

Clinical Article

Accelerated L5-S1 Segment Degeneration after Spinal Fusion on and above L4-5 : Minimum 4-Year Follow-Up Results

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Objective : Many biomechanical and clinical studies on adjacent segment degeneration (ASD) have addressed cranial segment. No study has been conducted on caudal segment degeneration after upper segment multiple lumbar fusions. This is a retrospective investigation of the L5-S1 segment after spinal fusion at and above L4-5, which was undertaken to analyze the rate of caudal ASD at L5-S1 after spinal fusion on and above L4-5 and to determine that factors that might have influenced it.

Methods : The authors included 67 patients with L4-5, L3-5, or L2-5 posterior fusions. Among these patients, 28 underwent L4-5 fusion, 23 L3-5, and 16 L2-5 fusions. Pre- and postoperative radiographs were analyzed to assess degenerative changes at L5-S1. Also, clinical results after fusion surgery were analyzed.

Results : Among the 67 patients, 3 had pseudoarthrosis, and 35 had no evidence of ASD, cranially and caudally. Thirteen patients (19.4%) showed caudal ASD, 23 (34.3%) cranial ASD, and 4 (6.0%) both cranial and caudal ASD. Correlation analysis for caudal ASD at L5-S1 showed that pre-existing L5-S1 degeneration was most strongly correlated. In addition, numbers of fusion segments and age were also found to be correlated. Clinical outcome was not correlated with caudal ASD at L5-S1.

Conclusion : If caudal and cranial ASD are considered, the overall occurrence rate of ASD increases to 50%. The incidence rate of caudal ASD at L5-S1 was significantly lower than that of cranial ASD. Furthermore, the occurrence of caudal ASD was found to be significantly correlated with pre-existing disc degeneration.

KEY WORDS : Adjacent segment · Degenerative change · Lumbar spine fusion · Spinal stenosis.

INTRODUCTION

Degeneration that develops at mobile segments above or below a fused spinal segment is known as adjacent segment degeneration (ASD)⁹⁾. Many biomechanical and clinical studies on ASD have addressed cranial segment degeneration, and only a few studies have focused on the fate of caudal segment degeneration after upper segment fusion above the L5-S1 segment. Miyakoshi et al.⁷⁾ investigated lumbosacral degeneration after isolated L4-5 fusion and found no correlation between changes in L5-S1 disc height

and clinical outcome. Ghiselli et al.^{4,5)} investigated survivorship of the L5-S1 segment after isolated L4-L5 fusion and reported that only one patient in 32 had clinical symptoms that required foraminotomy and laminotomy at L5-S1 and also reported that prevalence rate of L5-S1 ASD was 7.2%. However, although these studies specifically focused on L5-S1 segment degeneration, they were restricted to the study of isolated L4-5 fusion. In these previous studies, multi-segment fusions in the thoracic and lumbar spine were included, but they did not address L5-S1 segment degeneration after multi-segment lumbar fusions.

Decision-making difficulties may arise when considering whether the L5-S1 segment should be included in a spinal fusion procedure. L5-S1 degeneration after upper segment fusion may also cause difficulties differentiating normal aging and pathologic processes. The focus in this study was placed on the analysis of the rate of caudal ASD at the L5-S1 seg-

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ment after upper lumbar segment fusion on and above L4-5, and to identify those factors that influence caudal ASD.

MATERIALS AND METHODS

Sixty-seven patients who had lumbar fusion involving the L4-5, L3-5, or L2-5 were included in this study. Patients with degenerative spondylolisthesis (50.7%), spondylostenosis (23.9%), isthmic spondylolisthesis (14.9%), and disc disease (10.4%) averaged 56.4 years of age (21 to 73 years), and included 42 females and 25 males. The mean follow-up period was 60.5 months (48 to 83 months). Fusions, performed at L4-5 (28 patients, 41.8%), L3-5 (23 patients, 34.3%), L2-5 (16 patients, 23.8%) levels included utilization of PLIF cages and pedicle screw fixation with laminectomy bone graft without posterolateral fusion. No statistically significant inter-group differences were evident in terms of sex, age, or follow-up period. Outcomes were measured utilizing a modified Whitecloud's questionnaire^{5,14}.

Postoperatively, dynamic X-rays utilized classic criteria to document fusion. Because we performed fusion utilizing PLIF cages and pedicle screw fixation without posterolateral fusion, we defined bone fusion as the (1) presence of adequate bone mass with trabeculation, (2) the absence of movement on dynamic radiographs, and (3) intact hardware. Anterior and posterior intervertebral disc heights were measured, and widths were determined by measuring anterior and posterior margins (Fig. 1). Disc heights were standardized using Farfan's method (Fig. 1)². PACS (Centricity Enterprise Web 2.0, GE Medical Systems, Milwaukee, WI) tools were used to measure disk heights. All the above measurements were taken by three persons independently and averages were then calculated. ASD was defined based on X-ray findings of (1) anterior or posterior spondylolisthesis, (2) facet joint hypertrophy, (3) osteophyte formation, (4) dynamic instability and (5) degenerative scoliosis^{8,9}.

SPSS for Windows Version 12.0K (SPSS, Chicago, IL) was used for all statistical analyses. The paired t-test was used to compare disc heights pre- to post-operatively. "Between-group" comparisons were conducted using Wilcoxon's Signed Ranks test and the Chi-squared test. Spearman's rank correlation analysis was used to determine independent contributions made by variable to postoperative L5-S1 degeneration and clinical outcome. *p* values of less than 0.05 were considered statistically significant.

RESULTS

Among the 67 patients, there were 3 patients (4.5%) with pseudoarthrosis only at the L4-5. These 3 patients did not

have ASD and symptoms, so did not require any further operative treatment. Thirteen patients (19.4%) demonstrated caudal L5-S1 ASD compared with a 23 patients (34.3%) frequency of cranial ASD, while 4 patients (6%) exhibited both findings (Table 1).

ASD according to the numbers of segments fused

The occurrence rate of ASD (caudal and cranial) was found to be significantly related to the number of segments fused. The occurrence rates for cranial vs. caudal ASD increased the number of segments fused. ASD as the L5-S1 level occurred in 10.7% (1 level fusion), 17.4% (2 level fusions), and 37.5% (3 level fusions) of patients undergoing fusions. Progressively, greater frequencies of cephalad ASD similarly correlated with the number of fused levels (Table 1).

Caudal ASD according to pre-existing L5-S1 degeneration

Spearman's rank correlation analysis showed that older patients and those with more advanced age (*p*<0.05), pre-existing L5-S1 degenerative disease (*p*<0.01), undergoing fusion at multiple levels (*p*<0.05), developed greater postoperative ASD (Table 1).

Disc height changes of L5-S1

We analyzed intervertebral disc heights at L5-S1 using Farfan's method (Fig. 1). Postoperative disc height changes at

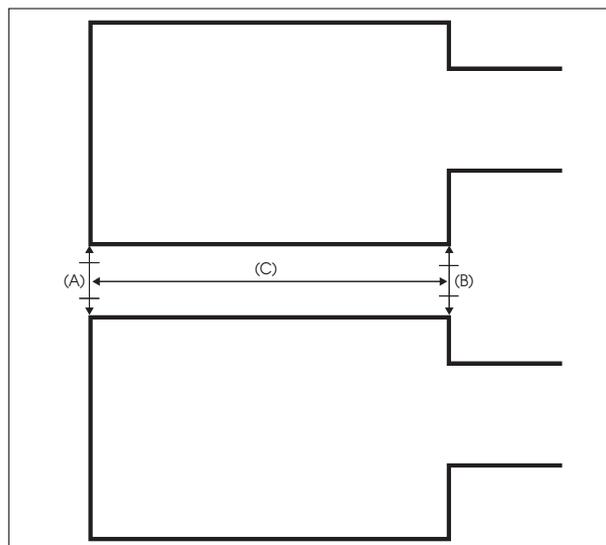


Fig. 1. Method used to determine intervertebral disc height and to standardize disc height using Farfan's method. Standardized intervertebral disc height is defined as [Anterior disc height (A)+ posterior disc height (B)]/distance between the anterior and posterior margin (C). Distance between the anterior and posterior margin (C) is defined the length of the line drawn between the points at the center of the disc.

Table 1. Summary of data according to the number of fused segments

Characteristic	L4-5 segment fusion (%)	L3-4-5 segments fusion (%)	L2-3-4-5 segments fusion (%)	Total (%)
No. of patients	28	23	16	67
Standardized pre-operative L5-S1 disc height*	0.65±0.12	0.61±0.16	0.68±0.08	0.65±0.13
Standardized post-operative L5-S1 disc height*	0.62±0.13	0.56±0.16	0.56±0.15	0.59±0.15
Caudal ASD on L5-S1 segment (a)	3 (10.7)	4 (17.4)	6 (37.5)	13 (19.4)
Cranial ASD (b)	7 (25)	9 (39.1)	7 (43.8)	23 (34.3)
Both (a) and (b)†	0	2 (8.7)	2 (12.5)	4 (6.0)
Preoperative L5-S1 segment degeneration (c)	6 (21.4)	6 (36.1)	4 (25.0)	16 (23.9)
Both (a) and (c)**	3 (10.7)	3 (13.0)	3 (18.8)	7 (13.4)

*Farfan's standardized disc height is defined as (anterior disc height+posterior disc height)/Width from anterior and posterior margin. It did not have a unit of measure. The values after the±mean the standard deviations. †Both (a) and (b) mean that there are caudal ASD on L5-S1 segment (a) and Cranial ASD (b), at the same time. So Both (a) and (b) belong to (a). **Both (a) and (c) mean that there are caudal ASD on L5-S1 segment (a) and preoperative L5-S1 segment degeneration (c), at the same time. Both (a) and (c) belong to (a). (a)+(b)+both (a) and (b)† +(c)+both (a) and (c)** are bigger than n

Table 2. L5-S1 Disc height

Characteristic	Pre-existing L5-S1 degeneration ($p<0.01$)	No pre-existing L5-S1 degeneration ($p<0.05$)
Standardized pre-operative L5-S1 disc height*	0.60±0.15	0.66±0.12
Standardized post-operative L5-S1 disc height*	0.48±0.12	0.62±0.14

*Farfan's standardized disc height is defined as (anterior disc height+posterior disc height)/width from anterior and posterior margin. It did not have a unit of measure. The values after the±mean the standard deviations

L5-S1 were more significantly reduced in patients with pre-existing L5-S1 degeneration (Table 2).

Factors influencing on caudal ASD

Spearman rank's correlation analysis showed a strong correlation between caudal ASD at L5-S1 and pre-existing L5-S1 degeneration (Spearman's rho (r)=-0.495, $p=0.000$), patient age (Spearman's rho (r)=-0.288, $p=0.018$), and numbers of segments fused (Spearman's rho (r)=-0.254, $p=0.038$). Pre-existing L5-S1 degeneration was found to be most correlated ($p<0.01$) with caudal ASD at L5-S1, and age and numbers of segments fused ($p<0.05$) were also found to be positively correlated.

Clinical outcomes

Using Whitecloud's outcome criteria, 15 patients had an excellent outcome, 39 a good outcome, 10 a fair outcome, and 3 had a poor outcome and Spearman's rank correlation analysis showed a strong correlation between a poor clinical outcome and age (Spearman's rho (r)=-0.257, $p=0.035$) and with cranial ASD (Spearman's rho (r)=-0.272, $p=0.026$). However, clinical outcome was not found to be correlated with the presence of caudal ASD.

DISCUSSION

In the present study, the factors found to influence the occurrence of caudal ASD at the L5-S1 segment were; pre-existing L5-S1 degeneration, numbers of segments fused, and patient age. Many clinical and biomechanical studies have described accelerated degeneration in lumbar segments

adjacent to a previous fusion, but again the focus has been on cranial ASD^{1,3,7,8,10-12,15}, and relative a few studies have addressed caudal segment degeneration^{4,6,13}. Ghiselli et al.⁵ investigated the survivorship of L5-S1 after isolated L4-L5 fusion, and in another study, Ghiselli et al.⁴ reported a rate of L5-S1 ASD of 7.2%. However, this study included multi-segment fusions in the thoracic and lumbar spine, and did not address L5-S1 segment degeneration after multi-segment lumbar fusions.

In the present study, pre-existing L5-S1 segment degeneration was found to be most correlated with the occurrence of caudal ASD at L5-S1. Moreover, pre-existing L5-S1 segment degeneration was more common in elderly patients and in patients in the 3-segment fusion group. When considering spinal fusion in a patient with pre-existing L5-S1 degeneration, the surgeon should determine whether this degeneration is symptomatic or not to decide L5-S1 including for fusion.

The second factor found to be correlated with the development of caudal ASD at L5-S1 was the number of segments fused. In a prior study by Ghiselli et al., the L5-S1 postoperative failure rate after L4-5 fusion was 10%, and only one of these failures developed significant clinical symptoms due to L5-S1 degeneration. In the present study, the rate of caudal ASD at L5-S1 after upper segment fusion on and above L4-5 was 19.4%. The reason for this higher prevalence in our study is attributed to the inclusion of multi-segment fusion, because the occurrence rate of caudal ASD at L5-S1 increased significantly with fused segment number, i.e., 10.7% for L4-5 fusion, 17.4% for L3-5 fusion, and 37.5% in L2-5 fusion.

In the present study, no significant correlation was found between caudal ASD and clinical outcome. Throckmorton et al.¹³⁾ also reported that ASD is usually had no clinically significance. As a result, only 3 of the 13 patients who developed caudal ASD needed a re-operation for symptom relief. Two patients operated by removal the previous hardware because of well fusion and L5-S1 fusion was done. 1 patient resolved symptoms by only decompression L5-S1.

Some limitations of the present study require elaboration. First, an MRI grading system is needed to more precisely compare L5-S1 degeneration before and after surgery. Furthermore, because of its retrospective nature, we were not able to perform a randomized control trial study, and thus, could not accurately verify whether adjacent segment degeneration was the result of natural aging of the lumbosacral segment or whether it was due to the influence of a previously fused upper segment. However, we believe that this study provides clues concerning the development of caudal ASD at L5-S1 after multi-segment lumbar fusion.

CONCLUSION

In the present study, the occurrence of caudal ASD was found to be significantly correlated with pre-existing disc degeneration, numbers of segments fused, and age. Despite the lack of a symptomatic correlation with caudal ASD at L5-S1, surgeons should carefully evaluate patients' symptoms and radiographic instability at L5-S1 before surgery, especially in elderly patients with preexisting L5-S1 degeneration and multi-segment fusion.

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