

# Complications in the Elderly Population Undergoing Spinal Deformity Surgery: A Systematic Review and Meta-Analysis

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## Abstract

**Study Design:** Systematic Review and Meta-Analysis.

**Objectives:** The elderly have an increased risk of perioperative complications for Adult Spinal Deformity (ASD) corrections. Stratification of these perioperative complications based on risk type and specific risk factors, however, remain unclear. This paper will systematically review perioperative risk factors in the elderly undergoing ASD correction stratified by type: medical, implant-related, proximal junctional kyphosis (PJK), and need for revision surgery.

**Methods:** A systematic review was performed using the PRISMA guidelines. A query of PubMed was performed to identify publications pertinent to ASD in the elderly. Publications included in this review focused on patients  $\geq 65$  years old who underwent operative management for ASD to assess for risk factors of perioperative complications.

**Results:** A total of 734 unique citations were screened resulting in ten included articles for this review. Pooled incidence of perioperative complications included medical complications (21%), implant-related complications (16%), PJK (29%), and revision surgery (13%). Meta-analysis calculated greater preoperative PT (WMD 2.66; 95% CI .36–4.96;  $P = .02$ ), greater preoperative SVA (WMD 2.24; 95% CI .62–3.86;  $P = .01$ ), and greater postoperative SVA (WMD .97; 95% CI .03–1.90;  $P = .04$ ) to significantly correlate with development of PJK with no evidence of publication bias or concerns in study heterogeneity.

**Conclusions:** There is a paucity of literature describing perioperative complications in the elderly following ASD surgery. Appropriate understanding of modifiable risk factors for the development of medical and implant-related complications, proximal junctional kyphosis, and revision surgeries presents an opportunity to decrease morbidity and improve patient outcomes.

## Keywords

adult spinal deformity, spinal deformity

## Introduction

Although spinal deformity can affect any age group, the elderly are disproportionately impacted with the prevalence of adult spinal deformity (ASD) being as high as 68% in those over the age of 60.<sup>1</sup> ASD may present with a multitude of symptoms, including intractable axial back pain due to sagittal, and/or coronal plane imbalances, symptoms due to stenosis such as neurogenic claudication or radiculopathy, among others. As a result, ASD patients report lower health-related quality of life (HRQoL) scores on patient-reported

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outcome measures.<sup>2</sup> ASD is heterogeneous in clinical presentation and characterized by both clinical and radiographic parameters with treatment guided toward improvement of HRQoL. Aging is frequently associated with de-novo or degenerative scoliosis and accounts for up to 53% of pathology in ASD patients  $\geq 65$  years old, where asymmetric degeneration of the intervertebral discs and facet joints can lead to spinal column instability, spinal stenosis, or nerve root impingement.<sup>3-5</sup> This contrasts with younger adults (<65 years old) where adult idiopathic scoliosis and degenerative scoliosis account for 43% and 29% of ASD pathology, respectively.<sup>5</sup>

Degenerative ASD patients typically present with higher comorbidity indices compared to idiopathic, congenital, and other ASD subgroups due to advanced age.<sup>6</sup> With an increase in the proportion of elderly patients being seen in developed countries and the resultant increase in ASD prevalence, more knowledge pertaining to the treatment challenges that this population faces will be necessary.

Compared to conservative management of ASD, surgical treatment has been previously shown to result in superior clinical outcomes. In a study by *Smith et al.*,<sup>7</sup> ASD surgical treatment of an aged patient cohort (65–85 years old) was found to result in a significant improvement in HRQoL similar to that seen in younger patients. Despite improved clinical outcomes, surgical correction of ASD has the potential for increased risk of complications in the elderly.<sup>8</sup> The incidence of perioperative complications in the elderly have been reported to be anywhere from 19.7% to 71%.<sup>5-7,9-15</sup> Ambiguity in the exact risk factors that predispose the elderly to perioperative complications (whether from comorbidities, age-associated reserve, surgical correction techniques employed, etc.) necessitates further study in order for appropriate complication mitigation strategies to be devised.

The current literature regarding perioperative complications in the elderly is vague. Complications is an umbrella term which can include anything from medical complications to surgical or implant-related complications to the need for revision surgeries. Grouping of these categories has resulted in some ambiguity in the literature, as well as some uncertainty about true estimates regarding complication rates. Here, we evaluate each of these complications separately and their associated risk factors in the current literature.

## Methods

A systematic review of the literature was performed using PRISMA (preferred reporting items for systematic reviews and meta-analyses) guidelines to report risk factors for perioperative complications for ASD corrections.<sup>16</sup>

### Data Sources and Search

A query of PubMed was performed to identify publications pertinent to ASD in older aged individuals (age  $\geq 65$  years) published

between 2005 and 2021. We searched for articles that reported on outcomes following surgical correction for ASD. The following keywords were used to search the database: “adult spinal deformity” and “adult spinal deformity surgery.” The AND, OR, and MeSH terms were used to improve search results.

### Eligibility Criteria

Inclusion criteria for studies were as follows: (1) mean population of patients age  $\geq 65$ , (2) studies in English, (3) studies published between 2005 and 2021, (4) study populations which received surgical correction for ASD, (5) studies with original patient data, (6) articles where postoperative complications were characterized, and (7) independent risk factors were identified. Exclusion criteria included (1) articles published prior to 2005, (2) systematic reviews, meta-analyses and reported case series without original patient data, and (3) corrective surgery for trauma or tumor.

### Study Selection and Data Collection

Studies were initially screened by title and abstract for relevance. Full-text review for eligibility and data extraction was then performed. Screening, selection for eligibility, and data extraction was performed independently by 2 authors with any dispute being resolved through discussion between the 2 reviewers. All articles searched within PubMed were exported into Endnote X7 software for deduplication. Risk factors in the reported data were pooled from the studies stratified by type of complication. All available data from included studies was included for analysis. Levels of evidence were assigned to each individual study using the Oxford Centre for Evidence-Based Medicine Table.<sup>17</sup>

### Statistical Analysis

Studies were pooled to calculate crude incidence. Meta-analysis was performed using mean differences with 95% CI Z-test values to describe continuous variables and odds ratios to describe dichotomous variables. A random-effects model was employed where there was significant heterogeneity otherwise, a fixed-effects model was utilized. Heterogeneity was significant when  $P < .10$  for the Chi-squared test and when  $I^2 > 50\%$ . Statistical analyses were performed using STATA 17.0 (Stata Corp, College Station, TX). To evaluate risk factors where there were no similarly reported variables between studies, we describe the results narratively presenting findings in the original research.

### Risk of Bias Across Studies

Egger’s test was used to detect publication bias when meta-analyses were performed using at least 3 studies. Significance was defined using the alpha threshold of .05 unless otherwise specified.

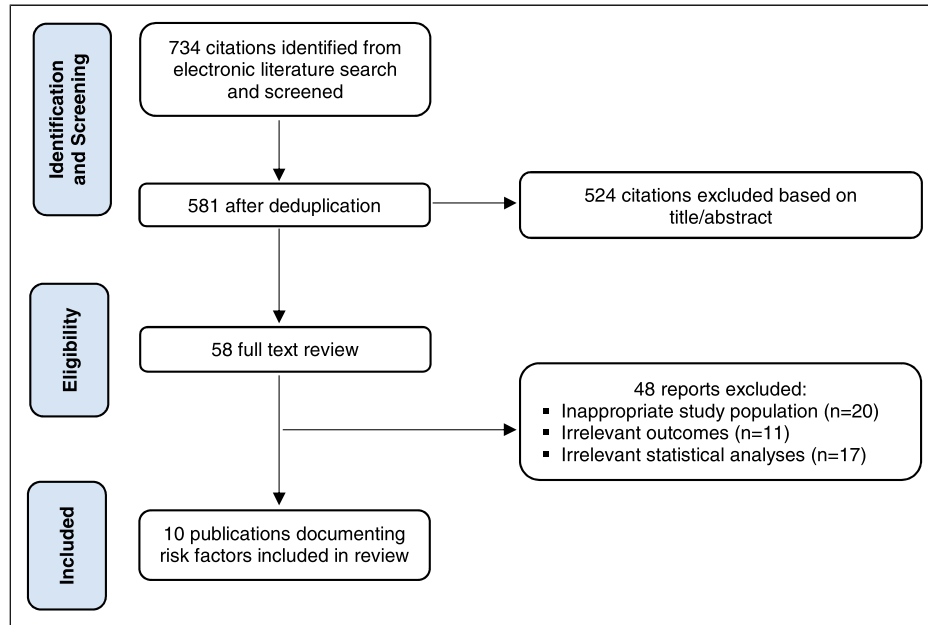


Figure 1. Schematic depicting search algorithm for systematic literature review.

Table 1. Study characteristics of articles included in review.

Study	Total N	Age Mean ± SD	PSO N (%)	3CO N (%)	Levels Fused Mean ± SD	Medical Complications N (%)	Implant-Related Complications N (%)	PJK N (%)	Revision N (%)
Daubs et al. 2007	46	66.8 ± 6.2	19 (41.3%)	NR	9.1 ± 3.2	17 (37%)	NR	NR	12 (26%)
Puvanesarajah et al. 2016	2293	range: 65-84	NR	NR	NR	NR	NR	NR	241 (10.5%)
Park et al. 2017	160	67.6 ± 6.1	24 (15%)	NR	6 ± 2.4	NR	NR	27 (16.9%)	NR
Wang et al. 2018	226	65.5 ± 8.1	3 (1.33%)	NR	NR	44 (19.5%)	NR	NR	NR
Nguyen et al. 2019	260	65.2 ± 9.8	59 (22.7%)	70 (26.9%)	10.5 ± 3.2	NR	20 (7.7%)	NR	83 (32%)
Jung et al. 2019	76	68.3	NR	28 (36.8%)	9.9 ± 3.2	NR	9 (11.8%)	NR	NR
Im et al. 2020	83	70.3 ± 5.7	68 (82%)	NR	8	NR	NR	30 (36.1%)	NR
Lau et al. 2020	405	64.5	—	405 (100%)	NR	81 (20%)	35 (7.7%)	NR	NR
Kawabata et al. 2020	230	72.2 ± 8.5	NR	95 (46.8%)	7.9 ± 2	NR	91 (45%)	51 (25.24%)	35 (17.3%)
Xi et al. 2021	114	65.51 ± 8.05	NR	NR	NR	NR	NR	63 (55.3%)	NR
	3893	67 ± 7.50	173/775 (22%)	598/971 (62%)	8.56 ± 2.8	142/677 (21%)	155/971 (16%)	171/587 (29%)	371/2829 (13%)

## Results

### Study Selection

The search result in the database identified 734 articles in English during the 16-year study period. Additional screening and review narrowed the search to 58 articles. Forty-eight of these articles were excluded based on the age of the study population, extraneous outcome measures, and lack of complication risk-stratification. Ten publications were included in this review. The selection process included in this review is shown in Figure 1.

### Study Characteristics

Baseline characteristics of the articles included in this review are presented in Table 1. The pooled demographics of the ten studies included 3893 patients with a mean age of  $67 \pm 7.50$ . Patients had  $8.56 \pm 2.8$  levels fused on average. All studies were retrospective and classified as level IV evidence.

### Risk Factors for Medical Complications

The crude incidence of medical complications in 3 studies was 21%. There were no similarly reported variables across studies for the development of medical complications. Individually reported independent risk factors for medical complications included increased age, age >69 years old, patients who underwent a pedicle subtraction osteotomy, American Society of Anesthesiologists (ASA) grade >2, and operative duration.<sup>9,15</sup>

### Risk Factors for Implant-Related Complications

The crude incidence of implant-related complications in 4 studies was 16%. Meta-analyses of 3 studies<sup>18-20</sup> revealed no significant relationship between body mass index (BMI), bone mineral density (BMD), fused number of instrumented vertebrae and development of implant-related complications (data not shown). Meta-analyses of 2 studies reported no relationship between uppermost instrumented vertebrae (UIV) above T6, UIV below T6, lower instrumented vertebrae (LIV) to the sacrum and relationship to the development of implant-related complications (data not shown).<sup>19,20</sup> Individually reported independent risk factors for implant-related complications included increased age at surgery, greater postoperative global tilt, greater preoperative thoracolumbar kyphosis, and pedicle subtraction osteotomy at S1.<sup>19,21</sup>

### Risk Factors for PJK

The crude incidence of PJK in 3 studies was 29%. Commonly reported variables across all studies included spinopelvic parameters on radiographs including thoracic kyphosis (TK), pelvic tilt (PT), sagittal vertical axis (SVA), and pelvic incidence minus lumbar lordosis (PI-LL). Meta-analyses of 3 studies<sup>22-24</sup> resulted in greater preoperative PT (WMD 2.66;

95% CI .36–4.96;  $P = .02$ ), greater preoperative SVA (WMD 2.24; 95% CI .62–3.86;  $P = .01$ ), and greater postoperative SVA (WMD .97; 95% CI .03–1.90;  $P = .04$ ) to significantly correlate with development of PJK (Figures 2–4). Preoperative, postoperative, and change in TK had no significant correlation with development of PJK. Pre- and postoperative measures of PI-LL had no statistically significant correlation with development of PJK on meta-analyses (data not shown). Individually reported independent risk factors for the development of PJK included greater postoperative thoracic kyphosis, dorsal displacement of the L1 plumb line measured as the L1 to gravity line distance, and greater BMI.<sup>23,24</sup>

### Risk Factors for Revision Surgery

The crude incidence of revision surgeries in 4 studies was 13%. There were no similarly reported variables across studies for the risk of revision surgery. The individually reported risk factors for revision surgery included greater time to clinical follow-up and presence of osteoporosis.<sup>18,25</sup>

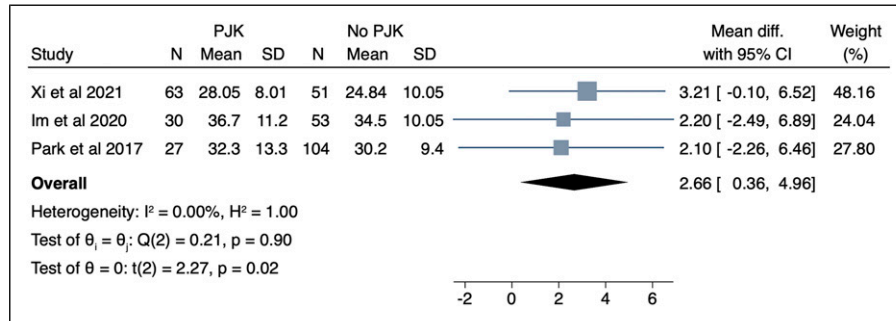
### Risk of Bias Across Studies

For variables exploring implant-related complications, Egger's test showed no evidence of publication bias (BMI  $t = -.05$ ,  $P = .97$ ; fused number of instrumented vertebrae  $t = 2.11$ ,  $P = .28$ ). Heterogeneity was low and not significant in the meta-analyses for variables exploring risk of PJK preoperative PT (p for heterogeneity = .90,  $I^2 = 0\%$ ), preoperative SVA (p for heterogeneity = .36,  $I^2 = 3\%$ ), and postoperative SVA (p for heterogeneity = .92,  $I^2 = 0\%$ ). The test for heterogeneity was significant in the meta-analyses for preoperative, postoperative and change in TK (preoperative TK p for heterogeneity = .004,  $I^2 = 82\%$ ; postoperative TK p for heterogeneity = .01,  $I^2 = 79\%$ ; change in TK p for heterogeneity = .13,  $I^2 = 51\%$ ). Egger's test revealed no evidence of publication bias (preoperative TK  $t = -2.17$ ,  $P = .27$ ; postoperative TK  $t = -.61$ ,  $P = .65$ ; change in TK  $t = -1.97$ ,  $P = .30$ ; preoperative PT  $t = -.44$ ,  $P = .74$ ; preoperative SVA  $t = -1.22$ ,  $P = .44$ ; postoperative SVA  $t = -.28$ ,  $P = .83$ ).

## Discussion

### Current Management

When adjusted by extent of spinal deformity and surgical treatment, Oswestry Disability Index (ODI) and Scoliosis Research Society-22 (SRS-22) pain scores are markedly worse in older individuals compared to a younger matched cohort following ASD correction.<sup>10</sup> In a study by Smith et al., older patients were found to have more disability (worse ODI scores) at baseline compared to younger patients. However, the older patient cohort was also then found to have a similar postoperative improvement as the younger patient cohort in the study at the 2-year follow-up timepoint. Despite potential



**Figure 2.** Forest plot showing relationship between preoperative pelvic tilt and PJK.

for perioperative complications, older patients stand to benefit from surgical intervention for ASD.<sup>7</sup>

Surgical treatment for ASD has increased linearly over time, with interbody fusions and three-column osteotomies becoming more common.<sup>26</sup> In a paper by *Sing et al.*, between 2004 and 2011 the incidence of ASD correction surgery was found to be increasing most for patients aged 65–69 years old, followed by those aged 70–74.<sup>27</sup> Another smaller study found that use of decompression and osteotomy for ASD correction are more often used in the elderly (65–85 years old), as opposed to patients aged 25–64 where the use of Smith-Petersen osteotomies is much more common. Furthermore, pelvic fixation is also more commonplace in older patients.<sup>7</sup>

**Radiographic Correction**

The SRS-Schwab classification correlates spinopelvic radiographic parameters with HRQoL outcomes which include the following: (1) pelvic incidence minus lumbar lordosis, (2) pelvic tilt, (3) sagittal vertical axis (SVA). This classification serves as a framework for alignment goals in ASD.<sup>28</sup> The most widely used radiographic parameter to measure extent of sagittal malignment is assessed through the SVA, which is defined by the distance from a vertical line drawn from the middle of the C7 vertebral body (C7 vertical tilt/plumb line) to the posterosuperior endplate of S1.

Correcting ASD by radiographic spinopelvic parameters has traditionally been done by applying average threshold values to all patients. Correcting sagittal alignment based on age has recently gained traction in the literature. A retrospective study of 903 patients with ASD reported that the average/optimal spinopelvic alignment goals traditionally used (PI-LL < 10, PT < 20, SVA < 4 cm) is less applicable to patients with high pelvic incidence and increased age.<sup>29</sup> This is because patient compensation tends to increase over time in order to adapt to age-related changes in sagittal alignment (such as an increased sagittal vertical axis, increased pelvic tilt due to loss of lumbar lordosis, spinopelvic mismatch, and an increased T1 pelvic angle). Patients >65 years old with ASD demonstrate age-related increases in lower-body compensatory mechanisms reaching ideal spinopelvic alignment 1 year

**Table 2.** PT: pelvic tilt, LL: lumbar lordosis, SVA: sagittal vertical axis. Ideal age-specific alignment parameters correlate to HRQoL and patient-reported outcomes. This table was taken from an article published by *Lafage et al.* (DOI: [10.1097/BRS.0000000000002146](https://doi.org/10.1097/BRS.0000000000002146)).

Ideal age-specific alignment criteria			
Patient population (age)	PT (°)	PI-LL (°)	SVA (mm)
<35	11.0	-10.5	-30.5
35–44	15.4	-4.6	-5.5
45–54	18.8	0.5	15.1
55–64	22.0	5.8	35.8
65–74	25.1	10.5	54.5
≥74	28.8	17.0	79.3

after surgery with greater compensation in patients who were under corrected for ASD.<sup>30</sup> Moreover, aggressive over-correction of ASD can contribute to complications such as proximal junctional kyphosis.<sup>31</sup> For example, the ideal PI-LL mismatch for a younger patient (45–54 years old) is .5° which gradually increases to 17° in those at least 74 years old (Table 2). Similarly, SVA is ideal when close to 1 cm in patients <54 years old, whereas that number gradually increases to almost 8 cm in those at least 74 years old. Essentially, an age-appropriate achievement of PI-LL and SVA correction exists where overcorrection past these points may be associated with complications and worse outcomes.

**Medical Complications**

A very well-established risk factor for medical complications is increased age with patients >69 years old being 9 times more likely to develop medical complications.<sup>9</sup> Interestingly, 1 retrospective review of 300 patients found that increased age did not significantly predict development of medical complications compared to those aged 50–64, 65–79, and ≥80 years old. However, this study did find that older patients presented with higher complication rates. The authors attributed this discrepancy to the extrapolation of data from databases vs single-institution cohorts.<sup>12</sup> Inclusion of studies solely reported from databases may give rise to certain biases due to the limited amount of information one can extrapolate from databases.

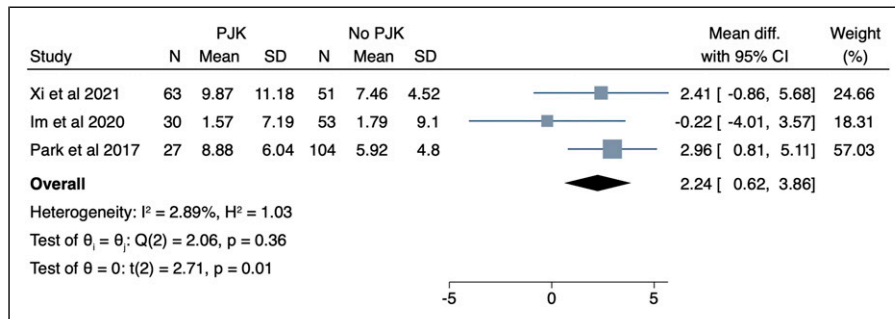


Figure 3. Forest plot showing relationship between preoperative SVA and PJK.

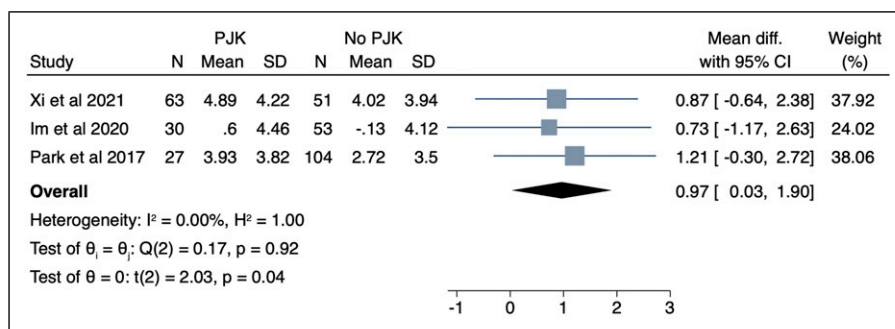


Figure 4. Forest plot showing relationship between postoperative SVA and PJK.

The medical complication rates in elderly patients  $\geq 65$  for the studies included in this review range from 20% to 37%.<sup>9,21</sup>

*Daubs et al.* reported that for every year-increase in a patient’s age, there is a 23% increased risk of developing a postoperative complication. Patients with and without postoperative complications were compared in the study and demonstrated significant improvement in ODI scores with no correlation in change in ODI scores with age. This suggests that while increased age is associated with the development of complications, it may have little impact on HRQoL.<sup>9</sup> *Soroceanu et al.* also reported that medical complications ultimately do not affect clinical outcome. Despite medical complications, patients experience significant improvement in HRQoL similar to that of patients without medical complications.<sup>32</sup>

Patients who undergo a PSO are at an increased risk of medical complications.<sup>9</sup> Rigid spinal deformities often require spinal osteotomies for correction. Three-column osteotomies such as pedicle subtraction osteotomy (PSO) or vertebral column resection can be used to achieve appropriate spinal column correction. Anticipation of these risks may be a way to mitigate medical complications. Therefore, other correction strategies and techniques such as multiple lateral interbody fusions in order to release lateral osteophytes or aggressive posterior transforaminal interbodies should each be considered. Performing a PSO in the elderly should only be performed when absolutely necessary given its association with increased EBL, operative time, etc. and subsequent hardware and/or medical complications.

### Implant-Related Complications

Late surgical complications are typically due to continuous mechanical stress that can result in implant-related complications. Implant-related complications encompass a wide variety of pathologies including proximal junction kyphosis, distal junction kyphosis, pseudoarthrosis, rod breakage, vertebral fracture, among others.

The incidence of implant-related complications is reported to be anywhere from 4.2% to 45% in the elderly.<sup>12,19</sup> *Kawabata et al.*<sup>19</sup> reported the following types of mechanical failure in an elderly patient cohort: vertebral fracture (20%), rod fracture (13%), pseudarthrosis (7%), and distal junctional kyphosis (4%).

Other studies report screw loosening to be more prevalent in patients  $\geq 75$  years old compared to rod breakage.<sup>33</sup> These can have poor outcomes as *Yamato et al.*<sup>34</sup> reported an 18% incidence of rod fracture (mean age 68.5) in a cohort of 304 patients with 66.7% of these patients requiring revision surgeries.

Increased postoperative global tilt was an independent risk factor for implant-related complications in the elderly. Global tilt was defined as the sum of the pelvic tilt and the C7 vertical tilt. Interestingly, there was no significant association in postoperative sagittal vertical axis or postoperative pelvic tilt between patients who developed implant-related failure vs those who did not.<sup>19</sup> This brings up a salient point in determining which radiographic parameters are most predictive of

complication risks. One can infer that overcorrection of spinopelvic parameters leading to an increased postoperative global tilt can result in complications. Cautious determination of age-appropriate thresholds for ASD correction should be performed to mitigate these risks.

### Proximal Junctional Kyphosis

PJK most commonly occurs above UIV and is defined as kyphosis of 10 or more degrees greater than preoperative measurements. Progression from PJK to proximal junctional failure (PJF) necessitates revision surgery. PJF is defined by both kyphosis and structural failure of the vertebral body.

Lafage *et al.*<sup>31</sup> reported increased age at surgery as a risk factor for development of PJK. Incidence of PJK was reported at 50.2% in those >65 years old. This retrospective cohort study involving 679 patients with ASD demonstrated that patients >65 years old who developed PJK were overcorrected compared to non-PJK patients when comparing 1-year postoperative PI-LL mismatch to age-adjusted alignment criteria.

### Revision Surgeries

A cohort study evaluating the risk of revision surgeries in 553 patients who were surgically treated for ASD found an incidence of 19.9% revision surgeries at a 2-year follow-up period and an incidence of 7.2% patients who underwent more than 1 single revision surgery. When stratified by age, revision risk was at 25.4% for 60–70 year olds and 23.3% for patients over the age of 70.<sup>35</sup> Another study reported a 47.3% revision rate in age  $\geq 70$ . This study reported comparable rates of revisions in age  $\geq 70$  compared to age 41–55, as well as non-significant differences between the amount of hardware failures, pseudarthrosis, PJK, or sagittal malalignment indicated for the revisions.<sup>13</sup> Puvanesarajah *et al.*<sup>25</sup> reported the following revision rates in 2293 patients aged 65–84: 10.5% at 1 year, 15.4% at 2 years, 17.2% at 3 years, 18.2% at 4 years, and 18.5% at 5 years.

In a propensity score-matched analysis, there was no significant difference in the amount of revision surgeries in advanced age when comparing cohorts aged 50–65 and >70 years old.<sup>10</sup>

Indications for revision risks appear to be similar across age groups. Puvanesarajah *et al.* found the following indications for revisions in a cohort age 65–84: instrument failure accounted for 53.5% for revisions at 1 year and 62.3% of revisions at 5 years. Infections accounted for 24.1% of revisions at 1 year and 21.2% of revisions at 5 years.<sup>25</sup> Pitter *et al.*<sup>35</sup> found the following indications for revisions in a younger cohort with a median age of 53: implant failure 38.2%, infection 11.8%, curve progression 10.9%, pseudarthrosis 10.9%, neurologic deficit 10.9%, and PJK 7.3%.

Osteoporosis increases revision risk in the elderly.<sup>25</sup> Osteoporotic compression fractures can result in kyphotic deformities typically within the thoracic and lumbar spine. Osteoporosis is exceedingly common in patients with ASD age  $\geq 65$ .<sup>5</sup> In a retrospective cohort study of 110 patients (age  $73.86 \pm 5.20$ ), fragility vertebral fractures of  $\geq 10$  degrees of kyphosis presented with worse global spinal alignment (measured via the T1 pelvic angle) and increased disability indices.<sup>36</sup> In terms of mitigation strategies, perioperative daily teriparatide treatment when compared to bisphosphonate treatment, has shown decreased amounts of adjacent vertebral fractures in patients  $\geq 75$  years of age with both ASD and osteoporosis.<sup>33</sup>

BMP use is associated with lower risk of revision surgery reported at both 4- and 5-year follow-up in the elderly.<sup>25</sup> A prospective clinical trial reported increased rates of fusions in ASD patients treated with recombinant human bone morphogenetic-protein-2 without graft supplementation.<sup>37</sup>

### Mortality

Elderly patients (age >65) with ASD present with increased mortality postoperatively when compared to ages 25–64.<sup>6</sup> Jain *et al.*<sup>38</sup> reported the perioperative mortality rate to be .9% in a 3519-patient sized cohort of >65 year olds at 6 weeks postoperatively and to be 1.8% at 2 years follow-up.

### Summary of Evidence

In our systematic review with meta-analysis, we have reported the incidence of medical complications, implant-related complications, PJK, and incidence of revision surgery in the elderly. We have reported the individual risk factors stratified by risk type. Despite lack of high-level evidence studies included in this review, our meta-analyses demonstrate that increased preoperative pelvic tilt, increased preoperative and postoperative SVA significantly correlates with development of PJK.

### Limitations

Several limitations exist in our study. The paucity of literature regarding perioperative complications in the elderly limited the power and stability of our meta-analysis. Subsequently, a single study can influence the sensitivity of the meta-analysis, which is especially the case for analyses stemming from unadjusted variables. Ultimately our review is novel as it remains the first to discuss perioperative complications in the elderly stratified by risk type.

### Conclusion

Current literature has established that surgical correction for ASD in the elderly is associated with increased risk of complications. Despite these risks, the elderly demonstrate improved HRQoL measures postoperatively similar to younger patients.<sup>7</sup> There is ambiguity in the literature

regarding independent risk factors for perioperative complications in the elderly. There is a need for appropriate stratification of complications to assess for true measures of risks. Appropriate understanding of modifiable risk factors for the development of medical complications, implant-related complications, proximal junctional kyphosis, and revision surgeries presents an opportunity to decrease morbidity and improve patient outcomes. Elderly ASD patients represent a challenging demographic that require a unique set of skills. An appropriate perioperative risk assessment should be performed to mitigate development of complications and need for additional surgery. Elderly patients should be counseled on risks prior to surgical intervention to guide expectations and management.

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