Clinical and radiological results of two hybrid reconstructive techniques in noncontiguous 3-level cervical spondylosis

Clinical article

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Object. To date, formulation of the optimal surgical protocol for noncontiguous multilevel cervical spondylosis remains controversial, and the corresponding clinical data continue to be limited. The purpose of this study was to compare the clinical and radiological outcomes of two hybrid reconstructive techniques in noncontiguous 3-level cervical spondylosis (2 contiguous disc levels and 1 “skip” disc level [nonoperated level between 2 operated levels]). The incidence of adjacent-segment degeneration (ASD) was also evaluated.

Methods. Sixty-three consecutive patients with noncontiguous 3-level cervical spondylosis who underwent two different hybrid methods of treatment were retrospectively reviewed. The patients were divided into 2 groups, the fusion group and the arthroplasty group. A titanium mesh cage and an anterior cervical plate were used after the anterior cervical corpectomy, and then a stand-alone cage (the fusion group) or an artificial cervical disc (the arthroplasty group) was used after the discectomy. Clinical outcomes were assessed using the Japanese Orthopaedic Association (JOA) scale score and the JOA scale score improvement rate preoperatively and during follow-up. Radiological results were assessed using global angle and global range of motion (ROM) of the cervical spine. The ASD was also evaluated.

Results. The JOA scores of the patients significantly improved postoperatively and were well maintained within the follow-up period, as did the JOA scale score improvement rate. The mean global angle of the cervical spine of the patients significantly increased postoperatively. At the last follow-up evaluation, the mean global ROM was retained by patients in the arthroplasty group (p > 0.05) but not by patients in the fusion group (p = 0.00). There was no significant difference in the incidence of ASD between the 2 groups (p = 0.114). However, at the skip levels, patients in the fusion group had a higher incidence of ASD than patients in the arthroplasty group (p = 0.038).

Conclusions. Both of the hybrid procedures (anterior cervical corpectomy and fusion [ACCF] + anterior cervical discectomy and fusion, and ACCF + cervical disc arthroplasty [CDA]) yielded favorable clinical and radiological outcomes in the treatment of noncontiguous 3-level cervical spondylosis. Moreover, the ACCF + CDA procedure may have the ability to decrease the likelihood of ASD in appropriate patients.

(http://thejns.org/doi/abs/10.3171/2014.8.SPINE13791)

Key Words • anterior cervical decompression and fusion • noncontiguous multilevel cervical spondylosis • cervical disc arthroplasty • hybrid reconstructive techniques • adjacent-segment degeneration

Anterior cervical decompression and fusion, commonly including anterior cervical discectomy and fusion (ACDF) and anterior cervical corpectomy and fusion (ACCF), has proven to be effective in the treatment of cervical spondylosis.23 However, many authors have reported that the increased biomechanical stress on the motion segment adjacent to the fused segment after fusion may accelerate the incidence of degenerative pathology at these adjacent levels, that is, so-called adjacent-segment degeneration (ASD).13,14 Therefore, cervical disc arthroplasty (CDA) was developed to preserve cervical motion, thus potentially reducing or delaying the onset of ASD. Many studies have reported that CDA is comparable to fusion regarding clinical outcomes.11,24 Unfortunately, there has been no definitive evidence of a significant reduction of ASD when CDA is performed instead of fusion.5,16,19,25

Abbreviations used in this paper: ACCF = anterior cervical corpectomy and fusion; ACDF = anterior cervical discectomy and fusion; ASD = adjacent-segment degeneration; CDA = cervical disc arthroplasty; JOA = Japanese Orthopaedic Association; ROM = range of motion.

*Drs. Kan and Kang contributed equally to this work.*
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Up to the present time, formulation of the optimal surgical protocol for multilevel cervical spondylosis has remained controversial, especially for noncontiguous multilevel spondylosis. Furthermore, clinical data from these patients remain limited. In this purely retrospective study, we compared the clinical and radiological outcomes of two hybrid reconstructive techniques (ACCF + ACDF and ACCF + CDA) in the treatment of noncontiguous 3-level cervical spondylosis (2 contiguous disc levels and 1 “skip” disc level [nonoperated level between 2 operated levels]). The incidence of ASD within the follow-up period was also evaluated.

Methods

Study Population

After the Research Ethics Board of Shanghai Changzheng Hospital approved the protocol for this study and patient informed consent was obtained, we retrospectively reviewed the medical records of 63 consecutive patients who underwent surgical treatment between January 2002 and May 2012 because of cervical spondylosis at 2 contiguous levels and 1 skip level.

The inclusion criteria included: 1) skeletally mature patients; 2) diagnosis of cervical disc herniation or cervical spondylosis; 3) cervical pathology at 2 contiguous disc levels and 1 skip disc level; 4) normal sagittal alignment with the absence of focal or global kyphosis; and 5) unresponsiveness to conservative treatment for at least 3 months. Patients with radiological instability of the cervical spine, obvious osteoporosis of the cervical spine, congenital deformations, infections, neoplasms, previous cervical spine surgery, chronic systemic illnesses such as rheumatoid arthritis, and neurodegenerative diseases were excluded in this study.

Surgical Methods

All patients underwent anterior cervical corpectomy and discectomy through the standard right-sided anterior approach. During the operation, patients were supine with their necks in neutral extension, maintaining the physical curve of the cervical spine. A corpectomy was performed at the 2 contiguous levels, and then a discectomy at the skip level. The basic techniques for exposure, corpectomy, discectomy, and decompression were performed as described in previous reports. Extensive decompression was performed, including removal of the herniated nucleus pulposus, osteophytes, and posterior longitudinal ligament.

According to various reconstructive techniques, the patients were divided into 2 groups, the fusion group and the arthroplasty group. Patients were treated with ACCF + ACDF before 2008, and with ACCF + CDA after 2008. In each of the 2 groups, a titanium mesh cage and an anterior cervical plate (Orion or Zephir Anterior Cervical Plate System, Medtronic Sofamor Danek; Codman or SLIM LOC Anterior Cervical Plate System, DePuy AcroMed, Inc.) were used after the corpectomy, and then a stand-alone cage (fusion group; Fig. 1 left) or a Discover (DePuy Spine) artificial cervical disc (arthroplasty group; Fig. 1 right) was used after the discectomy. Before the implantation of the Discover artificial cervical disc, the disc space/vertebral end plates were prepared to most appropriately accommodate the 7.0° angle of the prosthesis. Both the titanium mesh cages (Medtronic Sofamor Danek or DePuy AcroMed, Inc.) and the stand-alone cages (DePuy Spine; Solis cage, Stryker Spine) were packed with morselized local bone from the corpectomy. The surgeries were performed by 1 senior surgeon (X.C.) and under fluoroscopic control. After the operation, all patients were allowed to sit up and walk on postoperative Day 2 with Philadelphia neck collars (Huabang Medical Instrument Co.), which were worn for the first 12 weeks postoperatively by patients in the fusion group and for the 1st week in the arthroplasty group.

Clinical and Radiological Evaluation

Clinical and radiological outcomes were evaluated preoperatively; 2 days, 3 months, and 6 months postoperatively; and then at every 12-month interval. Clinical outcomes were assessed using the Japanese Orthopaedic Association (JOA) scale score and JOA scale score improvement rate. The JOA score improvement rate was defined as:

\[
\text{Improvement rate} = \frac{\text{postoperative JOA scores} - \text{preoperative JOA scores}}{17 - \text{preoperative JOA scores}} \times 100\%.
\]

Radiological evaluation included flexion, extension, and neutral-position lateral radiographs in a standing position. Sagittal plane angulation was assessed using the global angle of the cervical spine, which was calculated using Cobb’s angle formed by lines along the inferior endplate of C-2 to the inferior endplate of C-7 on a neutral lateral image. The global range of motion (ROM) was assessed by the difference in the global angle between the flexion and extension lateral images. Adjacent-segment degeneration was evaluated by a radiological grading system created by Hilibrand et al.
This grading system was based on evidence of disc space narrowing and/or osteophyte development on plain radiographs, signal changes in the disc space, and/or disc herniation with or without nerve root compression on MRI and CT. Grades ranged from 1 (no disease) to 4 (severe disease; Table 1). These evaluations were performed by 1 senior spine surgeon (L.J.) who was not involved in the surgery.

**Statistical Analysis**

Statistical analysis was performed using SPSS version 17.0 (SPSS Inc.). For continuous variables, normally distributed variables were presented as means ± standard deviations. Nonnormally distributed variables were presented as medians. For categorical variables, counts and percentages of each category were presented. Comparisons of continuous variables between preoperative and postoperative parameters within groups were made using the paired t-test. The chi-square test was used in the comparisons for categorical variables. Probability values less than 0.05 were considered statistically significant.

**Results**

All of the 63 patients completed the follow-up, with a median follow-up duration of 36 months (range 6–66 months). There were 35 men and 28 women, with a mean age at operation of 47.16 years (range 32–60 years). There were 32 patients in the fusion group and 31 patients in the arthroplasty group. The general characteristics of the patient population are presented in Table 2. There were no statistically significant differences between the 2 groups in terms of age, sex ratio, preoperative global angle, preoperative ROM, preoperative JOA scores, and follow-up duration (p > 0.05).

**Clinical Results**

The clinical results, including JOA score and JOA score improvement rate, were compared between the 2 groups. The changes over the follow-up duration are shown in Fig. 2. In each of the groups, the JOA score significantly improved after the operation and was well maintained within the follow-up period, as did the JOA score improvement rate. Although patients in the arthroplasty group had better results than patients in the fusion group, no significant differences in the mean JOA score and JOA score improvement rate between the 2 groups were found at any follow-up point.

**Radiological Results**

The radiological results assessed using the global angle and global ROM were compared between the 2 groups, and the changes over the follow-up duration are shown in Fig. 3. In each of the groups, the mean global angle significantly increased postoperatively, and no significant difference in the mean global angle between the 2 groups was found at any follow-up point. The changes in these parameters over time was similar. However, in both groups, there were different changes in the mean global ROM, which was retained by patients in the arthroplasty group but not by patients in the fusion group within the follow-up period. The arthroplasty group retained a mean global ROM of 39.66° ± 9.55° at the last follow-up evaluation, which was not significantly different from the preoperative measurements (p > 0.05). The mean global ROM in the fusion group was 24.98° ± 9.95° at the last follow-up, which was significantly different from the preoperative measurements (p = 0.00).

Adjacent-segment degeneration of the 2 groups evaluated by Hilibrand’s method is shown in Table 3. A total of 22 disc-levels (22.92%) in the fusion group and 13 disc-levels (13.98%) in the arthroplasty group developed ASD during the follow-up period. A comparison using the Pearson chi-square test found no statistically significant difference in the incidence of ASD between the 2 groups (p = 0.114). However, at the skip levels, patients in the fusion group had a higher incidence of ASD than patients in the arthroplasty group, and a significant difference was found using the Pearson chi-square test (p = 0.038). There were 4 cases of symptomatic ASD, in-

<table>
<thead>
<tr>
<th>Grade</th>
<th>Disease</th>
<th>Plain Radiography</th>
<th>MRI</th>
<th>CT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>none</td>
<td>normal</td>
<td>normal</td>
<td>normal</td>
</tr>
<tr>
<td>2</td>
<td>mild</td>
<td>narrowing of disc space, no posterior osteophytes</td>
<td>normal</td>
<td>normal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>signal change in intervertebral disc herniated nucleus pulposus w/o neural compression herniated nucleus pulposus; no nerve-root cutoff or spinal cord compression</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>moderate</td>
<td>&lt;50% of normal disc height, posterior osteophytes</td>
<td>herniated nucleus pulposus w/o neural compression herniated nucleus pulposus</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>severe</td>
<td>same as for Grade 3</td>
<td>spinal cord compression w/ or w/o nerve-root compression nerve-root cutoff w/ or w/o spinal cord compression</td>
<td></td>
</tr>
</tbody>
</table>

* According to the scale of Hilibrand et al. 13

**TABLE 2: General characteristics of the study population**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Fusion Group</th>
<th>Arthroplasty Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>no. of patients</td>
<td>32</td>
<td>31</td>
</tr>
<tr>
<td>mean age ± SD (yrs)</td>
<td>47.88 ± 7.35</td>
<td>46.42 ± 7.11</td>
</tr>
<tr>
<td>sex (male/female ratio)</td>
<td>17:15</td>
<td>18:13</td>
</tr>
<tr>
<td>preop global angle ± SD (°)</td>
<td>16.39 ± 3.72</td>
<td>17.54 ± 3.39</td>
</tr>
<tr>
<td>preop ROM ± SD (°)</td>
<td>40.29 ± 11.87</td>
<td>40.48 ± 7.83</td>
</tr>
<tr>
<td>preop JOA score ± SD</td>
<td>9.34 ± 1.15</td>
<td>9.55 ± 1.26</td>
</tr>
<tr>
<td>follow-up duration ± SD (mos)</td>
<td>31.25 ± 16.57</td>
<td>30.90 ± 12.03</td>
</tr>
</tbody>
</table>

* The p value between groups for each variable was > 0.05 (no statistically significant differences).
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including 3 cases in the fusion group and 1 case in the arthroplasty group. One of these patients required a second surgical procedure (Fig. 4), and the other patients were treated conservatively.

In our series, a total of 7 patients demonstrated complications (Table 4), including epidural hematoma (1 case in the arthroplasty group), CSF leakage (1 case in the fusion group), and dysphagia (3 cases in the fusion group and 2 cases in the arthroplasty group). At the last follow-up evaluation, bone fusion was successfully achieved in all patients, and no other complications were observed within the follow-up period. There was no significant difference in the complication rates noted between the 2 groups (p = 1.000).

Discussion

Anterior cervical decompression and fusion has become a standard operative treatment for cervical spondylosis, and has achieved excellent clinical outcomes. However, a high incidence of ASD after cervical fusion has been reported. The general view is that ASD can result partly from the increased biomechanical stress on the motion segment adjacent to the fused segment. Therefore, to conquer the problems of fusion, CDA was developed, which would have the ability to restore and maintain the motion, segmental anatomy, and function, thus potentially reducing or delaying the onset of ASD. Many studies have reported that CDA is safe and effective with equivalent or
superior clinical outcome to anterior cervical decompression and fusion,11,22 but whether CDA can reduce ASD remains controversial. Kim et al.17 performed a systematic review and found that CDA showed lower rates of adjacent-level ossification development compared with ACDF at both short- and long-term follow-up. Garrido et al.10 reported that CAD with Bryan cervical disc prosthesis (Medtronic Sofamor Danek) was associated with a lower incidence of adjacent-level ossification compared with arthrodesis with plate fixation at 2- and 4-year follow-up evaluations. Coric et al.6 performed a randomized control trial with a minimum 2-year follow-up comparing 136 patients (arthroplasty group) and 133 patients (fusion group) and found a statistically significantly higher incidence of ASD in the fusion group. However, multiple clinical trials and subsequent follow-up studies have failed to demonstrate significant reduction of ASD when arthroplasty was performed instead of fusion.5,16,25 In a prospective study with a minimum 3-year follow-up, Maldonado et al.19 found equivalent clinical outcomes following either ACDF or CDA. However, there was no significant difference in terms of the incidence of ASD between the ACDF group and the CDA group (using the Discover artificial cervical disc). In a meta-analysis of randomized control trials, Bartels et al.2 concluded that, because of a lack of proven clinical benefit, the costly devices of CDA should not be used in daily clinical practice. In another meta-analysis of randomized control trials, Yang et al.25 also failed to conclude that CDA can significantly reduce the postoperative rate of ASD and symptomatic ASD.

Up to the present time, formulation of the optimal surgical protocol for multilevel cervical spondylosis, especially for noncontiguous multilevel spondylosis, has remained controversial. Furthermore, clinical data of noncontiguous multilevel spondylosis continue to be limited. Because not all diseased levels may meet acceptable criteria for CDA, some authors turned to hybrid surgery as an alternative to multilevel ACDF or CDA. Hey et al.12 conducted a prospective study with a minimum 2-year follow-up and found that hybrid surgery incorporating ACDF and CDA is comparable to ACDF and CDA in terms of safety and feasibility. Cardoso et al.4 evaluated a cervical hybrid arthroplasty

<table>
<thead>
<tr>
<th>Level</th>
<th>Fusion Group Grade (n = 32)</th>
<th>Arthroplasty Group Grade (n = 31)</th>
<th>p Value</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>preop</td>
<td>superior adjacent</td>
<td>30</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>skip (nonoperated)</td>
<td>31</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>inferior adjacent</td>
<td>30</td>
<td>2</td>
</tr>
<tr>
<td>last follow-up</td>
<td>superior adjacent</td>
<td>29</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>skip (nonoperated)</td>
<td>18</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>inferior adjacent</td>
<td>27</td>
<td>3</td>
</tr>
</tbody>
</table>

* There were 22 of 96 patients with ASD in the fusion group, compared with 13 of 93 in the arthroplasty group (p = 0.114, Pearson chi-square test). There were 3 of 32 patients with symptomatic ASD in the fusion group, compared with 1 of 31 in the arthroplasty group (p = 0.613, Fisher’s exact test).
† Compared using the Fisher’s exact test.
‡ Compared using the Pearson chi-square test.

Fig. 4. Images obtained in a 51-year-old man who underwent a reoperation for symptomatic ASD. A: Postoperative lateral radiograph obtained at the 5-year follow-up evaluation showing good positioning of the instrumentation, bone fusion of the fused segments, formation of an osteophyte bridge at the anterior edge of the vertebral body of the skip level (C5–6), and ossification of the anterior longitudinal ligament at the superior adjacent level (C2–3). B: Postoperative T2-weighted MR image obtained at the 5-year follow-up evaluation showing C5–6 disc herniation and high signal intensity of the spinal cord. C: Postoperative lateral radiograph obtained on the 2nd day after the second operation (removal of the anterior cervical plate + ACDF).
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**TABLE 4: Complications of patients in the 2 groups**

<table>
<thead>
<tr>
<th>Complications</th>
<th>Fusion Group</th>
<th>Arthroplasty Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>total cases (%)</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>epidural hematoma</td>
<td>0</td>
<td>1 (3.23)</td>
</tr>
<tr>
<td>CSF leakage</td>
<td>1 (3.13)</td>
<td>0</td>
</tr>
<tr>
<td>dysphagia</td>
<td>3 (9.38)</td>
<td>2 (6.45)</td>
</tr>
</tbody>
</table>

* The p value between groups was 1.000.

(ACDF + Prestige ST cervical disc [Medtronic Sofamor Danek]) in patients with multilevel cervical spondylosis, and found that this hybrid cervical arthroplasty is a safe and effective alternative to multilevel fusion. Barbagallo et al. reported a hybrid arthroplasty technique (ACDF combined with Prodisc-C [Synthes Spine], Prestige LP, or Bryan disc) and also found good outcomes.

In this study, we compared the clinical and radiological outcomes of two hybrid reconstructive techniques in the treatment of noncontiguous 3-level cervical spondylosis. Symptoms of a majority of patients in both groups were significantly improved after the operation, and no statistical difference in clinical outcomes, restoration of cervical lordosis, and incidence of complications was determined between the 2 groups. Both of the hybrid reconstructive techniques were effective and safe. Regarding the incidence of ASD, our results demonstrated that there was no statistical difference between the 2 groups. However, at the skip (nonoperated) levels, the fusion group had a higher incidence of ASD. To date, the etiology of ASD after anterior cervical surgery is still unclear, especially in patients with noncontiguous multilevel spondylosis. Many authors have noted that the biomechanical effects on the adjacent segments are greater after the fusion of multiple segments.

One possible reason for our results is the greater stress at the skip levels in the fusion group compared with that in arthroplasty group.

**Conclusions**

Both of the hybrid procedures (ACCF + ACDF and ACCF + CDA) yielded favorable clinical and radiological outcomes in the treatment of noncontiguous 3-level cervical spondylosis, involving 2 contiguous disc levels and 1 skip disc level. Moreover, ACCF + CDA may have the ability to decrease the likelihood of ASD in appropriate patients. This retrospective study did have some limitations, such as a small sample size and a median follow-up duration of only 36 months. In the future, a large-sample, long-term follow-up, prospective cohort study will be needed. Furthermore, factors that affect the long-term clinical outcome, such as ASD, should be evaluated in controlled clinical trials.

**Disclosure**

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper. Author contributions to the study and manuscript preparation include the following. Conception and design: Chen, Kan, Kang, Jia. Acquisition of data: Kan, Kang. Analysis and interpretation of data: Kan, Kang, Guo. Drafting the article: Kan. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Chen. Statistical analysis: Kan. Kang. Administrative/technical/material support: Chen. Study supervision: Chen, Jia.

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Manuscript submitted August 22, 2013. Accepted August 29, 2014. Please include this information when citing this paper: published online October 17, 2014; DOI: 10.3171/2014.8.SPINE13791. Address correspondence to: Xiongsheng Chen, M.D., Ph.D., Department of Orthopedics, Shanghai Changzheng Hospital, Second Military Medical University, No. 415, Fengyang Rd., Shanghai 200003, China. email: chenxiongsheng@vip.sohu.com.