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Original Article

Anterior cervical discectomy and fusion versus anterior cervical corpectomy and fusion in Chinese patients with cervical spondylitis myelopathy following spinal cord injuries: a surgical intervention trial

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Abstract: Clinical effectiveness and complication rates of anterior cervical corpectomy and fusion (ACCF) and anterior cervical discectomy and fusion (ACDF) in Chinese patients with cervical spondylitis myelopathy following spinal cord injury are not known. The purpose of this study was to evaluate clinical effectiveness and complication rates of ACCF and ACDF in Chinese patients with cervical spondylitis myelopathy (CSM) after spinal cord injuries. In this pilot, single-center, and prospective study, patients with CSM following spinal cord injuries, undergoing ACCF and ACDF, were enrolled and randomized at the Department of Orthopedic, The First Affiliated Hospital of Soochow University, Suzhou, China (allocation ratio: 1:1). Clinical, radiological, and surgical outcomes were assessed from each enrolled subject before and after the operative procedure. Clinical outcomes, including Japanese Orthopedic Association and Neck Disability Index scores, were lower in patients of both groups. However, reduction was numerically greater in the ACDF group, compared to the ACCF group ($P>0.05$). Also, the length of hospital stay was shorter in ACCF patients, compared to the ACDF group ($P>0.05$). Radiological outcomes, such as Cobb angles (C2 to C7 region), rate of fusion, implant sagging, and implant displacement, were improved from baseline in both groups. However, improvement was greater in patients with ACCF, compared to the ACDF group. Also, lower incidence of implant sagging and implant displacement was found in both groups. However, incidence rates were lower in the ACDF group, compared to the ACCF group. Present trial results suggest that ACCF and ACDF were effective and safe in Chinese patients with CSM after spinal cord injuries. However, clinical, radiological, and surgical outcomes were better in patients that underwent ACDF, compared to ACCF. Also, complication rates were lower with ACDF than with ACCF.

Keywords: Cervical spondylitis myelopathy, spinal cord injury, anterior cervical discectomy, anterior cervical corpectomy

Introduction

Spinal cord injuries (SCI) are common causes of disability. Incidence rates have been increasing, with estimated rates of 15 to 40 cases per million worldwide [1]. In China, incidence of SCI doubled in 2011 (14%), compared to the incidence rate of SCI (7%) in 2003 [2]. Spinal cord injuries (SCI) severely affect the physical, psychological, and social well-being of patients, significantly enhancing the financial burden for patients, families, and health care systems [3]. Mobility restriction is a main problem associated with SCI patients. It increases secondary complications, such as obesity, cardiovascular disease, diabetes, depression, and pressure sores, negatively impacting quality of life [4].

Cervical spondylitis myelopathy (CSM), following SCI, is a serious and progressive disease, mainly affect QoL. It has been considered one of the most common causes of disabilities in the elderly population [5-8]. Cervical spondylitis myelopathy is generally triggered by a contraction of the spinal canal (cervical) because of progressive hereditary alterations. The key therapeutic treatment option for patients with CSM is surgical intervention. The best surgical intervention among patients with CSM remains controversial. The most common surgical intervention for CSM is the anterior procedure, now commonly accepted in several countries [5-10]. Anterior procedure for CSM consists of two types: anterior cervical discectomy and cortectomy with fusion. Of the anterior methods, ante-

rior cervical discectomy and fusion expand the frontal region of the spinal cord and reserve the steadiness of the vertebral column. Another common anterior method for CSM is anterior cervical corpectomy and fusion. Anterior cervical discectomy and fusion is associated with increased risk of inadequate decompression of the spinal cord, narrow optical coverage, and damage to the spinal cord. In contrast, anterior cervical cortectomy with fusion (ACCF) offers wide decompression of the spinal cord, helping with autografting. However, ACCF surgical intervention for CSM is more problematic and challenging. It has been associated with greater occurrence of complications, such as spinal cord injuries, damage of the spinal cord root, extreme hemorrhaging, and implant dislocation [7-10]. A meta-analysis evaluating 8 studies, containing 878 patients, suggested that ACDF is better than ACCF in the angle of C2 to C7 at the final follow-up (P<0.00001), C5 palsy (P=0.02), blood loss (P<0.00001), fusion rate (P=0.04), graft subsidence (P=0.004), and total complications (P=0.0009). However, there were no significant differences in length of hospital stay, operation times, JOA scores, NDI scores, preoperative angle of C2 to C7, dysphagia, hoarseness, infections, cerebral fluid leakage, donor site pain, epidural hematoma, graft dislodgment, and pseudo-arthrosis (all P> 0.05). One meta-analysis suggested that both ACDF and ACCF are good plans, with positive clinical outcomes. However, ACDF is a better choice in radiographic outcomes and total complications for treatment of multilevel CSM [11].

Clinical effectiveness and complication rates of ACCF and ACDF in Chinese patients with CSM after SCI remain unknown. Therefore, the current study investigated the clinical effectiveness and complication rates of ACCF and ACDF in Chinese patients with CSM, following SCI. This pilot, single center, and prospective pilot study was designed to evaluate clinical effectiveness and complication rates of ACCF and ACDF in Chinese patients with cervical spondylitis myelopathy following spinal cord injuries. The primary objective of this pilot study was to compare clinical effectiveness and complication rates of ACCF and ACDF in Chinese patients with cervical spondylitis myelopathy following spinal cord injuries. Present results may serve as a basis for conducting large multi-centric and multi-country clinical trials, assessing the association of clinical effectiveness and complication rates of ACCF and ACDF in patients with CSM, following SCI.

Subjects and method

In this trial, patients of both genders, aged between 18 and 65 years, with a confirmed diagnosis of CSM following SCI, undergoing ACCF and ACDF, enrolled at the Department of Orthopedic, The First Affiliated Hospital of Soochow University, Suzhou, China, were included (in allocation ratio of 1:1). Subjects with complete neurological damage after SCI that met all of the following inclusion criteria were eligible for enrollment: 1) Neurological damage caused by SCI at least for 1 year; 2) Subjects with no vertebral canal stenosis at the time of the SCI; 3) Subjects that had burst vertebral fractures, in the absence of facet dislocation, at the level of the spinal cord in the vertebral canal, not at the level of the spinal cord cone or the nervous roots; 4) Subjects aged <65 years at the time of the injury; and 5) Did not experience neurological alterations as a result of previous surgical interventions (if any). Exclusion criteria included: 1) Subjects with vertebral canal stenosis during SCI; 2) Subjects that had vertebral fractures at the level of the spinal cord cone or the nervous roots; and 3) Subjects >65 years at the time of SCI. Patients with any other conditions which may have confounded study results were excluded, per the discretion of the investigator. Moreover, subjects that were not willing to give written consent to participate in this pilot study were excluded during the screening phase. The study and study protocol was reviewed and approved by the Institutional Ethics Committee of Soochow University, China. All ethical principles laid down in the Helsinki Declaration of 1964, as revised in 2013, were followed.

Clinical, radiological, and surgical outcomes were assessed from each enrolled subject, before and after the operative procedure. Clinical outcomes included time spent in the hospital, Japanese Orthopedic Association scores, and Neck Disability Index scores. Radiological outcomes were also assessed before and after surgery, including Cobb angles (C2 to C7 region), rate of fusion, implant sagging, and implant displacement. Surgical outcomes were assessed before and after surgery, including loss of blood, procedure period, dysphagia,

Table 1. Demographic and clinical characteristic in Chinese patients with cervical spondylitis myelopathy following spinal cord injuries

Variable	ACDF group N=100 n (%)	ACCF group N=100 n (%)	*P* value
Age (year), Mean (SD)	46.2 (1.2)	45.2 (2.1)	>0.05*
Female/male, n (%)	40 (40)/60 (60)	30 (30)/70 (70)	>0.05#
BMI, kg/m^2, Mean (SD)	25.14 (1.3)	24.14 (1.2)	>0.05*
Cobb angles (C2 to C7 region), Mean (SD)	4.12 (0.7)	3.93 (0.8)	>0.05*
Japanese Orthopedic Association scores, Mean (SD)	9.28 (1.1)	9.02 (1.2)	>0.05*
Neck Disability Index scores, Mean (SD)	28.28 (1.1)	27.12 (1.7)	>0.05*
Medical history			
Type 2 diabetes mellitus, n (%)	9 (9)	7 (7)	>0.05#
Hypertension, n (%)	5 (5)	4 (4)	
Atherosclerosis, n (%)	4 (4)	3 (3)	
Dyslipidemia, n (%)	6 (6)	5 (5)	

Values are presented as Mean (SD) or as absolute number (%). N=Total number of subjects, n=number of subjects in each category. *using unpaired t test; #using Chi-squared test.

harshness, palsy of C5 region, septicity, cerebral liquid outflow, donor location discomfort, epidural hemorrhage, and quasi arthrosis.

Apart from clinical, radiological, and surgical outcome assessment, this study also assessed Quality of Life (QoL) of patients after surgical intervention. QOL-feedback forms were administered to each enrolled subject. They were instructed to answer the questions and give scores (range 0 to 5) for each sub-scale captured on the QOL-feedback form. QOL-feedback contained questionnaires concerning four key domains (physical, social, psychological, and contextual) to assess QoL of SCI patients. Each domain consisted of 4 to 6 questions, with a total of 22 single QoL scales captured in the QOL-feedback form. QoL scores ranged from 0 (low QoL) to 5 (high QoL) for each single QoL scale. The physical domain of QOL-feedback questionnaires contained questions about physical capacity in everyday life, physical activity, nutrition, mobility, sleep, and pain. The social domain of QOL-feedback questionnaires contained questions about family, work, leisure time, finances, friends, and partners. The psychological domain of QOL-feedback questionnaires contained questions about coping, energy, relaxation, pleasures, self-confidence, and remedial exercises. The contextual domain of QOL-feedback questionnaires contained questions about the health system, relationship to the physicians and therapist, nature and environment energy, culture, and housing. QOL-Feedback tool has been found more useful for SCI patients than the SF-36 questionnaire since it eliminates limitations of SF-36, assessing the physical function domain. The SF-36 is useful in assessing physical and mental health statuses, including disease burden in patients with chronic health problems. However, its role in screening health problems in patients with chronic diseases remains uncertain [12]. Additionally, correlation of the physical function scale of SF-36 among different populations was often poor. Therefore, SF-36 is less beneficial in examining differences in groups of patients with SCI [12]. The result of convergent validity of the 'QOL-Feedback' revealed that there was a high correlations of QOL-Feedback scales with corresponding subscales of SF-36 [12].

Statistical analysis

Since this trial was a pilot trial, no formal sample size calculation was performed. However, this study planned to include at least 100 Chinese children. Quantitative variables are presented as mean (± standard deviation) and were analyzed by parametric and nonparametric statistical tests, depending on the number of groups for comparison and the distribution of data. Two-sided statistical tests were used. Normality testing (Kolmogorov-Smirnov test or Shapiro-Wilk test) was used to check the distribution of quantitative data. Categorical variables are presented as absolute numbers and/or

Table 2. Comparison of clinical outcomes after ACCF and ACDF in Chinese patients with cervical spondylitis myelopathy following spinal cord injuries

Variable	ACDF group N=100 n (%)	ACCF group N=100 n (%)	*P* value
Time spent in hospital, Mean (SD)	15.2 (1.2)	18.2 (2.1)	0.051*
Japanese Orthopedic Association scores, Mean (SD)	14.18 (1.1)	13.72 (1.0)	0.057*
Neck Disability Index scores, Mean (SD)	15.18 (1.1)	15.12 (1.7)	0.089*

Values are presented as Mean (SD) or as absolute number (%). N=Total number of subjects, n=number of subjects in each category. *using unpaired t test.

Table 3. Comparison of radiological outcomes after ACCF and ACDF in Chinese patients with cervical spondylitis myelopathy following spinal cord injuries

Variable	ACDF group N=100 n (%)	ACCF group N=100 n (%)	*P* value
Cobb angles (C2 to C7 region), Mean (SD)	23.4 (1.2)	18.2 (1.1)	0.04*
Improvement in rate of fusion, n (%)	22 (22)	19 (19)	0.048#
Implant sagging, n (%)	1 (1)	4 (4)	0.04#
Implant displacement, n (%)	2 (2)	3 (3)	0.052#

Values are presented as Mean (SD) or as absolute number. N=Total number of subjects, n=number of subjects in each category. *using unpaired t test; #using Chi-squared test.

percentages of subjects in each category. Data was analyzed using GraphPad Prism (version 6.0).

Results

Patient disposition and baseline characteristics

A total of 220 patients were entered during the screening phase. Of these, a total of 200 patients that visited the hospital at the time of pre-operative consultation were enrolled and assigned to the ACCF and ACDF group (100 patients in each group). All enrolled subjects agreed to participate in this trial, willingly providing data. Most patients were male (ACCF: 60%, ACDF: 70%), with a mean (SD) age of 46.3 (1.4) years. Demographics and clinical characteristics of all patients are presented in **Table 1**.

Comparison of clinical outcomes between ACDF and ACCF

Time spent in hospital, JOA scores, and NDI scores were recorded for each patient of the ACCF and ACDF group. Length of hospital stay was shorter in patients with ACCF, compared to the ACDF group. However, differences were not statistically significant (P>0.05). JOA scores were recorded for each patient. Pre-operative and post-operative JOA scores were compared between the ACCF and ACDF group. It was found that patients undergoing ACDF had numerically lower JOA scores, compared to patients of the ACCF group. NDI scores were also recorded for each patient. Pre-operative and post-operative NDI scores were compared between patients of the ACCF and ACDF group. It was found that ACDF patients had lower NDI scores, compared to ACCF patients. Overall, patients undergoing ACDF had slightly better clinical outcomes, compared to patients undergoing ACCF (**Table 2**).

Comparison of radiological outcomes between ACDF and ACCF

Radiological outcomes, such as Cobb angles (C2 to C7 region), rate of fusion, implant sagging, and implant displacement, before and after surgery, were recorded for each patient of the ACCF and ACDF group. Cobb angles (C2 to C7 region) between ACCF and ACDF groups was found similar before surgical intervention. After surgical intervention, statistically significant differences between ACCF and ACDF were noted, favoring ACDF, compared to the ACCF group. Rate of fusion, implant sagging, and implant displacement between ACCF and ACDF groups were similar before surgical interven-

Table 4. Comparison of surgical outcomes after ACCF and ACDF in Chinese patients with cervical spondylitis myelopathy following spinal cord injuries

Variable	ACDF group N=100 n (%)	ACCF group N=100 n (%)	*P* value
Loss of blood, Mean (SD)	107 (1.2)	138.2 (1.1)	0.032*
Procedure period, Mean (SD)	164 (2.1)	189 (2.4)	0.021*
Dysphagia, n (%)	12 (12)	17 (17)	0.034#
Harshness, n (%)	2 (2)	7 (7)	0.041#
Palsy of C5 region, n (%)	1 (1)	4 (4)	0.038#
Septicity, n (%)	0 (0)	1 (1)	0.058#
Cerebral liquid outflow, n (%)	2 (2)	7 (7)	0.038#
Donor location discomfort, n (%)	2 (2)	6 (6)	0.058#
Epidural hemorrhage, n (%)	0 (0)	2 (2)	0.08#
Quasi arthrosis, n (%)	1 (1)	2 (2)	0.06#

Values are presented as Mean (SD) or as absolute number. N=Total number of subjects, n=number of subjects in each category. *using unpaired t test; #using Chi-squared test.

tion. After surgical intervention, statistically significant differences between ACCF and ACDF were noted, favoring ACDF, compared to the ACCF group. This study found that incidence of implant sagging and implant displacement were less in the ACDF group, compared to the ACCF group. Overall, ACDF patients had slightly better radiological outcomes than ACCF patients (**Table 3**).

Comparison of surgical outcomes between ACDF and ACCF

Surgical outcomes, such as loss of blood, procedure period, dysphagia, harshness, palsy of C5 region, septicity, cerebral liquid outflow, donor location discomfort, epidural hemorrhage, and quasi arthrosis, before and after surgery, were recorded for each patient of ACCF and ACDF groups. Statistically significant differences between ACCF and ACDF groups in loss of blood, dysphagia, harshness, palsy of C5, septicity, cerebral liquid outflow, donor location discomfort, epidural hemorrhage, and quasi arthrosis were found, suggesting better surgical outcomes for ACDF patients. Incidence of loss of blood, dysphagia, harshness, palsy of C5, septicity, cerebral liquid outflow, donor location discomfort, epidural hemorrhage, and quasi arthrosis were less in the ACDF group, compared to the ACCF group (**Table 4**). Overall, ACDF patients had better surgical outcomes than ACCF patients.

Comparison of quality of life (QoL) between ACDF and ACCF

The mean QoL score of each single scale of physical domain of QoL was higher in the ACDF group, compared to the ACCF group. Differences were statistically significant in all QoL parameters, namely physical capacity, physical activity, mobility sleep, and pain. However, there were no statistically significant differences in QoL scores of nutrition. Similar trends of improvement in QoL were observed for other key domains of QoL (social, psychological, and context). In social and psychological domains, significantly higher QoL scores were observed in all QoL parameters. Moreover, higher energy and self-confidence was observed. Similar trends of improvement in QoL were observed in the context domain QoL scores of all parameters. In the context domain, QoL scores for all parameters were significantly higher in ACDF, compared to ACCF. The mean (SD) of each scale of the QoL domain is summarized in **Table 5**. Total QoL scores of each domain of the QoL assessment tool were calculated and compared between ACDF and ACCF individuals. Results of this comparison show that total QoL scores of each domain were significantly higher in ACDF, compared to ACCF (**Table 6**). Overall, significant improvement in quality of life was observed in individuals undergoing ACDF.

Discussion

The current study is the first in China comparing clinical effectiveness and complication rates of ACCF and ACDF in Chinese patients with CSM, following SCI. Cervical spondylitis myelopathy is generally triggered by a contraction of the spinal canal (cervical) because of progressive hereditary alterations [11]. The key therapeutic treatment option for patients with CSM is surgical intervention (invasive technique). The best choice of surgical interventions (invasive technique) among patients with CSM remains debatable. ACDF (anterior cervical discectomy and fusion) has been associated with increased risk of inadequate decompression of the spinal cord, narrow optical coverage, and dam-

Table 5. Comparison of quality of life (QoL) after ACCF and ACDF in Chinese patients with cervical spondylitis myelopathy following spinal cord injuries

Quality of Life parameters	ACDF group N=100 n (%)	ACCF group N=100 n (%)	*P* value
Physical domain			
Physical capacity	4.07 (0.42)	2.94 (0.34)	<0.05*
Physical activity*	4.35 (0.37)	3.39 (0.26)	<0.05*
Nutrition[n.s]	3.93 (0.46)	3.88 (0.57)	>0.05[n.s]
Mobility*	4.26 (0.38)	2.97 (0.34)	<0.05*
Sleep*	3.50 (0.22)	3.34 (0.22)	<0.05*
Pain*	3.71 (0.40)	3.48 (0.22)	<0.05*
Social domain			
Work	4.33 (0.29)	3.54 (0.21)	<0.05*
Leisure Time	4.26 (0.37)	3.51 (0.22)	<0.05*
Family	4.37 (0.20)	4.23 (0.39)	<0.05*
Finances	4.24 (0.39)	3.42 (0.23)	<0.05*
Friends	4.30 (0.19)	3.88 (0.30)	<0.05*
Partner	4.38 (0.28)	3.98 (0.32)	<0.05*
Psychological domain			
Remedial exercises*	4.23 (0.38)	2.86 (0.35)	<0.05*
Coping*	3.17 (0.10)	2.93 (0.31)	<0.05*
Energy*	3.36 (0.11)	2.91 (0.35)	<0.05*
Relaxation*	3.98 (0.47)	3.38 (0.10)	<0.05*
Pleasure*	4.21 (0.40)	3.95 (0.29)	<0.05*
Self-confidence*	3.96 (0.33)	2.91 (0.33)	<0.05*
Context domain			
Health system*	4.25 (0.34)	3.97 (0.32)	<0.05*
Relationship to physician and therapist*	4.26 (0.30)	3.90 (0.30)	<0.05*
Nature and environment*	4.05 (0.44)	3.33 (0.11)	<0.05*
Housing[n.s]	3.99 (0.29)	3.91 (0.26)	>0.05[n.s]

Values are expressed as Means (SD). N=total number of individuals with non-missing value. *$P<0.05$, [n.s]$P>0.05$ for between group comparison. $P<0.05$ indicates statistically significant differences, and *P* value was calculated using parametric test (un-paired test).

Table 6. Comparison total QoL scores after ACCF and ACDF in Chinese patients with cervical spondylitis myelopathy following spinal cord injuries

Quality of Life (QoL) domain	ACDF group N=100 n (%)	ACCF group N=100 n (%)	*P* value
Physical QoL	3.62 (0.15)	3.35 (0.11)	<0.05*
Social QoL	4.14 (0.37)	3.69 (0.35)	<0.05*
Psychological QoL	3.55 (0.22)	3.06 (0.21)	<0.05*
Context QoL	4.15 (0.21)	3.70 (0.30)	<0.05*

Values are expressed as Means (SD). N=total number of individuals with non-missing value *$P<0.05$ for between group comparison. $P<0.05$ indicates statistical significant difference, and *P* value was calculated using un-paired test.

age to the spinal cord. Similarly, ACCF (anterior cervical cortectomy with fusion) offers wide decompression of the spinal cord and helps with autografting. However, the ACCF surgical intervention for CSM is more problematic to conduct, having been associated with greater occurrence of problems, including damage of the spinal cord root, extreme hemorrhaging, and implant dislocation [11]. The purpose of this trial was to evaluate clinical effectiveness and complication rates of ACCF and ACDF in Chinese patients with CSM, following SCI. Present results suggest that both surgical interventions (ACCF and ACDF) are effective and safe in Chinese patients with CSM following SCI. However, clinical, radiological, and surgical outcomes were better in ACDF patients than in ACCF patients. Moreover, complication rates were lower in ACDF patients than ACCF patients. Results of this study are consistent with previous findings and reports of meta-analyses [11, 13]. Previous studies have shown that surgical treatments of two-level CSM using ACDF or ACCF are similar in terms of clinical outcomes. However, regarding the amount of bleeding and radiological results, two-level ACDF was found to be superior to one-level ACCF in terms of procedure times [14]. One meta-analysis evaluated 15 studies, including 1,368 cases of multilevel CS-

M using ACDF or ACCF. This pooled analysis showed that blood loss and number of complications in ACDF was significantly less than in ACCF. However, comparisons between ACDF and ACCF for other clinical outcomes, such as procedure time, bone fusion failure, and post JOA scores, showed no significant differences between ACDF and ACCF [11, 14].

The current trial was designed as a pilot trial and conducted at single trial center in China (limitation of trial). Therefore, present findings cannot be generalized to the overall Chinese population. A large multi-centric randomized clinical trial should be conducted in the future to confirm present findings.

Conclusion

Present results suggest that both surgical interventions (ACCF and ACDF) are effective and safe in Chinese patients with CSM following SCI. However, clinical, radiological, and surgical outcomes were better in patients that underwent ACDF than ACCF. Moreover, complication rates were lower in ACDF patients than ACCF patients.

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Disclosure of conflict of interest

None.

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