative data on linear trends of major morbidity and mortality in primary posterior lumbar fusion surgery between 1998 and 2008. Over this period the total number of operations increased significantly. Patient age and comorbidity burden also increased over time. During the ten-year study period the length of hospital stay decreased, whereas routine discharges to patients’ customary residence remained unchanged. Adjusted in-hospital mortality also remained unchanged, whereas the incidence of most peri-operative major complications increased.

Our data demonstrate a mean increase in the number of primary posterior lumbar fusions of 11.6% per year. Although regional differences in the rate of lumbar fusion in the United States have been described previously, our data confirm an absolute, as well as a population growth-adjusted, increase in these procedures. This increase has been reported previously. Further analysis of types of fusion demonstrated a 15-fold increase in complex spinal fusions between 2002 and 2007. This constant increase in the total number and complexity of lumbar spinal fusions might be attributed to advances in implant design and manufacture, surgical techniques and management strategies. Although the surgical indications for fusion may remain similar, new technologies and improvements in peri-operative management allow surgeons to perform complex operations on patients with higher comorbidity and advanced age.

We found an increase in mean patient age of over four years within one decade. This may be attributable to the ageing population in general as well as to a steeper increase in lumbar fusions in elderly people. The comorbidity burden also increased between 1998 and 2008. Age and the presence of comorbidities have previously been linked to increased rates of complications and mortality after surgical procedures. In this context, our finding of increasing mean patient age over time must be viewed with concern.

A reduction in length of hospital stay, as shown in our study, has been described in other fields of spinal surgery, possibly due to improved peri-operative management strategies, pain control and improved rehabilitation regimes. In addition, increasing financial pressure by insurance carriers is likely to be a significant factor. However, the rates of patient discharge to their customary residence remained stable over the ten-year study period, suggesting that advances in post-operative care may be partially responsible for this trend.

Significant gender differences were observed, with more women undergoing lumbar fusion at any given time. This gender gap increased over time to reach a level of 12.6% weighted towards women in 2008. Such increased rates in women undergoing primary and revision lumbar fusion have previously been shown.

Unadjusted in-hospital mortality rates decreased from 0.17% in 1998 to 0.12% in 2008, and similar mortality rates were reported by Shen, Silverstein and Roth. These researchers also concluded that medically complicated and elderly patients are at an increased risk for in-hospital mortality and early post-operative complications. Fu et al reviewed over 10 000 lumbar operations and reported that all patients who died following these operations were over 60 years old. However, after adjusting for length of stay, the decrease in in-hospital mortality was not found to be significant. Our data represent unchanged adjusted in-hospital mortality, even though the mean age and comorbidity burden increased from 1998 to 2008. Shifts in the patient population and improvements in management might explain this stability of mortality rates. Although mortality risk might be increased in the elderly, this is counterbalanced by a significantly decreased mortality rate among younger patients. Furthermore, advances in peri-operative care might counterbalance the increased risk of peri-operative mortality posed by an older and medically unfit patient population. Our findings clearly underline the importance of ongoing research in optimising peri-operative management strategies. As there is a trend towards increasing comorbidity and age among patients undergoing lumbar fusion, future efforts to improve patient care, targeting multiple peri-operative factors, will have to be pursued in order to ensure satisfactory outcomes.

The analysis of major peri-operative complications is shown in Table II. The most significant increase was seen in the incidence of sepsis, cardiac complications other than acute myocardial infarction, pneumonia and pulmonary embolism. This increase in pulmonary and cardiac complications has already been reported in patients undergoing cervical fusion. Although pulmonary embolism is relatively rare following lumbar surgery and routine screening for detection of asymptomatic thrombosis might not be indicated, our data show a significant increase in pulmonary embolism over the past decade, and these findings are comparable with previously published data. Owing to the shift towards elderly patients, prospective studies should...
important, as it is known that posterolateral, PLIF and example, the exact procedural details are unknown. This is tions associated with the analysis of the NIS database. The profile.25 Furthermore, the database only allows interpreta-

Our findings must be interpreted according to the limita-
tions associated with the analysis of the NIS database. The clinical information gained from the NIS is limited. For example, the exact procedural details are unknown. This is important, as it is known that posterolateral, PLIF and TLIF procedures differ significantly in their risk–benefit profile.23 Furthermore, the database only allows interpretation of inpatient complications and mortality rates. The rates of peri-operative complications are likely to be higher than shown in this study because post-operative complications and deaths outside the hospital are not captured. Additionally, possible coding bias has to be considered. Using the ICD-9-CM coding system leaves a large number of alternative code options for each entity.

In general, there is a lack of detailed information relating to spinal surgery in the available databases, and thus it seems prudent that a specialty-specific registry be pursued. With such an approach more detailed and important information could be captured that might lead to opportunities to study outcomes and linear trends in a more comprehensive manner.

In conclusion, this study confirms a nationwide increase in the number of primary posterior lumbar fusions. Gener-

Table I. Linear trend analysis showing trends in percentages of spinal pathologies among patients undergoing posterior lumbar spine fusion

<table>
<thead>
<tr>
<th>Pathology</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>Regression coefficient</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degenerative disc disease</td>
<td>43.7</td>
<td>41.9</td>
<td>44.8</td>
<td>47.8</td>
<td>48.4</td>
<td>47.6</td>
<td>45.1</td>
<td>44.6</td>
<td>45.3</td>
<td>44.1</td>
<td>43.5</td>
<td>-0.006</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Spinal stenosis</td>
<td>10.4</td>
<td>9.7</td>
<td>10.7</td>
<td>10.0</td>
<td>9.4</td>
<td>9.8</td>
<td>10.0</td>
<td>9.8</td>
<td>9.9</td>
<td>10.7</td>
<td>11.3</td>
<td>0.011</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Scoliosis</td>
<td>1.7</td>
<td>2.1</td>
<td>1.9</td>
<td>2.0</td>
<td>1.5</td>
<td>1.2</td>
<td>1.4</td>
<td>1.4</td>
<td>1.2</td>
<td>1.2</td>
<td>1.1</td>
<td>-0.064</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Spondylolisthesis</td>
<td>6.8</td>
<td>7.9</td>
<td>7.1</td>
<td>6.0</td>
<td>6.0</td>
<td>6.0</td>
<td>5.5</td>
<td>5.5</td>
<td>5.1</td>
<td>4.7</td>
<td>4.2</td>
<td>-0.056</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Trauma</td>
<td>2.5</td>
<td>2.4</td>
<td>1.9</td>
<td>1.4</td>
<td>1.4</td>
<td>1.7</td>
<td>1.9</td>
<td>1.3</td>
<td>1.6</td>
<td>1.6</td>
<td>1.2</td>
<td>-0.049</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Oncologic</td>
<td>0.4</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.4</td>
<td>0.3</td>
<td>0.2</td>
<td>0.3</td>
<td>0.2</td>
<td>0.3</td>
<td>0.2</td>
<td>-0.045</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Other</td>
<td>5.9</td>
<td>6.3</td>
<td>6.2</td>
<td>5.0</td>
<td>5.6</td>
<td>4.7</td>
<td>4.1</td>
<td>4.3</td>
<td>4.6</td>
<td>3.7</td>
<td>4.5</td>
<td>-0.045</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Multiple spinal diagnoses (≥ 2)</td>
<td>28.5</td>
<td>29.4</td>
<td>27.1</td>
<td>27.4</td>
<td>27.3</td>
<td>28.7</td>
<td>31.8</td>
<td>32.8</td>
<td>32.1</td>
<td>33.8</td>
<td>33.8</td>
<td>0.035</td>
<td>&lt; 0.0001</td>
</tr>
</tbody>
</table>

Table II. Linear trend analysis showing the rate per 1000 in-hospital days of peri-operative complications after lumbar spinal fusion surgery

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cerebral infarction</td>
<td>0.34</td>
<td>0.28</td>
<td>0.26</td>
<td>0.28</td>
<td>0.23</td>
<td>0.27</td>
<td>0.28</td>
<td>0.41</td>
<td>0.33</td>
<td>0.30</td>
<td>0.42</td>
<td>0.035</td>
<td>0.051</td>
</tr>
<tr>
<td>Sepsis</td>
<td>0.58</td>
<td>0.62</td>
<td>0.54</td>
<td>0.58</td>
<td>0.55</td>
<td>0.75</td>
<td>0.69</td>
<td>0.70</td>
<td>0.93</td>
<td>0.84</td>
<td>1.03</td>
<td>0.064</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Shock/cardiac arrest</td>
<td>0.16</td>
<td>0.13</td>
<td>0.21</td>
<td>0.21</td>
<td>0.30</td>
<td>0.28</td>
<td>0.15</td>
<td>0.28</td>
<td>0.26</td>
<td>0.21</td>
<td>0.29</td>
<td>0.046</td>
<td>0.02</td>
</tr>
<tr>
<td>Acute myocardial infarction (AMI)</td>
<td>0.65</td>
<td>0.75</td>
<td>0.88</td>
<td>0.73</td>
<td>0.51</td>
<td>0.77</td>
<td>0.80</td>
<td>0.63</td>
<td>0.62</td>
<td>0.69</td>
<td>0.73</td>
<td>-0.007</td>
<td>0.527</td>
</tr>
<tr>
<td>Cardiac complications (non-AMI)</td>
<td>5.13</td>
<td>5.16</td>
<td>4.99</td>
<td>5.37</td>
<td>5.42</td>
<td>5.80</td>
<td>6.83</td>
<td>6.99</td>
<td>6.88</td>
<td>8.16</td>
<td>8.44</td>
<td>0.059</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>1.88</td>
<td>2.01</td>
<td>1.99</td>
<td>2.24</td>
<td>2.40</td>
<td>2.55</td>
<td>3.05</td>
<td>2.83</td>
<td>3.30</td>
<td>3.00</td>
<td>3.57</td>
<td>0.063</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Pulmonary embolism</td>
<td>0.31</td>
<td>0.47</td>
<td>0.47</td>
<td>0.41</td>
<td>0.48</td>
<td>0.38</td>
<td>0.61</td>
<td>0.63</td>
<td>0.53</td>
<td>0.65</td>
<td>0.69</td>
<td>0.059</td>
<td>&lt; 0.0001</td>
</tr>
</tbody>
</table>

NATIONAL IN-HOSPITAL MORBIDITY AND MORTALITY TRENDS AFTER LUMBAR FUSION SURGERY BETWEEN 1998 AND 2008

In conclusion, this study confirms a nationwide increase in the number of primary posterior lumbar fusions. Gener-

ally, patients presented at an older age and had an increased comorbidity burden over time. However, adjusted mortal-

ity rates remained stable between 1998 and 2008, whereas non-myocardial infarction cardiac, pulmonary and septic complications increased. These findings suggest that although advances in peri-operative medicine may have a positive impact on the extreme outcome of mortality, the increases in many major complications reflect the increasing demands on the peri-operative health-care team brought about by increases in comorbidity burden and advanced age. Future endeavours in the peri-operative arena will need to focus on interventions targeted to maintain adequate outcomes in a patient population that is increasingly medically unfit and elderly.

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cial party related directly or indirectly to the subject of this article.

References
4. Ma Y, Passias P, Gaber-Baylis LK, Girardi FP, Memtsoudis SG. Comparative in-
5. Memtsoudis SG, Vougioukas VI, Ma Y, Gaber-Baylis LK, Girardi FP. Perioper-


