Revista Argentina de Clínica Psicológica
2018, Vol. 27, N°3, 479 - 486
DOI: 53555/03276716.2018.1077

Evaluation of the Effects of Fusion Surgeries Applied in Degenerative Cervical Spine Diseases on the Development of Adjacent Segment Disease with Clinical and Radiological Findings

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Aims: Cervical fusion is one of the most frequent procedures to treat degenerative disease of the cervical spine, but the emergence of specific pathogen-free adjacent segment disease (ASD) is one of the most critical issues after surgery. Our study aims to evaluate the adjacent segment changes after cervical spine surgery with a focus on ASD and its sharing factors.

Methods: Our study designed as a retrospective study of patients who underwent cervical spine surgery from January 2017 to January 2018 at Private Kocaeli Academy Hospital, Department of Neurosurgery. Celebrate and validation of clinical predictors of outcome, combined scoring system of Neck Disability Index (NDI) and Visual Analog Scale (VAS) among patients on methods study. Clinical assessments pain assessment was carried out using the VAS and NDI. Radiological data using x-ray, computarized tomography (CT), and magnetic resonance imaging (MRI) to determine disc height, cervical lordosis, and the presence of ASD were evaluated.

Results: In our study 150 patients (mean age 47.5 years) were identified. Patients had a mean VAS of 7.5 preoperatively which dropped to 3.1 postoperatively, and a mean NDI of 45 preoperatively which improved to 15 postoperatively (all $p < 0.001$). However, both VAS (4.8) and NDI (25) scores after surgery were significantly higher for patients with ASD (n=45) than for those without ASD. Radiographically, disc height improved (from 5.2 to 7.5 mm, $p < 0.001$) as did cervical lordosis (from 12.5° to 8.3°, $p < 0.05$). Overall, the incidence of ASD was 30%, mainly occurring at the C5-C6 level (33.3%). A specifically impressive finding was that at follow-up, 70% of patients had neither degenerative disease nor disc herniation of adjacent level radiculopathy (30%) and disc herniation (16.7%) were common at adjacent levels.

Conclusion: The cervical spine fusion surgery can improve outcomes in terms of pain and disability, but ASD is a real problem postoperatively. These results highlight the need for long-term follow-up and preventive intervention for degenerative changes at adjacent segments.

Keywords: adjacent segment disease, cervical spine surgery, cervical fusion, degenerative cervical spine disease

Introduction

Cervical spine surgery is often performed for degenerative diseases such as myelopathy, spinal stenosis, and herniated discs. While surgery may relieve symptoms and improve quality of life, a major concern is that adjacent segment disease (ASD) may develop after surgical intervention (1). Autograft spinal degeneration refers to the gradual breakdown of spinal segments adjacent to the surgical site. It can lead to symptom relapse and further surgical intervention, according to our study (2).

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The seven vertebrae of the cervical spine form the neck and support the skull, enable head and neck to move, and help protect spinal cord and nerve roots (3). However, many conditions can involve this the spinal column segment and lead to symptoms, dysfunction, and even neurological deficits (4). Common diseases associated with it are major tumor injuries, cervical vertebrae spinal canal constriction and degenerative disc degeneration. These disorders can each affect the stability, alignment, and biomechanics of the cervical spine and surgery may be indicated when conservative measures fail (5).

Degenerative disc disease is a frequent indication for cervical spine surgery. As the discs dry out and stiffen, they shrink losing their ability to absorb shock between the vertebrae (6). This may lead to pain, stiffness, and in severe cases, nerve root compression due to disc

herniation or osteophyte formation (bone spurs). Stenosis can compress the spinal cord or nerve roots (7). Bone spur growth, ligament thickening, and disc bulging are examples of degenerative processes that frequently cause this constriction (8). Neck pain, radiculopathy, and potentially irreversible myelopathy are all possible symptoms for patients with spinal stenosis (9).

ASD refers to the natural, gradual, and patient-specific degeneration of adjacent segments from the repaired or fused spine area. The gradual redistribution of load to adjacent segments following a fusion surgery can lead to increased disc degeneration, facet joint arthritis, and other structural changes at these levels (10). Basically ASD is known symptomatic when the symptom significantly affects the quality of life of the patient such as pain, neurological impairment or functional limitation. Clinically important ASD is critical when making decisions regarding cervical spine procedures, as it often requires additional medical treatment or surgery. An appreciation of the effects of ASD is essential for predicting long-term outcomes, guiding surgical planning, and setting patient expectations (11). ASD after cervical spine surgery is attributed to biomechanical changes due to index spinal fusion that are segmental in nature, and restrict motion at the treated interfacing segment. This restraint then quickly hastens the degeneration of ligaments, facet joints and intervertebral discs by redistributing increased load and stress to adjacent segments. Consequently, this surgical fusion disrupts the biomechanical load distribution throughout the cervical spine, increasing the likelihood of degeneration across the segment (12).

Risk factors for ASD include the age of the patient, and older individuals may have preexisting degenerative changes that predispose them to ASD more quickly (13). Longer fusion segments and preexisting degeneration at adjacent levels add to the risk of ASD (because greater mechanical alterations at the spine may render adjacent segments more susceptible). These combined aspects make up what is known as ASD. These variables make ASD a complex, multivariable syndrome following cervical spine surgery (14). Because of its recurrent painful, neurological symptoms, and functional impairment, it may severely affect the long-term outcome of patients. Some use cases may need extra handling to aid in symptom treatment or to get it back to stable. The recurrence of ASD symptoms may hamper satisfaction and recovery and thus negatively influence overall quality of life (15).

Alternative, motion-preserving treatments such as cervical disc replacement seek to maintain natural spinal motion, which could potentially offload adjacent segments from excessive mechanical burden compared to traditional fusion. Although the incidence of ASD is an issue, surgical approaches are critical to potentially mitigating it. While the methods can maintain mobility and thus decrease the risk of neighbouring segments degenerating over time, surgical planning that incorporates the risk of ASD is paramount to optimizing outcomes (16).

Our study aims to evaluate the clinical and radiological changes at adjacent segments after cervical spine surgery, especially about ASD and its determinants.

Methods

Our study was a retrospective study. A number of patients was N=150 underwent routine cervical spine surgery in the Private Kocaeli Academy Hospital, Department of Neurosurgery between January 2017 and January 2018. This study was approved by the Kocaeli University Faculty of Medicine Ethical Committee. Inclusion criteria included all eligible patients aged 20 to 75 years, undergoing cervical spine fusion or fixation surgery before this study, had related imaging studies (x-ray, CT, or MRI), and consented to be involved in the study. Those who were deceased, refused to participate, or had cancers were excluded from this study. The sample size calculation formula was = {Z2*(p)*(q)}/Δ2. Changing the values were: P = 4.8% = 0 P = prevalence; Z value for the selected confidence level = 1.96 (for the 95% confidence level from the standard normal distribution). P Prevalence q=1-P = 1-0.048 = 0.952 and Δ= acceptance margin of error=0.005. Clinical evaluations assessed neck pain (resting and/or movement) and/or radicular pain in the upper limb(s) with and without neurological signs. Celebrate and validation of clinical predictors of outcome, combined scoring system of Neck Disability Index (NDI) and Visual Analog Scale (VAS) among patients on methods study. Clinical assessments pain assessment was carried out using the VAS and NDI. Radiological evaluations consisted of cervical spine x-rays in anteroposterior and lateral views at neutral, flexion, and extension positions. Sagittal x-rays taken preoperatively were used to compare with these images to assess for any displacement of the vertebral body. Displacement was measured and compared sagittally against the sagittal diameter of the underlying vertebrae, and graded into 0-25%, 25-50%, 50-75%, and 75-100% categories (Grade I, II, III, and IV respectively). Disc height was evaluated relative to adjacent levels, with a normal height defined as equal to the height of adjacent discs unless degeneration was documented. Based on a percentage loss of disc height, disc height loss was also classified and graded into mild, moderate, and severe degeneration. Symptomatic ASD was defined as the identification of radicular or myelopathic symptoms related to failed fusion adjacent to a degenerated level at two visits. Symptomatic ASD was managed according to standard care practices for cervical spine pathology, which for the initial step quartile included a towel cervical orthosis and analgesics. If neither radiculopathy nor new-onset myelopathy improved, MRI, CT and/or dynamic x-rays were performed to exclude compressive lesions. We used paired t-tests to compare outcomes within each group, and the student t-test to compare

outcomes between groups. Statistically data were analysed by SPSS 23 software.

Four grades were assigned to the degenerative changes at the surrounding levels based on the radiological findings in Table 1.

Table 1. Grading of Degenerative Changes at Adjacent Levels in Imaging Findings

Grade	Disease Finding	Plain Radiography	Magnetic Resonance Imaging (MRI)	Computed Tomography (CT), Myelography, or Both
I	None	Normal	Normal	Normal
II	Mild: Narrowing of disc space, no posterior osteophytes	Signal change in intervertebral disc	Normal	
III	Moderate: < 50% of normal disc height	Herniated nucleus pulposus without neural compression	Herniated nucleus pulposus; no nerve-root cut-off or spinal cord compression	
IV	Severe: Same as for Grade III	Spinal cord compression with or without nerve-root compression	Nerve-root cut-off with or without spinal cord compression	

Results

The demographic and clinical characteristics of 150 patients undergoing surgery reveal an average age 47.5 ± 27.5 years, with the majority being male (60%) and the remaining 40% female. Surgical indications and patient characteristics; 45% of patients had a herniated disc, 35% had cervical stenosis and 20% underwent surgery for other indications (Table 2). Initial preoperative pain on a scale of 0 to 10 measured by VAS was high (7.5 ± 1.2). After surgery, this decreased to 3.1 ± 1.5, demonstrating a significant decrease in pain ($p<0.001$). Corresponding to the previous analysis, disability measured with the NDI also was significantly reduced from a mean of preoperative NDI of 45 ± 10 to a post-operative NDI of 15 ± 8 ($p<0.001$). This suggests that surgery lead to improved quality of life based on modest but notable improvements in pain and disability.

Table 2. Demographic and Clinical Characteristics of Patients

Characteristic	Value (n=150)
Mean Age (years)	47.5 ± 27.5
Gender	
- Male	90 (60%)
- Female	60 (40%)
Indication for Surgery	
- Herniated Disc	67 (45%)
- Cervical Stenosis	52 (35%)
- Other (tumor, trauma, etc.)	31 (20%)
Preoperative VAS	7.5 ± 1.2
Postoperative VAS	3.1 ± 1.5 ($p<0.001$)
Preoperative NDI	45 ± 10
Postoperative NDI	15 ± 8 ($p<0.001$)

ASD can significantly impact patient outcomes after surgery (Table 3). Pain, function, and likelihood of reoperating varied greatly between those with ASD and without. For individuals diagnosed with ASD following their procedure, the average pain score on the VAS was notably elevated at 4.8 ± 1.7 compared to 2.5 ± 1.3 for patients without ASD. Similarly, disability measured using the NDI showed worse results for those with ASD, at 25 ± 10 versus 10 ± 5. Both differences proved statistically significant. Furthermore, reoperation rates diverged substantially - while only 5% (5 of 105) without ASD required additional surgery, that number jumped to 33% (15 of 45) for patients experiencing ASD. These results clearly link the presence of ASD to higher post-surgical pain and disability levels as well as a dramatically increased chance of needing repeat surgery. Patients and doctors must acknowledge how ASD could impact recovery.

Table 3. Comparison of Clinical Outcomes Based on ASD

Outcome Measure	ASD Present (n=45)	No ASD (n=105)	p-value
Postoperative VAS	4.8 ± 1.7	2.5 ± 1.3	< 0.001
Postoperative NDI	25 ± 10	10 ± 5	< 0.001
Need for Reoperation	15 (33%)	5 (5%)	

Table 4 reveals that the radiographic results showed the significant variation in other major spine parameters post surgery. The mean disc height before surgery was 5.2 ± 1.0 mm and after surgery, it increased to 7.5 ± 1.2 mm with a statistically significant p-value of less than 0.001 (highly significant). Meaning, the procedure was able to at least restore disc height. The shift mean from 12.5 ± 5.0 degrees preoperative to postoperative average of 8.3 ± 4.5 degrees was associated with a statistically significant moderate loss of cervical lordosis, or natural curvature of the cervical spine ($p<0.05$). For the cohort, 30% of patients (45/150) developed ASD, a postoperative complication common to segments adjacent to the surgical site. The MRI results demonstrated an increase in signal intensity and disc bulging at these neighbouring levels, reflecting degenerative changes in adjacent segments that were likely induced by altered spinal mechanics as a result of surgery. Our radiographic findings reflect a relatively high prevalence of ASD and degenerative changes at adjacent levels, but the early effectiveness of surgical decompression, instrumentation, disc height restoration, and some cervical curvature modification.

Table 4. Radiological Outcomes

Radiological Parameter	Preoperative Value	Postoperative Value	p-value
Disc Height (mm)	Mean 5.2 ± 1.0	Mean 7.5 ± 1.2	< 0.001
Cervical Lordosis (degrees)	Mean 12.5 ± 5.0	Mean 8.3 ± 4.5	< 0.05
Incidence of ASD	-	45 (30%)	-
MRI Findings (Adjacent Levels)	-	Increased signal intensity and disc bulging	-

Table 5 shows that the data on frequency of spinal level operated upon showed that the mid to lower cervical spine levels detractor among narrative reviews. The most common levels of surgery were C5-C6 (23.3%), followed by C4-C5 (20%), C6-C7 (13.3%) and C3-C4, respectively. On a patient level, the lowest frequencies were C7 (10%), C6 (8%), C5 (6.7%) and C4 (5.3%). This suggests that the greatest number of procedures were performed within the C5-C6 and C4-C5 levels, which is consistent with cervical spine degeneration. This is most likely because they are more dynamic and therefore subject to disease and degeneration. This frequency distribution parallels the clinical trend of cervical disc degeneration at these locations in that it reflects a pattern of surgical emphasis on regions that are both highly mobile and common sites for degenerative changes.

Table 5. Statistical Analysis of Distribution of Operated Levels at Index Surgery (n=150)

Operated Level	Frequency (n)	Percentage (%)
C4	8	5.3%
C5	10	6.7%
C6	12	8.0%
C7	15	10%
C3-C4	20	13.3%
C4-C5	30	20%
C5-C6	35	23.3%
C6-C7	20	13.3%

Table 6 reveals that the present follow-up, the distribution of radiculopathy shows that 70% of patients did not have any radiculopathy. Of the 30% who had radiculopathy (n=45), the most commonly affected level was C4, with 13.3% of patients reporting radiculopathy at this level compared to only 10% and 6.7% at C5 and C6 levels, respectively. This pattern indicates that, in general, surgery was successful in preventing or resolving nerve-related pain for most patients; however, radiculopathy continued to be a problem for some patients, particularly at the upper cervical levels (C4 and C5). These results emphasize the sequences of cervical levels that remain sensitive to nerve injury despite treatment, presumably related to the anatomical and functional properties which render certain levels susceptible to post-operative stress or degenerative change.

Table 6. Percentage Distribution of Radiculopathy at Current Follow-up by Cervical Level (n=150)

Cervical Level with Radiculopathy	Frequency (n)	Percentage (%)
C4	20	13.3%
C5	15	10%
C6	10	6.7%
No Radiculopathy	105	70%

Table 7 reveals that at adjacent levels after surgery, 70% had some degenerative or structural changes in the spinal segments next to the operated level and 30% had no new changes. Among the patients with changes, degeneration was the predominant finding (30% of patients), which suggests a high incidence of adjacent-segment degeneration or progressive wear among those undergoing surgery. The incidence of disc herniation was 16.7%, which might imply that the adjacent discs were under higher stress in some cases, which may be due to adjusting spinal mechanics following surgery. Facet joint hypertrophy, seen in 13.3% of patients, indicates adaptive or degenerative alteration associated with regressive changes probably related to hyperfunctioning stress on the facet joints. Reference also described ligament ossification in 10% of patients 68 which is considered as one cause for the decreased mobility, and induce adjacent levels impairment or new progression. These data confirm that (while surgery appears to resolve symptoms at the index level) degenerative changes and/or compensatory changes in adjacent segments are a common experience following surgical intervention, termed "ASD". It emphasizes the need for longitudinal assessments of adjacent segments to prevent or mitigate time-dependent changes that may jeopardize patient outcomes.

Table 7. Distribution of Cases According to New Changes at Adjacent Level (n=150)

Adjacent Level Change	Frequency (n)	Percentage (%)
Degeneration	45	30%
Disc Herniation	25	16.7%
Facet Joint Hypertrophy	20	13.3%
Ossification of the Ligament	15	10%
No New Changes	45	30%

Table 8 reveals that the level of C5-C6 (33.3%), C4-C5 (26.7%) and C6-C7 (20%) were the most commonly affected levels, respectively. Surgical distribution of ASD by spinal level demonstrated that the majority suffered degenerative changes in the mid-cervical spine. C3-C4 (13.3%) and C7-T1 levels had the lowest frequencies, respectively. This pattern suggests that mid-cervical levels are more susceptible to clinically detectable neighbouring segment degeneration after surgery, especially at C5–C6 where the individual segment mobility and mechanical load appear increased. The high incidence of ASD at these levels reflects their susceptibility to stress, likely exacerbated by altered spinal dynamics following surgery at adjacent levels. In light of their more frequent occurrence of ASD affecting distant surgical outcomes, this distribution highlights the importance of vigilance and tracing post-operative mid-cervical segments.

Table 8. Statistical Analysis of Distribution of Cases According to ASD Levels

ASD Level	Frequency (n)	Percentage (%)
C3-C4	20	13.3%
C4-C5	40	26.7%
C5-C6	50	33.3%
C6-C7	30	20%
C7-T1	10	6.7%

Figure 1 reveals that motion segment mobility is measured directly above and below the implant insertion site. Anterior cervical discectomy and fusion surgery was performed on the C5-C6 disc area. The distance between the bases of the C4-C5 and C6-C7 spinous processes was measured. A motion segment's mobility was defined as the change in the distance between flexion and extension measured in mm. Radiographs taken the day before surgery were also used to assess the mobility of segments just above and below the implant insertion location.

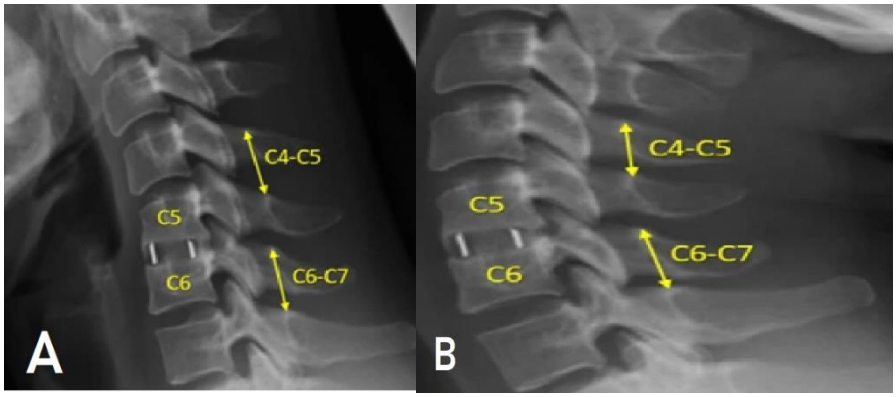

Figure 1. (A) Flexion x-ray, (B) Extension x-ray

Discussion

The large reduction in VAS and NDI values from preoperative to postoperative measurements indicates that patients undergoing cervical fusion surgery had considerable pain relief and functional benefit. The VAS score decreased significantly from an average of 7.5 in the preoperative period to 3.1 at postoperative follow-up ($p<0.001$), indicating that cervical spine fusion surgery is an effective procedure for treating radicular and neck pain. Thus, this reduction suggests that the procedure has dealt with the likely sources of discomfort by perhaps minimizing nerve impingement, decompressing neural structures and stabilizing the spine. This finding is in line with previous studies showing that the structural support and stability offered by fusion surgeries promote improved pain outcomes (17).

The functional state of the patients was also significantly improved: NDI indicated a substantial decrease from the mean value of 45 to 15 ($p<0.001$). The findings are consistent with previous studies, including the one conducted by Howell who reported similar results regarding pain and function following cervical fusion surgery, with their study also demonstrating significant improvement in patients (18). The NDI score decreased after surgery, showing that individuals had increased mobility and a considerable reduction in the constraints caused by their cervical disease. This improvement demonstrates how cervical fusion can reduce mechanical instability, resulting in increased mobility and less pain during activities (19).

While pain and functional improvement have clearly improved, the high percentage of 30% with ASD in this sample opens up questions about long-term results. In the ASD group, values of VAS 4.8 and NDI 25 after surgery. These results are consistent with Lee et al., who found that the levels of discomfort and disability were higher among individuals diagnosed with ASD than non-ASD controls (20).

The trends in VAS and NDI scores show an overall improvement in the patients' comfort and functions of day-to-day living which is vital as pain and impairments significantly affect the quality of life. For patients with traumatic or degenerative cervical spine conditions, functional improvements like increased range of motion and decreased reliance on painkillers are essential because they facilitate their return to daily activities and may lessen the financial burden of chronic pain management on healthcare systems (21).

Radiologically, the disc height improved from 5.2 mm before surgery to 7.5 mm after surgery ($p<0.001$), indicating that the disc space was successfully restored after fusion. However, the noted reduction in cervical lordosis from 12.5° to 8.3° ($p<0.05$) prompts inquiries regarding possible biomechanical alterations after surgery. This decrease in lordosis may put nearby segments at greater risk for stress, which could result in degenerative alterations. According to earlier studies, such as those conducted by Scheer et al., changes in cervical alignment following surgery may have a role in the emergence of ASD. Nerve compression and mechanical instability may result from deterioration and shrinking of the intervertebral space, which is frequently linked to a disc height of 5.2 mm before to surgery. The symptoms of this constriction, which include discomfort, decreased range of motion, and neurological impairments, are frequently brought on by disc degeneration, trauma, or persistent cervical spondylosis (22).

The fact that the postoperative disc height increased to 7.5 mm indicates that the fusion procedure was successful in restoring this spacing, which relieved pressure on the spinal nerves and helped to stabilize the cervical spine. The main advantages of disc height

restoration are the reduction of nerve impingement and spinal instability symptoms; the wider foramen created by the increased disc space lessens the risk of nerve root compression, improving nerve health and reducing radicular pain symptoms; and the restoration of disc height can have a positive effect on load distribution throughout the spine, preventing further degeneration at adjacent segments. These benefits are corroborated by the notable post-operative VAS and NDI improvements, which show that the restored height contributes to both pain reduction and improved functionality (23).

At neighbouring levels, radiographic outcomes were new disc herniation (16.7%) and degeneration, lending further support to the notion that spinal fusion results in increased load on adjacent segments. This is further supported throughout the literature suggesting that the immobile nature of the fused segment can cause increased stress on both adjacent segments as well as distant segments resulting in accelerated degeneration. The reoperation rate (33% in the ASD group) is also a concerning trend; however, this finding is consistent with other studies suggesting that patients with ASD might need more aggressive therapies (24).

This suggests that whereas morphologic features of ASD on imaging may indicate degenerative foundation, the majority of people will not endure clinical symptom or practical decrease originating in these modifications. Consistent with previous research that showed structural changes in imaging were not always correlated with patient symptoms, 70% of patients with ASD had no abnormalities (25). Given the degenerative changes at segments neighbouring to the fused spine in ASD, radiculopathy may be anticipated. Nonetheless, as not all structural rearrangements produce clinical features, this study does suggest. As degenerative changes occur at segments close to the fused spine in ASD, radiculopathy may be expected. This study suggests that not all structural alterations lead to clinical symptoms, nevertheless. This implies that although radiological signs of ASD can point to underlying degeneration, most individuals do not experience clinical discomfort or functional impairment as a result of these alterations. 70% of patients with ASD have no symptoms, which is consistent with earlier research showing that structural alterations on imaging did not always correspond to patient symptoms (26).

Our study indicates that symptomatic ASD following cervical fusion occurs in only a small percentage of patients. This discrepancy may be due to compensatory mechanisms within the cervical spine that can adapt to degenerative changes without causing significant nerve compression adequate to produce radiculopathy. For example, recent work suggests that asymptomatic radiological findings are common among the postoperative population yielding recommendations to complement imaging data with a thorough clinical synthesis. Compared to previous studies in the literature, our study's results reinforce the complex relationship between surgical outcomes, ASD, and patient quality of life. The prevalence of ASD and related symptoms, as observed in the study conducted by Seo et al., emphasizing the loss of ability to control over long-term outcomes with cervical fusion (27).

The results of this study support the intricate connection between surgical outcomes, ASD, and patient quality of life when contrasted with previous research. A similar rate of ASD and related symptoms, for instance, was noted in the work by Kepler et al., highlighting the difficulty in controlling long-term results following cervical fusion (28).

Conclusion

Although cervical spine fusion surgery provides essential function and pain relief, the associated development of ASD merits further investigation. Highly prevalent in our cohort, and related to clinical symptoms, ASD emphasizes the importance of postoperative patient monitoring and assessment. Further studies should focus on identifying predictors of ASD and interventions to reduce the risk to improve long-term outcomes after cervical spine fusion.

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