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Review Article

Adjacent Segment Degeneration and Adjacent Segment Disease: Implications following Spinal Fusion Surgery

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Abstract

Spinal fusion is a common and effective option for patients with symptomatic degenerative disc disorders. However, concerns have raised over the probability of adjacent segment degeneration (ASDe) and adjacent segment disease (ASDi) following spinal instrumentation. Current study sought to document evidence on the incidence of ASDe and ASDi after lumbar fusion surgery and the risk factors precipitating adjacent pathologies. Given the benefits of spinal fusion surgery, it remains unclear whether adjacent pathologies are attributed to the natural degeneration or the adjacent fusion.

***Keywords:** Adjacent segment degeneration, Adjacent segment disease, Spinal fusion surgery, Lumbar spine*

Introduction

Spinal fusion was introduced by Albee [1] to treat Pott disease as well as by Hibbs [2] who conducted spinal fusion for spinal deformity. These authors claimed that by virtue of spinal fusion, the surgeon could remove the pathological process including infection, inflammation, or deformity, ameliorate painful motion, and decompress neural elements with adequate stabilization of the affected spine level [1, 2]. Spinal fusion has been hailed as the standard of therapy for many pathologic disorders affecting the human spine throughout the last 50 years. Thoracolumbar spinal fusion with instrumentation has shown a high degree of effectiveness in stopping the development and treatment of scoliotic deformities in adults and adolescents. According to reports, anterior cervical fusion combined with decompression in the cervical spine has more than a 90% chance of relieving radicular symptoms and stabilizing or improving myelopathy results [3, 4]. In the lumbar region, prospective randomized trials have demonstrated that lumbar decompression combined with posterolateral fusion is an excellent method of surgical treatment for patients with degenerative spondylolisthesis [5].

Considering that spinal fusion surgery is likely to be successful in relieving patients' symptoms, the long-term effects of spinal fusion surgery may be less important. However, because spinal fusions, especially those for idiopathic scoliosis, are performed at a young age, there is a growing concern about the long-term viability of the spinal motion segments adjacent to these fusions.

These concerns are further reinforced by the increased rates of cervical and lumbar spine surgery in the United States over the past 20 years [6]. In particular, as the indications for lumbar spinal fusions expand, the number of patients with mechanical low back pain increases, and the clinical success rate declines; thus, concerns about the impact of these procedures have been increasing.

In this article, the terms “adjacent segment degeneration” (ASDe) and “adjacent segment disease” (ASDi) are used to define the pathologies after different types of adjacent-level arthrodesis. ASDe was used to describe radiographic changes observed at the level adjacent to the previous spinal fusion and does not necessarily correlate with clinical findings. On the contrary, ASDi is used to refer to the development of new clinical symptoms that correspond to radiological changes close to the level of the previous spinal fusion [7-9]. The current article reviews the role of spinal fusion in the development of ASDe and ASDi. These pathologies of the cervical and lumbar spine are regarded as two separate entities because of the different biomechanical environments of cervical and lumbar fusion.

Lumbar Spinal Fusion

The lumbosacral junction is distinguished by specific adaptations for greater stability, such as increased intrafacet distance and the presence of iliolumbar ligaments, which increase the stability of this level rendering better ability to handle the increased stresses adjacent to the sacrum and pelvis. Although they are enclosed in a stable, lordotic region of the spinal column, the spinal motion segments from L2 to L5 are substantially more mobile, each accommodating a wider range of motion [10]. Biomechanical investigations of lumbosacral fusions have shown that greater intradiscal pressures at adjacent levels occur with simulated spinal fusion surgeries and that the intradiscal pressures remarkably increase with the number of levels fused [11]. It has also been shown that lumbosacral fusions increase the motion at the non-fused adjacent levels and that this transfer of motion appears to be greatest with the use of instrumentation [12]. Some surgeons evaluated their patients' radiological and clinical follow-up after lumbar spinal fusion procedures to validate the association between spinal fusion and acceleration of adjacent segment alterations, with conflicting results.

Lehmann et al. [13] evaluated 32 patients with more than 30 years of follow-up after lumbar fusion surgeries in one of the longest follow-up studies in the spine literature. Despite the fact that nearly half of the patients developed instability in the segment above and a third became stenotic at the level above, ASDe were not associated with any clinical symptoms. Likewise, Luk et al. [14] followed 22 patients who had undergone lumbosacral fusion for 13 years. These researchers discovered hypermobility in the adjacent levels as well, particularly with prolonged follow-up. These radiographic abnormalities, however, did not appear to be associated with the patient's clinical symptoms. Penta et al. [15] compared the long-term follow-up of 52 patients who underwent anterior lumbar interbody fusion at the lumbosacral junction to a similar group of patients treated without surgery in a study attempting to compare the natural history of the lumbar segments in fused and non-fused patients. It is worth noting that, they discovered no difference in rates of ASDe, with approximately one-third of patients in both groups showing degenerative alterations at the level above the spinal fusion. Furthermore, these researchers discovered that lengthening of the fused segments did not appear to affect the extent of degeneration at nearby levels.

Contrary to these findings, Rahm, and Hall [16] reported a 5-year follow-up of 49 individuals. Patients in their study had posterior lumbar fusion with instrumentation and, in many cases, posterior lumbar interbody fusion. They discovered that more than a third of their patients had ASDe and had poorer clinical outcomes. Moreover, they discovered that pseudarthrosis appeared to be a protective factor against the development of neighboring segment degeneration in their patient cohort. Whitecloud et al. [17] reported an apparent biomechanical effect in the progression of ASDe. These researchers looked at 14 individuals who had previously had lumbar fusion surgery and had ASDi that required additional surgery. They comprehended that obtaining a solid fusion at the adjacent level was substantially more challenging, with a pseudarthrosis rate of 80% among people who had fusion without instrumentation.

A few studies have been published that particularly looked at the development of adjacent segment pathology following previous lumbar spinal fusion surgeries. Etebar and Cahill [18] examined 125 patients who had previously undergone instrumented lumbar fusion and had an average of 4.5 years of follow-up. The authors found that 14% of the patients acquired ASDi owing to deterioration at adjacent levels, requiring surgical intervention. Ghiselli et al. [19] investigated the development of L5-S1 adjacent segment pathology in a sample of 32 patients who had undergone L4-L5 posterolateral fusion for degenerative spondylolisthesis and spinal stenosis. Thirty-one of the 32 patients had not acquired ASDi after an average follow-up of 7.3 years, while there was a trend for progressive disc degeneration at this level with increasing length of follow-up.

Throckmorton et al. [20] published a study delving into the effect of ASDe on the outcome of posterior lumbar spinal fusion surgery. They divided a group of lumbar spinal fusion patients into those who were fused next to a "degenerated disc" (dehydration and/or disc space collapse on magnetic resonance imaging) and those who were fused next to a "normal" disc. They compared the clinical outcomes of the Short Form-36 (SF-36) between groups with deteriorated and normal adjacent discs and discovered that the clinical outcomes of the individuals with normal adjacent discs were substantially poorer. Furthermore, there was no difference in the necessity for additional surgical treatments between the two groups. The authors inferred that evidence of ASDe was insufficient to engage those levels in the fusion construct.

Ghiselli et al. [21] examined a group of 223 patients who were followed for an average of 6.7 years for the development of ASDi requiring additional surgery due to degenerative alterations adjacent to thoracolumbar, lumbar, and lumbosacral fusions. According to a Kaplan-Meier survival analysis, the authors determined that 37% of the patients in their cohort would be predicted to require further surgical surgery for lumbar spine adjacent segment illness within 10 years of their index procedure. They discovered that the chance of ASDi necessitating subsequent surgery was highest in individuals receiving "floating lumbar fusion" (i.e., excluding the thoracic or sacral areas) and lowest in patients receiving thoracolumbar fusion.

Risk factors for adjacent segment pathologies

Having reviewed articles previous literature, Paul Park [22] inferred that age, posterior lumbar interbody fusion, injury to the facet joint of the adjacent segment, long-segment fusion, sagittal alignment, pre-existing degenerated disc at the adjacent level, lumbar lordosis, osteoporosis, female gender, postmenopausal state were potential risk factors for adjacent segment changes. In 2020, Wang and Ding [8] launched a meta-analysis to assess the risk factors related to ASDe. The rate of ASDe was reported 18.6% after posterior lumbar fusion surgery ranging from 8.5& to a staggering 69.4%. The pooled results from this meta-analysis indicated that the gender of patients, history of diabetes, preoperative Oswestry Disability Index (ODI), the type of fusion , type of bone graft (auto- vs allograft), fusion to S1 (vs non-fusion to S1), and diagnosis (lumbar disc herniation, lumbar spinal stenosis, lumbar spondylolisthesis) were not linked to a considerable increase in the incidence of ASDe. Nonetheless, older age, Body Mass Index (BMI), a history of smoking and hypertension, preoperative ASDe, long-segment fusion, superior facet violation, high lumbosacral joint angle, post-operative lumbar lordosis, and preoperative pelvic incidence (PI) were associated with a substantial increase in the incidence of ASDe.

Anandjiwala [23] showed that preoperative ASDe at an adjacent level was a paramount indicator of developing ASDe. Preoperative Pfirrmann's classification (article) of more than three in the radiographic adjacent segment was considered a potential risk factor of ASDe. Beyond and above that, it was found that preoperative superior facet violation was associated with an increasing rate of ASD. In fact, preoperative superior facet violation is a type of degeneration at the adjacent segment, rendering limited adaptability to biomechanical alterations [8]. In a study by Bagheri et al. [24] patients with higher preoperative BMI demonstrated a significant increase in the risk of developing ASDe that was in line with the previous studies [24-26]. In a recent meta-analysis [8], the history of smoking and hypertension was regarded as a risk of ASDe, but the reason remained unclear.

Saghebdoust et al. [7] conducted the newest comparative study on dynamic and rigid stabilization of the lumbar spine, in which all of their patients had preoperative ASDe at the adjacent level. They aimed to analyze the effect of using dynamic rod constructs (DRC) on preventing ASDe, and ASDi from developing over a period of three years after lumbar fusion. The rate of ASDe was 56.6% without any significant difference between the DRC and rigid fusion groups. However, they showed that DRC had a promising role in averting ASDi as well as favorable ODI scores. The incidence of ASDi in their cohort was reported 19.8% with a significant difference between the two groups (DRC: 14.3% vs rigid fusion: 24.8%). By contrast, both groups had roughly similar rates of ASDe throughout the follow-up.

Another study by Fuster et al. [27], showed that higher degenerative disc changes according to Pfirrmann's classifications were an independent risk factor for ASDe development, whereas, Saghebdoust et al. [7] did not detect any contributing factor for ASDe progression. However, in line with the previous study [7], they discovered that DRC could be a preventive factor for ASDi.

Conclusion

A number of long-term follow-up studies of lumbar fusion surgeries indicate that ASDe and ASDi are frequent. Above posterior lumbar fusions and below thoracolumbar scoliosis fusions appear to be the most commonly affected locations. Among lumbar fusion surgeries, those conducted between the thoracolumbar and lumbosacral junctions (dubbed "floating fusions") tend to be the most vulnerable to adjacent segment pathologies. Moreover, the treatments performed at a single level with extensive degenerative alterations at the adjacent level, appear to be the most perilous as well. However, based on the current scientific literature, it is still unclear whether these radiographic and clinical findings are the result of spinal fusion with the iatrogenic production of a rigid motion segment or the natural progression of the underlying degenerative disease. Meanwhile, further large-scale, well-designed studies, especially on probable preventive effects of dynamic stabilization techniques on ASDe and ASDi are highly recommended.

Conflict of Interest

The authors declare that they have no conflict of interest.

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