Int J Clin Exp Med 2018;11(10):10929-10939
www.ijcem.com /ISSN:1940-5901/IJCEM0068900

Original Article

Posterior surgery may be the best option for the treatment of cervical spondylotic myelopathy: a comparative study in China

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Received May 11, 2017; Accepted May 9, 2018; Epub October 15, 2018; Published October 30, 2018

Abstract: The present study was conducted with aims of evaluating the efficacy and safety of three surgical procedures in the treatment of patients with cervical spondylotic myelopathy (CSM). A total of 182 CSM patients were selected and assigned into the anterior surgery group (n = 71), posterior surgery group (n = 55) and anterior-posterior surgery group (n = 56). Various parameters including Pavlov ratio (PR), range of motion (ROM), cervical curvature index (CCI), cord signal change (CSC), Square (S), and incidence of adverse reactions or complications were recorded. Visual analogue scale (VAS) was used to determine the intensity of pain right after surgery and after a period of 3 years. The modified Japanese orthopaedic association scale (mJOA) was employed in order to evaluate the efficacy. The patients in the anterior surgery group presented with a lower incidence of adverse reaction and complications, decreased VAS scores, as well as increased long-term rate of pain relief 3 months after the surgery in comparison with patients in the posterior surgery group and the anterior-posterior surgery group after surgery ($p < 0.05$). Based on the results of the imaging examination, the imaging indexes among the three groups showed a significant improvement 6 months after surgery as compared to the indexes before surgery ($p < 0.05$). Furthermore, the anterior surgery group had a higher PR and wider ROM than the other two groups 6 months after surgery ($p < 0.05$). The aforementioned findings highly indicated that the treatment of CSM with anterior surgery can lead to better efficacy and postoperative results in comparison with posterior surgery or combined anterior-posterior surgery.

Keywords: Anterior cervical surgery, posterior cervical surgery, anterior-posterior cervical surgery, cervical spondylotic myelopathy, efficacy, safety

Introduction

As the most common cause of spinal cord dysfunction across the world, the incidence of cervical spondylotic myelsopathy (CSM) related hospitalization was 4.04 per 100,000 people per year in the national cohort of eastern Asia [1]. This incidence was also found to be higher among elderly and male patients [2]. The causative factors for the disease are the degeneration of various components of the vertebra, including intervertebral disk, supporting ligaments of the vertebral body and facet joints [3]. Static factors, including disk desiccation, protrusion of osteophytic spurs, hypertrophy of the ligamentum flavum and ossification of the posterior longitudinal ligament, may lead to narrowing of the spinal canal and compression of the spinal cord [4]. Continuous compression of the spinal cord can cause irreversible damage including necrosis and demyelination of the gray matter [5]. Surgery should be considered in patients with moderate to severe CSM and/or patients with worsening neurologic deficits, as a result of spondylotic changes [6]. The surgical fusion of the spinal column and decompression of the spinal cord can limit further injury in many cases and stimulate recovery of the functions of the spinal cord [7]. A variety of anterior, posterior and combined approaches have been advocated to achieve adequate spinal cord decompression, avoid kyphosis and restore or maintain sagittal alignment [8]. However, the most efficacious surgical

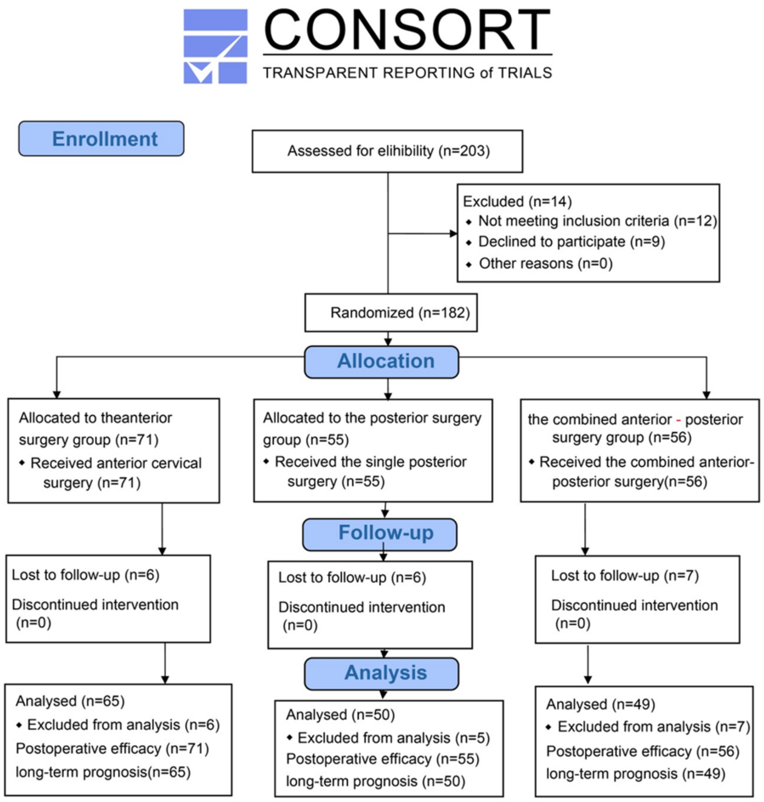

Figure 1. A CONSORT flow diagram for inclusion of study population. Totally 201 CSM patients undergoing surgical treatment from January 2011 to March 2013 were collected. Among these patients, 12 cases failed to meet inclusion criteria and 9 cases were unwilling to participate in the experiment. Finally, 182 CSM patients participated in the study.

approach in the treatment of CSM remains undetermined.

The surgical treatment options are centered on decompression with or without stability augmentation through fusion [9]. Altogether, the three surgical approaches can be divided into anterior, posterior, and combined (anterior and posterior) methods [10]. The anterior surgical approach was first introduced by Cloward, who demonstrated that it can be performed in a relatively safe and readily manner [11]. Among the several kinds of the anterior approaches, anterior cervical corpectomy and fusion (ACCF) has been associated with comparatively good fusion rates; however, at the price of more complications [12, 13]. Anterior cervical discectomy and fusion (ACDF) is able preserve the stability of the spinal column and decompress the anterior spinal cord [14]. ACDF is also known to have a shorter operative period and comparatively less blood loss compared with arthroplasty [15]. But due to the risk factors including incomplete decompression, limited visual exposure and injury to the spinal cord, a higher rate of pseudoarthrosis as well as a secondary risk of an increase in the number of fusion surfaces associated with it, ACDF is not considered to be the optimal surgical method [16]. The posterior surgical options is always the preferred surgical approach when treating multilevel compressions, such as in the cases of treating older patients with advanced multilevel spondylosis, congenital stenosis and certain cases of ossification of the posterior longitudinal ligament (OPLL) [17]. The posterior approach depends on decompression through both direct removals of abnormal posterior structures and indirect spinal cord translation [18]. The anterior or posterior approach is respectively preferred in cases with congenitally narrow spinal canal, or severe anterior spinal compression due to a huge central disc accompanied by posterior pathologic conditions. The combination of anterior and posterior approach can result in complete spinal decompression [11]. At present, there are a few studies, which focus on the variation in the long-term prognosis caused by the three aforementioned surgical approaches. What's more, due to the lack of well-designed prospective studies or randomized controlled trials, a lack of consensus remains on which of these surgical approaches are most applicable in terms of patient outcomes and/or complication profiles. Therefore, in the present study, long-term prognoses of CSM patients treated by the three surgical approaches were discussed in order to provide a criterion for selecting a clinically suitable surgical approach in the treatment of CSM.

Materials and methods

Ethic statement

Patients involved in the experiment had signed an informal consent regarding the procedure. This study was performed with the approval of

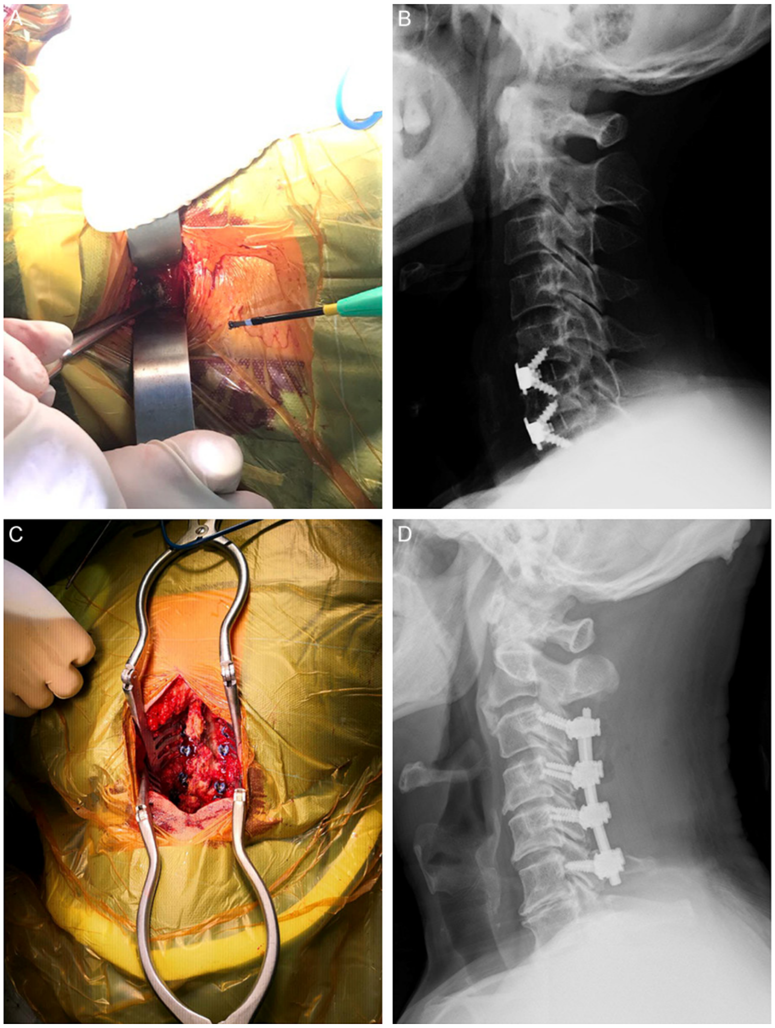

Figure 2. A 60-year-old male patients with cervical spondylotic myelopathy who received anterior cervical surgery (A: Surgical photo; B: X-ray after surgery); A 58-year-old male patients with cervical spondylotic myelopathy who received posterior cervical surgery (C: Surgical photo; D: X-ray after surgery).

the Ethics Committee of Shanghai Hospital, the Second Military Medical University.

Subjects

A total of 201 patients with CSM, that were undergoing surgical treatment from January 2011 to March 2013 were selected for the study. A CONSORT flow diagram for the study has been shown in **Figure 1**. With the exclusion of the 21 patients, this study included 182 CSM patients aged between 27 to 74 years old, with mean age of 51.82 ± 7.13 years old, including 93 males and 89 females. According to the location of the nerve pressure in the patients, 182 CSM patients were assigned to anterior surgery group (n = 71, 37 males and 34 females), posterior surgery group (n = 55, 29 males and 26 females), and anterior-posterior surgery group (n = 56, 27 males and females). Patients suffering from fracture blocks and ruptured intervertebral discs pressing the spinal cord anteriorly with or without slight dislocation were assigned to the anterior surgery group. Patients who've undergone posterior decompression treatment earlier through vertebral plate and anterior decompression through vertebral pedicle were assigned to the posterior surgery group. The remaining patients with old fractures and spinal canal stenosis or had fresh burst fracture and dislocation were assigned to the anterior-posterior surgery group. The inclusion criteria were as follows: all patients should meet the diagnostic criteria for CMS [19]; clinical manifestation of CSM symptoms, cervical cord damage confirmed by a Magnetic resonance imaging (MRI) or computed tomography (CT) angiography; all patients should've undergone non-operative treatment 3 months post-surgery, and the symptoms did not show any significant improvement; patients who haven't received any surgical treatment for CSM, without symptoms of lumbar spinal stenosis oppression; and with complete medical records. Exclusion criteria were as follows: patients who've undergone surgery for combined severe spinal deformities such as vertebral fractures, dislocations and tumors (4 cases were excluded); patients with other types of cervical spondylopathy (3 cases were excluded); patients with nervous system, endocrine or systemic diseases which could affect the evaluation criteria (5 cases were excluded). Modified Japanese Orthopedic Association (mJOA) was used to assess spinal cord function [20], which was in turn used to classify the severity of CSM.

Surgical treatment

Anterior cervical surgery: patients were intubated and were made to lie down in supine position following the administration of general anesthesia. Next, an incision was made in the skin, subcutaneous tissue and platysma through the conventional anterior cervical approach, and the prevertebral space, the vertebral body and the anterior part of the intervertebral disc were exposed. Then the part of the vertebral body compressing the spinal cord was extracted, and a drainage tube was implanted through the incision (**Figure 2A**, **2B**).

Posterior cervical surgery: patients were intubated, placed in the prone position and the surgery was performed after general anesthesia was administered. The surgical procedure included the following steps: through the posterior midline approach, an incision was made on the skin, subcutaneous tissue, aponeurotic fascia and the ligamentum nuchae; the vertical spinal muscle near the bilateral lamina was removed, and intervertebral joints were exposed bilaterally; the part of the vertebral body compressing the spinal cord was extracted, and a drainage tube was inserted through the incision (**Figure 2C**, **2D**).

In combined anterior-posterior surgery: anterior surgery was performed first, and then after a week posterior surgery was performed. The drainage tube was removed within 24~48 hours after operation. Patients who've undergone three surgical approaches were administered with small dose of methylprednisolone (40 mg/d) antibiotic through an intravenous infusion, and at the same time, they were given oral analgesic and anti-inflammatory drugs. If necessary, large dosages anti-inflammatory drugs were administered after operation. All patients wore cervical collars to protect their neck. Two months after the removal of the stitches, all patients continued to wear the cervical collar on their necks for additional two months. Conventional cervical anteroposterior and lateral X-rays examination and cervical CT scan were performed on the patients within 3 days after operation.

CT and magnetic resonance imaging (MRI) examinations

For the cervical spine, X-ray positive lateral film was performed on patients as it was preferred over flexion and extension film. Cervical spine CT and cervical spine MRI were taken within 6 months before and after the surgery for inspection purposes.

Pavlov ratio (PR) was used to measure the sagittal diameter of the cervical spine and corresponding centrum radius ratio. The cervical canal rate of 3 consecutive segments was less than 0.75, which was considered as the standard value for cervical spinal canal stenosis.

Range of motion (ROM) was employed for the cervical spine Cobb angle measurement procedure. The over flexed angle $\alpha 1$ and over extended angle $\alpha 2$ of cervical spine X-ray dynamic measuring film were measured to calculate ROM, which was calculated as using the formula ($\alpha 1 + \alpha 2$).

Cervical curvature index (CCI) connected C2 to the posterior edge of C7 in a straight line A. The distance between posterior edge of vertebral body C3-C6 and a1, a2, a3 and a4 on the straight line A were measured separately, after which the CCI was calculated using the formula $(a1 + a2 + a3 + a4)/A \times 100\%$.

Cord signal change (CSC): the spinal cord signal of T2 weighted images (T2WIs) were detected using an MRI. The increased signal intensity (ISI) of T2 was positively linked with the severity of CSM and ISI percentage of post-operative patients was calculated.

Spinal canal area measurement (S): GE Company Advantage Workstation 4.0 used T2 weighted images (WIs) to measure the spinal canal area.

Dislocation, displacement and other complications: 6 months after the surgery, an X-ray examination was conducted in order to detect collapse and displacement in patients. Any postoperative adverse effects and complications experienced by the patients in each group were recorded.

Visual analogue scale (VAS) and modified Japanese orthopedic association (mJOA) score

Visual analogue scale (VAS) was used to measure the degree of pain. The pain scores were respectively evaluated to calculate the rate of pain relief before, after and 3 years after the surgery, and they were evaluated on a 0-10-point scale: with 0-point implicating absence of any symptoms, while 10 point indicates most serious symptoms.

Table 1. Clinical features of patients with cervical spondylotic myelopathy among the three groups

Clinical features	Anterior surgery group (n = 71)	Posterior surgery group (n = 55)	Anterior-posterior surgery group (n = 56)	*p* value
Gender (male/female)	37/34	29/26	27/28	0.918
Age (years old)	50.96 ± 7.63	51.75 ± 5.65	53.00 ± 7.71	0.278
BMI	20.38 ± 3.94	21.77 ± 3.93	21.22 ± 3.69	0.128
Smoking	28	25	25	0.719
Drinking	27	20	14	0.754
Diabetes	26	18	21	0.546
Hypertension	21	23	19	0.356
Duration (month)	52.26 ± 17.23	51.98 ± 14.03	54.27 ± 17.58	0.746
Two-intervertebral space	25	19	14	0.458
Three-intervertebral space	32	22	25	0.829

Note: BMI, body mass index. Indicators of different groups are compared by one-way analysis of variance.

Table 2. The incidence of postoperative adverse reaction and complications of patients with cervical spondylotic myelopathy among the three groups (%)

Adverse reaction	Anterior surgery group (n = 71)	Posterior surgery group (n = 55)	Anterior-posterior surgery group (n = 56)	*p* value
Dysphagia	21.1	7.3	12.5*	0.031
Nerve root anomaly	11.3	12.7	16.1	0.724
Healing difficulty	2.8	7.3	5.4	0.512
Cerebrospinal fluid leakage	1.4	3.6	7.1	0.247
C5 nerve palsy	4.2	3.6	5.4	0.903
Anemia	2.8	9.1	21.4*	0.003
Rheumatoid disease	5.6	7.3	19.6*	0.025
Chronic lung disease	14.1	20.0	33.9*	0.025
Coagulation disorders	2.8	5.5	16.1*	0.016
Electrolyte disturbances	4.2	9.1	17.9*	0.037
Nervous system disease	5.6	10.9	21.4*	0.024
Renal failure	7.0	12.7	26.8*	0.007
Pathological weight loss	1.4	5.5	16.1*	0.005
Complication rate	11.3	27.3*	28.6*	0.028

Note: *, $p < 0.05$, compared with the anterior surgery group. Indicators of different groups are compared by one-way analysis of variance.

The mJOA was used to calculate the clinical improvement rate. Recovery was calculated using the formula [Postoperative mJOA score-Preoperative mJOA score]/[17-Preoperative mJOA score] × 100%. According to the improvement rate, the postoperative curative effect could be expressed as excellent (≥ 75%), good (50%~74%), valid (25%~49%) and invalid (< 25%).

Follow-up

Follow-up started on the first day following surgery. The last follow-up was on January 2016. The same physician at the cervical spine specialist clinic reviewed all the patients in the three groups once a year for 3 years after the surgery, and the follow-up rate was 90.10%. The clinical observation index and imaging index were observed and recorded for independent evaluations separately.

Statistical analysis

All data were analyzed using SPSS 20.0 statistical software. Data recorded were expressed as mean ± standard deviation (SD). Paired T test was highlighted to compare the data within a group, an Independent Sample T test was employed to compare the data between two

Table 3. Image indexes of patients with cervical spondylotic myelopathy among the three groups at 6 months before and after surgery

Group	Anterior surgery group (n = 71)			Posterior surgery group (n = 55)			Anterior-posterior surgery group (n = 56)		
	Before surgery	After surgery	p	Before surgery	After surgery	p	Before surgery	After surgery	p
PR	0.69 ± 0.08	0.88 ± 0.26	< 0.001	0.66 ± 0.07	0.74 ± 0.23*	0.015	0.68 ± 0.06	0.74 ± 0.11*	< 0.001
ROM (°)	41.21 ± 13.06	23.95 ± 10.49	< 0.001	42.65 ± 14.03	32.85 ± 9.29*	< 0.001	42.70 ± 10.49	30.67 ± 5.55*	< 0.001
CCI (%)	12.82 ± 2.40	10.21 ± 1.81	< 0.001	13.18 ± 2.09	10.88 ± 1.49	< 0.001	13.96 ± 5.50	14.51 ± 6.02	0.615
ISI	51.33 ± 9.20	30.10 ± 7.70	< 0.001	57.94 ± 8.50	29.95 ± 7.67	< 0.001	71.58 ± 10.40	30.83 ± 6.58	< 0.001
S (mm^2)	6.10 ± 0.87	9.71 ± 0.77	< 0.001	7.52 ± 0.76	9.84 ± 0.81	< 0.001	8.32 ± 0.82	9.62 ± 0.89	< 0.001

Note: *, $p < 0.05$, compared with the anterior surgery group. PR, Pavlov Ratio, ROM, range of motion, CCI, cervical curvature index, ISI, increase signal intensity, S: spinal canal area movement. Data of CCI (%) is compared by Chi-square test. Indicators of different groups are compared by one-way analysis of variance. Indicators in the same group are analyzed by independent sample *t* test.

groups and a one way analysis of variance (ANOVA) was employed to compare the data among the three groups. Enumeration data was expressed in the form of percentage or rate, and the chi square test was performed to analyze it. $p < 0.05$ was considered to be a statistically significant value.

Results

Clinical characteristics of CSM patients among the three groups

Table 1 shows the comparison of clinical characteristics of CSM patients among three groups. No significant difference was observed in terms of gender, age, weight, smoking, drinking, diabetes, hypertension, duration of preoperative symptoms, and intervertebral space among the three groups (all $p > 0.05$).

Postoperative adverse reactions or complications of CSM patients in the three groups

Six months after surgery, the X-ray film showed that the CSM patients had good anchor location without shedding and shift and with good histocompatibility. In addition, all of these patients presented with good union and no wound infection, effusion or delayed healing. Postoperative adverse reactions and complications experienced by the patients of the three groups are illustrated in (**Table 2**). Compared with the anterior surgery group, the posterior group showed no significant difference in the extent of dysphagia, nerve-root anomalies, suppressed healing, cerebrospinal fluid leakage, C5 nerve root palsy, proportions of anemia, rheumatoid disease, chronic lung diseases, coagulation disorders, electrolyte disorders, nervous system disease, renal failure and pathological weight loss (all $p > 0.05$). There was no significant difference in terms of nerve-root anomalies, suppressed healing, cerebrospinal fluid leakage and C5 nerve root palsy exhibited between the anterior-posterior surgery and anterior surgery groups (all $p > 0.05$). On the contrary, the anterior-posterior surgery group showed significantly higher extent of dysphagia, proportions of anemia, rheumatoid disease, chronic lung diseases, coagulation disorders, electrolyte disorders, nervous system disease, renal failure and pathological weight loss in comparison with the anterior surgery group (all $p < 0.05$). The occurrence of adverse reactions or complications in the posterior surgery group and the anterior-posterior surgery group was suggestively higher compared to the anterior surgery group (both $p < 0.05$).

Results of imaging examinations of CSM patients among the three groups 6 months after surgery

Six months after surgery, the imaging indexes in the three groups significantly improved compared to the indexes before surgery (all $p < 0.05$). In comparison to the indexes before surgery, PR, ROM, CCI, ISI and the S in the posterior surgery group and the anterior surgery group showed a great deal of improvement 6 months after the surgery. Although there was no significant difference in CCI ($p > 0.05$) in the anterior surgery group, PR, ROM, ISI and the S showed a significant improvement 6 months after surgery compared to the indexes before surgery (all $p < 0.05$). PR comparatively lowered, while ROM was increased in the posterior surgery group and the anterior-posterior surgery group in comparison with the anterior surgery group (both $p < 0.05$). The anterior-posterior surgery group presented with significantly

Table 4. VAS scores and rate of pain relief for the CSM patients among the three groups

Group	Anterior surgery group (n = 65)	Posterior surgery group (n = 50)	Anterior-posterior surgery group (n = 49)	*p* value
Before surgery	4.68 ± 1.94	4.62 ± 2.12	4.18 ± 2.00	0.801
After surgery	2.28 ± 1.06#	2.29 ± 1.17#	2.36 ± 1.30#	0.929
Three years later after surgery	0.72 ± 0.51#	1.29 ± 0.88*,#	1.16 ± 0.78*,#	< 0.001
Postoperative pain relief rate	45.67 ± 18.30	43.12 ± 21.49	37.79 ± 21.75	0.404
Long term pain relief rate	75.82 ± 26.96	62.87 ± 26.98*	63.06 ± 26.78*	0.011

Note: *, $p < 0.05$, compared with the anterior surgery group; #, $p < 0.05$, compared with the VAS scores before surgery. Postoperative and long-term pain relief rates are analyzed by Chi-square test. The other indicators of different groups are compared by one-way analysis of variance.

Table 5. JOA scores of patients with cervical spondylotic myelopathy among the three groups before and after operation

Group	Anterior surgery group (n = 65)	Posterior surgery group (n = 50)	Anterior-posterior surgery group (n = 49)	*p* value
Before surgery	8.56 ± 3.16	8.56 ± 3.35	8.61 ± 3.57	0.996
After surgery	11.72 ± 4.04#	12.16 ± 4.33#	11.91 ± 4.92#	0.869
Three years later after surgery	13.10 ± 4.39#	12.71 ± 4.37#	12.61 ± 5.10#	0.832
Postoperative rate of improvement	43.09 ± 23.86	47.78 ± 26.05	47.14 ± 29.13	0.576
Long term rate of improvement	61.97 ± 26.19	55.21 ± 25.84	57.30 ± 30.26	0.396

Notes: #, $p < 0.05$, compared with the JOA scores before surgery. Postoperative and long-term rates of improvement are analyzed by Chi-square test. The other indicators of different groups are compared by one-way analysis of variance.

improved CCI compared with the anterior surgery group 6 months after surgery ($p < 0.05$). Even after 6 months of the surgery, no significant difference was observed in the ISI and S among the three groups (all $p > 0.05$) (**Table 3**).

Comparison on VAS scores and rate of pain relief for the CSM patients among the three groups

During the 3 years of follow up, 6 patients from the anterior surgery group, 5 patients from the posterior surgery group and 7 patients from the anterior-posterior surgery group were lost. All patients were evaluated with VAS score before and after surgery. The postoperative VAS scores and scores 3 years after the surgery were significantly lowered in the three groups compared to the scores before surgery. The scores 3 years after the surgery in the three groups were significantly lower than the postoperative VAS scores (all $p < 0.05$). 3 years after surgery, the VAS scores were higher but the long-term pain relief rate was comparatively lower in the posterior surgery and anterior-posterior groups than that in the anterior surgery group (all $p < 0.05$). There was no significant variation observed in the postoperative pain relief rate among the three groups (all $p > 0.05$, **Table 4**).

Comparison on postoperative efficacy and long-term prognosis of CSM patients among the three groups

The postoperative neurological functions in the three groups improved at different rates. The JOA scores significantly increased right after or 3 years after the surgery compared to the scores prior to the surgery in the three groups (all $p < 0.05$). There was no significant difference in the JOA scores, postoperative rate of improvement, and long-term rate of improvement among the three groups before, after and 3 years after the surgery (all $p > 0.05$) (**Table 5**). The postoperative and long-term efficacy of patients in the three groups was as follows (**Table 6**): the postoperative results were 39.44% in the anterior surgery group, 40.85% in the posterior surgery group and 38.03% in the anterior-posterior surgery group. The acquired results also showed that there was not a major difference in the observed values of the three groups (all $p > 0.05$). The long-term efficacy in the anterior surgery group was significantly better than that in the posterior sur-

Table 6. Postoperative efficacy and long-term prognosis of patients with cervical spondylotic myelopathy among the three groups (%)

Group	Anterior surgery group (n = 65)	Posterior surgery group (n = 50)	Anterior-posterior surgery group (n = 49)
Postoperative efficacy			
Excellent	9	17	14
Good	19	12	13
Valid	27	14	13
Invalid	10	7	9
Postoperative excellent-good rate	39.44%	40.85%	38.03%
Long-term efficacy			
Excellent	27	17	21
Good	28	15	12
Valid	8	16	15
Invalid	2	2	1
Long-term excellent-good rate	77.46%	45.07%*	46.48%*

Notes: *, $p < 0.05$, compared with the anterior surgery group. Postoperative and long-term excellent-good rates are analyzed by Chi-square test. The other indicators of different groups are compared by one-way analysis of variance.

gery and anterior-posterior surgery groups (both $p < 0.05$).

Discussion

CSM is a disease characterized by degenerative cervical spondylosis, which leads to the dysfunction of the spinal cord. Surgery is crucial in the treatment of CSM, which conventionally includes anterior approach, posterior approach as well as a combination of anterior-posterior surgeries [21]. However, choosing the most suitable surgical approach has always been a debate. It has been well acknowledged that the reference factors that should be considered when choosing the surgical procedure include compression pathological location, sagittal alignment, the range of degenerative process, preoperative neck pain, past surgical history and patient's age [22]. Thus, the present study compared all these three approaches in terms of complications, postoperative nerve function and other various factors, to provide theoretical basis for clinical surgery management in CSM patients.

The findings suggested that the anterior approach had a lower rate of postoperative adverse reaction, complications and axial symptoms as well as a better long-term prognosis than the remaining two groups. Generally, the anterior surgical procedure includes three major approaches, which include cervical disc replacement (CDR), ACDF and ACCF [18]. Anterior approach not only offers direct decompression in CSM, but also provides the restoration of cervical lordosis and can also reduce surgery related hemorrhage [23]. Due to its desirable distraction and release functions and the superiority of its recovery rate of sagittal alignment over the posterior approach, the anterior approach could contribute to better kyphosis correction [8]. However, when CSM at the 3rd stage or more was treated, ACCF had an increasing failure rate, which might have been caused by its lack of stability [24]. The results from the present study revealed that the complication rate and the axial symptom rate were lower in the anterior group in comparison with the other two groups, while the cervical curvature index was higher than in the other groups. Otherwise, the anterior approach did not appear to be the most preferable approach based on other indexes. Therefore, anterior approach can reduce the postoperative complication rate and promote cervical physiological curvature, contributing to better long-term prognosis of CSM.

Meanwhile, in the present study, it was also demonstrated that the anterior approach can improve postoperative neurological function. Based on a study conducted by Luo *et al.*, it was revealed that that the anterior approach provided a better postoperative neural function compared to posterior approach in the treatment of multilevel CSM, but there was no difference in the neural function recovery rate between the anterior approach and posterior approach [25]. Recently, Zhu *et al.* reported that better postoperative neural function has closer links to the anterior approach than the posterior approach in the treatment of multilevel CSM. In addition, it has also been demonstrated that the postoperative JOA scores were better in the anterior surgery group than the posterior surgery group [26]. Moreover, Toshikazu *et al.* revealed that anterior decompressions are technically more demanded in the treatment of massive OPLL, and are counterintuitively safer than laminoplasty [27]. Besides, more and more scholars indicate that anterior decompression and fusion (ADF) for OPLL with an occupying ratio greater than 60%, for ADF had a significantly better recovery rate at final follow-up evaluation in comparison to those in the laminoplasty group [28-30].

Whereas, the VAS score of combined anterior-posterior surgery were much lower than the other two surgical procedures. The combined anterior-posterior surgical approach, which is useful in restoring and decompressing sagittal alignment as well as large ventral compression in multilevel CSM, have a higher ability in aiding the improvement of neurological function compared with the anterior approach. It also has the highest JOA recovery rate amongst the three approaches [31], making it the best surgical choice for treating multi-segmental CSM with optimal cord decompression [32]. Although it is an efficient and effective treatment for CSM, it has been found that the procedure is associated with minor complications, absence of neurologic deficits, and high levels of neurologic improvement [33]. Other disadvantages of the combined anterior-posterior surgery include higher rates of complications, increased mortality and increased length of stay (LOS) [34]. This study has also provided further evidence that the highest JOA scores and neurological improvement rates were found in the anterior-posterior surgery group. Besides, the VAS score and ROM were significantly lower than the other two groups. As a result, the combined anterior-posterior surgery can reduce axial symptoms and improve ROM in CSM patients.

Overall, since there is a clinical equipoise regarding the surgical approach when treating CSM, the present study indicated that the anterior surgery might be the optimum choice for the treatment of CSM because of its long-term efficacy. The finding from the study also provided a clinical basis for the treatment of CSM, and is believed to facilitate the CSM-protect clinical trial, which may lead to improved treatment outcomes for CSM patients.

In conclusion, our findings revealed that the anterior surgery was more efficient and had better post-operative results compared to the results obtained from the posterior or combined anterior-posterior surgeries, hence, it is the best choice in the treatment of CSM. However, the number of affected segments was not taken into account in this study, and they should be considered in further researches.

Acknowledgements

This study was supported by Lumbosacral Biomechanical Evaluation and Computer Aided Bionic Research (No. 81253885) and the Research of Space Trajectory Instantaneous Center of Rotation and Segmental Stability of Lumbosacral Vertebral (No. 8167090274). We are grateful for the contributions and useful suggestions of all the reviewers on our article.

Disclosure of conflict of interest

None.

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