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Adjacent Segment Disease Perspective and Review of the Literature

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ABSTRACT

Background: Adjacent segment disease has become a common topic in spine surgery circles because of the significant increase in fusion surgery in recent years and the development of motion preservation technologies that theoretically should lead to a decrease in this pathology. The purpose of this review is to organize the evidence available in the current literature on this subject.

Methods: For this literature review, a search was conducted in PubMed with the following keywords: adjacent segment degeneration and disease. Selection, review, and analysis of the literature were completed according to level of evidence.

Results: The PubMed search identified 850 articles, from which 41 articles were selected and reviewed. The incidence of adjacent segment disease in the cervical spine is close to 3% without a significant statistical difference between surgical techniques (fusion vs arthroplasty). Authors report the incidence of adjacent segment disease in the lumbar spine to range from 2% to 14%. Damage to the posterior ligamentous complex and sagittal imbalances are important risk factors for both degeneration and disease.

Conclusion: Insufficient evidence exists at this point to support the idea that total disc arthroplasty is superior to fusion procedures in minimizing the incidence of adjacent segment disease. The etiology is most likely multifactorial but it is becoming abundantly clear that adjacent segment disease is not caused by motion segment fusion alone. Fusion plus the presence of abnormal end-fusion alignment appears to be a major factor in creating end-fusion stresses that result in adjacent segment degeneration and subsequent disease. The data presented cast further doubt on previously established rationales for total disc arthroplasty, at least with regard to the effect of total disc arthroplasty on adjacent segment degeneration pathology.

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INTRODUCTION

Adjacent segment disease (ASDis) has become a common topic in spine surgery circles because of the significant increase in fusion surgery in recent years and the development of motion preservation technologies that theoretically should lead to a decrease in this pathology.[1-4] ASDis is defined as new degenerative changes at a spinal level adjacent to a surgically treated level or levels in the spine, accompanied by related symptoms (radiculopathy, myelopathy, or instability). Adjacent segment degeneration (ASDeg) represents the radiographic changes without the symptomatology.[5] An important question remains unanswered: are adjacent disc degeneration and disease the result of the natural history of age-related degeneration or are they the result of adjacent segment fusion that has led to the adjacent segment changes?

ETIOLOGY

The etiology of ASDis is most likely multifactorial; no study to date has proven that a single risk factor directly correlates with this pathology. The natural history of degeneration, changes in intradiscal pressure, anatomy disruption, and sagittal malalignment have been proposed as etiologic factors for this pathology.[1-3]

NATURAL HISTORY

As the cervical spine ages, degenerative changes tend to occur naturally, a progression that compli-

cates attempts to determine whether ASDis results from surgical fusion, natural history, or other causes.

Boden et al[6] studied asymptomatic subjects using magnetic resonance imaging (MRI) of the cervical spine. Imaging abnormalities were found in 14% of the individuals aged <40 years and 28% of the individuals aged >40 years, clearly indicating an age-related degeneration.

In a study of cervical noninstrumented arthrodesis patients who had undergone single or multilevel anterior cervical discectomy and fusions (ACDF), Hilibrand et al[7] observed that age, abnormal segmental motion, and preexisting disease were risk factors for the development of ASDis. The incidence of ASDis was less in patients with multilevel fusions than in patients with single-level fusions. This finding is in conflict with the belief that fusion increases biomechanical stress at the adjacent level. A multilevel fusion, in which the exerted bending moment is greater than that of a single-level fusion, is intuitively expected to lead to an increased incidence of ASDis. Observations such as the one made by Hilibrand et al likely result from the fact that most ACDFs are performed at the most degeneration-prone levels, leaving the remaining degeneration-resistant levels unfused. In such cases, the incidence of ASDis is diminished.

Matsumoto et al[8] compared patients who had undergone ACDF to healthy control patients at 10-year follow-up. After performing MRI studies, the authors concluded that ACDF increases the incidence of adjacent level degeneration. A major drawback of this study is that the groups did not represent matched cohorts and the patients in the ACDF group were older (approximately 6.2 years) than the patients in the control group. Additionally, the fact that this group had already undergone ACDFs suggests that these patients were more susceptible to the development of disc degeneration than the patients in the control group.

Although no conclusive etiology exists for ASDis, natural history seems to be an important factor.

ANATOMY DISRUPTION ADJACENT TO PRIOR SURGICAL LEVEL

Soft tissue disruption adjacent to the surgical level is considered a potential cause of ASDeg and subsequent ASDis. Nassr et al found a threefold increase in degeneration at the level where a needle was placed for radiographic localization purposes.[9] The authors alleged that the puncture of the annulus caused the subsequent degeneration. Other studies have demonstrated the association between adjacent level ossification and the positioning of the ACDF plate within 5 mm of the adjacent level, highlighting the importance of preserving the soft tissue anatomy of the adjacent level to avoid further adjacent segment degeneration.[10,11]

INTRADISCAL PRESSURE ADJACENT TO THE SURGICAL LEVEL

Biomechanical studies have shown increased intradiscal pressure (mechanical stress) on the adjacent discs after a single-level fusion model.[12] This pressure is particularly high in flexion-extension when fusion is compared to total disc arthroplasty (TDA) and baseline. In theory, the increase of mechanical stresses may lead to an increase in ASDeg and ultimately to ASDis. Even though this theory was the rationale for the development of TDA, current clinical studies have failed to demonstrate this direct correlation, and so far the difference in ASDis incidence among the fusion vs TDA groups is not statistically significant.[13]

SAGITTAL ALIGNMENT AND POSTURE

Postoperative spinal malalignment is a major stressor of intradiscal mechanics and a contributor to a motion segment and ASDeg in the cervical and lumbar spines.[14-21] Several studies have shown that postoperative spinal pelvic parameters, most notably a large pelvic incidence angle and small lumbar lordotic angle, are associated with greater risk of adjacent segment stresses and degenerative changes.[15,17-22] Specifically regarding lumbar lordotic angle, the maintenance of lumbar lordosis following fusion results in a diminished incidence of adjacent segment stresses and instability compared to a kyphotic spine.[17,22] Sagittal alignment is strongly related to segmental mobility and disc degeneration.[14-21,23,24]

THE EVIDENCE: FUSION VS TDA AND ADJACENT SEGMENT DISEASE

Cervical Literature

Many randomized controlled trials (RCTs) have been published on TDA of the cervical spine vs fusion (Table 1). Even though the results favor TDA over fusion, none of the RCTs has demonstrated a statistically significant difference regarding the incidence of ASDis.[25-31] The reported annual incidence of ASDis in fusion patients is approximately 3%.[4] Nunley et al[25] reexamined current evidence on ASDis in patients who underwent TDA and found an annual incidence of 3.1% regardless of the patient's age, sex, smoking habits, and design of the disc replacement device.

Burkus et al[29] have shown that TDA using a Prestige ST ball-in-socket device (Medtronic) is a motion-preserving procedure that at 24-month follow-

Table 1. Summary of Relevant Studies on Cervical Adjacent Segment Degeneration and Disease

Author, Year	Study Design	Group, n/Mean Age	Device	F/U, Years	ASDeg/ASDis	*P* value	Conclusions
Coric, 2013[30]	RCT	ACDF: 33 TDA: 41 Age: 49.5	Bryan Disc, Kineflex|C	6	Symptomatic Disease ACDF: 3.0% TDA: 4.9%	>0.05	Both groups showed low adjacent-level reoperation rates. Both cervical TDA and ACDF appear to be viable options for the treatment of single-level cervical radiculopathy.
Nunley, 2012[25]	RCT	ACDF: 57 TDA: 113 Age: 44.5	3 different devices	4	Symptomatic Disease ACDF: 14.3% TDA: 16.8%	>0.05	The risk of developing ASDis was equivalent after both ACDF and TDA procedures in cervical DDD. Osteopenia and concurrent lumbar DDD significantly increase the risk.
Maldonado, 2011[31]	PC	ACDF: 105 TDA: 85 Age: 46	Discover	3	Radiological Degeneration ACDF: 10.5% TDA: 8.2%	>0.05	Lower degeneration was observed with the motion preservation TDA without difference in the incidence of ASDis.
Burkus, 2010[29]	RCT	ACDF: 265 TDA: 276 Age: 43	Prestige ST	5	Symptomatic Disease ACDF: 13.0% TDA: 8.0%	>0.05	TDA maintained physiological segmental motion at 24 months and had a reduced rate of secondary surgeries compared with ACDF.

ACDF, anterior cervical discectomy and fusion; ASDeg, adjacent segment degeneration; ASDis, adjacent segment disease; DDD, degenerative disc disease; F/U, follow-up; PC, prospective cohort; RCT, randomized controlled trial; TDA, total disc arthroplasty. Devices and manufacturers identified in the studies are Bryan Disc (Medtronic), Discover (DePuy Synthes), Kineflex|C (SpinalMotion), Prestige ST (Medtronic).

up maintained a greater range of motion compared to ACDF. The incidence of ASDis was lower in the TDA group than the ACDF group; however, the difference was not statistically significant.

Maldonado et al[31] compared radiographic degeneration in patients who had undergone either ACDF or TDA; they found a lower rate of ASDeg in the TDA group but no correlation with a lower incidence of symptomatic disease.

Nunley et al[25] studied more than 200 patients randomized between ACDF and TDA using 3 different disc replacement devices. The incidence of ASDis was equivalent in both groups. However, they observed that the presence of lumbar degenerative disease and osteopenia increases the risk of developing symptomatic cervical ASDis.

Coric et al[30] reported a surprisingly low rate of ASDis following surgery and concluded that both ACDF and TDA are viable options for the treatment of single-level cervical radiculopathy.

A series of published meta-analyses on the same subject has shown minimal clinically relevant differences between TDA and ACDF; most importantly, no significant difference was demonstrated in terms of ASDis.[26-28,32-34]

Lumbar Literature

The reported incidence of lumbar spine ASDeg and ASDis ranges widely (Table 2); this range can be attributed to the variety of techniques used to address the lumbar spine pathology.[35]

In a systematic review, Harrop et al compared arthrodesis vs arthroplasty in the lumbar spine.[36] In the fusion group, the incidence of ASDeg was 34% and the incidence of ASDis was 14%. In the TDA group, the incidence was significantly lower—9% ASDeg and 1% ASDis. A limitation of the study was that the patients in the arthrodesis arm were signifi-

Table 2. Summary of Relevant Studies on Lumbar Adjacent Segment Degeneration and Disease

Author, Year	Study Design	Parameters	Results	*P* value	Conclusions
Harrop, 2008[36]	Systematic Review (27 articles)	Arthrodesis: 1732 patients Arthroplasty: 758 patients	ASDeg - Arthrodesis group: 34% - Arthroplasty group: 9% ASDis - Arthrodesis group: 14% - Arthroplasty group: 1%	<0.001	Better results were achieved with the motion preservation technique. However, groups were not comparable, with older patients in the arthrodesis arm. Multivariate logistic regression indicated that higher odds of ASDeg were associated with: older patients ($P<0.001$). The study found a stronger correlation between fusion and ASDis compared to arthroplasty (class C recommendation).
Min, 2007[39]	Cohort	ALIF: 25 patients PLIF: 23 patients - No intergroup differences	Radiological Degeneration (ASDeg) - ALIF: 44% - PLIF: 82.6%	0.008	ALIF was associated with a lower incidence of ASDeg. Result associated with the fact that the pedicle screws were placed percutaneously and damage to the integrity of the posterior complex was significantly lower.
Wai, 2006[37]	Prospective Cohort	ALIF: 39 patients Intervention: MRI Minimum follow-up time: 20 years	Advanced radiological degeneration (ASDeg) - Adjacent level: 9 (23.1%) - Nonadjacent level: 7 (17.9%)	0.56	Degenerative changes occurred over multiple levels or at levels not adjacent to the fusion, suggesting that degeneration may be more likely related to constitutional factors.

ALIF, anterior lumbar interbody fusion; ASDeg, adjacent segment degeneration; ASDis, adjacent segment disease; PLIF, posterior lumbar interbody fusion.

cantly older and likely more susceptible to degeneration.

For more than 20 years, Wai et al followed patients who had undergone anterior lumbar interbody fusion (ALIF) with MRI.[37] They found that 6% of the patients required surgery at the adjacent level and noted a similar incidence of adjacent level degeneration compared with nonadjacent levels (23.1% and 17.9%, respectively). The authors concluded that the ASDis was more likely related to the natural history of disc degeneration rather than altered biomechanics at the adjacent level.[37]

Ishihara et al[38] found the incidence of ASDeg to be 52% at the rostral adjacent level and 70% at the caudal adjacent level after ALIF for isthmic spondylolisthesis, but they did not correlate these findings with symptomatic disease.

Min et al[39] compared ALIFs vs posterior lumbar interbody fusions (PLIFs) for lumbar spondylolisthesis. They found the incidence of ASDeg to be 44% with ALIF and 82.6% with PLIF. In the ALIF group, posterior instrumentation with pedicle screws was performed percutaneously. This result suggests that ALIF may reduce damage to the integrity of the posterior complex, which is known to be an important risk factor for ASDis.

Radcliff et al found an annual ASDis incidence of 2% to 3% after decompression and stabilization procedures.[40] Factors consistently associated with ASDis included laminectomy adjacent to a fusion and a sagittal imbalance.

CONCLUSION

The incidence of ASDis in the cervical spine is close to 3% per year and no statistical difference is

observed when TDA is compared to fusion.[1-4,25,29-31] In the lumbar spine the incidence ranges from 2% to 14%.[35-40] Damage to the posterior ligamentous complex and sagittal imbalances are important risk factors.

Insufficient evidence exists at this point to support the idea that TDA is superior to ACDF regarding minimizing the incidence of ASDis.

The literature clearly suggests that ASDis is not caused by motion segment fusion alone.[4,14,16,24,41] Fusion plus the presence of abnormal end-fusion alignment (usually kyphosis) appears to be a major factor in creating end-fusion stresses that result in ASDeg and ASDis. The data presented cast further doubt on previously established rationales for TDA, at least with regard to the effect of TDA on ASDeg pathology.

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