Clinical Study

Incidence and prevalence of surgery at segments adjacent to a previous posterior lumbar arthrodesis

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Abstract

BACKGROUND CONTEXT: Adjacent segment disease (ASD) after lumbar spinal fusion has been an important reason behind the development of nonfusion stabilization technology. However, the incidence, prevalence, and factors contributing to adjacent segment degeneration in the lumbar spine remain unclear. A range of prevalence rates for ASD have been reported in the lumbar spinal literature, but the annual incidence has not been widely studied in this region. Conflicting reports exist regarding risk factors, especially fusion length.

PURPOSE: To determine the annual incidence and prevalence of further surgery for adjacent segment disease (SxASD) after posterior lumbar arthrodesis and examine possible risk factors.

STUDY DESIGN: Retrospective cohort study.

PATIENT SAMPLE: Nine hundred twelve patients who underwent 1,000 consecutive posterior lumbar interbody fusion procedures, with mean follow-up duration of 63 months (range, 5 months–16 years).

OUTCOME MEASURES: Further surgery for ASD or surgery-free survival.

METHODS: A postal and telephone survey. Follow-up rate: 91% of patients. The annual incidence and prevalence of ASD requiring further surgery were determined using Kaplan–Meier survivorship analysis. Cox proportional-hazards (Cox) regression was used for multivariate analysis of possible risk factors. Significance was set at \( p < .05 \).

RESULTS: Further surgery for ASD occurred following 130 of 1,000 or 13% of procedures at a mean time of 43 months (range, 2.3–162 months). The mean annual incidence of SxASD over the first 10 years, in all patients, was 2.5% (95% confidence interval [95% CI], 1.9–3.1) with prevalences of 13.6% and 22.2% at 5 and 10 years, respectively. Cox regression modeling found that the number of levels fused (\( p < .0003 \)), age of the patient, fusing to L5, and performing an additional laminectomy adjacent to a fusion all independently affect the risk of SxASD. The mean annual incidence figures in the first 10 years after a lumbar fusion were 1.7% (95% CI, 1.3–2.2) after fusion at single levels, 3.6% (2.1–5.2) after two levels, and 5.0% (3.3–6.7) after three and four levels. The 5- and 10-year prevalences were 9% and 16%, 17% and 31%, and 29% and 40% after single-, two-, and three-/four-level fusions, respectively. The risk of SxASD in patients younger than 45 years was one-quarter (95% CI, 10–64) the risk of patients older than 60 years (\( p < .003 \)). A laminectomy adjacent to a fusion increases the relative risk by 2.4 times (95% CI, 1.1–5.2; \( p < .03 \)). Stopping a fusion at L5 is associated with a 1.7-fold increased risk (95% CI, 1.2–2.4; \( p < .007 \)) of SxASD compared with a fusion to S1, for fusions of the same length.
CONCLUSION: The overall annual incidence and predicted 10-year prevalence of further surgery for ASD after lumbar arthrodesis were 2.5% and 22.2%, respectively. These rates varied widely depending on the identified risk factors. Although young patients who underwent single-level fusions were at low risk, patients who underwent fusion of three or four levels had a threefold increased risk of further surgery, compared with single-level fusions (p<.0001), and a predicted 10-year prevalence of 40%. © 2011 Elsevier Inc. All rights reserved.

Keywords: Adjacent segment disease; Spinal fusion; Lumbar

Introduction

Thirty years ago, Ehni asserted that, “fusion generates a conflict between immediate benefit and late consequences” [1]. There remains a widely held belief that creation of rigid sections in the lumbar spine will lead to excessive stress on and premature degeneration of the motion segments adjacent to an arthrodesis [1–23]. This belief is supported by in vitro evidence of increased stresses and intradiscal pressures at segments adjacent to a lumbar spinal fusion [24–29]. If true, it is important that clinicians, their patients, and health economists have an accurate knowledge of the incidence and risk factors for the development of adjacent segment disease (ASD) after lumbar arthrodesis. Such knowledge will enable a better understanding of the role and place for nonfusion stabilization technology [21,30–32].

A number of clinical studies have examined the prevalence of symptomatic ASD at various time points after lumbar fusion [2–5,15,17,22,23,33–35]. Harrop et al. [36] recently reported the results of a systematic review of the published rates of radiographic adjacent segment degeneration and symptomatic ASD after lumbar spinal fusion. They emphasized the difference between these two conditions and noted a range in the reported prevalence rates of ASD, between 0% and 36%, over various time intervals.

In 1999, Hilibrand et al. [37] reported the results of their detailed study of both the incidence and prevalence of ASD in 374 patients after anterior cervical fusion. They defined “annual incidence” as the percentage of patients in whom new disease developed during the course of a given year of follow-up, having been disease free at the start of that year, and found this to be 2.9%. They defined “prevalence” as the percentage of all patients in whom symptomatic ASD developed within a given period of follow-up. With the exception of a limited investigation by Ghiselli et al. [3], a similar study to that of Hilibrand et al. does not appear to have been carried out in the lumbar spine.

The aim of the present study was to determine annual incidence and prevalence figures for the lumbar spine in a large consecutive patient cohort. The substantial cohort size and uniform surgical technique aided subgroup analysis and investigation of potential risk factors for surgery for adjacent segment disease (SxASD). Similar Kaplan–Meier (K-M) [38] statistical methodology to Hilibrand et al. [37] was used to determine annual incidence and prevalence. Potential surgical and demographic risk factors for SxASD were explored using Cox proportional-hazards (Cox) regression modeling [39]. To reduce potential inaccuracy in retrospective diagnosis of clinically significant ASD, the authors chose to examine rates of surgery for ASD using the end point of further surgical intervention rather than the presence of symptoms or radiographic signs of degeneration.

Material and methods

Study population

The study population comprised 912 consecutive patients with lumbar degenerative disease who underwent a total of 1,000 fusion procedures, by a single surgeon (WRS), using a posterior lumbar interbody fusion (PLIF) technique, between October 1993 and November 2009.

There were 412 male and 588 female patients. Mean age at the time of the index surgery was 63 years (range, 14–92). The mean number of lumbar spine surgeries before the index fusion procedure was 0.8±1.0 (range, 0–6). Clinical outcome data, recorded prospectively on patients after September 2000, showed a mean preoperative Oswestry Disability Index score of 46.5±15.8 (?standard deviation) and 12-Item Short-Form Health Survey Physical Components Summary of 29.3±7.6. Mean body mass index was 27.9±4.8 (range, 17–52). Fusion involved one or more levels between T9 and the sacrum (see Fig. 1).

The primary indication for the index surgical intervention was the failed conservative management of severe low back pain and/or radiculopathy associated with lumbar degenerative pathology. The surgical indications and associated deformities are summarized in Tables 1 and 2. Levels for fusion were decided on the basis of clinical symptoms and radiological signs. Patients with acute fracture, dislocation, or malignancy were excluded.

Patients were subjected to postal and/or telephone survey. Inquiry was made of the reason for the time, nature, and level of any further lumbar surgery for degenerative disorders. Follow-up was available on 91% of patients and 92% of procedures. Eleven percent of patients are known to have died before follow-up without undergoing further surgery. The mean duration of follow-up was 5 years and 3 months (range, 6 months–16 years). Minimum 5-year follow-up was available on 390 procedures.

In the case of deceased patients, date of death or last follow-up and the details of any further lumbar surgery...
before death were recorded. After patients reached the end point of further fusion surgery, they were reentered into the database with the extension fusion surgery treated as a new index procedure. All procedures were included in the primary statistical analysis (including the fusion extensions). A second K–M analysis was conducted in which the extension surgeries were excluded.

Surgical technique

All patients underwent decompression and open PLIF with restoration of coronal and sagittal alignment using “insert and rotate” interbody spacers and pedicle screw instrumentation [40,41]. The upper half of the spinous process and laminae were preserved at the most cranial instrumented/fused vertebra, except in patients who had undergone complete laminectomy at a previous surgery. Care was taken to avoid violation of the facet joints at the motion segment immediately cranial to the fusion, by the pedicle screw instrumentation.

Statistical analysis

Kaplan–Meier survivorship analysis [38] curves were determined for all patients and for the following subgroups:

- age—stratified into three groups: younger than 45 (n=130), 45 to 60 (n=199), and older than 60 years (n=671)
- number of levels fused—single-level (n=593), two-level (n=219), and three/four-level (n=118) fusions.

The annual incidence for each given year of follow-up was determined by dividing the number of patients who underwent surgery for ASD in that year by the number of patients who had been disease free at the start of the year. The mean annual incidence with 95% confidence intervals (95% CI) was calculated for all patients and subgroups. Similar figures for prevalence were determined.

Cox proportional-hazards regression modeling was used for multivariate analysis of the following potential risk factors for SxASD:

- age—stratified into three groups: younger than 45 (n=130), 45 to 60 (n=199), and older than 60 years (n=671)
- number of levels fused—stratified into four groups: single level (n=593), two levels (n=216), three or four levels (n=117), and five+ levels (n=60)
- sex—male or female
- previous surgery—0 to 6
- laminectomy adjacent to the index fused levels—yes or no
- level of the distal fused vertebra—L1, L2, L3, L4, L5, or S1
- deformity—stratified into six groups: nil, degenerative spondylolisthesis, lytic spondylolisthesis, degenerative scoliosis <15°, degenerative scoliosis >15°, and kyphosis/flat back.

Variables were entered stepwise into the regression model. Significance was set at p<.05. Kaplan–Meier analyses were performed using Xlstat version 2009.6.03 (Addinsoft SARL, Paris, France) and the Cox modeling using Medcalc version 11.2.1.0 (MedCalc Software, Mariakerke, Belgium).

Results

Further surgical intervention for ASD was required following 130 or 13.0% of the 1,000 procedures. One hundred eighteen of the ASD surgeries involved further arthrodesis at one or more adjacent levels. Twelve procedures involved
decompression only. The mean time to further surgery for ASD in the study population was 42.8 months (range, 2.3–162 months).

Results of the K–M analysis for all patients are shown in Table 3. The K–M survivorship analysis predicted 5-, 10-, and 15-year prevalence rates of 13.6%, 22.2%, and 27.3%, respectively. The mean annual incidence of all patients undergoing further surgery for ASD was 2.5% (95% CI, 1.9–3.1). The annual incidence of SxASD was relatively constant over 15 years for single-level fusions. Linear regression analysis showed a declining incidence over time for three- and four-level fusions (Fig. 2).

![Number of Levels Fused](image1)

![Levels Fused](image2)

Fig. 1. (Top) Number of levels fused at index surgery. (Bottom) Levels fused at index surgery.
The annual incidence and prevalence rates of SxASD after all fusions and following one-, two-, and three/four-level fusions are shown in Table 4. Kaplan–Meier analysis revealed significant differences in the incidence of SxASD according to the numbers of levels fused (Fig. 3, p<.0001, log-rank test). This univariate analysis was supported by the results of the multivariate Cox regression analysis. There was no significant difference in the results of the K–M analysis after removing those patients who had been reentered after extension surgery for ASD.

The results of the Cox analysis of possible risk factors for ASD are shown in Table 5. The risk of patients younger than 45 years requiring further surgery was one-quarter (95% CI, 10–63) the risk of patients older than 60 years (p=.003). The results of the Cox modeling of the age covariate on survival are shown in Fig. 4.

Performing a laminectomy at a level adjacent to the fusion increased the relative risk of SxASD by 2.4 times (95% CI, 1.1–5.2; p=.03).

The Cox analysis found that, for fusions of the same length, stopping a fusion at L5 is associated with an increased risk of SxASD compared with a fusion to S1. Table 6 provides figures for the number and percentages of patients who underwent SxASD at segments rostral and caudal, relative to the lowest vertebra fused (L5 or S1) and for the number of levels fused.

<table>
<thead>
<tr>
<th>Variables rejected as independent and significant contributors (p&gt;.1) to the Cox regression model were:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• sex</td>
</tr>
<tr>
<td>• fusion of more than four levels</td>
</tr>
<tr>
<td>• type of deformity</td>
</tr>
<tr>
<td>• lowest fused level: L4 or above.</td>
</tr>
</tbody>
</table>

### Discussion

Many authors have suggested that the creation of rigid segments may predispose to the degeneration of segments adjacent to a fusion [1–10,14–23]. In the current series, 13% of 1,000 PLIF procedures required further surgery after the development of degenerative disease at an adjacent level, at an average of 43 months after the index procedure (range, 2.3–162 months). Cheh et al. [2] reported a rate of clinical ASD of 30.3% for 188 patients at an average follow-up of 7.8 years. Gillet [22] found that 20% of 78 patients followed for a minimum of 5 years, after instrumented posterolateral fusion, required further surgery. Chen et al. [4] reported clinical ASD in 9.7% of 185 patients, where the average follow-up was 3.5 years. Harrop et al. [36] noted in their 2008 systematic literature review...
that 173 of 1,216 or 14% of patients, in 16 articles, developed symptomatic ASD. The sample sizes in these articles varied between 41 and 215 and the average lengths of follow-up were between 3.5 and 21.5 years. They commented on a significant difference in the reported rates of ASD ($p < .0001$) depending on the level of evidence—150 of 870 or 17% of patients developed ASD in Level III studies compared with 23 of 346 or 7% in Level IV studies.

The present study had a high follow-up rate (91%) and used K–M survivorship analysis to determine the risk of further surgery for ASD. The mean annual incidence of further surgery following the 1,000 procedures was found to

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**Table 4**

Mean annual incidence (over first 10 years with 95% CI) and prevalence rates (percentages with standard errors) of surgery for ASD after all fusions and single-, two-, and three/four-level fusions

<table>
<thead>
<tr>
<th>Number of levels fused</th>
<th>ASD annual incidence mean, % (95% CI)</th>
<th>5 y Prevalence, % (SE)</th>
<th>10 y Prevalence, % (SE)</th>
<th>15 y Prevalence, % (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All patients</td>
<td>2.5 (1.9–3.1)</td>
<td>13.6 (1.3)</td>
<td>22.2 (2.0)</td>
<td>27.3 (2.7)</td>
</tr>
<tr>
<td>One level</td>
<td>1.7 (1.3–2.2)</td>
<td>9.0 (1.4)</td>
<td>15.7 (2.3)</td>
<td>22.2 (3.5)</td>
</tr>
<tr>
<td>Two levels</td>
<td>3.6 (2.1–5.2)</td>
<td>17.2 (3.2)</td>
<td>30.9 (5.1)</td>
<td>36.1 (5.9)</td>
</tr>
<tr>
<td>Three/four levels</td>
<td>5.0 (3.3–6.7)</td>
<td>28.9 (5.2)</td>
<td>40.2 (6.9)</td>
<td>40.2 (6.9)</td>
</tr>
</tbody>
</table>

ASD, adjacent segment disease; 95% CI, 95% confidence interval; SE, standard error.

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Fig. 2. (Top) Linear regression of annual incidence by year of follow-up (single levels, $R^2 = 0.07$, $p = .3$). (Bottom) Linear regression of annual incidence by year of follow-up (3 and 4 level fusions, $R^2 = 0.73$, $p < .0001$).
be 2.5% (95% CI, 1.9–3.1) and the predicted 5- and 10-year prevalence rates were 13.6% and 22.2%, respectively. While the predicted prevalence rates were higher than the observed rate, the results of the K–M analysis should be regarded as a more accurate measure as the methodology takes account of variation in follow-up intervals and censorship through death or loss to follow-up [38]. Hilibrand et al. [37] used this statistical methodology when they reported the results of their study into the incidence and prevalence of ASD after anterior cervical fusion. They found a relatively constant annual incidence of 2.9%. In our study, the annual incidence was relatively constant for single-level fusions but tended to decline over time with two- and three- or four-level fusions (Fig. 2).

Ghiselli et al. [3] also used K–M survivorship analysis to examine the incidence and prevalence of SxASD in 215 patients after lumbar arthrodesis. They reported an annual incidence of 3.9% (95% CI, 2.8–5.1) and predicted prevalence rates of 16.5% and 36.1% for SxASD at 5 and 10 years, respectively. With the exception of the present study, Ghiselli et al. are the only investigators, to the authors’ knowledge, to use K–M methodology to determine the annual incidence of ASD in the lumbar spine. The mean annual incidence reported by Ghiselli et al. was higher than that found in the present series. The reason for the difference in the determined incidence rates of the two studies is uncertain but may be related to the use of two different patient groups in the study of Ghiselli et al. The validity of results derived from a K–M survivorship analysis depends on unsselected follow-up of the study population. It is noted that 50 of the 215 patients in the study of Ghiselli et al. were sourced from a separate external cohort, having undergone their index surgery at another institution or by another surgeon. Thirty of 50 (60%) underwent further surgery, having undergone their index procedure at a mean age of 41.9 years (compared with the combined study group mean of 50 years). It is unclear if the source of this subgroup was a random sample of or the entire external cohort.

Like Ghiselli et al. [3], the present study used Cox proportional-hazards multivariate regression modeling to explore possible risk factors for further surgery. Based on this methodology, we found that several factors significantly and independently influenced the relative risk of SxASD. These were the number of levels fused, age (stratified to three groups, <45 years, 45–60 years, and >60

<table>
<thead>
<tr>
<th>Covariate</th>
<th>b</th>
<th>SE</th>
<th>p</th>
<th>Exp (b)</th>
<th>95% CI of Exp (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>45–60</td>
<td>−0.587</td>
<td>0.24</td>
<td>.012</td>
<td>0.55</td>
<td>0.34–0.87</td>
</tr>
<tr>
<td>≤45</td>
<td>−1.364</td>
<td>0.47</td>
<td>.003</td>
<td>0.25</td>
<td>0.10–0.63</td>
</tr>
<tr>
<td>Number of levels fused</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 or 4</td>
<td>1.121</td>
<td>0.24</td>
<td>&lt;.0001</td>
<td>3.0</td>
<td>1.89–4.86</td>
</tr>
<tr>
<td>2</td>
<td>0.775</td>
<td>0.21</td>
<td>.0003</td>
<td>2.1</td>
<td>1.42–3.25</td>
</tr>
<tr>
<td>L5 (Lowest level fused)</td>
<td>0.498</td>
<td>0.19</td>
<td>.007</td>
<td>1.7</td>
<td>1.15–2.41</td>
</tr>
<tr>
<td>Additional laminectomy</td>
<td>TRUE</td>
<td>0.870</td>
<td>0.40</td>
<td>.03</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Values in bold indicate the relative risk.
years), stopping a fusion at L5 and performing a laminectomy adjacent to the fusion.

With regard to the number of levels fused, the authors’ study has found a significant difference (p < 0.0001) in the annual incidence figures after one-, two-, and three/four-level fusions, namely: 1.7% (95% CI, 1.3–2.2); 3.6% (95% CI, 2.1–5.2); and 5.0% (95% CI, 3.3–6.7) (Table 5). The literature contains conflicting reports as to the role of the number of levels fused as a risk factor for SxASD in the lumbar spine. In his retrospective review of 106 lumbar fusions, Gillet [22] noted that only 11% of the 37 single-level fusions later required an extension of their fusion and always after more than 5 years. In the case of two-level fusions, the prevalence of reoperation increased to 27%, and for three- and four-level fusions, the prevalence was 33%—rates similar to those of the present study. Neither Wiltse et al.[6] nor Kumar et al. [5] were able to find a significant association between the number of levels fused and the subsequent development of ASD. Like Hili-brand et al. in the cervical spine, Ghiselli et al., using K–M survivorship analysis and also Cox proportional-hazards regression in the lumbar spine, found no correlation between the length of the fusion and SxASD. As those authors stated, this finding was contrary to their hypothesis that “after multi-level fusion, more motion would be transferred to the adjacent segments, thus leading to a more rapid onset of disc degeneration and new disease at the adjacent levels.” As noted above, the results of the study of Ghiselli et al. may have been influenced by the different attributes of the two study cohorts.

Increasing age was also found to be a risk factor for SxASD in the present series. Other authors have commented on increasing age as a risk factor for ASD [15–17,35]. Min et al. [13] found the opposite to be true and Ghiselli et al. found no correlation with age in their study. When the patients in the present study were stratified into three age groups (<45, 45–60, and >60 years), and these groups were subjected to both K-M and Cox analysis, a significant difference was observed in the rates of SxASD among the groups. In the under 45-age group, only five of the 130 patients required SxASD. Although there may be a tendency for younger patients to have fewer segments fused or a different pathology to older patients at the index surgery, the multivariate Cox regression analysis confirmed age to be an independent covariate. It would, therefore, appear to be an important factor to note when comparing the results of different published studies. For example, Wai et al. [33] have questioned the role of fusion on the development of ASD after anterior lumbar interbody fusion but in a relatively young patient population.

The index pathology may play a role in the incidence of SxASD. Gillet [22], found a low rate of reoperation (2.4%) in patients fused for lytic spondylolisthesis and followed for more than 5 years. Guigui et al. [23] found the incidence of ASD higher in those fused for stenosis. The present study did not identify deformity type as an independent relative risk for SxASD.

The issue of floating a fusion remains controversial in the literature [4,42]. Although the present study did find a higher relative risk (1.7 ×, p = .007) if a fusion ends at L5 rather than S1, it should be noted that this assumes the same number of segments are included. The increased risk of SxASD with a longer fusion (to make the fusion reach to S1) may counteract the risk of stopping at L5 (see Table 6). We found no significant difference in the prevalence of SxASD between

![Fig. 4. Cox proportional-hazards regression survival curve for the age covariate, stratified into three groups (<45, 45–60, and >60 years).](image)

Table 6

The percentages (number) of patients undergoing surgery for ASD at segments rostral, caudal, or both according to the number of levels fused and the lowest vertebra fused (L5 or S1)

<table>
<thead>
<tr>
<th>Lowest vertebra fused</th>
<th>All patients</th>
<th>1 Level, % (n)</th>
<th>2 Levels, % (n)</th>
<th>3 or 4 Levels, % (n)</th>
<th>5+ Levels, % (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>462</td>
<td>209 (5.3)</td>
<td>124 (15.3)</td>
<td>83 (19.3)</td>
<td>46 (22.9)</td>
</tr>
<tr>
<td>Rostral ASD</td>
<td></td>
<td>5.3 (11)</td>
<td>15.3 (19)</td>
<td>19.3 (16)</td>
<td>2.2 (10)</td>
</tr>
<tr>
<td>L5</td>
<td>442</td>
<td>323 (3.4)</td>
<td>70 (14.3)</td>
<td>32 (18.8)</td>
<td>17 (18.8)</td>
</tr>
<tr>
<td>Caudal ASD</td>
<td></td>
<td>3.4 (11)</td>
<td>14.3 (10)</td>
<td>18.8 (6)</td>
<td>35.3 (6)</td>
</tr>
<tr>
<td>Rostral ASD</td>
<td></td>
<td>6.2 (20)</td>
<td>7.1 (5)</td>
<td>6.3 (2)</td>
<td>0 (2)</td>
</tr>
<tr>
<td>Both rostral and caudal ASD</td>
<td>0.6 (2)</td>
<td>1.4 (1)</td>
<td>6.3 (2)</td>
<td>0 (2)</td>
<td></td>
</tr>
<tr>
<td>All ASD for L5</td>
<td>10.2 (33)</td>
<td>22.9 (16)</td>
<td>31.3 (10)</td>
<td>0 (0)</td>
<td></td>
</tr>
</tbody>
</table>

ASD, adjacent segment disease.
L4–L5 and L4–S1 fusions although the trend was to more SxASD after the L4–S1 fusions. Reoperation for ASD occurred more frequently at levels cranial rather than caudal to L4–L5 fused segments.

As with other studies of ASD, there are strengths and weaknesses of the present study. The large number of consecutive patients, the high rate of follow-up, and the relative uniformity of treatment by a single surgeon adds power to subgroup analysis of an otherwise heterogeneous patient series: age, indications, deformity, number of and levels fused. However, in the present study, ASD has been examined after only one type of lumbar fusion. The surgeon involved (WRS) had his own threshold for deciding when and which spinal segments to fuse. Decisions regarding whether to float or fuse to the sacrum, whether to always fuse after laminectomy and whether to fuse segments showing evidence of degeneration are discretionary. Consequently, interpretation of the results of the present study must be made within the scope of an individual surgeon’s practice.

With regard to the PLIF surgical technique used in the current series, Cheh et al. [2] found no difference in rates of ADS between those patients who underwent circumferential fusion and those who underwent posterior-only fusion. Rahm and Hall [17], however, reported a higher incidence of ASD after PLIF when compared with posterolateral fusion. Wai et al. [33] found only three of 39 patients (8%) followed for a minimum of 20 years after anterior lumbar interbody fusion underwent further surgery for ASD. The mean patient age at the index surgery in their series was not given but based on the mean age at follow-up appears to have been 38 years. As noted above, this may have influenced the results. Although Wiltse et al. [6] felt the addition of pedicle screw instrumentation decreased the incidence of ASD, other surgeons have found that the placement of pedicle screw instrumentation may increase the rate of ASD [5,15,16].

The authors chose the end point of further surgery for ASD rather than attempt to retrospectively identify and quantify clinically significant (symptomatic) ASD. Simplifying the methodology, this way carries the risk of underestimating the rate of clinically significant ASD, as some patients with symptomatic ASD may be excluded for various reasons, such as intercurrent illness or patient preference.

A number of authors have published on the importance of postoperative spinal balance on the development of ASD [13,42,43]. The authors are presently undertaking a detailed analysis of the current series to determine the contribution of postarthrodesis spinal balance. Pre-existing degeneration as a risk factor for SxASD has been a subject of controversy [3,18,44] and will also be studied in the current patient series.

In the future, further study will be required of larger and preferably multicentered cohorts using various fusion techniques to gain a better understanding of the risk factors for the development of ASD. This knowledge and the results of randomized clinical trials will enable an evidence-based approach to the role of “dynamic stabilization” techniques.

References
