CERVICAL SPINAL KYPHOTIC DEFORMITY
A Comparative Cohort Study Analyzing Success of Surgical Correction

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ABSTRACT

Cervical spine kyphotic deformities are common sequelae of degenerative disease. Patients may present with a combination of symptoms including myelopathy and radiculopathy. We retrospectively studied a cohort of 78 patients who underwent decompression and reconstruction of the cervical spine for such deformities. Decompression and reconstruction were done by vertebrectomy (51%), multilevel interbody arthrodesis (40%), posterior decompression and reconstruction (4%), and circumferential surgery (5%).

In those patients whose pretreatment kyphotic deformity was more severe than -15 degrees, 10 of 27 required revision compared with only 4 of 51 patients whose initial deformities were less than -15 degrees (p<0.005, Fisher exact test). For patients requiring revision surgery, the average degree of pretreatment kyphosis was -25.1 ± 16.6 degrees compared with -12.4 ± 10.0 degrees preoperative angulation for those patients who were effectively treated via their primary procedure (p<0.001, unpaired t-test). The mean preoperative kyphosis was -14.6 degrees, which was improved to a mean postoperative lordosis of +5.3 degrees.

For patients with symptomatic cervical kyphotic deformity, consideration should be given to decompression and stabilization. In patients whose pretreatment deformity is -15 degrees or greater, strong consideration should be given to circumferential decompression and reconstruction with internal fixation and arthrodesis.

Key words: cervical spine, kyphotic deformity, internal fixation, arthrodesis

INTRODUCTION

The management of patients with neurological symptoms and signs of cervical spinal kyphotic deformities poses a variety of clinical dilemmas. “Which patients should be treated?”, “When should they be treated?”, and “How should they be treated?” are the three most common and difficult challenges.

A variety of authors have addressed one or more of these issues in the past but none has provided more than thoughtful experience and Class III medical evidence[1,3,9-13]. In this report we provide our experiences with 78 consecutive patients with symptomatic cervical spinal kyphotic deformities of a
A degenerative cervical kyphotic deformity presenting with myelopathy. Plain radiographs demonstrate a 47° kyphotic angulation centered over C4. A sagittal and axial cervical MRI reveal severe cervical stenosis and compression of the cervical spinal cord.

variety of etiologies, treated with surgical reconstruction and arthrodesis. Our goal was to determine the prognosis of cervical kyphotic deformities with respect to the type of surgical decompression and reconstruction procedure performed.

METHODS

Seventy-eight consecutive patients with symptomatic cervical kyphotic deformities measuring at least plus five degrees were entered and followed in a prospective fashion between January 1993 and December 1999. (Figure 1). Patients presented with neck pain, documented swallowing dysfunction, radiculopathy, and myelopathy. Several patients had advanced chin-on-chest kyphotic deformities. The assessment of all patients included a neurological examination, a self-described pain level assessment, the Nurick Functional Scale assessment, cervical spine x-rays and cervical magnetic resonance (MR) imaging. Patients with dysphagia were evaluated with swallowing studies. The degree of cervical spinal sagittal deformity was determined using the posterior tangent method at C2 and C7 [6,7,12], and consideration was given to the best operative option(s) for each patient to accomplish neural decompression and effective spinal reconstruction and stabilization. The clinical outcome and success or failure of attempted reconstruction and arthrodesis was documented. Patients were followed after surgery at two weeks, three months, six months, twelve months, and yearly intervals thereafter unless they re-presented with new difficulties. Patients who experienced progression of their cervical spinal deformity despite treatment, and those who failed initial treatment were managed with a more aggressive (second) surgical approach. The degree of sagittal angle correction at last follow-up was compared to each patient’s preoperative deformity.

Treatment of patients involved initial, attempted preoperative closed reduction of their deformity. For lesser deformities, postural reduction was accomplished with positioning at the time of surgery. For greater, particularly more chronic deformities, halo-ring cranio-cervical traction was utilized in the critical care setting, typically initiated 24 hours prior to surgery in an attempt to reduce the degree of deformity. (Figure 2a) Either anterior, posterior, or combined decompression operations were performed followed by standard anterior and/or posterior reconstruction and fusion procedures. (Figure 2b) Most procedures included internal fixation in addition to bony reconstruction. Anterior reconstruction involved either a multilevel interbody fusion or vertebrectomy followed by strut graft fusion with or
Figure 2a: A degenerative cervical kyphotic deformity presenting with myelopathy (see figure 1). This patient's deformity improved significantly after traction.

Figure 2b: MR study after anterior vertebrectomy and strut fusion procedure. Late follow-up lateral c-spine x-ray after dorsal fixation and fusion procedure completed 1993.

Table 1: Etiologies of cervical kyphotic deformities in 78 patients who presented with a combination of myelopathy, radiculopathy, cervicalgia, and dysphagia.

<table>
<thead>
<tr>
<th>Etiology</th>
<th>Number (n = 78)</th>
<th>Degree of Kyphosis</th>
</tr>
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<tbody>
<tr>
<td>Degenerative</td>
<td>34 (44%)</td>
<td>+13</td>
</tr>
<tr>
<td>Iatrogenic</td>
<td>31 (40%)</td>
<td>+17</td>
</tr>
<tr>
<td>Delayed traumatic</td>
<td>8 (10%)</td>
<td>+15</td>
</tr>
<tr>
<td>Osteomyelitis</td>
<td>2 (3%)</td>
<td>+8.5</td>
</tr>
<tr>
<td>Ankylosing spondylitis</td>
<td>2 (3%)</td>
<td>+13</td>
</tr>
<tr>
<td>Congenital</td>
<td>1 (1%)</td>
<td>+23</td>
</tr>
</tbody>
</table>

without rigid anterior internal fixation plate/screw systems. Halo immobilization was utilized for ten weeks in patients treated with strut graft fusion without internal fixation. Posterior reconstruction was accomplished using on-lay autologus bone grafts with posterior segmental fixation.

A detailed analysis of the entire cohort of patients was accomplished. We selected reconstruction failure as an endpoint and reviewed the entire series of patient data in an attempt to identify which patients failed cervical spinal reconstruction and compared the extent of their preoperative sagittal deformity and the treatment they were provided in an attempt to provide Class II medical evidence on this issue.

**RESULTS**

The causes of cervical kyphotic deformities in this series of 78 patients are outlined in Table I. The majority of patients presented with progressive cervical myelopathy (68%) and neck pain (64%). Radiculopathy was present in 17 patients (21%). Ten patients had chin-on-chest deformities which interfered with eating and drinking. The cohort had a mean preoperative kyphosis of plus 14.8 degrees and a mean postoperative lordosis of minus 5.3 degrees. The mean follow-up for this patient cohort was 4.9 years, range 9 months to 8 years.

Forty patients underwent anterior vertebrectomy (average 2.1 levels) followed by strut graft fusion reconstruction (Table 2). Internal fixation (rigid anterior plate/screw systems) was used as a reconstruction adjunct in 30 of 40 of these patients. Twelve weeks halo immobilization was used in the
Table 2: Surgical decompression and reconstruction in 78 patients who presented with cervical kyphosis. Approaches were anterior (corpectomy or disectomy) or posterior (laminectomy) with reconstruction using anterior strut grafts/anterior fixation and/or posterior on-lay grafts/posterior segmental fixation.

<table>
<thead>
<tr>
<th>Surgery</th>
<th># of Patients</th>
<th># of Levels</th>
<th>Preoperative Kyphosis (°)</th>
<th>Preoperative Lordosis (°)</th>
<th>Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior corpectomy</td>
<td>40</td>
<td>2.1</td>
<td>+16.6</td>
<td>-5.2</td>
<td>12</td>
</tr>
<tr>
<td>Anterior disectomy</td>
<td>31</td>
<td>2.4</td>
<td>+11.4</td>
<td>-6.2</td>
<td>1</td>
</tr>
<tr>
<td>Posterior</td>
<td>3</td>
<td>3.0</td>
<td>+13.7</td>
<td>+5.0</td>
<td>1</td>
</tr>
<tr>
<td>Combined</td>
<td>4</td>
<td>5.2</td>
<td>+20.0</td>
<td>-7.0</td>
<td>0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>78</td>
<td>2.4</td>
<td>+14.6</td>
<td>-5.3</td>
<td>14</td>
</tr>
</tbody>
</table>

Table 3: Comparison between anterior corpectomy with fixation and anterior corpectomy without fixation.

<table>
<thead>
<tr>
<th>Anterior Corpectomy (n=40)</th>
<th>Graft incorporation with stability</th>
<th>Reconstruction failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal fixation (n=30)</td>
<td>23 (77%)</td>
<td>7 (23%)</td>
</tr>
<tr>
<td>No internal fixation (n=10)</td>
<td>5 (50%)</td>
<td>5 (50%)</td>
</tr>
</tbody>
</table>

Ten patients treated without internal fixation. The mean preoperative kyphosis in this subgroup of patients was minus 16.6 degrees. The mean postoperative lordosis was plus 5.2 degrees. There were 12 (30%) reconstruction failures in this subgroup of patients over time which necessitated surgical revision. Five of these patients did not have internal fixation placed initially; seven patients in this group were treated with internal fixation at the time of the primary procedure. The absence of internal fixation did not predict graft failure (P > 0.10 Chi-square) (Table 3). Five of the failure patients underwent two-level vertebrectomy. Six were treated with three-level vertebrectomy. One failure was a four-level vertebrectomy.

Multi-level anterior cervical disectomy with osteophyte excision (average 2.4 levels treated) for ventral cord decompression followed by interbody fusion and internal fixation was accomplished in 31 patients (Table 2). The mean preoperative kyphosis of this subgroup of patients was plus 11 degrees. The mean postoperative lordosis was minus 6.2 degrees. One patient in this group treated at three interspace levels with internal fixation experienced reconstruction failure (3%) requiring revision.

Three patients underwent posterior only decompression, internal fixation and fusion procedures over an average of four cervical levels. These patients had important primary dorsal cord compression in addition to kyphosis or developed post-laminectomy kyphosis (Figure 3) (Table 2). This subgroup of patients had a mean preoperative kyphosis of plus 13.7 degrees and a mean postoperative kyphosis of plus five degrees. One patient treated in this fashion (33%) experienced reconstruction failure necessitating operative revision.

Four patients underwent combined anterior and posterior decompression, fusion, and internal fixation procedures as their primary treatment (Table 2). The preoperative kyphosis in this subgroup of patients was plus 20 degrees. The mean postoperative lordosis was minus 7.0 degrees. No patient in this treatment group experienced reconstruction failure (Figure 4).
Fourteen of 78 patients in this series (18%) required a second surgical procedure for revision after initial reconstruction failure (to be discussed). Seven other patients (9%) underwent subsequent delayed surgery for symptomatic adjacent level degenerative disease during the course of their follow-up period. The development of adjacent level disease in these seven patients was neither associated with the severity of the initial deformity, the degree of postoperative deformity correction, or the number of levels initially treated.

For the entire cohort of 78 patients in this series, the mean preoperative kyphosis ± standard deviation was plus 14.6 ± 12.3° (Table 2). For those patients whose decompression and reconstruction procedures did not require revision (n=64, Group I), the mean preoperative kyphosis was plus 12.4 ± 10.0°. For the 14 patients (Group II) who failed initial treatment and required operative revision and reconstruction, the mean preoperative kyphosis was plus 25.1 ± 16.6°. When Groups I and II (those who had initial success versus those whose initial reconstruction failed) were analyzed using an unpaired t-test, the difference in the degree of preoperative kyphotic deformity was significant (p < 0.001, Table 4).
Table 4: Statistical comparisons between the degree of kyphosis in patients who did not require revision surgery (Group I) and those who did (Group II). A second statistical comparison between the rate of revision for those patients with kyphosis <15° (Group A) and those who had a kyphotic deformity > 15° (Group B).

<table>
<thead>
<tr>
<th>Classification</th>
<th>N</th>
<th>Kyphosis ± SD (degrees)</th>
<th>Reconstruction Failure</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I (No revision)</td>
<td>64</td>
<td>+12.4 ± 10.0*</td>
<td>0</td>
<td>*p&lt;0.001</td>
</tr>
<tr>
<td>Group II (Revision)</td>
<td>14</td>
<td>+25.1 ± 16.6</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Group A (Minor sagittal deformity)</td>
<td>51</td>
<td>+15</td>
<td>4**</td>
<td>**p&lt;0.005</td>
</tr>
<tr>
<td>Group B</td>
<td>27</td>
<td>+15</td>
<td>10**</td>
<td></td>
</tr>
</tbody>
</table>

* unpaired t-test
** Fisher exact test

The critical degree of cervical kyphosis in this series appeared to be approximately plus 15°. For further analysis, patients were stratified into two additional groups; those who had initial sagittal kyphotic deformities less than plus 15° (Group A) and those whose initial kyphotic deformities were more severe than plus 15° (Group B). Group A (<15°) consisted of 51 patients, (Table 4) four of whom required revision of their initial constructs (7.8%). In contrast, Group B (>15°) consisted of 27 patients, ten of whom required re-operation (37.0%). Using contingency tables, the presence of an initial kyphotic deformity greater than 15° strongly correlated with the likelihood of reconstruction failure when it was attempted via a unilateral approach (ventral or dorsal) (p < 0.005, Fisher exact test).

The majority of patients in this series underwent initial decompression and reconstruction via the anterior approach. Forty patients underwent cervical vertebrectomy for cord decompression while 31 patients underwent multi-level anterior cervical disc excision, osteophyte resection, and interbody fusion. Patients treated with interbody decompression and fusion had multi-level interspace pathology resulting in cord and root compression. They were patients with kyphotic deformities that were reducible with pre-operative traction and intraoperative positioning and immobilization (Figure 5). Patients treated with corpectomy had irreducible ventral cord compression that extended beyond the interspaces and had cervical kyphotic deformities that could not be reduced with pre-operative traction and intraoperative positioning and immobilization.

Myelopathy was present in 52 patients and was improved in 43 (83%) at last follow-up. Seven patients were unchanged over time and two had progression of myelopathy despite successful surgical decompression, reconstruction and fusion. Average pre-operative Nurick scores in those 52 patients was 3.4. Average follow-up Nurick scores were 2.8. Neck pain described by 50 patients preoperatively was subjectively improved in 35 patients (70%). Radiculopathy identified in 17 patients preoperatively, was improved in 16 patients at last follow-up (94%). Immediate complications following surgery included transient recurrent laryngeal nerve palsy in two patients, a transient C5 radiculopathy in one patient, a cerebral spinal fluid (CSF) leak requiring a lumbar drain in one patient and a pneumothorax from central line insertion requiring a chest tube in another.
No patient sustained a permanent neurological injury (root or cord) from surgery and no patient required reoperation for hematoma, pseudomeningocele, or CSF leak. There were no complications of craniocervical traction or halo ring/vest use.

Three patients in this series (5%) had cerebral palsy, a known co-morbidity associated with cervical kyphotic deformity [2,5]. Two of three of these difficult management patients required operative revision (one early, one late). The third patient developed symptomatic adjacent level disease requiring treatment four years after his initial successful reconstruction procedure.

**DISCUSSION**

The pathophysiology and the spinal biomechanics of cervical spinal kyphotic deformities have been previously described [4]. A variety of operative options exist for the treatment of symptomatic patients with cervical kyphosis and several investigators have offered case series documenting their experiences with patients with this disorder [1,8,11,13]. While ventral correction appears to be the most favored operative option, to date no investigator has offered more than Class III medical evidence on this issue. We performed a comparative cohort analysis of 78 consecutive patients treated for symptomatic cervical kyphosis and used reconstruction success as an end point in an attempt to provide Class II prognostic evidence regarding the influence that pre-treatment deformity had on success or failure of attempted surgical reconstruction. During the course of this clinical investigation, only rigid internal fixation constructs were utilized. We did not utilize more contemporary less rigid or translational internal fixation systems during this early period.

Analysis of reconstruction success with respect to operative treatment provided revealed that posterior-only decompression, reconstruction and fusion resulted in the least amount of deformity correction and a one in three failure rate. We report this as an observation without statistical significance noting the lack of numbers of patients in this treatment group.

Anterior decompression, reconstruction and fusion resulted in better overall deformity correction and a greater likelihood of reconstruction success, particularly when accomplished via an interbody approach as compared to decompression involving vertebrectomy. Patients who underwent vertebrectomy and strut fusion were more likely to require a subsequent reconstruction procedure due to construct failure than those who underwent anterior cervical discectomy, interbody decompression and fusion (30% vs. 3%, p < 0.005, Fisher exact test). This outcome may have occurred for several reasons. Patients who underwent vertebrectomy and strut fusion were more likely to have a greater degree of pretreatment kyphosis than those who underwent disc space decompression/interbody fusion (plus 16.6° versus plus 11.4°) and were more likely to have irreducible deformities despite pre-operative traction (Table 2). Biomechanically, vertebrectomy with strut reconstruction (+/- internal fixation) permitted only two points of fixation in contrast to multi-level disc space reconstruction which permitted segmental fixation and fusion. The use of combined anterior and posterior approaches afforded the greatest deformity correction and the highest likelihood for reconstruction success (Figure 4).

When we analyzed reconstruction success versus failure and the degree of the preoperative deformity, we found a statistically significant relationship: Patients with preoperative cervical kyphosis greater than plus 15 degrees had a high likelihood of reconstruction failure when treated via a single operative approach, compared to those patients with preoperative deformities less than plus 15 degrees, or patients with preoperative deformities greater than plus 15 degrees but treated via a combined approach.

Based on these findings we suggest that when possible, patients with symptomatic cervical kyphotic deformities should be treated anteriorly with multi-level interbody decompression, followed by fusion and segmental internal fixation. If the patient’s preoperative deformity is greater than plus 15 degrees, consideration should be given to combined anterior/posterior decompression, reconstruction, and fusion techniques. The use of more contemporary translational internal fixation systems was not assessed with this patient cohort and may offer
important advantages over rigid systems when
performing multi-level anterior decompression and
reconstruction procedures.

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This paper has provided Class II evidence on surgical correction for cervical spine kyphotic deformity by analyzing the entire cohort study of 78 consecutive patients in seven years. The kyphotic deformities were caused by a variety of diseases, and were associated with symptoms such as neck pain, radiculomyelopathy or swallowing disturbance. They were treated by either anterior, posterior, or combined decompression operations, and followed by standard anterior and/or posterior reconstruction and fusion procedures. There were 12 (30%) reconstruction failure in patients treated by anterior vertebrectomy, while anterior decompression and fusion showed 3% revision rate. The authors suspected that vertebrectomy and strut fusion were more likely to have a greater degree of pretreatment kyphosis and/or only two-point fixation in contrast to those of multi-level disc space reconstruction. They found patient’s preoperative cervical kyphosis greater than plus 15 degrees would be critical in consideration of reconstruction strategies. Thus, they concluded patients with symptomatic mild to moderate cervical kyphotic deformities can be treated with anterior multi-level interbody decompression, followed by fusion and segmental internal fixation, while combined decompression and fusion techniques should be performed in cases of kyphosis greater than 15 degrees. This paper shows an important clinical data on surgical tactics for cervical kyphotic deformity, and should be thoroughly understood by all spinal surgeons.

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The authors conducted a cohort study on 78 consecutive patients with symptomatic cervical spinal kyphotic deformities of a variety of etiologies. They attempted to determine the prognosis of these patients with respect to type of surgical procedures that was not randomly allocated. They selected reconstruction failure as an endpoint. Forty patients underwent anterior vertebrectomy with strut graft fusion reconstruction. The internal fixation with anterior plate/screw was used in 30 of these patients: reconstruction failure in 7 cases (23%). The external fixation with twelve weeks halo was performed in 10: graft failure in 5 cases (50%). The result (P>0.10 Chi-square) suggests that the absence of internal fixation did not predict graft failure. However, this negative result seems counterintuitive. Whether there might have been type II error or insufficient power in this cohort study is beyond the scope of this comment. It seems promising that there was only one reconstruction failure in thirty-one that underwent disectomy/ostectomy with interbody fusion. They demonstrated that patients with preoperative cervical kyphosis greater than plus 15 degree had a high likelihood of reconstruction failure (P>0.005, Fisher’s exact test) when treated via a single operative approach. The recommendation is that the disease should be treated anteriorly with multi-level interbody decompression followed by fusion and segmental internal fixation. Combined anterior/posterior decompression, reconstruction, and fusion should be considered for the patients with preoperative deformity greater than plus 15 degree. This study provided invaluable experience of Dr. Hadley’s group on the surgical treatment for symptomatic cervical spinal kyphotic deformities as a case series other than statistical description by cohort study. We look forward to a further study using more contemporary translational internal fixation system.