Original article

Post-traumatic lower cervical spine instability: Arthrodesis clinical and radiological outcomes at 5 years

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ABSTRACT

Background: Anterior cervical fusion is widely used to treat spinal injuries. Radiological evidence of disc abnormalities may develop on either side of the fused segment, raising concern about the potential for inducing adjacent-segment disease. Here, we report the long-term clinical, functional, and radiological outcomes after anterior cervical fusion.

Hypothesis: Anterior cervical fusion influences the development of adjacent-segment disease.

Materials and methods: In a retrospective study, 15 patients aged 17 to 50 years were re-evaluated more than 5 years after anterior spinal fusion to treat post-traumatic cervical-spine instability. We used the Neck Disability Index (NDI) to assess function. Static and dynamic radiographs of the cervical spine were obtained.

Results: NDI values indicated good clinical and functional outcomes, and fusion was achieved consistently. Adjacent-segment disease was a consistent finding at last follow-up but induced no neurological manifestations. Complete fusion of a level adjacent to the treated level was noted in 2 patients. Revision surgery for adjacent-segment disease was not required in any patient.

Conclusion: The causative factors of adjacent-segment disease are controversial. Disc degeneration is a normal manifestation of the ageing process. Nevertheless, disc disease is more prevalent at levels adjacent to interbody fusion than in the normal population, suggesting accelerated disc degeneration due to increased loading of the adjacent levels. Furthermore, lesions that are missed during the pre-operative work-up may play a role, as the available investigations do not always have high negative predictive values.

Level of evidence: Level IV, retrospective study.

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1. Introduction

Anterior cervical fusion is widely used to treat lesions causing instability of the lower cervical spine [1], as well as certain complex C2 pedicle fractures [2]. Convincing evidence indicates good short-term outcomes [3]. In the long term, degenerative disc disease frequently develops on either side of the fused segment. The potential role for interbody fusion in this outcome deserves evaluation.

Adjacent-segment disease is defined as radiographic deterioration of a mobile spinal segment adjacent to a fused segment [4]. This definition does not require the development of new symptoms. Adjacent-segment disease is usually asymptomatic [5] and rarely requires revision surgery [5–7]. In patients who underwent anterior cervical fusion to treat post-traumatic lesions, Goffin et al. reported degenerative disc changes adjacent to the fused segment in 60% of patients [8] and adjacent-segment disease in 92% of patients 3 years after the injury [9]. Risk factors for adjacent-segment disease consist of C5-C6 and C6-C7 lesions, single-level fusion, and pre-existing disc disease [10].

Most studies focused on patients who required surgery to treat degenerative lesions or who had post-traumatic instability but were older than 50 years of age.

Here, our objective was to evaluate whether anterior cervical fusion induced adjacent-segment disease or whether the adjacent disc changes reflected the unavoidable progression of degenerative disc disease.

2. Materials and methods

We retrospectively evaluated patients aged 15 to 50 years who were treated for lower cervical spine instability due to...
post-traumatic lesions and had follow-up durations longer than 5 years. Our surgical department admits only patients aged at least 15 years. We set the upper age limit at 50 years to eliminate patients with degenerative disc disease.

We assessed cervical spine instability according to Allen’s classification [11] and neurological impairments according to the classifications devised by Frankel et al. [12] and the ASIA [13]. These assessments were performed at admission, after surgery, and at each visit. We used the functional Neck Disability Index (NDI) [14] to assess quality of life.

Adjacent-segment disease was diagnosed using static antero-posterior and lateral radiographs and dynamic radiographs of the cervical spine. We defined adjacent-segment disease as disc disease at adjacent levels that were normal on the baseline radiographs. Evidence of disc disease consisted in any of the following:

- static views: osteophytes, loss of disc height, and/or sub-chondral bone sclerosis, as described by Goffin et al. [9];
- dynamic views: segmental hypermobility > 3 mm (evaluated in flexion and extension as shown in Fig. 1).

The NDI score can range from 0 to 24 and the results are categorised as follows: 0–4, no impairment; 5–14, moderate impairment; and 15–24, severe impairment.

The patients were re-evaluated at the outpatient clinic with radiographs 3 and 6 weeks after surgery, a computed tomography scan (CT) 3 months after surgery, and radiographs 1 and 5 years after surgery.

We used a single-centre retrospective study design. Follow-up was 5 years. The radiographs were assessed by an orthopaedic surgeon and a radiologist working independently of each other. Statistical comparisons relied on the non-parametric Mann-Whitney U test (StatXact 7.0 from Cytel, Cambridge, MA, USA).

3. Results

We included 15 patients, 9 males and 6 females, with a mean age at injury of 33.5 years (range, 17–50 years). Mean follow-up was 103 months (8.5 years), with a range of 80 months (6.6 years) to 140 months (11.7 years).

The cause of the injury was a motor vehicle accident in 10 patients and a fall from a high height in 5 patients. Fig. 2 reports the distribution of the lesion levels.

Fig. 3 recapitulates the various lesion types. All patients having a fracture of a single articular process had concomitant disc damage requiring fusion.

Neurological impairments were present initially in 6 patients, including 2 with isolated radicular sensory symptoms, 3 with radicular sensory and motor symptoms, and 1 with Frankel C tetraparesis and anterior spinal cord contusion.

Each of the 15 patients underwent emergent anterior spinal fusion via a right-sided antero-lateral approach. In patients with persistent dislocation, reduction was achieved by gradual cervical spine traction using Gardner-Wells tongs. Patients with neurological impairments underwent surgery within 6 hours after the injury.

Fusion was achieved using a locking plate and a tricortical bone graft harvested from the iliac crest. In 3 patients, the tricalcium phosphate bone substitute Biosorb® (Aesculap, Chaumont France) was implanted.

Post-operative immobilisation was achieved using a foam collar for 3 months.

3.1. Outcomes after 1 year

Complete neurological recovery was noted after 1 year in 3 patients, including 2 patients with isolated sensory impairments and 1 patient with radicular sensory and motor impairments. Recovery was only partial in the patient with a Frankel C neurological status and anterior spinal cord contusion, as well as in the other 2 patients with radicular sensory and motor impairments.

Two post-operative complications were recorded. Transient dysphonia was noted in 1 patient. In the other patient, secondary displacement without neurological manifestations was diagnosed post-operatively, ascribed to inadequate initial reduction, and managed with additional posterior fusion. None of the patients experienced haematoma formation, dysphagia, surgical-site infection, or dural tears.

Radiographs obtained after 1 year showed graft fusion in all 15 patients. Adjacent segment disease was noted at the supra-
infra-jacent level in 3 patients: a single adjacent disc was affected in 1 patient and both adjacent discs in 2 patients.

3.2. Outcomes after more than 5 years

The 3 patients with partial neurological recovery after 1 year had persistent neurological impairments after 5 years.

Mean NDI was $3.93 \pm 2.82$ with a range of 0 to 11 (worst possible score, 24). The NDI was 0 to 4 in 10 patients, indicating no impairment. Moderate impairment with NDI values of 5 to 14 was noted in 5 patients. None of the patients had NDI values greater than 15. Two patients reported neck pain during weather changes, but only 1 of them took paracetamol occasionally.

Adjacent-segment disease was noted in all 15 patients more than 5 years after surgery. Radiographic disc disease was visible at the infra-jacent level in 2 patients, supra-jacent level in 6 patients, and both adjacent levels in 7 patients. Complete fusion of a level adjacent to the surgically fused segment was noted in 2 patients: a 50-year-old woman with C6-C7 surgical fusion developed fusion of the infra-jacent level and a 50-year-old man with C6-C7 surgical fusion developed fusion of the supra-jacent level.

Deterioration of the disc beyond the level adjacent to the surgical fusion was noted in 5 patients. Of the 3 patients with adjacent-segment disease 1 year after surgery, 1 exhibited deterioration of the disc beyond the level adjacent to the surgical fusion. Disc deterioration beyond the adjacent level more than 5 years after surgery was not significantly associated with age ($P = 0.063$) or level of the lesion ($P = 0.375$).

Cervical spine hypermobility was noted in 3 patients, whose characteristics are listed in Table 1. Mean age was 40 years in patients with instability and 31.75 years in those without instability (non-significant difference, $P = 0.75$).

4. Discussion

Radiographic changes at levels adjacent to cervical spinal fusion have been extensively described in degenerative conditions [4,5,10]. These radiographic changes were present in 92% of cases in long-term studies [9], and the frequency of new neurological symptoms was 25% after 10 years [10].

In an asymptomatic population, 95% of males and 70% of females exhibited degenerative disc disease at one or more levels [15]. These data suggest that disc disease may develop as part of the normal ageing process and that adjacent-segment disease may merely constitute a manifestation of age-related spinal degenerative disease.

In our study, however, 2 women aged 17 and 20 years at the time of injury had adjacent-segment disease at last follow-up, at the age of 25 years. In contrast, Gore et al. found no cases of disc disease in a population of females aged 20 to 25 years. Adjacent-segment disease was present in 4 males who were aged 19, 24, 22, and 25 years at initial surgery and 30, 31, 30, and 32 years at re-evaluation; whereas only 25% of males aged 30 to 35 years had radiographic evidence of disc disease [15].

These data support a role for an exogenous factor in the development of disc disease. Biomechanical studies have documented differences between fused and non-fused segments in terms of load distribution on the discs adjacent to the fused segment, with increased intra-discal pressures [16]. In a study of 25 patients followed-up for 5 to 9 years after fusion to treat post-traumatic lesions, Goffin et al. found adjacent-segment disease in only 60% of cases [8]. In our study, the presence of adjacent-segment disease in all patients after 5 years invites a discussion of the possible contribution of surgical interbody fusion to the early development of disc disease.

Mechanical loads are transferred to the supra- and infra-jacent segments after interbody fusion. Eck et al. reported that 20° of flexion after C5-C6 fusion increased the intra-discal pressure by 73% in the supra-jacent disc and by 43% in the infra-jacent disc [16]. The mobility sector increases in both flexion and extension. Pospiech et al. reported a 60% increase in intra-discal pressure in the disc infra-jacent to C4-C5 fusion during axial rotation [17].

Slight anterior translation during neck flexion is normal. Park et al. reported increased anterior translation at the supra-jacent level after fusion [18]. Similarly, in our study, 3 of the 15 patients exhibited hypermobility during flexion-extension at one of the two adjacent discs more than 5 years after surgery. The variations in lesion type and level, patient age, and presence of neurological impairments precluded the identification of risk factors for hypermobility.

None of the patients had nerve root pain or neurological deficits after surgical fusion in our study. In other studies, these events occurred in 25% of patients within the first 10 years [5,19,20]. However, our patients were younger and therefore less susceptible to degenerative disease of the cervical spine. Follow-up varied from 5 to 10 years. In a population studied by Hilibrand et al. after anterior fusion, the proportion of patients with neurological abnormalities increased at a constant rate of 3% per year [10]. Applying this value to our study would result in 24% of patients having neurological manifestations, since mean follow-up was longer than 8 years. The patients studied by Hilibrand et al. had a mean age of 51 years (range, 17–83 years), and the reason for surgical fusion was spondylisis in all cases. In contrast, our patients had a mean age of 33 years (range, 17–50 years) and required surgery for post-traumatic lesions. Thus, the patients in the study by Hilibrand et al. were at higher risk for decompensation of cervical spine degenerative disease compared to our patients.

The mean NDI value in our study was 3.93, with most patients reporting no impairments, in keeping with previously published data. Among patients studied by Xu et al., 75% had good or excellent functional outcomes after 10 years [21]. After 5.5 years, Koller et al. recorded excellent outcomes in 14 patients, good outcomes in 7, fair outcomes in 5, and poor outcomes in none [22].

Weather-related pain was reported by 2 of our patients. This symptom was probably unrelated to the surgical fusion, as among 200 initially asymptomatic individuals aged 25 to 69 years, 24 (12%) developed neck pain within 4.9 years [23].

Another hypothesis regarding the detection of adjacent-segment disease after surgical fusion is underestimation of the lesions during the pre-operative evaluation. In one study, magnetic resonance imaging (MRI) detected only 48% of lesions found during surgery [24]. All patients without anterior longitudinal ligament (ALL) disruption found during surgery had no MRI evidence of ALL disruption. All patients with ALL disruption at surgery had MRI evidence of ALL disruption. However, among patients with no MRI evidence of ALL disruption, only 38% had no gross ALL lesions.

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**Table 1**

<table>
<thead>
<tr>
<th>Sex</th>
<th>Age</th>
<th>Type of lesion</th>
<th>Level of arthrodesis</th>
<th>Neurological deficit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>50</td>
<td>Bilateral articular process fracture/dislocation</td>
<td>C6-C7</td>
<td>Yes</td>
</tr>
<tr>
<td>Male</td>
<td>33</td>
<td>Bilateral articular process fracture</td>
<td>C4-C5</td>
<td>Yes</td>
</tr>
<tr>
<td>Male</td>
<td>37</td>
<td>Bilateral articular process fracture</td>
<td>C3-C4</td>
<td>No</td>
</tr>
</tbody>
</table>

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detected during the intra-operative exploration of the ligament (negative predictive value, 0.38). Thus, MRI evidence of ALL disruption is reliable, whereas a normal MRI appearance of the ALL is far less so. Findings were similar for the intervertebral discs. In our study, however, the contribution of missed lesions is difficult to evaluate, as MRI was not performed routinely and the long follow-up precludes collection of intra-operative findings from the surgeons.

Needle puncture of an intra-vertebral disc is followed by degenerative lesions at the punctured level in 60% of cases after 2 years, compared to 29% in the absence of needle puncture [25]. This statistically significant difference establishes that a trauma-related lesion missed during the pre-operative work-up can cause degenerative lesions in an adjacent disk. However, when interpreting this finding, the difference between needle-induced disc lesions and disc lesions related to high-energy neck trauma should be borne in mind.

It has been suggested that passive dynamic radiographs of the cervical spine may be helpful in comatose patients. However, the false-negative rate is high [26] and this method is consequently not advisable. Anekestin et al. used dynamic CT of the neck, most notably to assess the cervico-thoracic junction, which is not clearly visible on dynamic radiographs [27]. However, the number of patients was too small to allow definitive conclusions about the efficacy of this evaluation.

Siddiqui and Jackowski measured height and angulation differences after cervical fusion achieved using a cage or a tricotrical graft [28]. Loss of height was only 1% in the cage group compared to 5% in the graft group. Kyphosis was 1° with the cage and 4° with the graft. However, none of these differences was statistically significant.

The excellent fusion rate in our study reflects the ease with which interbody fusion occurs after a traumatic injury [28]. The spontaneous development of fusion at the adjacent levels may therefore be ascribable to healing of undiagnosed lesions.

5. Conclusion

Interbody fusion at the cervical spine is a proven and reliable method for treating unstable lesions of the lower cervical spine. The complication rate is low and the clinical and functional outcomes are good.

The development of radiographic evidence of disc degeneration is unavoidable. Whether surgical fusion influences the occurrence of disc degeneration should be considered. Adjacent-segment disease in patients with a history of surgical fusion is more common than degenerative disc disease in the general population.

The consistent development of adjacent-segment disease in our study suggests that fusion may precipitate the development of degenerative disc disease. Sufficient attention should be given to lesions that may have been inadequately assessed or missed during the pre-operative work-up.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References