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The Early Effect of Anterior Cervical Discectomy and Fusion on Adjacent Segment Degeneration in Cases of Cervical Degenerative Disease: A Clinical and Retrospective Study

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Abstract

BACKGROUND: The cervical spine is the most mobile part of the spine in the sagittal plane. It is important for surgeons to have reliable, simple, and reproducible parameters to analyze the cervical spine pre-operative and post-operative. Despite anterior cervical discectomy and fusion (ACDF) is a common procedure, adjacent segment failure after surgery is an ongoing clinical concern; adjacent segment disease (ASD) occurs in approximately 3% of patients per year, with an expected incidence of 25% within the first 10 years following fusion. It has been suggested that the increased stress placed on adjacent segments after successful ACDF may increase the rate of symptomatic disc disease at those segments, so our study focuses on how to evaluate ASD using magnetic resonance imaging (MRI) and X-ray.

METHODS: The retrospective study conducted on 72 patients in the department of neurosurgery at Kasr Al-Ainy hospitals to evaluate ASD after ACDF for degenerative cervical spondylosis using pre-operative and post-operative cervical spine X-ray lateral view as well as MRI for cervical spine after 2 years from the date of surgery.

RESULTS: Among the 72 patients in our study, the follow-up MRI after 2 years showed new pathology in 14 patients (19.4%) while 58 patients (80.6%) showed no new pathology; also 20 patients (27.8%) presented with new complaints while 52 patients (72.2%) had no new complaints and only 3 patients (4.16%) were scheduled for surgery.

CONCLUSION: ASD is an ongoing process of degeneration that could be accelerated by ACDF procedures, but not every adjacent segment degeneration or symptomatic disease requires additional surgery. Cervical mal-alignment greatly affects the neck pain rather than development of other new neurological manifestations and plays a role in adjacent segment failure which should be considered during cervical fusion surgeries. ASD must be differentiated from adjacent segment degeneration using clinical examination and imaging to help in patients' follow-up and decision-making of further intervention.

Introduction

Cervical degenerative disease is common among elderly people which manifests by neck pain, cervical radiculopathy, or myelopathy [1]. The degree and location of spinal cord compression are heterogeneous. Spinal cord compression can result from ventral pathologies such as herniated discs and disc osteophyte complexes or from dorsal compression from facet and ligamentum flavum hypertrophy; these changes can be confined to one level or can involve multiple levels [2].

There is no well-defined pattern of neurologic deficits in cervical spondylotic myelopathy. Symptoms usually begin insidiously with varying signs and symptoms that can include: Neck pain, upper limb numbness or paresthesia, gait disturbance which is a common early symptom, sensory deficits, weakness in the lower extremities with the upper motor neuron characteristics, and bladder dysfunction [3].

Diagnosis requires a careful correlation between the findings from the history, physical examination, and imaging studies. Magnetic resonance imaging (MRI), computed tomography (CT), and X-rays can be used to diagnose cervical spondylotic myelopathy, providing a quantitative assessment of central canal narrowing [4]. MRI is generally considered the test of choice as it is superior in providing intramedullary detail of spinal cord pathology, but CT provides better images of bone and other calcified tissues [5].

The choice of operative procedure should take in consideration the patient's clinical and radiological characteristics, age, comorbidities, lifestyle, procedure-specific risks, and finally, the experience and comfort level of the surgeon with various surgical procedures [6].

Anterior cervical discectomy and interbody fusion (ACDF) is considered the standard procedure for the treatment of degenerative cervical disc diseases. It has been suggested that the increased stress placed on adjacent segments after successful ACDF may increase the rate of symptomatic disc disease at those segments,

that is why spine surgeons are becoming interested in alternatives to fusion, such as total disc arthroplasty [7]. The goal in using these devices is to replace the diseased disc while preserving and restoring motion at the treated level, avoiding the compensatory increase in motion of contiguous segments, and protecting patients from progressive disc degeneration in adjacent segments. Although early clinical experience is growing, the biomechanics of cervical disc arthroplasty have not been fully delineated in the literature [8], [9].

Adjacent segment degeneration is defined as two kinds of post-arthrodesis adjacent level pathology; the term adjacent segment degeneration describes radiographic changes observed at levels next to the previously fused segment or segments; this degeneration may not correlate with clinical symptoms. In contrast, adjacent segment disease (ASD) refers to the development of new symptoms referable to a motion segment adjacent to the site of a previous anterior arthrodesis in the cervical spine [10], [11]. Studies suggest that a wide variation in the prevalence of adjacent segment degeneration (25–92%) exists following fusion. A small portion of these patients (9–17%) eventually develops symptomatic disease that requires additional surgery. However, the studies are not conclusive as to whether fusion itself causes accelerated degeneration of neighboring motion segments [12], [13], [14].

The radiologic evaluation of the cervical spine in the post-operative period included lateral radiographs in neutral and in full active flexion-extension, to obtain a time series of cervical lordosis and sagittal range of motion (ROM) changes. On the basis of the radiographic images, cervical lordosis was measured using the Cobb method. The Cobb angle was determined as the angle of intersection of two tangential lines drawn along the inferior end plate of the C2 and the inferior end plate of the C7. Lordosis was expressed as a positive value and kyphosis was expressed as a negative value so as sagittal ROM was determined by measuring the difference in alignment between maximum flexion and extension [15] that was measured as the sum of flexion and extension Cobb angle of C2–C7 (Figure 1) [16].

Patients and Methods

This is a retrospective and cross-sectional study conducted on 72 patients with cervical spondylosis as verified clinically and radiologically 2-year post-operative. Patients were operated on by ACDF in the neurosurgery department, Cairo University Hospitals. Patients' follow-up was performed in the period from January 2019 to July 2021.

Patients were followed up 2 years after surgical intervention being assessed for the following prognostic factors: Age, sex, symptoms, and number of affected levels in addition to doing a new MRI and lateral X-ray of the cervical spine for all patients whether they were presenting with symptoms or not.

Inclusion criteria

Patients with clinical signs and symptoms of cervical spondylosis, radiologic findings of cervical spondylosis, degenerative disc disease, patients underwent single, double, triple, or quadruple levels of ACDF were included in the study.

Exclusion criteria

Osteoporotic, traumatic, neoplastic, and infection cases, posterior or combined anterior with posterior approach, pediatric age group, ACDF with plate or arthroplasty and associated conditions such as amyotrophic lateral sclerosis or multiple sclerosis, rheumatoid arthritis, and ankylosing spondylitis were excluded from the study.

Outcome measures

Two-year post-operative patient's pain assessment was done through visual analog score (VAS) [17] and neck disability index (NDI) [18].

Myelopathy grade and functional status were evaluated using the following:

- Assessment of the improvement and deterioration of myelopathy using Nurick's classification
- Modified Japanese orthopedic association was also used for the assessment of myelopathy and functional state compared to pre-operative parameters.

Statistical methods

Data were coded and entered using the Statistical Package for the Social Sciences version 26 (IBM Corp., Armonk, NY, USA). Data were summarized using mean, standard deviation, median, minimum and maximum in quantitative data, and using frequency (count) and relative frequency (percentage) for categorical data. For comparison of serial measurements within each patient, the non-parametric Friedman test and Wilcoxon signed rank test were used [19]. For comparing categorical data measured pre and post, McNemar test was used [20]. $p < 0.05$ was considered as statistically significant.

Results

A retrospective and cohort study conducted on 72 patients who previously suffered from cervical

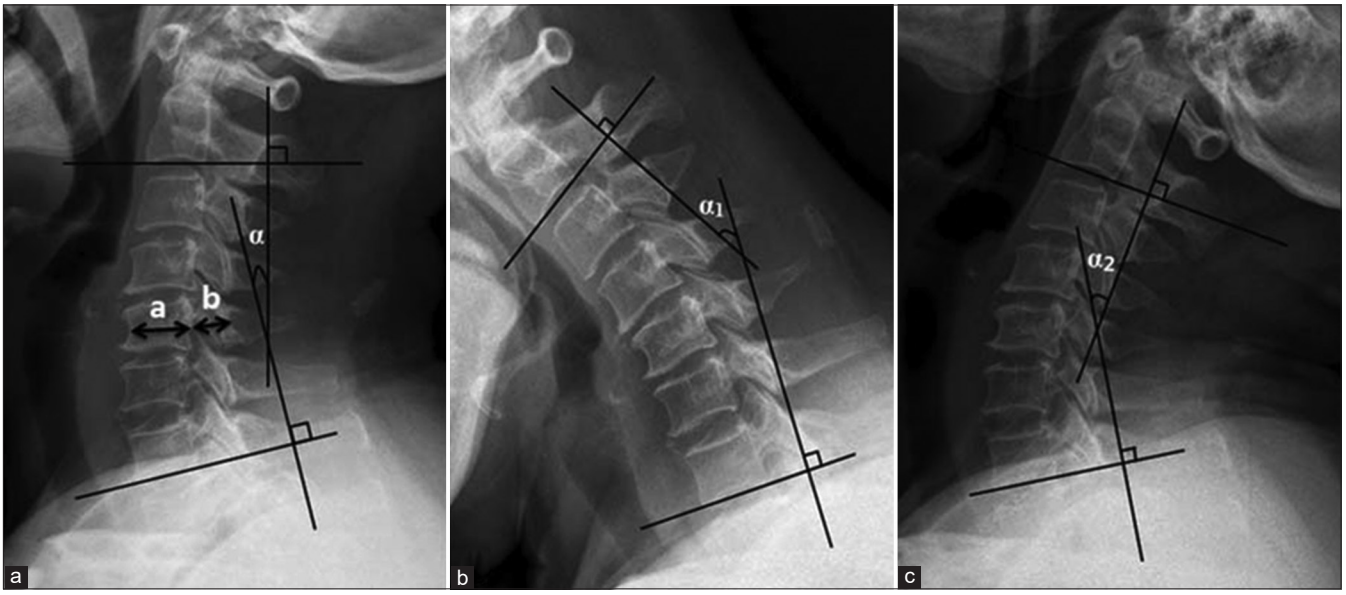

Figure 1: Measurement of anteroposterior diameter (a), C2–7 Cobb angle (a), and cervical range of motion (b and c) b, anteroposterior diameter. Palov's ratio = b/a. (α), the C2–7 Cobb angle. Cervical range of motion=α1 + α 2 [16]

degenerative disc disease proceeded to surgical intervention by ACDF through PEEK cage aiming for evaluation of the effect of ACDF on adjacent segment failure by doing new MRI cervical spine and X-ray lateral view to measure the Cobb's angle and ROM as well as assessment of development of new symptoms 2-year post-operative and Neck Disability Index to evaluate the patients performance.

Among the 72 patients, 58.3% were males and 41.7% were females. The age range was from 28 years to 68 years; with the least age group from (20 year to 30 year) in only two patients and three patients from (60 year to 70 year), while the most affected age groups were from (40 year to 50 year) in 32 patients and 19 patients from (50 year to 60 year).

Out of the 72 patients, 45 patients (62.5%) were operated on by single level ACDF, 24 patients (33.3%) were operated on by double level ACDF, and three patients (4.2%) were operated on by three levels ACDF.

The most commonly operated level was C5-6 in 41 patients either alone or with other levels; the second most operated level was C4-5 in 36 patients followed by the level C6-7 in 15 patients then comes the level C3-4 in 10 patients (5.6%).

The follow-up MRI after 2 years showed new pathology in 14 patients (19.4%) while 58 patients (80.6%) showed no new pathology.

The MRI findings 2-year post-operative revealed the level C4-5 was the most common to show adjacent segment degeneration in seven patients while four patients showed degeneration in the level C5-6, three patients showed degeneration in the level C6-7, and one patient showed degeneration in the level C3-4 together with the C4-5 level.

In the clinical follow-up 2 years' post-operative, 20 patients (27.8%) presented with new complaints while 52 patients (72.2%) showed no new complaints. Comparing the previous manifestations to the follow-up, 2 years' post-operative revealed that the 11 myelopathic patients (15.3%) showed modest improvement, while the 21 patients presented with the upper limb weakness 29.2% only 4.2% had significant improvement.

Out of the 61 patients (84.7%) who were presenting with neck pain, 46 patients showed resolution of pain with only 15 patients still suffering of neck pain 0.8%, while the 43 patients (84.7%) who were presenting with brachialgia,40 patients showed resolution of pain with only three patients still suffering of brachialgia 4.2%.

Neck pain and brachialgia were assessed using VAS score for the evaluation of the severity of pain which is used as is used as a good indicator for cervical alignment influencing the adjacent segments and NDI to evaluate affection of patient's functionality.

We found that VAS score of brachialgia pre-operative ranged from (0.00 to 10.00) while the VAS score of brachialgia post-operative ranged from (0.00 to 4.00) indicating a significant improvement.

The VAS score of pre-operative neck pain ranged from (1.00 to 10.00), the VAS score of post-operative neck pain ranged from (0.00 to 8.00) indicating a significant improvement.

The pre-operative NDI in patients with single level ACDF ranged from (2.00 to33.00), double level ACDF ranged from (8.00 to 32.00), and triple level ACDF patients ranged from (16.00 to 33.00), while the post-operative NDI in patients with single level ACDF ranged from (1.00 to19.00), double level ACDF ranged from (2.00 to 22.00), and triple level ACDF patients ranged from (10.00 to 20.00) and the 2-year post-operative NDI in patients with single level ACDF ranged from (1.00 to 26.00), double level ACDF ranged from (2.00 to 18.00),

and triple level ACDF patients ranged from (10.00 to 34.00).

The overall NDI assessment ranging from (2.00 to 33.00) pre-operative, (1.00 to 22.00) post-operative, and (1.00 to 34.00) 2-year post-operative.

The relation between the number of operated levels and the pre-operative NDI showed statistical significance when single level was compared to double and triple levels but it showed no statistical significance when it was comparing pre-operative NDI between double and triple levels.

The relation between the number of operated levels and the post-operative NDI showed statistical significance when single level was compared to double but it showed no statistical significance when it was comparing post-operative NDI between single and triple as well as double and triple levels.

The relation between the number of operated levels and the 2-year post-operative NDI showed statistical significance when single level was compared to double and triple levels but it showed no statistical significance when it was comparing the 2-year post-operative NDI between double and triple levels.

The overall Cobb's angle measurement ranged from (–15 to 40) pre-operative and from (–10 to 40) 2 years' post-operative showing that Cobb's angle has improved post-operative indicating better cervical alignment with no great differences among the number of levels of ACDF done.

It is thought that there is a relation between the sagittal alignment and development of adjacent segment failure whether adjacent segment degeneration or disease was supported by the fact that the patients showing new pathology in the MRI done 2-year post-operative had the Cobb's angle pre-operative ranged from (–15.00 to 20.00) and the Cobb's angle 2-years post-operative ranged from (–5.00 to 33.00), while the patients developed new clinical manifestations 2-year post-operative had the Cobbs' angle pre-operative ranged from (–15.00 to 40.00) and the Cobb's angle 2-year post-operative ranged from (–5.00 to 40.00).

Patients showing new pathology in the MRI done 2 years post-operative had the NDI ranged from (1.00 to 20.00) while the patients with no new MRI pathology had the NDI ranged from (1.00 to 34.00).

Patients showing new pathology in the MRI done 2-year post-operative their Cobb's angle pre-operative ranged from (–15.00 to 20.00) and the Cobb's angle 2-year post-operative ranged from (–5.00 to 33.00), while the patients with no new MRI pathologies the Cobb's angle pre-operative ranged from (–10.00 to 40.00) and the Cobb's angle 2-year post-operative ranged from (–10.00 to 40.00).

Patients developed new clinical manifestations 2-year post-operative had the Cobb's angle pre-operative ranged from (–15.00 to 40.00) and the Cobb's angle 2-year post-operative ranged from (–5.00 to 40.00), while the patients with no new clinical manifestations had the Cobb's angle pre-operative ranged from (–10.00 to 30.00) and the Cobb's angle 2-year post-operative ranged from (–10.00 to 40.00).

We noticed that there was a direct relation between the Cobb's angle and the neck pain (as assessed using the VAS score) especially post-operative which highlights the importance of planning a proper sagittal alignment during surgery for CDD as it may play a role in improvement of the neck pain. It was observed that the correlation coefficient between the 2-year post-operative Cobb's angle and the neck pain post-operative was –0.253 which was statistically significant with $p = 0.032$. The negative value of correlation coefficient indicates that there is an inversely proportion relation between the Cobb's angle and neck pain evaluated by VAS score.

Two-year post-operative; out of the 72 patients, 20 patients were newly symptomatic; 10 patients had new radiological finding in the 2-year post-operative MRI while the other 10 patients did not show new pathology, while among the 52 asymptomatic patients, only four patients had new radiological finding in the 2-year post-operative MRI rather than the 48 patients who did not show any new pathology.

Two-year post-operatively; out of the 72 patients, the brachialgia VAS score in patients who had new radiological finding in the 2-years post-operative MRI ranged from (0.00 to 4.00) while the brachialgia VAS score in patients who did not show any new radiological finding in the 2-year post-operative MRI ranged from (0.00 to 4.00).Moreover, we found that out of the 72 patients; the neck pain VAS score in patients who had new radiological finding in the 2-year post-operative MRI ranged from (0.00 to 8.00) while the neck pain VAS score in patients who did not show any new radiological finding in the 2-year post-operative MRI ranged from (0.00 to 6.00).

Discussion

The aim of this study was to observe if the compensatory dynamic stress on adjacent segments after ACDF may predispose to symptomatic disc diseases in these contiguous levels, to prove its effect on patients' quality of life and the need for further intervention.

The age did not show statistical significance; all studies think that ASD could occur at any age, supporting the fact that cervical degenerative disease is an aging process but it has no direct effect on the timing of neither surgery nor its outcome [12], [21], [22], [23].

Male patients were more than female patients [21], [23] unlike other two studies that had the

number of females more than that of males [12], [22]; this reveals that the difference in gender distribution shows no significance and no direct relation to development of ASD.

Single level procedures were the most commonly performed followed by the double-level, with C5-6 was the most commonly operated level [12], [22], [21], [24]; This finding is attributed in our opinion to the fact that C5-6 and C4-5 are the levels of maximum stress as a part of the normal degenerative process in the natural history of the cervical spine that is exacerbated after rigid fixation of adjacent levels especially in the presence of degeneration in the neighboring levels.

Among cervical fusion procedures, those performed for a single level with advanced degenerative changes at the adjacent level appear to be at greatest risk, but it is still unclear whether these radiographic and clinical findings resulted from the spinal fusion due to the iatrogenic production of a rigid motion segment or if these changes represent the progression of the natural history of underlying degenerative disease [25] and that ASD is not primarily a complication of fusion surgery and is in part due to the natural course of cervical spondylosis [24].

The number of failed levels was less in multilevel ACDF and could be explained as, after a multilevel arthrodesis, less motion would be transferred to the fewer remaining motion segments due to the rigid fixation, leading to a slower onset of new disease at the adjacent levels and that patients who had a multilevel arthrodesis were significantly less likely to have symptomatic ASD than were those who had had a single-level arthrodesis [12], [25], this could be markedly influenced by the choice of proper PEEK cage size as regards to disc space height and fusion rates [26], with a little relation of the biomechanical variations of the PEEK cage types and design that was of a little importance [27].

In the clinical follow-up after 2 years, 20 patients presented with new complaints while 52 patients had no new complaints. We found that the mean VAS score of brachialgia and neck pain pre-operative was greater than that of the post-operative VAS score indicating significant improvement; this is consistent with Spanos *et al.* as they observed that the immediate post-operative mean VAS score was reduced significantly, which was maintained significant at 6-month and 12-month postoperatively [22].

The pre-operative NDI in patients underwent single level ACDF and double level ACDF declined gradually through the immediate post-operative and 2-year post-operative periods while the NDI in patients underwent triple level ACDF decreased postoperatively but showed another increase after 2 years, in our opinion, this could be a part of the degenerative process [21], [22], [28], [29].

These were statistically significant indicating that the more the number of the degenerated levels the higher the NDI value that decreased over the period of 2 years implying improvement of the patients' functional activities.

Patients who had developed new clinical manifestations showed only slight increase or worsening of Cobb's angle in the 2-year post-operative follow-up compared to the pre-operative, while the patients with no new clinical manifestations had significant increase the Cobb's angle; moreover, that the development of new pathology in the MRI done 2-year post-operative relative to the mean Cobb's was not significant; demonstrating that the correction of cervical lordosis and preserving cervical alignment correlates with ASDs (symptoms) but not necessarily with development of adjacent segment degeneration (radiological finding in the MRI), so we assume that cervical sagittal imbalance does not necessarily cause ASD in the form of radiological finding in the MRI, it is more related to developing neck pain reflected on Cobb's angle changes rather than new MRI findings; however, development of new pathology in the MRI was not necessarily associated with development of symptoms that cervical sagittal imbalance arising from cervical sagittal malalignment plays an independent role in exacerbating adjacent segment failure after multilevel fusion and should be considered during cervical fusion surgical planning [21], [23], [28], [30], [31].

Restoration of post-operative sagittal balance is a crucial factor which may predict the development of ASD and sufficient preservation of cervical lordosis may decrease the incidence of ASD in patients undergoing anterior cervical surgery for degenerative cervical disease [32].

On the other side; Park *et al.* believe that "ASD is associated with a natural degenerative process instead of operative complications that ASD is a part of a natural process but it is influenced by surgical interference and sagittal alignment indeed" [29].

Two-year post-operative; out of the 20 patients having new symptoms; 10 patients had new radiological finding in the 2-year post-operative MRI; while among the other 52 asymptomatic patients, only four patients had new findings in the 2-year post-operative MRI, there was no correlation between the adjacent segment degeneration and the development of clinical symptoms referable to these radiographic changes.

Most authors believe that the development of new radiological finding after ACDF is an inevitable event as a part of the natural history of the cervical degenerative disease that is not necessarily accompanied by development of symptoms requiring surgical intervention [13], [33], [34], [35].

We noted that only 19.4% developed adjacent segment degeneration (radiological findings) while 27.8% developed ASD; with 10 patients (13.8%) of

those showing new MRI pathology having clinical manifestations and only 3 patients (4.16%) were scheduled for surgery.

Studies with different follow-up periods suggest that a wide variation in the prevalence of adjacent segment degeneration (25% to 92%) exists following fusion; progression of disc degeneration was not related in every case to the development of clinical symptoms that authors concluded that ACDF does indeed accelerate ASD. However, they were not able to conclude that radiographic evidence of disc degeneration is correlated to symptomatic disease, although, small portion of these patients eventually develops symptomatic disease that requires additional surgery [13], [14], [34], [36].

Unlike one study had a high rate of ASD after they followed 180 patients managed with ACDF and reported that 92% of patients showed radiographic changes at adjacent levels [37].

Our study was limited by the short duration of patients' follow-up which is not enough to assess ASD, the relatively small number of patients and the reliability of pain assessment on VAS score which is not a constant measure that is liable for human tolerance variability and exaggerations. Thus, we suggest the future research to include a multi-center and prospective study with higher number of patients together with longer duration and more frequent follow-up periods as well as including patients underwent surgeries and those on conservative management.

The future studied should be directed to the motion preserving arthrodesis and arthroplasty as well as inclusion of the pre-operative decisions for cervical degenerative diseases.

Conclusion

Adjacent segment failure is an ongoing process of degeneration that could be accelerated by ACDF procedures; however, not every adjacent segment degeneration or symptomatic disease requires additional surgery.

Adjacent segment degeneration and subsequent symptomatic disease have been a clinical concern after fusion because sagittal imbalance due to malalignment ameliorates adjacent segment failure after ACDF and should be considered during surgical planning of cervical fusion as well as preexisting degeneration in the adjacent levels.

ASD must be differentiated from adjacent segment degeneration using clinical examination and imaging to help in patients' follow-up and decision-making of further intervention.

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