Outcomes of three anterior decompression and fusion techniques in the treatment of three-level cervical spondylosis

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Abstract The purpose of this article is to compare the outcomes of three different anterior approaches for three-level cervical spondylosis. The records of 120 patients who underwent anterior approaches because of three-level cervical spondylosis between 2006 and 2008 were reviewed. Based on the type of surgery, the patients were divided into three groups: Group 1 was three-level anterior cervical discectomy and fusion (ACDF); Group 2 anterior cervical hybrid decompression and fusion (ACHDF, combination of ACDF and ACCF); and Group 3 two-level anterior cervical corpectomy and fusion (ACCF). The clinical outcomes including blood loss, operation time, complications, Japanese Orthopedic Association (JOA) scores, C2–C7 angle, segmental angle, and fusion rate were compared. There were no significant differences in JOA improvement and fusion rate among three groups. However, in terms of segmental angle and C2–C7 angle improvement, Group 2 was superior to Group 3 and inferior to Group 1 (all $P < 0.01$). Group 2 was less in operation time than Group 3 ($P < 0.01$) and more than Group 1 ($P < 0.01$). Group 3 had more blood loss than Group 1 and Group 2 (all $P < 0.01$) and had higher complication rate than Group 1 ($P < 0.05$).

No significant differences in blood loss and complication rate were observed between Group 1 and Group 2 ($P > 0.05$). ACDF was superior in most outcomes to ACCF and ACHDF. If the compressive pathology could be resolved by discectomy, ACDF should be the treatment of choice. ACHDF was an ideal alternative procedure to ACDF if retro-vertebral pathology existed. ACCF was the last choice considered.

Keywords Anterior cervical corpectomy and fusion · Anterior cervical discectomy and fusion · Anterior cervical hybrid decompression and fusion · Cervical spondylosis

Introduction

Cervical spondylosis is a common cause of neurologic morbidity, substantially decreasing quality of life. The presence of kyphosis and ventral compression often suggests a ventral surgical intervention. However, it is controversial over the optimal way of decompressing the neural elements and reconstructing the anterior cervical spine in the treatment of adjacent three-level cervical spondylosis. Three-level anterior cervical discectomy and fusion (ACDF) has been revealed with high morbidity of nonunion due to multiple graft–host interfaces [1–5], and two-level anterior cervical corpectomy and fusion (ACCF) with high risk of instrument related complications [1, 6–9]. As a result, anterior cervical hybrid decompression and fusion (ACHDF), a compromised procedure between ACDF and ACCF is advocated [10–12]. It involves a combination of single-level corpectomy (adjacent discectomies) and additional single-level discectomy, preserving a vertebral body intact within the area of decompression. It has less

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graft–host interfaces than multilevel ACDF and segmental fixation with plate being placed over the entire constructs in this procedure can offer greater mechanical stability than end-construct fixation in multilevel adjacent corpectomies. Nevertheless, there were few related clinical studies evaluating the outcomes of this procedure and comparing it with ACDF and ACCF [10–12]. Therefore, in this study, we retrospectively evaluated the outcomes of these three techniques in the treatment of adjacent three-level cervical spondylosis and made comparisons in outcomes among three-level ACDF, ACHDF and two-level ACCF.

Materials and methods

Patient population

We reviewed the records of patients who underwent surgical treatment because of adjacent three-level degenerative cervical spondylosis between 2006 and 2008. All patients had symptoms and signs of neural compression at three adjacent segments that were refractory to conservative treatment. Patients who underwent prior cervical spine surgery or underwent surgery for infection, neoplasm and trauma were excluded. Patients with inadequate radiographs and follow-up were also excluded.

Surgical technique

Before surgery, clinical evaluation along with MRI, CT scan and radiographic studies of the cervical spine were performed. The choice of the operation was dependent on the characteristics of cord compression. The segments with

retro-vertebral compressive pathology such as ossification of posterior longitudinal ligament (OPLL), large end plate osteophytes, and huge prolapsed intervertebral disc were decompressed by corpectomy, and that with soft disc herniation by discectomy. Operations were performed by the same experienced spine surgeon at a single institution. Anterior cervical discectomy and corpectomy were performed as described previously [13, 14].

Based on the type of surgery, the patients were divided into three groups: Group 1 consisted of patients who underwent three-level ACDF (Fig. 1a); Group 2 ACHDF (combination of ACDF and ACCF) (Fig. 1b); and Group 3 two-level ACCF (Fig. 1c). After decompression, grafting bed was firstly prepared via burring the endplates with exposure of the subchondral bone. Then, titanium mesh (DePuy Spine) filled with local autograft bone was used to span the defect generated by corpectomy/corpectomies, and PEEK interbody cage (DePuy Spine; Synthes) was used to fill the space generated by discectomy. Finally, anterior cervical locking plate (DePuy Spine) was placed over the entire construct. In Group 1 and Group 2, segmental fixation was performed, with screws inserted into the intact vertebral bodies/body within the area of decompression. Postoperatively, all patients wore a Philadelphia collar for at least 3 months.

Outcomes evaluation

Perioperative parameters (blood loss, operation time, complications), clinical parameters (Japanese Orthopedic Association [JOA] scores), and radiologic parameters (C2–C7 angle, segmental angle, fusion rate) were collected and reviewed by independent experienced spine surgeons.

Fig. 1 Postoperative lateral radiographs of three surgical techniques. **a** Three-level anterior cervical discectomy and fusion (ACDF). **b** Anterior cervical hybrid decompression and fusion (ACHDF). **c** Two-level anterior cervical corpectomy and fusion (ACCF)

Lateral radiographs in flexion and extension and in neutral position before surgery, at 3, 6, and 12 months after surgery and annually thereafter were assessed. The segmental angle and C2–C7 angle were measured by Cobb's method. The C2–C7 angle was defined as the angle formed by the inferior aspects of C2 and C7, and surgical segmental angle was defined as the angle formed by the upper endplate of the superior vertebrae body and the lower endplate of the inferior vertebrae body on plain lateral radiographs in neutral position (Fig. 2a, b). Lordosis was recorded as a positive value and kyphosis as a negative value. The measurements were repeated thrice and the results were averaged.

Bone fusion was judged by the absence of motion more than 2 mm between the spinous processes on flexion–extension lateral radiographs, the absence of radiolucent gap between the graft and end plate, and the presence of continuous bridging trabeculae at the graft and end plate junction [15]. CT scan was not routinely obtained to evaluate bone fusion.

The recovery rate of JOA score was calculated according to the formula:

$$\text{Recovery rate} = (\text{Postoperative score} - \text{Preoperative score}) / (17 - \text{Preoperative score}) \times 100\%.$$

Statistical analysis

Statistical analyses were performed using SPSS version 17.0. The data were presented as the mean $\pm$ standard deviation. Comparisons between preoperative and postoperative parameters within groups were made using paired

t test. Intergroup comparisons were made using the analysis of variance, or χ^2 test. Probability values less than 0.05 were considered statistically significant.

Results

Finally, 120 patients (67 males and 53 females) with a mean age of 53.5 ± 9.6 years (range, 34–77) were included in the study. The levels involved were 57 cases at C3–C6 and 63 at C4–C7. The general information was presented in Table 1. No significant intergroup differences were found in terms of age, sex ratio, operation levels, and follow-up duration. Postoperative complication included hematoma, pseudarthrosis, C5 palsy, implant failure, cerebrospinal fluid (CSF) leakage, and titanium mesh subsidence. The hematomas were removed by emergency surgery, without permanent neurological deficits. The patient with pseudarthrosis was asymptomatic and did not receive second surgery. One patient in Group 3 developed screw fractures in the superior vertebral and required a second operation. The residue complications were all cured after conservative management, without secondary complications.

After operation, the segmental angle, C2–C7 angle and JOA score were greatly improved in all of the three groups (Table 2). The intergroup comparisons of outcomes were presented in Table 3. There were no significant differences in JOA improvement and fusion rate among these three groups. However, in terms of segmental angle and C2–C7 angle improvement, Group 2 was superior to Group 3 and inferior to Group 1 (all *P* values < 0.01). Group 2 was less

Fig. 2 C2–C7 angle was defined as the angle formed by line *a* and line *b* and segmental angle by line *c* and line *d* on lateral radiographs in neutral position. **a** Preoperative radiograph. **b** Postoperative radiograph

Table 1 General information of patients (mean $\pm$ standard deviation)

Information	Group 1	Group 2	Group 3
No. of patients	43	53	24
Sex (male/female)	24:19	35:18	13:11
Age (years)	52.7 $\pm$ 9.4	53.4 $\pm$ 9.5	55.2 $\pm$ 10.1
Operation levels			
C3–6	26 Cases	29 Cases	13 Cases
C4–7	17 Cases	24 Cases	11 Cases
Follow-up (months)	37.7 $\pm$ 7.2	37.3 $\pm$ 7.0	37.3 $\pm$ 7.3
Complications (no.)	1 (2.3%)	8 (15.1%)	6 (25%)
Hematoma	0	1 (1.9%)	1 (4.2%)
Pseudarthrosis	1 (2.3%)	0	0
C5 palsy	0	1 (1.9%)	0
Implant failure	0	0	1 (4.2%)
Titanium mesh subsidence	0	5 (9.4%)	3 (12.5%)
CSF leaks	0	1 (1.9%)	1 (4.2%)

Table 2 Radiological and neurological parameters before and after operation (mean $\pm$ standard deviation)

	Group 1	Group 2	Group 3
Preop-SA (°)	0.6 $\pm$ 10.4	6.9 $\pm$ 8.3	7.5 $\pm$ 6.8
Postop-SA (°)	15.6 $\pm$ 6.4*	16.3 $\pm$ 7.2*	9.8 $\pm$ 7.0*
Preop-CA (°)	−0.1 $\pm$ 12.6	9.7 $\pm$ 8.6	8.7 $\pm$ 9.5
Postop-CA (°)	14.9 $\pm$ 7.2*	17.8 $\pm$ 7.7*	11.4 $\pm$ 7.5*
Preop-JOA	8.3 $\pm$ 1.7	8.1 $\pm$ 2.2	7.7 $\pm$ 1.6
Postop-JOA	13.7 $\pm$ 1.9*	13.1 $\pm$ 2.3*	13.0 $\pm$ 2.0*

SA segmental angle, CA C2–C7 angle, JOA Japanese Orthopaedic Association, *preop* preoperative, *postop* postoperative

* $P < 0.01$, compared with the preoperative data using paired t test

in operation time than Group 3 ($P < 0.01$) and more than Group 1 ($P < 0.01$). Group 3 had more blood loss than the other two groups (all P values < 0.01) and had higher complication rate than Group 1 ($P < 0.05$). No significant differences in blood loss and complication rate were observed between Group 1 and Group 2 ($P > 0.05$).

Table 3 Intergroup comparisons (mean $\pm$ standard deviation)

Group	MOT (min)	MBL (ml)	MSAI (°)	MCAI (°)	JOA IR	CR (%)	FR
1	97.4 $\pm$ 17.1*	143.3 $\pm$ 72.7	15.1 $\pm$ 8.4*	15.1 $\pm$ 9.9*	0.6 $\pm$ 0.2	2.3	97.7% (42/43)
2	105.9 $\pm$ 19.1*	161.6 $\pm$ 78.8	9.4 $\pm$ 5.2*	8.1 $\pm$ 5.2*	0.6 $\pm$ 0.2	15.1	100% (53/53)
3	119.2 $\pm$ 16.4*	208.5 $\pm$ 136.9*	2.3 $\pm$ 1.9*	2.7 $\pm$ 4.5*	0.6 $\pm$ 0.1	25 $^{\Delta}$	95.8% (23/24)

MOT mean operation time, MBL mean blood loss, MSAI mean segmental angle improvement, MCAI mean C2–C7 angle improvement, CR complication rate, FR fusion rate, JOA IR JOA improvement rate

$^{\Delta}$ $P < 0.05$, compared with Group 1 using Fisher exact test; * $P < 0.01$, compared with the other two groups using analysis of variance

Discussion

Three-level spondylosis is a common degenerative disease leading to motor and sensory dysfunction, most of which require surgical intervention. Anterior decompression and fusion can remove the ventral compressive pathology and reconstruct the alignment of cervical spine, yielding good clinical results. However, it is controversial over the ideal option of anterior decompression methods.

Since its initial description by Smith and Robinson [16] and Cloward [17], ACDF for cervical spondylosis has been reported with good clinical outcome and fusion rates. However, three-level ACDF have been proved to be associated with high rate of nonunion even anterior plate was used [1–5]. The reported nonunion rate can be up to 54% [1]. The high rate may be attributed to increased number of graft–host interfaces, the increased stresses on the multiple graft sites and the resultant motion [1, 5]. In 2005, Fraser and Hartl [5] conducted a meta analysis of studies published after 1990 in which fusion rates achieved with each procedure were reported for patients with degenerative cervical disease at one, two, and three disc levels. They found that the nonunion rate increased with increased number of graft–host interfaces. The nonunion rate for ACDF with plating was 2.9% in one-level, 5.4% in two-level, and 17.5% in three-level. In our study, 1 of 43 patients (2.3%) who underwent three-level ACDF and plate fixation developed pseudarthrosis. We attributed this low pseudarthrosis rate to ideal grafting bed preparing because burring the endplates with exposure of the subchondral bone could cause a 4.4% decrease in the pseudarthrosis rate per level [18].

Anterior cervical corpectomy and fusion can not only resolve retro-vertebral compressive pathology easily but also reduce the graft–host interfaces. Therefore, it can achieve sufficient decompression and lower the rate of nonunion. In the study by Swank et al. [1], the nonunion rate of three-level ACDF was 54%, while two-level ACCF was 44%. The nonunion rate was lower in ACDF than in ACCF in their studies. However, ACCF had high risk of instrument-related complications [6, 7, 19–23]. Vaccaro et al. [6] performed two-level ACCF with anterior plate fixation in 33 patients, three of which developed graft

displacement. The failure rate was 9%. Sasso et al. [7] reported a similar failure rate, 6% in two-level ACCF. In our study, 1 of 24 patients (4.2%) who underwent ACCF with anterior plate fixation developed implant failure. It was postulated that anterior plating, which effectively increased stiffness and decreased local cervical motion after corpectomy, might excessively load the graft and promote pistoning and failure of multi-level constructs [8, 9]. In addition, we found that ACCF had more operation time and blood loss compared to ACDF and was inferior to ACDF in terms of segmental angle improvement and C2–7 angle improvement. Therefore, ACCF seemed not to be an ideal decompression option.

In order to conquer the problems with ACCF and ACDF, ACHDF developed. It was a combination of ACCF and ACDF in fact. It consisted of one-vertebral corpectomy (adjacent discectomies) and additional single-level discectomy, leaving one vertebral intact in the area of decompression [11, 12, 24]. It had less graft–host interfaces than three-level ACDF, theoretically lowering the rate of pseudarthrosis. The middle vertebral body preserved intact in this procedure not only increased the inherent mechanical stability of the post-decompressed cervical spine [11], but also allowed segmental plate fixation which was superior in biomechanics to end-construct plate fixation in two-level ACCF [24–26]. ACHDF with plate fixation was more rigid in flexion–extension and lateral bending than two-level corpectomy with end-construct plate fixation. It allowed the large-cantilever forces generated across the cervical spine to be diffused across multiple screw–host interfaces. Therefore, it could decrease the likelihood of graft and plate dislodgements [24]. In the study by Ashkenazi et al. [11], all of 12 patients who underwent this hybrid procedure yielded bone fusion. In our study, 53 patients underwent ACHDF with locking plate fixation. All of them achieved bone fusion.

There were controversies on the differences in outcomes between ACCF and ACHDF. Liu et al. [10] reported that there were no significant differences in cervical lordosis improvement, neurological function improvement and bone fusion between ACCF (16 cases) and ACHDF (12 cases). But Wei-bing et al. [12] found that ACCF (39 cases) had more graft/implant-related complications than ACHDF (20 cases) despite similar neurologic function improvement. To be noted, in his study, the plate only spanned the area of corpectomy and did not cover the level with interbody cage. Because standalone cage has risk of subsidence and dislodgment, we placed the plate over the entire construct. In our study, we compared ACHDF with ACCF and ACDF in clinical outcomes. We found that these three surgical techniques had similar neurologic function improvement and bone fusion rate. However, ACHDF not only had less blood loss and operation time than ACCF, but also was

superior to ACCF in terms of segment angle improvement and C2–C7 angle improvement. As compared to ACDF, nevertheless, hybrid procedure had more operation time and was inferior in terms of segment angle improvement and C2–C7 angle improvement. Therefore, corpectomy was associated with more blood loss and operation time, and less cervical lordosis improvement than discectomy.

Regarding postoperative complications rate, ACDF was lower than ACCF and ACHDF, but significant difference was only observed between ACDF and ACCF. Hematoma developed in two patients who underwent corpectomy. More blood loss and longer operation time with corpectomy than discectomy might be one of the important pathologic factors. Operation time has been associated with postoperative complications [27, 28]. On the other hand, titanium mesh subsidence is a common problem encountered in corpectomy and fusion. In our study, although we preserved the bony endplates and added washers at the end of mesh to increase the area of mesh–host interfaces, titanium mesh subsidence developed in five patients in hybrid procedure (9.4%) and three patients in ACCF (12.5%).

There were some limitations in this study. Firstly, it was a retrospective study. The patient's number in ACCF group was small. Patient selection to belong in one of the three groups was done according with the characteristics of cord compression, and therefore could possibly affect the postoperative JOA score. Secondly, bone fusion was mostly judged by plain radiographs and CT scan was not routinely employed. And different graft material used in these three groups might have influence on the fusion rate. Finally, the patient's habits and occupation were not considered. This could affect the postoperative alignment of cervical spine. Therefore, in order to draw a conclusion, multi-center prospective study is needed.

In conclusion, three-level ACDF was superior in most outcomes to the other two surgical techniques. If the compressive pathology could be resolved by discectomy, ACDF should be the treatment of choice. ACHDF was an ideal alternative procedure to ACDF, if retro-vertebral pathology existed. And ACCF was the last choice considered.

Conflict of interest statement None of the authors has any potential conflict of interest.

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