Reviews

Patient-Related Risk Factors for the Development of Lumbar Spine Adjacent Segment Pathology

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Objectives

Individual risk factors for the development of adjacent segment pathology (ASP) need to be investigated and identified to address possible modifiable factors in advance and improve outcomes and reduce medical costs. This study aimed to review the literature regarding patient-related risk factors and sagittal alignment parameters associated with ASP development.

Methods

The authors performed an extensive review of the literature addressing the objectives mentioned earlier.

Results

Certain patient factors such as age, gender, obesity, preexisting degeneration, osteoporosis, postmenopausal state, rheumatoid arthritis, and facet tropism may contribute to adjacent segment degeneration. Genetic influences, such as polymorphisms of the vitamin D receptor and collagen IX genes, can also be a potential cause for disc degeneration with consequent deterioration of the motion segment.

The influence of sagittal imbalances, particularly after lumbar fusion, is a significant parameter to be taken into account as an independent risk factor for ASP development.

Conclusions

Patient-specific risk factors, such as age, gender, obesity, preexisting degeneration, and genetic features increase the likelihood of developing ASP. On the other hand, sagittal alignment plays a significant role in the development of this condition.

INTRODUCTION

Most studies define adjacent segment disease (ASD) as the clinical translation of the radiographic changes associated with adjacent segment degeneration (ASD). However, there is no validated outcome measurement to diagnose or quantify ASD.^{1–4} Some authors, such as Lee et al.,⁵ consider reoperation rate as the most reliable parameter for the definition of ASD and recommended its use as the primary criterion to define adjacent segment pathology. Indeed, the “classic” definition of ASD does not always warrant revision surgery, either due to patient comorbidities and preferences, surgeon reluctance, or effective conservative treatment.^{6–8}

An increase in mechanical stresses after fusion may lead to an increase in ASDeg and ultimately to the development of ASD. The rate of changes from adjacent segment degeneration generally manifests 5 to 10 years after surgery. The development of adjacent segment pathology following lumbar fusion is a significant cause of revision surgery.¹ At ten years of follow-up, about 25% of patients undergoing short lumbar fusion will develop ASDeg.⁹ Ghiselli et al.¹⁰

predicted a 10-year prevalence of ASDeg of 36.1%, with 27.4% of the patients in their cohort requiring adjacent-level surgery.

Previous studies have identified several individual risk factors associated with ASD such as age, gender, obesity, preexisting degeneration, rheumatoid arthritis, and genetic factors, including polymorphisms of the vitamin D receptor and collagen IX genes.^{11–13}

The etiology of ASD has also been related to changes following spinal fusion that irreversibly alter the normal biomechanics of the spine by eliminating motion at the fused segment, which causes enhanced mechanical stress at the adjacent segments with the subsequent hastening of degenerative changes.^{12–14} The relationship between sagittal balance, spinopelvic parameters, and lumbar lordosis is essential for the sagittal profile of the spine and, if not corrected, can promote an imbalance that leads to the development of ASD.

The ability to determine a patient’s risk factors for the development of ASD is extremely important since they may be modifiable factors that, if corrected, can improve outcomes and alleviate medical costs. This study proposes to

review the literature regarding individual risk factors and sagittal alignment parameters associated with the development of ASD.

ETIOLOGY

Due to the multifactorial etiology of ASD, correlating singular variables and their potential impact on the development of this pathology is difficult. The risk factors for ASD development can be separated into patient-related factors and surgical factors, directly modified by the surgeon during the procedure.^{15–19} Certain patient factors such as age, gender, obesity, preexisting degeneration, osteoporosis, postmenopausal state, rheumatoid arthritis, and facet tropism may contribute to adjacent segment degeneration.^{1,15,20,21}

Genetic influences, such as polymorphisms of the vitamin D receptor and collagen IX genes, can also be a potential cause of disc degeneration with consequent deterioration of the motion segment.¹¹ Alentado et al.²² reported an association between coronary artery disease and the development of ASD. Other medical comorbidities, including hypertension, hyperlipidemia, diabetes, smoking history, current smoking status, preoperative ASA grade, pain level, and duration of symptoms before the operation, were not significantly correlated with the development of ASD.²²

THE INFLUENCE OF BODY MASS INDEX (BMI)

BMI is an important independent predictor of back pain. Its severity is associated with the degree of dissatisfaction and outcomes after surgery for lumbar spinal stenosis and the rate of lumbar spine reoperations.^{23,24} A BMI increment leads to the increased loading on the lumbar spine that causes the intervertebral disks to lose height and ability to absorb forces, resulting in abnormal loading on surrounding facet joints, spinal ligaments, and paraspinal muscles.^{25–28}

In overweight or obese patients, as there is an increase in BMI not accompanied by muscle hypertrophy, the paraspinal musculature decreases its support capacity to maintain an upright posture, which leads to an increase in intradiscal pressure and segmental motion after lumbar fusion, creating a larger body mass that potentially adds more stress to the adjacent levels and accelerates the degenerative process.²⁹ As a result, BMI maybe not only is a factor related to the natural degeneration of healthy spines but may also play an important role in ASD.²⁹ Studies from Symmons et al.³⁰ and Liuke et al.³¹ provided evidence that BMI greater than 25 kg/m² increases the risk of lumbar disc degeneration. In a retrospective study including 190 patients after lumbar fusion for degenerative spine disease, Ou et al.³² found body mass index to be a risk factor for ASD. Because BMI is a clinically objective and modifiable variable, control of body weight can be an excellent variable to optimize during a patient's preoperative period that could enhance fusion surgery outcomes.

AGE AND ASD

It remains controversial if there is an association between age and adjacent segment disease.

As the spine ages, the degenerative cycle will progres-

sively modify functional anatomy, creating a rupture of stability, equilibrium, and proprioception. Aging is also associated with a decrease in spine flexibility and capacity in accommodating biomechanical alterations after fusion.

Some researchers have reported an increased incidence of ASD with advancing age.^{7,33,34} In a retrospective series of 490 patients, Lee et al.⁷ reported that patients older than 60 were more likely to have ASD requiring surgery. Cheh et al.¹⁶ and Sears et al.⁹ also found that age greater than 50 or 60 years was correlated with a greater prevalence of ASD. Effectively, most studies have shown an increase of ASD incidence with advancing.^{7,35–40} However, some studies have reported no correlation between ASD and age.^{41–43}

PREOPERATIVELY ADJACENT LEVEL DEGENERATION AND THE POTENTIAL DEVELOPMENT OF ASD

The absence of preoperative adjacent level degeneration also seems to have a relevant influence on the potential development of ASD. Lee et al.³⁸ determined that preexisting facet degeneration is associated with a high risk of ASD. In a prospective study including patients who underwent instrumented fusion for degenerative disease, Anandjiwala et al.²⁰ demonstrated an increased risk for developing ASD in patients with previous disc degeneration. In a retrospective study including 237 patients, Wang et al.⁴⁴ stated that preoperative disc degeneration at the adjacent level was significantly and independently associated with ASD. It has been confirmed by both clinical case studies and biomechanical analysis that postoperative ASDeg develops more frequently in patients who have advanced disc degeneration preoperatively.^{20,42,45,46} Furthermore, rates of ASD are lower in patients who underwent fusion for trauma or are congenitally fused, supporting the hypothesis that preexisting disease is a significant factor in ASD etiology rather than a long-term sequel from surgical intervention.^{47,48}

INTRADISCAL PRESSURE AND ASD

Changes in intradiscal pressure (IDP) can have multiple causes and are associated both with patient factors (e.g., BMI and natural degenerative process of the spine) and spine biomechanics, as well with the type and length of fusion.¹⁴ The increase of IDP blocks the diffusion of nutrients from the endplate, impairs disc nutrition, and is also reported as the most significant cause of disc degeneration.^{49,50}

Many authors have investigated adjacent-level IDP changes after lumbar fusion. An increase in intradiscal pressure was proposed as an etiological factor for the development of ASD,^{51,52} with biomechanical studies showing increased IDP on the adjacent discs after a single-level fusion model.^{53,54} Cunningham et al.⁵⁴ demonstrated a 45% increase in lumbar intradiscal pressures at motion segments cephalic to a fusion. This pressure was particularly high in flexion-extension when fusion was compared to total disc arthroplasty (TDA) and baseline. Primary spinal malalignment is also a risk factor for increased intradiscal pressure, leading to a greater risk for developing ASDeg in the lumbar spine.^{55–59}

THE INFLUENCE OF SAGITTAL ALIGNMENT

The pelvis is the cornerstone of sagittal spinal alignment. The revolutionary concept by Jean Dubousset's that "the entire pelvis is a vertebra" was the beginning of numerous investigations on the relationship between pelvic morphology and sagittal spinal alignment. Sagittal alignment, often misrepresented as sagittal balance, describes the ideal and "normal" alignment in the sagittal plane, resulting from the symbiosis between various organic factors, with pelvic morphology considered its foundation.

SAGITTAL BALANCE

Several studies have described the relationship between sagittal radiographic parameters and Health-Related Quality of Life (HRQOL) scores.^{60–65} It has been proven that sagittal balance is among the most reliable factors influencing ASD development.³⁶ In 2005, Glassman and colleagues⁶⁶ demonstrated a significant correlation between positive sagittal balance and patient-reported self-assessment measures, notably between increased positive sagittal imbalance and symptoms aggravation. Kumar et al.³⁶ concluded that patients with an average postoperative C7 plumbline and sacral inclination had the lowest risk of adjacent segment degeneration. Effectively, sagittal spinal alignment, especially maintaining the normal spinopelvic relationship, is essential for preventing ASD after interbody fusion.

LUMBAR LORDOSIS

Lumbar lordosis (LL) is a critical feature of spinal morphology which correlates with the risk of developing ASD.^{67,68} The concept of maintenance of lumbar lordosis following fusion as a protective factor to the risk of developing adjacent segment stress and instability was described by several authors such as Hioki et al.⁵⁸ and Chen et al.⁶⁹ A recent study⁷⁰ published in 2018 was the first to analyze the influence of LL on the biomechanical characteristics of the adjacent segment after L4-L5 TLIF. The results showed that as LL decreases, the stress of the adjacent disc increases. In conclusion, hypolordosis appears to increase the risk of adjacent segment deterioration.^{71,72}

PELVIC INCIDENCE AND ITS RELATIONSHIP WITH LUMBAR LORDOSIS

Pelvic incidence (PI) is strongly correlated with various pelvic and spinal positional parameters and is a useful predictor of LL. Boulay et al.,⁷³ in a prospective study from 2005 including 149 patients, proposed an equation to predict LL based on PI and explored the conditions of an "economic posture." PI has subsequently been generally acknowledged as a predictor of the amount of LL required to assume a balanced sagittal alignment.^{61,74} Lafage and colleagues⁷⁵ further refined this idea, demonstrating that PI matches LL and that increasing pelvic retroversion directly correlates with worsening patient-reported quality-of-life measures. These observations currently remain as the cornerstones of adult spinal deformity surgery and define the

goals of reconstructive surgery, with the formulas of the sagittal vertical axis (positive/negative) < 20 degrees and LL = PI ± 9 degrees being considered to provide the optimal balance values, associated with good patient-centered clinical status.⁶¹ Schwab et al.,⁶¹ in a study by authors of the International Spine Study Group, emphasized the relevance of pelvic incidence-lumbar lordosis (PILL) mismatch as an intrinsic part of the adult deformity and its restoration as the primary objective in the surgical management of adult deformity.

Effectively, the restoration of the relationship between LL and PI seems essential for postoperative outcomes as it accounts for different loading patterns in the lumbar spine, which may be relevant for the development of ASD. In a multivariate analysis,⁷⁵ a high PI was a risk factor for adjacent segment degeneration development. Moreover, Rothenfluh et al.⁷⁶ reported that patients who required reoperation for ASD are ten times more likely to have a PI and LL mismatch greater than 10 degrees. Thus, PI and LL imbalances are essential parameters to consider as risk factors for the development of ASD.

PELVIC TILT

Relative to pelvic tilt (PT), as it increases, it generates a posterior inclination of the pelvis, and a large PT is associated with increased pain and decreased function.⁷⁷ There are not many references in the literature regarding the relationship between PT and ASD. In a recent study considering risk factors of ASD after TLIF in 263 patients, the risk was 5.1 times greater in subjects with preoperative PT of more than 22.5°.⁶⁸ Therefore, it is reasonable to conclude that intrinsic factors and altered biomechanics associated with sagittal imbalances play a synergistic role in developing ASD after a fusion procedure.

CONCLUSIONS

Adjacent segment disease is a problem with a well-studied causal effect but with poorly understood risk factors, including several individual factors, hereditary and acquired, and causes associated with the surgical procedure. From this review, we can conclude that several risk factors directly related to the patient (e.g., age, gender, obesity, pre-existing degeneration, genetic influences) lead to an increased likelihood of developing ASD. On the other hand, sagittal alignment has an essential relevance in the development of this pathology.

DECLARATION OF CONFLICTING INTERESTS

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