Review Article

Incidence and risk factors of reoperation in patients with adjacent segment disease: A meta-analysis

ABSTRACT

Study Design: This was a systematic review of the literature and meta-analysis.

Objective: The objective of this study was to evaluate the current literature regarding the risk factors contributing to reoperation due to adjacent segment disease (ASD).

Summary of Background Data: ASD is a broad term referring to a variety of complications which might require reoperation. Revision spine surgery is known to be associated with poor clinical outcomes and high rate of complications. Unplanned reoperation has been suggested as a quality marker for the hospitals.

Materials and Methods: An electronic search was conducted using PubMed. A total of 2467 articles were reviewed. Of these, 55 studies met our inclusion criteria and included an aggregate of 1940 patients. Data were collected pertaining to risk factors including age, sex, fusion length, lumbar lordosis, body mass index, pelvic incidence, sacral slope, pelvis tilt, initial pathology, type of fusion procedure, floating versus sacral or pelvic fusion, presence of preoperative facet or disc degeneration at the junctional segment, and sagittal orientation of the facets at the junctional segment. Analysis of the data was performed using Comprehensive Meta-Analysis software (Biostat, Inc.).

Results: The overall pooled incidence rate of reoperation due to ASD from all included studies was 0.08 (confidence interval: 0.065–0.098). Meta-regression analysis demonstrated no significant interaction between age and reoperation rate ($P = 0.48$). A comparison of the event rates between males and females demonstrated no significant difference between male and female reoperation rates ($P = 0.58$). There was a significantly higher rate of ASD in patients with longer fusion constructs ($P = 0.0001$).

Conclusions: We found that 8% of patients in our included studies required reoperation due to ASD. Our analysis also revealed that longer fusion constructs correlated with a higher rate of subsequent revision surgery. Therefore, the surgeon should limit the number of fusion levels if possible to reduce the risk of future reoperation due to ASD.

Level of evidence: IV

Keywords: Adjacent segment disease, deformity, fusion, lumbar, spine, thoracic

INTRODUCTION

Posterior lumbar fusion is a widely performed procedure for treating a variety of conditions including scoliosis, spondylolisthesis, trauma, infections, or tumors. The number of patients undergoing lumbar fusion has increased significantly in the past 10–20 years.[1] Fusion surgery for spinal deformity is the definitive intervention for the management of this condition. Spinal fusion is intended to improve a patient's quality of life by achieving a stable correction of the deformity.[2]

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Despite various improvements in the efficacy of spinal fusion procedures, postoperative complications including revisions are still a reality.[3] The reoperation rate after spine deformity surgery has been reported to be 3.9%–25.8% in the literature.[4-7] Revision spine surgery is known to be associated with poor clinical outcomes, high rate of complications, and implant failures.[8,9] In addition, unplanned reoperation has been suggested as a quality marker for the hospitals where spine surgeries are performed.[10] Given the rising number of lumbar fusion procedures and new health-care policies regarding readmission and revision surgeries, spine surgeons need to be able to identify, adequately treat, and effectively decrease the risk of reoperation.

Adjacent segment disease (ASD) is a broad term referring to a variety of complications after spinal fusion including degenerative disc disease, facet arthritis, kyphosis, stenosis, compression fractures, listhesis, and instability,[11] posterior ligamentous complex disruption, or implant failure. Proximal junctional kyphosis (PJK), regarding which there are multiple proposed definitions, serves as one of the most discussed issues arising at an adjacent segment. One of the most widely reported definitions, proposed by Glattes *et al*., is defined as an increased sagittal Cobb angle of 10° or more than the preoperative measurement.[12] However, Bernhardt and Bridwell,[13] Lee *et al*.,[14] Helgeson *et al*.,[15] Hostin *et al*.,[16] and O'Shaughnessy *et al*.[17] have all reported differing definitions for PJK. Further complicating this issue, the interobserver reliability of measuring the proximal junctional Cobb angle has been reported to be as low as 0.55.[18] In addition, the clinical implications of PJK can be highly variable among patients. For example, Yagi *et al*. did not find any difference between the Scoliosis Research Society score and the Oswestry Disability Index between PJK and non-PJK patients at a 2- and 5-year follow-up.[19,20]

The purpose of our study was to evaluate the current literature regarding the risk factors contributing to reoperation due to ASD. Regardless of the radiological findings at the proximal end of the construct, further postoperative care of the patients is mostly dependent on whether the ASD is symptomatic. In these scenarios, factors leading to presentation before revision surgery include central or neural foraminal stenosis, sagittal imbalance, and pain which can be due to implant failure or fracture. To our knowledge, this is the first meta-analysis examining the risk factors of symptomatic ASD requiring reoperation after lumbar or thoracolumbar fusion.

MATERIALS AND METHODS

An electronic search was conducted using PubMed using the terms "adjacent," "segment," "disease," "pathology," "fusion," "lumbar," and "arthrodesis" [Figure 1]. Titles and abstracts were screened to determine which studies may be eligible for inclusion. Two of the authors were involved in the screening process (NW and AN). After the collation of these abstracts, full-length texts were reviewed and further deemed qualified after consideration of the criteria. Data pertaining to the ASD risk factors including age, sex, fusion length, lumbar lordosis (LL), body mass index (BMI), pelvic incidence (PI), sacral slope (SS), pelvic tilt (PT), initial pathology, type of fusion procedure, floating versus sacral or pelvic fusion, presence of preoperative facet or disc degeneration at the junctional segment, and sagittal orientation of the facets at the junctional segment were recorded and analyzed using Microsoft Excel (Redmond, WA). No funding source was utilized for this study.

We included studies that were (1) either retrospective or prospective, (2) published in English, (3) referred to lumbar or thoracolumbar spinal fusion either with or without the use of instrumentation, and (4) reported data regarding ASD requiring repeat surgical intervention in the whole group or subgroup of patients. Data regarding the reoperation rate and ASD risk factors were reported. We excluded studies that (1) examined procedures that may impact outcomes of patients with ASD (such as dynamic stabilization), (2) studies without clear report of at least one of the aforementioned risk factors or the rate of ASD reoperation, (3) studies that did not report the data and results clearly, (4) biomechanical studies, (5) case studies,

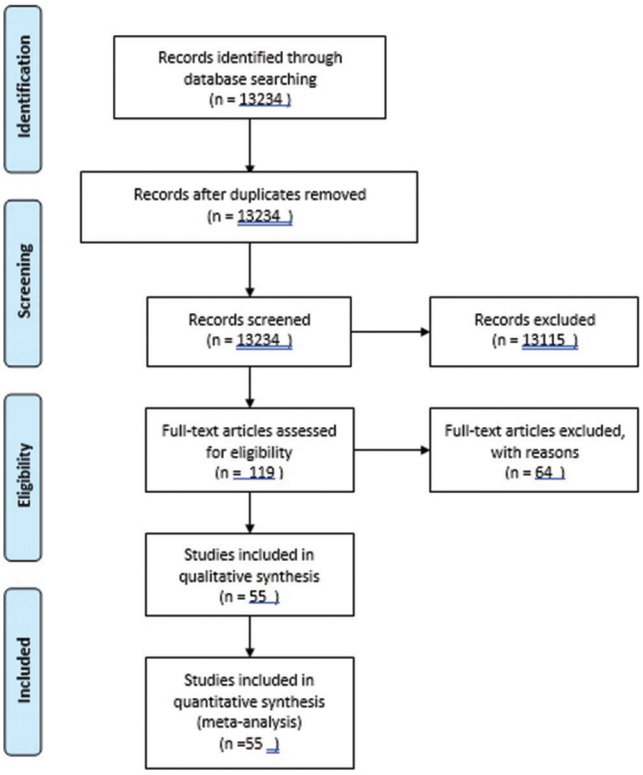

Figure 1: PRISMA flowchart showing the review of literature and selection process of the eligible studies

and (6) systematic reviews. A risk assessment summary based on the PRISMA protocol is provided in supplemental material.

Statistical analysis

The collected information from studies was imported into Comprehensive Meta-Analysis software (Biostat, Inc., Englewood, NJ, USA). We assessed whether there were enough eligible studies, and therefore statistical power, to examine each risk factor to be included in the analyses. Meta-regression or ANOVA was used for analysis. $P < 0.05$ was considered significant for all analysis and $P < 0.10$ was considered significant for *Q*-statistic.

Models were synthesized using random-effects model meta-analysis methods. We calculated the weighted pooled event rates of reoperation. A random-effects model was chosen due to variation among the individual studies' patient populations and surgical methods.[21] The mean prevalence was calculated with a 95% confidence interval (CI). Heterogeneity was assessed using *Q*-statistic and I^2 tests.[22] To study the interaction of risk factors with prevalence of reoperation rates, we conducted an analysis using meta-regression for continuous variables. We conducted subgroup analyses using ANOVA for categorical variables. Funnel plot and Egger's regression were used to assess publication bias.[23]

RESULTS

Fifty-five studies[1,24-77] with a total of 1940 participants met our inclusion criteria [Figure 1]. The average follow-up was 6.4 years. Reported surgical indications included instability, radiculopathy, cauda equina, imbalance, and

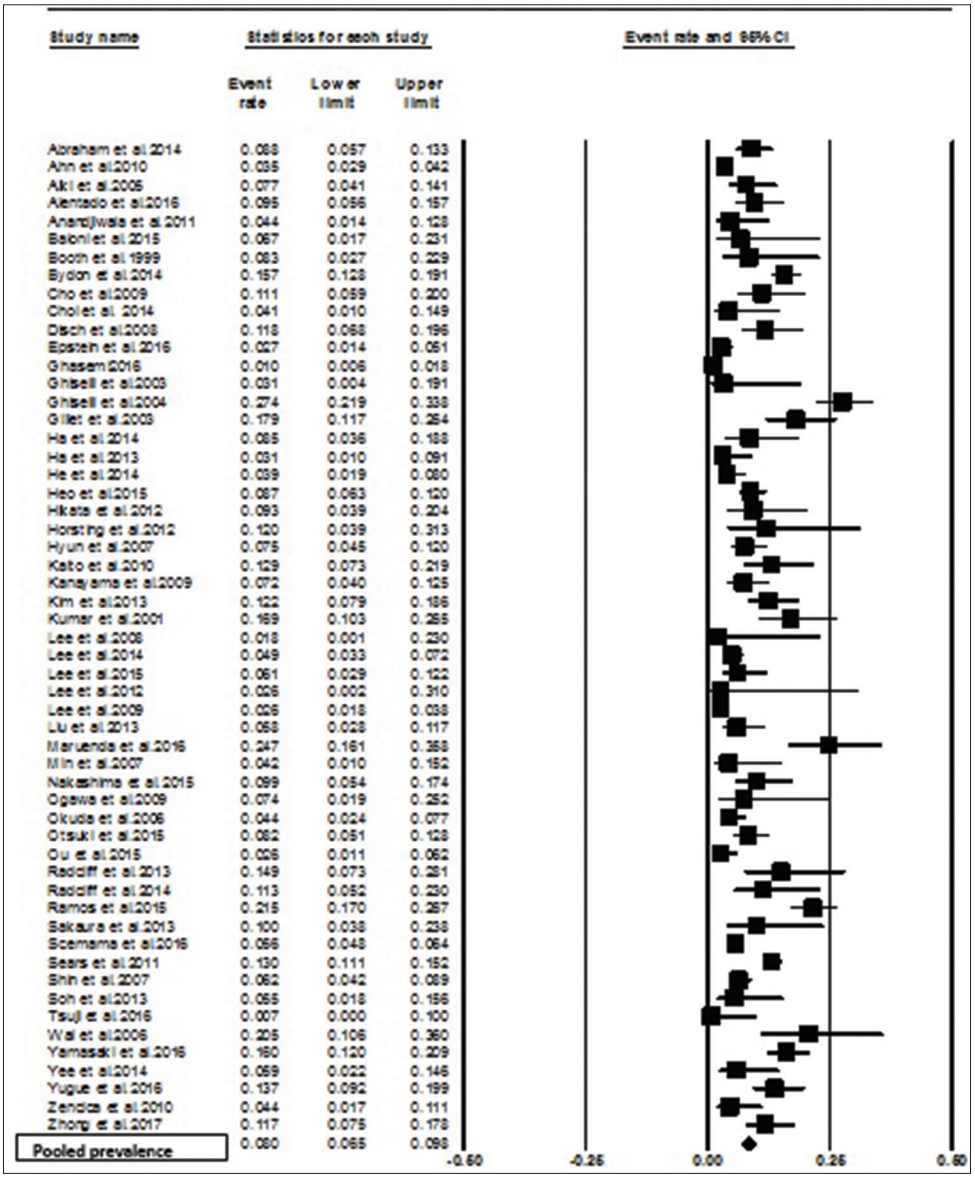

Figure 2: The reoperation rate due to adjacent segment disease in different studies

back pain. The pooled incidence rate of reoperation due to ASD was 0.08, meaning that about 8% of the patients from all studies who underwent spinal fusion surgery required reoperation due to ASD. The CI for the rate of reoperation was 0.065–0.098, which reveals that the mean rates of reoperation in the universe of studies could fall anywhere in this range.

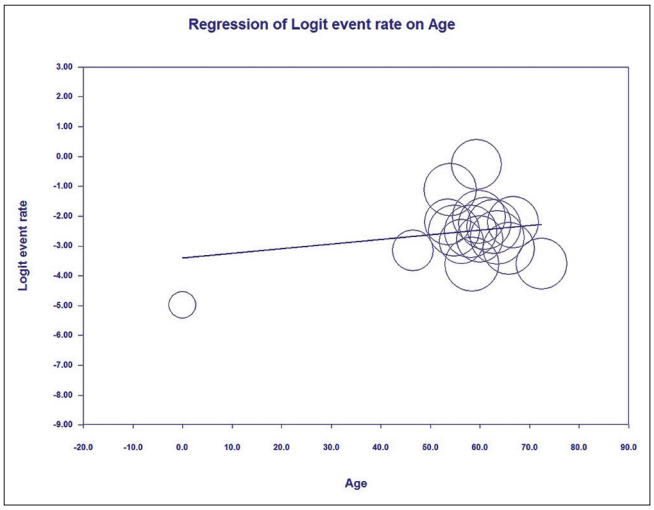

Figure 3: Scatterplot of the age meta-regression

The observed effect size varies somewhat among the included studies, which is to be expected due to sampling error. We need to determine if the observed variation falls within the range that can be attributed to sampling error (in which case there is no evidence of variation in true effects) or if it exceeds that range. The *Q*-statistic provides a test of the null hypothesis that all studies in the analysis share a common effect size. The *Q* value is 573.820 with 54° of freedom and $P < 0.001$. We can reject the null hypothesis that the reoperation rate is the same in all these studies. The I^2-statistic reveals what proportion of the observed variance reflects differences in true effect sizes rather than sampling error. Here, I^2 is 90.589. This reveals that about 90% of the variance in observed rates reflects variance in true rates rather than sampling error [Figure 2].

Since we have significant heterogeneity of event rates, we calculated the prediction interval to determine which was from 0.019 to 0.387.

Age

Age (mean age of participants with ASD, not the mean age of sample): Meta-regression: No significant interaction

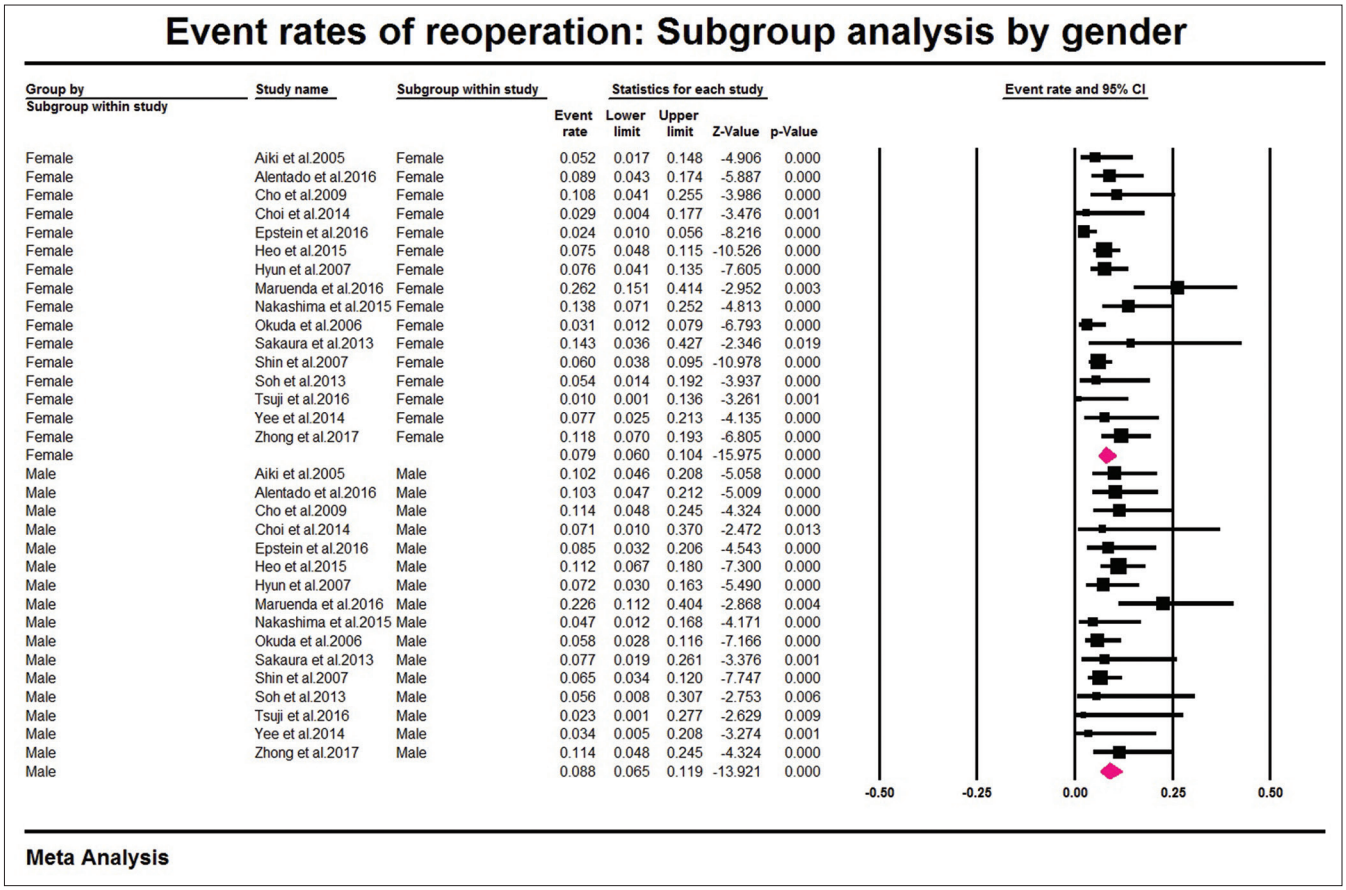

Figure 4: Analysis of the rate of reoperation based on sex

between age and reoperation event rates ($P = 0.48$) based on 17 studies that reported mean of participants needing reoperation for ASD [Figure 3].

Sex

Sixteen studies reported reoperation event rates by sex. For females, the pooled event rate is 0.079 with a CI of 0.060–0.104. For males, the pooled event rate is 0.088 with a CI of 0.065–0.119. The between-group comparison of the two event rates (0.079 vs. 0.088) resulted in a *P* value of 0.4. Hence, there is no significant difference in event rates between male and female subgroups [Figure 4].

Fusion length

Fusion length (mean fusion length of participants with ASD, not of total sample): Meta-regression analysis from 25 studies showed an interaction between event rates and fusion length with a significant $P = 0.0001$ [Figure 5].

Subgroup analysis of participants showed no significant difference in reoperation rates between participants who underwent fusion procedures extending or not extending to the sacrum/pelvis (floating and sacral procedures) where the *P* value of *Q*-statistic was 0.6. No valid conclusion could be made for BMI (3 studies), PI (5 studies), initial pathology (14 pathologies reported), and fusion procedures (8 procedures reported) since some pathologies and fusion procedures were reported in only 1–2 studies and subgroup analysis could not be performed. No other significant risk factors were identified based on the number of studies needed for a valid statistical analysis (LL, SS, PT, presence of preoperative facet or disc degeneration at the junctional segment, and sagittal orientation of the facets at the junctional segment).

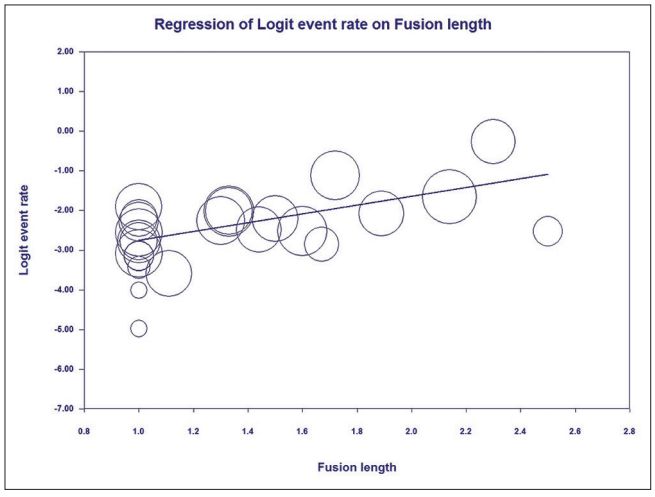

Figure 5: Scatterplot of the fusion length meta-regression

DISCUSSION

A recent study of the Healthcare Cost and Utilization Project Nationwide Inpatient Sample database showed that the annual number of spinal fusion in the US increased from 174,223 to 413,171 in 10 years[78] (from 1998 to 2008). Unplanned revision surgeries further increase health-care costs by increasing operating room utilization, lengthening surgical waiting list, and result in longer hospital stays.[79] These procedures can also negatively affect staff trust and self-confidence.[80] It is important to know risk factors for revision surgery as a guide for implementing preventative measures. ASD is the cause of revision surgery after spinal fusion. The present study reviewed the current literature to identify risk factors for reoperation on ASD.

There is much discrepancy among authors regarding the definition of ASD. For example, Cheh *et al*. reported almost 30% incidence of ASD in their cohorts. They mentioned that the high rate of ASD in their study was due to their generous definition of ASD.[81] In the current study, we focused on the clinical implications of ASD. We examined the current literature to evaluate what factor (s) affect the clinical outcomes of the patients after lumbar or thoracolumbar fusion procedures which required subsequent revision. Our study is designed to focus on the reoperation rate and risk factors of ASD rather than just radiological findings. As previously mentioned, radiological findings may not correlate with the clinical symptoms of the patient and therefore much be examined in context with the patient's clinical presentation. In a study by Abraham *et al*. on 217 patients, the incidence of radiological and clinical ASD was reported to be 29% and 18%, respectively. They reported the incidence of reoperation to be 9%.[24]

There is a great deal of controversy over the pathophysiology of ASD in the literature. While some biomechanical studies have shown increased stress at the facet joints of L4–L5 and L3–L4 after lumbosacral fusion, other studies have shown hypermobility in the segments next to the fused segments.[82,83] Further biomechanical studies have shown a shift in the center of rotation leading to increased stress over the facet and disc of the adjacent segment.[83]

Based on our analysis of the current literature, the length of the fusion is the most important risk factor for reoperation due to ASD. Liu *et al*. performed a literature review to evaluate the risk factors of radiographic PJK as defined by Glattes *et al*.[12] Those risk factors included surgery at the age of 55 years or older, fusion to S1, T5–T12 >40°, low bone mineral density, and sagittal vertical axis difference >5 cm.

Other risk factors include larger preoperative thoracic kyphosis, larger immediate postoperative thoracic kyphosis correction, male sex, thoracoplasty, use of pedicle screw on top of the construct, and fusion to lumbar levels below L2.[84,85]

It has also been argued that ASD is a normal degenerative process[86-88] which can also happen after lumbar discectomies. Bydon *et al*. reported a 4% incidence of ASD requiring return to the operating room during a period of just over 3 years after lumbar discectomy on a cohort of 751 patients.[89] Some preventative measures have been proposed based on the risk factors of ASD. These include preservation of the facet capsule and posterior ligamentous complex, use of hooks instead of pedicle screws, and vertebroplasty at the upper instrumented vertebrae.[90]

Based on our study, the length of the fusion construct is the most important risk factor impacting the risk for revision surgery due to ASD. Therefore, surgeons should seek to limit the number of fusion levels as much as possible so as to minimize the future development of ASD and subsequent need for reoperation. This may be potentially be achieved by stopping a fusion at a distal thoracic level in deformity surgeries in the absence of significant thoracic kyphosis and osteopenia or stopping at L4 in the absence of radiculopathy from the fractional curve.[90]

In conclusion, we reviewed the current literature to evaluate risk factors for revision spinal surgery due to ASD. We focused on the clinical implications of ASD rather than radiographic findings alone. Since the length of fusion construct was the most important risk factor contributing to revision surgeries, our recommendation is to minimize the number of the fusion segments whenever possible during these procedures. Limitations of this study include the inherent selection bias present in meta-analyses, the high heterogeneity of current data, and small sample sizes of primary studies evaluating ASD. Further research could shed additional light on this issue but would likely require large, prospective data collection pertaining to patients undergoing primary spinal fusion procedures with extensive and well-structured postoperative follow-up. Due to the cost, longitudinal nature, and need for a high patient volume required for such an analysis, a study of this nature would benefit from a multi-institution collaboration.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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