Prediction of Postoperative Alignment in Patients Undergoing Anterior Cervical Fusion Using Autologous Vertebral Bone Grafting

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Abstract

Cervical anterior fusion is useful for the treatment of patients with cervical disease, but carries the risk of postoperative worsening of the cervical spine alignment and kyphosis. Preoperative prediction of the risk for kyphosis could help to avoid such postoperative complications. We attempted to predict the postoperative development of kyphosis in 59 patients scheduled for cervical anterior fusion using autologous vertebral bone grafting. Of these, 36 underwent single and 23 two level fusion with median follow up of 58.2 months. Whole spine alignment, fused segment alignment, and mobility of the intervertebral disc were compared using pre- and postoperative radiographs. Alignment of the whole spine changed from 13.7° to 11.1°, and the angle of the fused segment changed from 3.6° to −3.2°. Postoperative alignment was not worse than the preoperative flexion posture in any of the 59 patients. Forty-nine patients with preoperative lordotic alignment did not develop postoperative kyphosis. Nine patients with preoperative straight alignment had several types of postoperative alignment, including kyphosis. Two patients with postoperative kyphosis showed marked loss in the angle of the fused segment, which affected mobility to flexion of the fused segment. One patient with preoperative kyphotic alignment manifested postoperative kyphosis. The postoperative alignment was influenced by the preoperative alignment. Kyphosis may develop in patients with preoperative straight alignment and large mobility to flexion of the fused segment. This information is useful for surgical planning of anterior cervical fusion using autologous vertebral bone grafting.

Key words: cervical spine, anterior fusion, alignment, kyphosis

Introduction

Anterior decompression of the cervical spine is a widely accepted treatment for patients with cervical canal disease resulting in nerve root or cord compression. However, the cervical spine alignment tends to undergo kyphotic change at the fused segment in nearly 50% of patients after anterior fusion, and kyphotic change involving the whole spine curvature in 35% of patients. The postoperative loss of sagittal plane balance is thought to accelerate adjacent level degenerative disc disease and kyphotic deformity may lead to adjacent segment disease and the development of neurological deficits. Exposure of intervertebral levels adjacent to the fused segments to greater mechanical stress may lead to junctional instability in the kyphotic but not the lordotic spine. Kyphotic alignment may accelerate degeneration of the adjacent level, so the development of postoperative kyphosis has a negative effect on the treatment outcome. To achieve excellent results, spinal deformity must be avoided and the correct alignment maintained. Complications still occur despite the development of several surgical techniques, devices, and postoperative treatments. A method for the preoperative prediction of the risk for kyphosis would allow steps to be taken to avoid postoperative development, thereby improving the probability of a good postoperative outcome.

We attempted to predict the risk for developing kyphosis in patients who underwent one or two level anterior fusion using autologous vertebral bone grafting for cervical spondylosis by studying the relationship between pre- and postoperative cervical alignment.
alignments.

Materials and Methods

Fifty-nine patients with cervical spondylosis, 25 women and 34 men aged from 23 to 73 years (mean 57 years), underwent anterior decompression and fusion, 36 at single and 23 at two levels, using autologous bone grafts obtained from cervical vertebral bodies between September 1990 and August 1996. Pre- and postoperative neutral, flexion, and extension radiography of the cervical spine was performed in all patients.

We usually employed a conventional anterior cervical approach from the right side and performed microscopic discectomy. A spinal saw (Williams microsurgical saw; R.C.W. Spine Co., Inc., San Luis Obispo County, Calif., U.S.A.) was used to remove 2 blocks of bone tissue from the cervical vertebral bodies above and below the intervertebral space. Then the posterior part of the vertebral bodies was removed and the spinal cord and roots decompressed by removing the posterior osteophytes, herniated discs, or the posterior longitudinal ligament. The 2 bone tissue blocks were fused by placing the cancellous and cortical bone parts top to bottom, respectively, and suturing with 3 interrupted sutures of 3-0 Dexon (Covidien Ltd., Mansfield, Mass., U.S.A.) to form a single graft. The bone grafts were then turned vertically 90 degrees and inserted into the space, then held firmly in place by the cancellous bone of the adjacent vertebra. Cranial traction was utilized in all grafted patients, and none underwent fixation with plates.

To obtain strong autologous bone grafts, patients with advanced osteoporosis, heavy smokers, and long-term hemodialysis patients were excluded from this study. Follow up ranged from 40 to 83 months (median 58.2 months). The treated level was C3-C4 in 2 patients, C4-C5 in 4, C5-C6 in 24, C6-C7 in 6, C3-C4 and C4-C5 in 3, C4-C5 and C5-C6 in 13, and C5-C6 and C6-C7 in 7.

Lateral cervical spine radiographs were taken with the patient in the sitting position with the neck flexed, neutral, and extended. Neutral position films were obtained with the patient in the natural posture without instructions relating to posture. The shoulder was in contact with the film tray; the distance between the radiation source and the film tray was set at 150 cm. Three radiographs were taken before and after the operation and examined. To assess the alignment of the whole cervical spine, we compared the angle formed by the line of the inferior rim of the C2-C7 vertebral bodies in the neutral and flexion positions on lateral radiographs of the cervical spine obtained before and after the operation (Fig. 1). Alignment was defined as lordotic (≥5°), straight (≥−5°−<5°), and kyphotic (<−5°). The curvature of the fused segment of the cervical spine was also measured. Lines were drawn parallel with the cranial endplate of the most cranial vertebra and the caudal endplate of the most caudal vertebra in the fused segment; then the angle of the lines was calculated. The mobility of the intervertebral disc was measured using the sliding method (Fig. 2).

Results

Alignment changed from 13.7° to 11.1° after anterior fusion. Better results were obtained with single than with two level fusion (13.8° to 12.6° vs.
Table 1  Preoperative alignment in 59 patients

<table>
<thead>
<tr>
<th>Group</th>
<th>Neutral</th>
<th>Flexion</th>
<th>No. of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lord</td>
<td>Lord</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Stra</td>
<td>8 (14%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kyph</td>
<td>41 (69%)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Stra</td>
<td>Stra</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Kyph</td>
<td>9 (15%)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Kyph</td>
<td>Kyph</td>
<td>1 (2%)</td>
</tr>
</tbody>
</table>

Kyph: kyphosis, Lord: lordosis, Stra: straight.

Fig. 3  Comparison of pre- and postoperative alignment. **Upper:** In 49 patients with preoperative lordosis (Group 1), the postoperative alignment was lordotic (Lord) or straight (Stra). **Middle:** In 9 patients with preoperative straight alignment (Group 2), the postoperative alignment was of several types including kyphotic (Kyph). **Lower:** In one patient with preoperative kyphotic alignment (Group 3), the postoperative alignment was kyphotic.

Fig. 4  Comparison of pre- and postoperative alignments. Postoperative alignment was not worse than preoperative flexion posture.

Fig. 5  Relationship between decrease in the angle of the whole spine alignment produced by surgery and decrease in the angle of the fused segment produced by non-instrumented fusion. **Upper:** The statistical correlation was weak in all patients (p < 0.05, R = 0.420). **Lower:** The statistical correlation was stronger in Group 2 (p < 0.05, R = 0.763). Two patients with postoperative kyphosis showed marked decrease in the angle of the fused segment.

13.5° to 8.7°). Significant worsening was observed after two but not after single level fusion (p < 0.05). The alignment of the fused segment changed from 3.6° to −3.2° and single level fusion produced better results than two level fusion (2.5° to −3.3° vs. 5.1° to −3.0°).
The patients were grouped based on their preoperative alignment (Table 1). Preoperatively, 49 patients had lordotic alignment (Group 1), 9 patients had straight alignment (Group 2), and one patient had kyphotic alignment (Group 3). Postoperatively, all Group 1 patients had lordotic or straight alignment, Group 2 patients had several types, including kyphotic, and the Group 3 patient had kyphotic alignment (Fig. 3). The postoperative alignment was not worse than the preoperative flexion posture in any of the 59 patients (Fig. 4).

Alignment of the fused segment was not correlated with postoperative alignment (Fig. 5). There was a weak statistical correlation between the postoperative decrease in the angle of the whole spine alignment and the decrease in the angle of the fused segment ($p < 0.05, R = 0.420$). This correlation was stronger in Group 2 ($p < 0.05, R = 0.763$). Both patients with postoperative kyphosis showed marked decrease in the angle of the fused segment, indicating that the decrease in the angle of the fused segment was related with postoperative alignment deterioration in Group 2.

The angle of the fused segment was correlated with the preoperative angle of the fused segment ($p < 0.05, R = 0.488$). Furthermore, the mobility to flexion of the fused segment was correlated with the decrease in the angle of the fused segment ($p < 0.05, R = 0.539$) (Fig. 6). This correlation was strongest in Group 2 ($p < 0.05, R = 0.806$).

Discussion

To predict cervical alignment after anterior fusion with the Williams-Isu method, we investigated alignment in the preoperative flexion posture. We found that postoperative alignment was not worse than the preoperative flexion posture, suggesting that the worst postoperative alignment can be expected to be better than the preoperative alignment of the flexion posture, reflecting the function of the posterior nuchal musculature. Progression to kyphosis of the spinal alignment after posterior decompression can be prevented by preservation of the posterior element.1,5,7,10) The posterior ligamentum and musculature are the primary static stabilizers of the cervical spine, acting as important posterior tension bands that stabilize the cervical spine in lordosis.5,10) In the kyphotic posture, the anterior and posterior elements of the spinal column resist compression and tension, respectively.12,13,17) Laminectomy after anterior fusion resulted in an increase in the rate of kyphosis,11) so the posterior tension band provided by the nuchal musculature is important for retaining alignment after anterior fusion. Therefore, the nuchal musculature must be protected because patients with preoperative kyphotic flexion posture are at increased risk for postoperative kyphosis.

None of our patients with preoperative lordotic alignment exhibited postoperative kyphosis. However, 2 patients with preoperative straight alignment showed postoperative kyphotic alignment, as did the single patient with preoperative kyphotic alignment. Our method does not correct alignment, so we did not expect it to correct preoperative kyphosis. Our results support the previous suggestions that preoperative alignment affects postoperative alignment, and that kyphotic changes are rare in patients with preoperative lordosis.14) In a previous series, 16% of patients with preoperative straight spine and 75% with preoperative kyphotic spine manifested postoperative kyphosis.14)

We also examined the relationship between the alignment of the fused segment and postoperative alignment. We calculated the decrease in the angle and found no strong correlation. However, patients with preoperative straight spine (Group 2) showed decrease in the angle of the fused segment which had a significant effect on the decrease in the angle of whole spine alignment. This observation suggests
that the angle of the fused segment is highly relevant in patients with straight spine, and that postoperative worsening of the alignment can be avoided by retaining or correcting the alignment of the fused segment.

Differences in the operative outcome may be related to differences in the preoperative alignment of the spine and may reflect the biomechanical factors acting in the cervical spine. Normal cervical alignment results from well-balanced anterior and posterior force-loads on the spinal column and the physiological axis resulting from additional force exerted on the spinal canal. If the correct physiological alignment is compromised, the axis is displaced anteriorly and the compression force on the anterior column is increased. In patients with compromised preoperative alignment, compression force is put on the anterior column and the vertebral bodies act to resist these increased compression forces to retain the correct alignment. The marked decrease in the angle of the fused segment after fusion may result in decreased resistance to the compression force on the anterior aspect, and may direct the compression force further forward. Consequently, excess decrease in the angle of the fused segment represents a risk factor for postoperative alignment deterioration in patients with compromised preoperative spinal alignment.

The angle of the fused segment must be preserved to maintain whole spine alignment in patients with poor preoperative alignment. We found that the postoperative angle of the fused segment was correlated with the preoperative angle, and that a decrease in the angle of the fused segment was correlated with the preoperative mobility to flexion of the fused segment. Therefore, the postoperative angle of the fused segment can be predicted from the preoperative alignment and mobility of the fused segment. The angle of the fused segment might be supported by the strength of the anterior column and by the bending force to the anterior aspect, representing an additional braking system for posterior elements. As preoperative mobility to flexion of the fused segment was correlated with the decrease in the angle of the fused segment, this may represent the posterior braking system. In fact, in patients with low mobility, the decrease in the angle of the fused segment was not high because the braking system was operational. The bending force on the anterior aspect is affected by the alignment of the whole spine. In patients with poor alignment, the increased bending force on the anterior aspect acts to worsen the angle of the fused segment, whereas in patients with high mobility to flexion of the involved fused segment, the braking system may be weak and the bending force may work in the direction of the angle of the fused segment, so leading to further exacerbation.

In the current series, 3 patients exhibited postoperative kyphosis. Although they did not experience symptom deterioration attributable to worsening of the alignment, we consider postoperative kyphosis an unacceptable treatment outcome because the deformity may lead to neurological deterioration. Therefore, the preoperative identification of patients at risk for postoperative alignment worsening would help to exclude treatment by the Williams-Isu method in such patients and facilitate the selection of patients who may benefit from our treatment method. Our technique is advantageous in that autologous vertebral bone is used and the harvesting of iliac bone grafts is not required. However, a disadvantage is the observed worsening of the angle of the fused segment. In addition, the strength of autologous vertebral bone and the required endplate sacrifice may influence the treatment outcome. On the other hand, although instrumented fusion may retain the angle of the fused segment, instrumentation failure may occur and the cost of instrumented fusion remains high.

The present results suggest that despite some disadvantages, patients who are not at risk for postoperative alignment degradation can be treated by our non-instrumented procedure. If preoperative examination identifies risk for postoperative kyphotic alignment, procedures to retain the correct alignment, such as the plating procedure that immediately stabilizes the decompressed levels, should be used to prevent the development of kyphosis. In patients without good alignment, attempts must be made to decrease the angle as little as possible by minimal fixation. If the preoperative alignment is not good, the mobility of the fused segment at forward bending may serve as a reference. The preoperative availability of this information facilitates surgical as well as postoperative treatment planning.

References

Commentary

Drs. Kim et al. have done a good job in showing us how to predict the post-operative condition in patients who require cervical discectomy and fusion. Obviously, these are skilled surgeons and have done a good job. In the United States, when we use autograft, it is most commonly taken from the hip bone but that is the minority of cases. The majority of the cases in the United States are now done with allografts. Plates are very, very common, especially on a two level procedure. Even using those techniques there is some settling. If there is a pseudarthrosis, it is usually the bottom level which fails to become solid. The authors excluded those patients with “advanced osteoporosis, heavy smokers, long term hemodialysis,” etc. Those are the ones we are most worried about. Admittedly, it is as minority of patients. Sometimes even plating doesn’t prevent the kyphosis and/or the pseudarthrosis.

I agree with the authors that it is important to try to maintain the normal lordotic curvature. For that reason, if a patient is kyphotic or has other risk factors, I will use oversized allograft spacers to force a correction. When that is done, I usually plate the plate. The big risk comes when you have more than two levels, especially four levels, and/or a corpectomy. Those patients present a special challenge as pointed out by the reference list. I am probably one of the last of a dying breed of surgeons who do single level non-instrumented fusions. So I welcome this article. I have to admit I am more cautious in two levels and in patients with preexisting kyphosis.

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The authors have attempted to predict the risk for developing kyphosis in 59 patients who underwent anterior fusion using autologous vertebral bone grafting (so-called Williams-Isu method) for cervical spondylolisthesis. Fifty-nine patients were divided into three groups: preoperative lordotic group (49 patients), preoperative straight group (9 patients) and preoperative kyphotic group (one patient). In the lordotic group, postoperative alignment was lordotic or straight. In the straight group, two patients showed postoperative kyphotic change and in the preoperative kyphotic
Alignment After Anterior Fusion

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The authors of this paper present an analysis (based on preoperative analysis of cervical spine curvature) of postoperative kyphosis in the setting of an anterior cervical diskectomy and fusion at one or two levels. Their analysis includes healthy subjects only. (The authors have excluded patients with “advanced osteoporosis, heavy smokers, and long term hemodialysis patients”). No patient received instrumented fusion. The authors conclude that patients with preoperative loss of the natural cervical lordosis (e.g. straight or kyphotic spines) are most likely to have post-operative kyphotic deformity.

The work here is clearly well performed and thorough. The authors have correctly emphasized the importance of understanding the engineering mechanics of the spine. The authors clearly recognized the importance of the posterior tension band in maintaining cervical stability and lordosis. Essentially, patients for whom the posterior tension band has already failed to maintain lordosis are at risk for further kyphosis in an anterior surgery. In that regard, the article serves to caution surgeons to consider a posterior approach in patients for whom a kyphotic deformity is present given the likelihood of continued kyphotic deformity. Indeed it has been the practice in our institution to strongly consider a posterior approach in patients for whom cervical lordosis has been lost. Also we generally have plated most ACDF patients to encourage fusion and to avoid the need for long-term external orthoses. In cases where an impressive anterior vector is present (e.g. large herniated disk), an anterior approach is considered. Further posterior fusion for correction of a symptomatic loss of normal lordosis is always an option. We look forward to further meticulous analysis of cervical deformity from this group.

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The authors of this paper continued to be kyphotic postoperatively. As the authors described, this surgical procedure cannot correct the preoperative alignment. Although there was a suspicion about the rigidity of the bone graft obtained from the vertebral bone, this graft has been confirmed to have enough supporting strength based upon the present results. This operative procedure can be safely and successfully applied for preoperative lordotic patients with one level lesion. For patients with multilevel lesions, more detailed study must be planned and followed up. Although the authors did not describe the reason why only one patient with preoperative kyphotic alignment was included in this study, we, as readers, are really eager to know whether this operation can be also safely and successfully applied to kyphotic patients. The authors’ operative procedure certainly has the advantage that autologous vertebral bone graft is used and the harvesting of iliac bone is not required. However, this operation needs a sufficient learning curve and special operative tools to be safely performed. To decide whether this operative procedure is useful for a wide range of patients with spondylotic lesion, a larger number of patients with preoperative lordotic or kyphotic alignment must be more meticulously followed up and analyzed.

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