Surgery for postarthrodesis adjacent–cervical segment degeneration

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Anterior cervical decompression and fusion has gained popularity because of its applicability to a variety of cervical spine disorders. The authors of long-term follow-up studies have demonstrated the development of degenerative changes in segments adjacent to fusion. So-called adjacent-segment disease causes symptomatic deterioration in up to 25% of the patients who have undergone anterior cervical decompression and fusion for cervical spondylitic myelopathy. The causes of this condition are debated in the literature. The authors provide a review of the available literature on the pathogenesis, prevention, and treatment of postarthrodesis adjacent-segment degenerative disease.

KEY WORDS • adjacent-segment disease • spinal fusion • spondylosis • cervical spine

In the 1950s Robinson and Smith described anterior discectomy and fusion in the treatment of degenerative disorders of the cervical spine. During the past several decades, anterior cervical discectomy and fusion has been demonstrated to be an effective procedure in the treatment of upper-extremity radicular pain, axial neck pain, and myelopathy-related symptoms.37,44,46,52,72 In long-term follow-up studies of anterior discectomy and fusion the authors have described the appearance of new degenerative disease at levels adjacent to fused segments.3,16,18,33,46 In up to 25% of patients degenerative disease may develop at adjacent segments within 10 years of initial surgery,46 and 7 to 15% of these patients have been reported to require reoperation.3,19

The cause of postarthrodesis adjacent–cervical segment degeneration remains debated. Some investigators have suggested that fusion of a segment of the cervical spine may create increased strain on the adjacent motion segments.21,37,74,83 Others, however, have contended that in patients in whom spondylotic degenerative changes develop at one level, the same is likely at other cervical levels; furthermore, they have argued that it may be the natural history of the maturing cervical spine that causes their degeneration (Fig. 1).46

There have been no prospective studies in which investigators directly compared anterior cervical decompression and fusion and posterior decompression without arthrodesis, to assess the difference in the development of accelerated degenerative effects. In this report we review the current theories regarding the development, prevention, and treatment of adjacent-level disease.

POSTFUSION ADJACENT–CERVICAL SEGMENT DISEASE

Cervical Spondylotic Myelopathy and Radiculopathy

Cervical spondylotic myelopathy is defined as the compression of the spinal cord due to degenerative changes in the cervical spine. It is the leading cause of spinal cord dysfunction in patients older than 60 years of age. In general, the clinical course in CSM is that of progressive decline, and essentially surgery is the mainstay of treatment.

The normal aging process of the degenerative cervical disc begins initially with loss of negatively charged proteoglycans and subsequently water molecules. Once there is loss of disc hydration, disc height loss occurs. The loss

Abbreviations used in this paper: ACF = anterior cervical fusion; CSM = cervical spondylitic myelopathy.
of disc height consequently promotes increased stress in the disc and anular disc bulging, which then causes the perioisteum of the adjacent vertebral bodies to become raised. Subperiosteal bone formation typically develops on the concavity of the curve, which in the cervical and lumbar spine causes anterior encroachment on the neural elements. The facet joints sustain increased stress as well, which can lead to capsular thickening and osteophyte formation within the joints. The ligamentum flavum is also affected by the loss of disc height, being subject to infolding and thickening. The altered stresses lead to endplate osteophyte formation. These changes cause a circumferential stenosis of the spinal canal with different components being more accentuated in different patients. The maturing cervical spine is prone to vertebral body collapse (subsidence) and angular deformation that may significantly contribute to the degenerative process.

The goal of the surgical treatment for CSM is the decompression of the spinal cord and the maintenance of spinal stability. Both anterior and posterior techniques have been described for the treatment of this entity. Although there is general agreement on the treatment of single-level spondylotic disease, the approach for multilevel CSM remains the subject of much debate. The debate includes the question of whether fusion of a segment of the cervical spine causes increased stress in the adjacent levels thus causing an increased rate of degeneration at these levels.

Adjacent-Level Disease

Adjacent-level disease is defined as the development of a new radiculopathy or myelopathy referable to a segment adjacent to a previously fused level in the cervical spine. The findings in numerous studies have suggested that in approximately 25 to 89% of patients undergoing long-term follow up after ACF, new degenerative changes occurred at adjacent levels (Fig. 2).

In a study involving patients treated for radiculopathy after they had already undergone fusion, Bohlman, et al., reported a 9% rate of new disease requiring reoperation. Gore and Sepic, in a review of 156 patients who underwent ACF for degenerated or protruded discs reported a 14% reoperation rate for the treatment of new symptomatic radiculopathy at another level. Other authors have also reported on new symptomatic spondylisis requiring reoperation following a prior fusion.

In a comprehensive review, Hilibrand, et al., followed 374 fusion-treated patients for up to 21 years and reported an annual incidence of degenerative adjacent-level changes of 2.9%. Using Kaplan–Meier survival analysis, they predicted a 25% prevalence of new symptomatic disease at a level adjacent to a prior fusion within 10 years.

Theories on the Cause of Adjacent-Level Disease

Controversies exist over the cause of adjacent-level disease. The natural history of cervical spondylosis has been implicated and there is some support for this in the literature. In the 1950s Kellgren and Lawrence observed that approximately half of a normal population would develop degenerative changes by the age of 50 years, and the changes could be documented on plain radiographs of the cervical spine.

Gore, et al., reviewed pre- and postoperative lateral
radiographs obtained in 90 patients who had undergone ACF and compared their findings with age- and sex-matched asymptomatic individuals; they reported the same incidence of degenerative change in both groups.

Hillibrand, et al.,46 observed that the levels most at risk for arthritic changes are those that most commonly develop adjacent-segment disease. He postulated that patients in whom adjacent-level disease develops after single-level fusion may harbor advanced disease at high-risk levels that was not symptomatic at the time and was therefore not addressed at surgery. This implies that the biological process of progressive cervical spondylosis may be the culprit of degenerative changes at the most mobile cervical segments, unrelated to any adjacent-segment arthrodessis. In support of this, Hillibrand, et al.,46 found symptomatic adjacent level disease less often after multilevel fusion presumably because the decompression included the higher-risk levels.

On the other hand, there is some radiographic5,16 and biomechanical evidence7,8,84,88 that points to increased stresses at motion segments adjacent to fused levels.37,74,92 Iseda, et al.,54 compared data in patients who had undergone anterior decompression and fusion with those in patients who had undergone expansive laminoplasty for cervical spondylotic disease. They observed a significant decrease in T₂-weighted signal intensities on magnetic resonance images of discs adjacent to the fused segment as early as 12 months postoperatively. This change was not observed in patients in whom expansive laminoplasty was performed.

Based on radiographic studies, other authors have also reported increased movement, shear strain, and degenerative changes at levels above and below previously fused cervical spine segments.3,16,69 Increased strain has also been demonstrated in biomechanical studies of discs immediately adjacent to immobilized cervical segments.27,33,62,84,88

TREATMENTS FOR ADJACENT-LEVEL DISEASE

Although the number of studies on the specific surgical treatment of recurrent myelopathy due to adjacent-segment disease is limited, there are more numerous studies in which authors have explored the various treatment modalities for the initial treatment of cervical spondylosis disease.3,16,84,88 The surgical-related goals and principles for the treatment of postarthrodesis adjacent-level disease are different from those for the initial procedure for spondylotic myelopathy.

It is important for the surgeon to understand the biomechanical principles of the cervical spine so that a proper strategy can be devised to address the pathological entity and at the same time minimize the risk of postoperative deformity and further adjacent-level degeneration. In the following sections we review several alternatives for treatment of postarthrodesis adjacent-level disease.

Nonfusion Techniques

In a patient presenting with new postfusion myelopathy or radiculopathy referable to adjacent-level degeneration, laminectomy may be considered as a treatment option. Laminectomy has been the mainstay of treatment for multilevel spondylotic myelopathy for years because it achieves decompression of the spinal cord in patients with neutral or lordotic alignment.75 The decision to perform laminectomy to treat adjacent-level disease, however, has to be made with caution. In patients with some degree of preoperative kyphosis, there is significant risk of recurrence of spondylotic myelopathy due to progressive postoperative kyphotic deformity.15,56,50,85

Moreover, postlaminectomy neurological deterioration is a well-documented sequela.23,25,26,32,60 If it is probably most prudent for the surgeon to use laminectomy for the treatment of symptomatic adjacent-level disease only after other options for treatment have been ruled out.

There is a very limited indication for a laminoforaminotomy in a patient with adjacent-level disease presenting mainly with unilateral radiculopathy and evidence of lateral disc herniation or bone spurs. One benefit of this technique is preservation of motion with the avoidance of arthrodessis.29,59,77 The theoretical risks of anterior surgery such as injury to neurovascular structures and esophageal dysfunction, which may be greater in reoperations,31,33,42,45,56,66,70,79,82 could also be potentially avoided.79

In carefully selected patients, this technique can provide good relief of radicular symptoms;1,2,24,30 however, care has to be taken to avoid the excessive disruption of the facet joint, which could lead to spinal destabilization and mechanical pain, and may necessitate arthrodessis at a later time. In addition, caution has to be exercised to prevent injury to the cord due to intraoperative retraction.

Fusion Techniques

A patient presenting with symptomatic adjacent-level disease can be treated with anterior decompression followed by fusion. As with CSM, the decision to undertake a discectomy alone or a more extensive decompression should take into consideration the extent of the compressive elements. In the specific treatment for adjacent-level disease, however, there are some additional elements that should be considered prior to the selection of technique.

If the compressive elements are limited to a single disc level, then a discectomy followed by fusion is a reasonable option. Some authors, however, have reported a lower rate of bone fusion in patients undergoing discectomies for adjacent-level disease compared with those undergoing corpectomy-related decompression for the same condition.47 In addition, some investigators have urged caution when discectomy is used in the presence of extensive osseous compression because of increased risk of neurological injury.52,75

If the compressive elements span across more than one disc level, as sometimes occurs in patients with adjacent-level disease or in those in whom the motion segment next to a prior fusion has sustained some translational or kyphotic degeneration as well, discectomy alone will not be adequate and a more extensive decompressive and reconstructive procedure is required.

Some investigators have reported excellent results after performing corpectomies followed by strut graft—augmented fusion for adjacent-level disease.6,11,28,32,47,61,70,80,86,87 In the treatment of patients with postarthrodesis adjacent-level disease, however, the surgeon will be well served by

Neurosurg. Focus / Volume 15 / September, 2003
possessing a sound understanding of the biomechanics of the cervical spine and the caveats of treating this condition.

When performing a corpectomy and strut graft–assisted fusion, it is important to note that the new fused segment is subjected to new stresses. In addition the plate system, which is also subject to this stress, may be at increased risk of failure. A cervical plate may shield stresses needed by the strut graft for fusion. The use of a cervical plate system after corpectomy may increase axial forces through the graft when the neck is placed in extension, which may contribute to failure by promoting subsidence. Furthermore, in cases in which the newly degenerated segment is at the cervicothoracic junction, care should be taken to ensure that a construct can withstand the additional junction-related stress. In these cases the surgeon may consider performing an additional level of fusion anteriorly or conducting supplemental posterior fusion to prevent hardware failure.

In addition to the biomechanical issues, there is also some evidence that complication rates are higher in patients who have undergone prior surgeries and in those who have required multilevel fusions.9,13,28,31,32,45,66,70,79,82 Regardless of the technique, careful review of the preoperative imaging studies, establishment of a surgical plan in light of biomechanical considerations, and adherence to good surgical technique will ensure the best chance of a good outcome and reduce the risk of intra- and postoperative complications.

**Artificial Cervical Joints**

Recently cervical prostheses have been designed to reconstruct a degenerated intervertebral disc while permitting segmental motion.34 This concept had been previously pursued with limited success in both the cervical and lumbar spine.4,22,58 Currently there are two studies in which the authors have reviewed the relatively short-term results of two different designs. Goffin, et al.,34 reviewed results after placing the Bryan Cervical Disc Prosthesis (Spinal Dynamics Corporation, Mercer Island, WA) (Fig. 3) in 60 patients who had presented with either spondylosis due to degenerative disease or disc herniation. No patients had undergone prior surgical intervention for their symptoms. The authors reported greater than 85% improvement in preoperative symptoms in their patients. Wigfield, et al.,89 reviewed their results after implanting the Frenchay artificial cervical joint in 15 patients. This prosthetic disc is a newer version of the Cummins joint that had been designed and used in the 1980s. The patients selected for this study were most at risk for adjacent-level disease with a standard anterior decompression and fusion. Despite two technical failures, the authors observed good clinical outcome in their remaining patients.89

Theoretically there may be advantages to preserving the normal motion of the cervical spine when treating a pathologically degenerated segment. The long-term effects of these prostheses, however, are yet to be determined. In a patient with a cervical prosthesis, the degenerative process may be accelerated because the properties of this device remain unchanged as the patients cervical spine ages and becomes stiffer. Moreover, their long-term functionality and safety are currently not known. Their influence on the development of postarthrodesis adjacent-segment degeneration remains to be seen. The incidence of adjacent-level disease related to these devices in long-term follow-up studies may perhaps help elucidate the cause(s) of this condition.

**CONCLUSIONS**

With sound knowledge of the factors that play a role in the pathogenesis of this disorder, the surgeon can create a proper surgical strategy to minimize the risk of postoperative deformity and accelerated degeneration and at the same time effectively treat patients presenting with adjacent segment disease. The role of artificial discs in the prevention of postarthrodesis degeneration remains to be seen.

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