**SUPPLEMENTAL DIGITAL MATERIAL**

**Table 1. Demographics of ASP after lumbar fusion surgery or motion sparing technique**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Author  (Year) | Study design | Population | Purpose | Inclusion/Exclusion | Treatment | How ASD defined/  classification |
| Lee  (2009) | Case control | N = 1069  Male: 35.7%  Age: 58.4 (range, 46-76) years  Follow-up: 4.3 years  F/U rate: NR  ASD: 28/1069 (2.6%)  Diagnosis:   * Spinal stenosis * Isthmic and degenerative spondylolisthesis * Lumbar degenerative kyphosis * Degenerative disc disease * Disc herniation | To describe the incidence and clinical features of adjacent segment pathology (ASP) after lumbar fusion and to determine its risk factors. | Inclusion:   * Patients 35 years and older   Exclusion:   * Less than 35 years of age * Uninstrumented fusion * Unsuccessful union * Missing initial MRI data | Lumbar or lumbosacral fusion (no limitations in the type of fusion) | A condition in which a patient showed the relief of symptoms for at least 6 months after the index operation, the newly developed symptoms were compatible with the lesions in adjacent segments demonstrated in radiological images, and the patient had revision surgery for that problem. |
| Kaito  (2010) | Retrospective cohort | N = 85  Male: 34.1%  Age: 64.1 (range, 36-83) years  Follow-up: 38.8 months (range, 24-84) months  F/U rate: 85/97 (87.6%)  Radiographic ASP: 14/85 (16.5%)  Clinical ASP: 13/85 (15.3%)  Diagnosis:   * L4 spondylolisthesis | To investigate the distracted disc height of the fused segment, caused by cage or bone insertion during surgery, as a novel risk factor for ASP after posterior lumbar interbody fusion (PLIF). | Inclusion:   * L4 spondylolisthesis * Complete medical records with radiographs * Minimum 2 years post-operative follow-up   Exclusion:   * Decompression * Fusion procedures other than L4-5 PLIF | L4-5 posterior lumbar interbody fusion | Radiographic ASP:   * Development of L3 antero- or retrolisthesis more than 3 mm * Decrease in L3-4 disc height of more than 3 mm * Intervertebral angle at flexion smaller than -5°   Clinical deterioration of L3-4 ASP:   * Decrease of 4 or more points on the JOA scale * Neurological impairment in accordance with L3-4 canal stenosis based on MRI |
| Ahn  (2010) | Retrospective cohort | N = 3,188 patients (3193 cases)  Male: 32.7%  Age: 57 (range, 46-68) years  Follow-up: 10 years  F/U rate: NR  ASP: 107/3188 (3.5%)  Diagnosis:   * Spinal stenosis * Degenerative spondylolisthesis * Spondylosis * Degenerative scoliosis | To examine the survival function and prognostic factors of the adjacent segments based on a second operation after thoracolumbar spinal fusion. | Inclusion:   * Available for follow up * Thoracolumbar spinal fusion * Symptom free period of at least 6 months was requested to exclude incomplete surgery   Exclusion:   * Incomplete F/U | Posterior interbody fusion and other techniques | ASP evaluated based on the radiographs and if the neurological symptoms recurred.  Second operation of the adjacent segments.  ASP classification and definition not defined. |
| Sears  (2011) | Retrospective cohort | N = 912 patients with 1,000 procedures  Male: 45.2%  Age: 63 (range, 14-92) years  Follow-up: 5 years and 3 months (range, 5 months-16 years)  F/U rate: 390/1000 (39%) procedures  Surgery for ASD:130/1000 (13%) procedures  Diagnosis:   * Foraminal stenosis * Disc herniation * Instability * Degenerative spondylolisthesis * Scoliosis * Kyphosis | To determine the annual incidence and prevalence of further surgery for adjacent segment pathology after posterior lumbar arthrodesis and examine possible risk factors. | Inclusion:   * Failed conservative management of severe low back pain * Radiculopathy associated with lumbar degenerative pathology   Exclusion:   * Acute fracture * Dislocation * Malignancy | Decompression and posterior lumbar interbody fusion | Adjacent segment disease defined as progressive degeneration of disease to adjacent levels following fusion. |
| Ghiselli  (2004) | Retrospective cohort | N = 215  Male: 41.4%  Age: 50 (range, 13-85) years  Follow-up: 6.7 (range, 1-41) years  F/U rate: NR  Surgery for ASD: 59/215 (27.4%)  Diagnosis:   * Spondylolisthesis * Spinal stenosis * Scoliosis * Instability * Disc herniation * Nonradicular back pain | To determine the rates of degeneration and survival of the motion segments adjacent to the site of a posterior lumbar fusion. | Inclusion:   * Radiographic evidence of a healed lumbar fusion after the index arthrodesis.   Exclusion:   * Unavailable preoperative radiographs. | Posterior lumbar fusion. | The diagnosis of adjacent segment pathology was based on the presence of instability, radiculopathy, or spinal stenosis that was symptomatic enough for the patient to elect revision surgery. |

Table 2.  **Risks and relative risks or odds ratios for clinical adjacent segment pathology by risk factor.**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Author  (Year) | Outcomes | | Risk factors evaluated | Multivariate effect estimates | | | Author’s Conclusions |
| Radiographic ASP | Clinical ASP | P value | Odds ratio or relative risk | Confidence interval |
| Kaito  (2010) | 14/85 (16.5%) | 13/85 (15.3%)  11/13 (84.6%) of these patients had additional surgery | L-3 intervertebral angle (flex) | 0.19 | OR = 0.82 | 0.61-1.10 | The distracted distance between the ASP groups and the control group was significant (p = 0.04). The excessive distraction of disc space is suggested as a novel risk factor for the development of the radiographic and symptomatic ASP. |
| L-3-4 disc height | 0.76 | OR = 1.77 | 0.05-65.52 |
| L-4 retrolisthesis | 0.81 | OR = 1.53 | 0.05-45.01 |
| L-4 distance of translation | 0.26 | OR = 0.07 | 0.00-7.50 |
| L-4 intervertebral angle (ext) | 0.66 | OR = 1.06 | 0.83-1.34 |
| L4-5 ROM | 0.13 | OR = 0.85 | 0.69-1.05 |
| L4-5 disc height | 0.10 | OR = 0.04 | 0.00-1.80 |
| Lumbar lordosis at L1-S1 | 0.78 | OR = 1.01 | 0.92-1.12 |
| Facet joint degeneration | 0.78 | OR = 0.84 | 0.25-2.83 |
| **Change in disc height** | **0.04** | **OR = 57.26** | **1.11-2966.52** |
| Final disc height | 0.54 | OR = 0.39 | 0.02-8.27 |
| Lumbar lordosis at L1-S1 | 0.46 | OR = 0.96 | 0.86-1.07 |
| L4-5 fusion angle | 0.28 | OR = 1.09 | 0.93-1.27 |
| Lee  (2009) | NR | 28/1069 (2.6%) | Disc degeneration | 0.17 | OR = 0.48 | 0.17-1.38 | Based on logistic regression analysis preexisting facet degeneration was a significant risk factor (p < 0.01) for developing ASP. |
| **Facet degeneration** | **<0.01** | **OR = 0.01** | **<0.01-0.12** |
| Instability | 0.70 | OR = 0.63 | 0.06-6.46 |
| Listhesis | 0.41 | OR = 0.38 | 0.04-3.75 |
| Rotational deformity | 0.83 | OR = 0.74 | 0.05-11.40 |
| Disc wedging | 0.63 | OR = 1.81 | 0.16-20.61 |
| Ahn  (2010) | NR | 107/3188 (3.5%) had additional surgery  Disease risk at 5 and 10 years was 3% and 6%,  respectively | **Old age (> 61 years)** | **0.000** | **OR = 3.931** | **2.579-5.991** | Likelihood of a second operation was high in the following patients:   * Old age * Degenerative disease * Multiple-level fusion * Male sex |
| **Male sex** | **0.004** | **OR = 1.758** | **1.196-2.586** |
| **Degenerative disease** | **0.000** | **OR = 2.943** | **1.716-5.045** |
| **Multi-segment fusion** | **0.001** | **OR = 1.932** | **1.315-2.84** |
| Posterior lumbar interbody fusion | 0.903 | OR = 0.973 | 0.629-1.550 |
| Sears  (2011) | NR | 130/1000 (13%) of procedures required additional surgery  Mean annual incidence of future surgery was 2.5%  Predicted 5 and 10 year prevalence of future surgery was 13.6% and 22.2%, respectively | Age 45-60 years\* | 0.012 | RR = 0.55 | 0.34-0.87 | The risk of ASP in patients younger than 45 years was one quarter the risk of patients older than 60 (p = 0.003)  A laminectomy adjacent to the fusion increases the relative risk by 2.4 times (p = 0.03)  Stopping a fusion at L5 is associated with 1.7-fold increased risk compared with a fusion to S1 for fusions of the same length (p = 0.007) |
| **Age < 45 years\*** | **0.003** | **RR = 0.25** | **0.10-0.63** |
| **3 or 4 levels fused** | **<0.0001** | **RR = 3.0** | **1.89-4.86** |
| **2 levels fused** | **0.0003** | **RR = 2.1** | **1.42-3.25** |
| **L5 as the lowest level fused** | **.007** | **RR = 1.7** | **1.15-2.41** |
| **Additional laminectomy** | **0.03** | **RR = 2.4** | **1.09-5.17** |
| Ghiselli  (2004) | NR | 59/215 (27.4%)  Disease risk at 5 and 10 years was 16.5% and 26.1%,  respectively | Diagnosis | 0.34 | NR | NR | Rate of symptomatic degeneration at an adjacent segment warranting either decompression or arthrodesis or predicted to be 16.5% at five years 36.1% at 10 years. |
| Age at time of surgery | 0.13 | NR | NR |
| Gender | 0.92 | NR | NR |
| Instrumentation† | 0.47 | NR | NR |
| **Segments adjacent to single level fusion‡** | **< 0.001** | **RR = 3.4** | **1.83-6.23** |

\*Compared to patients >60 years of age

†Patients with instrumentation (51%) were compared to patients without instrumentation (49%). The type of instrumentation NR.

‡Segments adjacent to single level fusion compared to segments adjacent to multiple level fusion.

Level of Evidence Summary Table for Included Studies *Critical appraisal for article on prognosis*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Methodological Principle | Sears  2010 | Ghiselli  2004 | Lee  2009 | Kaito  2010 | Ahn  2010 |
| Study design  Prospective cohort study  Retrospective cohort study  Case-control | √ | √ | √ | √ | √ |
| Patients at similar point in the course of their disease or treatment | √ | √ | √ | √ | √ |
| Patients followed long enough for outcomes to occur | √ | √ | √ | √ | √ |
| Complete follow-up of >80% | √ | √ | √ | √ | √ |
| Controlling for extraneous prognostic factors | √ | √ | √ | √ | √ |
| Evidence Level | II | II | III | II | II |