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Original Article

Comparative study of artificial cervical disc replacement and anterior cervical discectomy/fusion in the treatment of cervical spondylotic myelopathy

Xianjun Chen, Lin Shi, Xiao Yu, Qingjiang Pang, Ji Yang

Department of Orthopedics, Hwa Mei Hospital, University of Chinese Academy of Sciences, Ningbo, Zhejiang Province, China

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Abstract: Objective: The aim of the current study was to compare efficacy levels of artificial cervical disc replacement (ACDR) and anterior cervical discectomy/fusion (ACDF) in the treatment of cervical spondylotic myelopathy. Methods: A total of 60 patients with single-segment cervical spondylotic myelopathy, requiring surgery, were randomly divided into the ACDR group (group A) and ACDF group (group B), with 30 patients in each group. Operative times, blood loss, hospitalization times, and re-operation rates between the two groups were compared. Visual analogue scores (VAS), Japanese Orthopedic Association (JOA) scores, neck disability index (NDI) scores, cervical curvature index (CCI) scores, range of motion (ROM), adjacent segmental degeneration (ASD) rates, heterotopic ossification rates, and overall curative effects (satisfactory rates of Odom's criteria) were compared between the two groups before the operation and at 2 weeks, 3 months, 1 year, and 3 years after the operation. Results: There were no significant differences in operative times and hospitalization times between the two groups (both $P > 0.05$). Blood loss in group B was significantly higher than that in group A ($P < 0.05$). VAS scores, JOA scores, and NDI scores of the two groups were improved after the operation (all $P < 0.05$). VAS scores, JOA scores, and NDI scores at 3 months, 1 year, and 3 years after the operation in the two groups were improved, compared with those in the 2 weeks after the operation (all $P < 0.05$). VAS scores, JOA scores, and NDI scores at 3 months, 1 year, and 3 years after the operation showed no significant differences (all $P > 0.05$). There were no significant differences in VAS scores, JOA scores, NDI scores, and satisfactory rates of Odom's criteria between the two groups before or after the operation (all $P > 0.05$). Levels of CCI and ROM in group A were significantly higher than those before the operation (both $P < 0.05$). Levels in group B were lower than those before the operation (both $P < 0.05$). Rates of ASD and re-operations in group B were significantly higher than those in group A (both $P < 0.05$). The rate of heterotopic ossification in group A was significantly higher than that in group B ($P < 0.05$). Conclusion: ACDR for cervical spondylotic myelopathy provides good curative effects, compared with traditional ACDF. It also preserves or even improves movement of the cervical vertebra, greatly reducing re-operation rates. However, heterotopic ossification rates are significantly elevated. Thus, additional studies are required to improve this problem.

Keywords: Cervical spondylotic myelopathy, artificial cervical disc replacement, intervertebral disc decompression and fusion

Introduction

Due to changes in living and working habits, incidence rates of spondylosis have shown an increasing trend in recent years. The average age of incidence has trended younger, becoming a significant disease affecting both work and life [1]. Cervical spondylosis can be divided into cervical spondylotic radiculopathy, vertebral artery type of cervical spondylosis, sympathetic cervical spondylosis, and cervical spondylotic myelopathy [2]. Each type of cervical spondylosis has a specific clinical manifestation that can only be distinguished by imaging examinations. Treatment of cervical spondylosis usually involves physical therapeutics, medication, and surgical treatment [3, 4]. Physical therapeutics includes physiotherapy, cervical traction, and exercise therapy. However, cervical traction should be used cautiously in cervical spondylotic myelopathy, avoiding injuries to the spinal cord. Medication is mainly a symp-

tomatic treatment for pain or inflammation caused by cervical vertebral compression. Surgical treatment is optional if conditions permit for patients experiencing ineffective results through physiotherapy and medication. The current study examines surgical treatment of cervical spondylotic myelopathy. Cervical spondylotic myelopathy can cause spinal cord injuries after compression of the spinal cord. Clinical symptoms are obvious and muscle strength changes are likely to occur. Operation treatment is an effective method in relieving compression issues. Anterior cervical decompression and fusion (ACDF) is the classical procedure for treatment of cervical spondylotic myelopathy. Its clinical effects are also satisfactory. However, as time goes on after the operation, the operation procedure can influence the range of motion of the cervical vertebra. Degeneration of the adjacent vertebral body will also occur, often requiring a secondary operation [5-7]. Therefore, a new surgical method is necessary to solve the situation. Artificial cervical disc replacement (ACDR) is a new surgical procedure, developed in recent years. Compared with ACDF, ACDR is a nonfusion operation, replacing the diseased disc with an artificial disc. It can preserve the motion of the vertebral body. However, long-term effects and possible side effects require further study. The current study compares the effects of ACDF and ACDR in the treatment of cervical spondylotic myelopathy, aiming to discover a better treatment method.

Materials and methods

General materials

From January 1, 2015, to December 31, 2017, 60 patients with single segment cervical spondylotic myelopathy, admitted to HwaMei Hospital, University of Chinese Academy of Sciences, were selected.

Inclusion criteria [8]: (1) Patients diagnosed with cervical spondylotic myelopathy; (2) Single-level cervical spondylosis with lesion segments located in C3-C7; (3) Patients with no significant improvement or aggravation of the condition after 3 months of non-operative treatment; and (4) Ages ranged from 18 to 70 years.

Exclusion criteria: (1) Patients with significant cardiovascular and other important organ diseases; (2) Patients with severe osteoporosis or softening and obvious fracture defects; (3) Patients with cervical spinal canal stenosis, cervical tumor, infections, or deformities; and (4) Patients with a history of cervical spondylosis surgery.

The current study was approved by the Medical Ethics Committee of HwaMei Hospital, University of Chinese Academy of Sciences. All patients were informed of possible treatment risks and other treatment options if results were not satisfactory. Informed consent was obtained from all patients.

Research subjects

Sixty patients were divided into two groups, according to the random number table method, with 30 patients in each group. Group A included artificial cervical disc replacement (ACDR) patients. Group B included ACDF patients.

Treatment methods

Group A [10]: Patients were placed in the supine position. After general anesthesia, they were given pillows under the head, neck, and shoulders, enabling a moderate extension of the neck. After disinfection and towel laying, a transverse incision of the right neck was taken. The operative incision was exposed layer by layer. Thus, the anterior edge of the vertebral body was completely exposed. Next, the location needle was implanted. The diseased intervertebral discs and median lines were identified via imaging. The prospective replacement segment was exposed. The bone and fibrous rings in intervertebral space and adjacent vertebral body hyperplasia were then removed and replaced. The posterior longitudinal ligament without obvious degeneration was reserved, as far as possible. Spinal cord compression was completely relieved. After confirming the size and position of the prosthesis, a suitable type of Bryan prosthesis was inserted. Drainage tubes were placed and the incision was closed layer by layer. The patients were sent back to the ward, after awakening, under the protection of cervical gear.

Group B [11]: Patients were placed in the supine position. After general anesthesia, they were given pillows under the head, neck, and shoulders, enabling a moderate extension of

the neck. Anterior and right transverse incisions of neck were taken, layer by layer. The anterior edge of the vertebral body was exposed. The location needle was implanted. The lesion segment was located by imaging. Osteophytes and calcification of the diseased vertebral space were completely removed for full decompression. Next, the endplate of the upper and lower vertebrae was grinded, aiming to facilitate postoperative fusion. Autogenous iliac bone and vertebral body fragments were implanted into the intervertebral space. They were fixed with plates and screws at the anterior edge of the vertebral body. When the position was satisfactory, negative pressure drainage tubes were placed. The incision was closed layer by layer. The patients were sent back to the ward, after awakening, under the protection of cervical gear.

Postoperative management: The two groups of patients were fixed for at least 4 weeks after the operation. Proper rehabilitation exercise was carried out under the fixation of neck support. Neck exercises were gradually strengthened after the neck support was removed. Postoperative antibiotics were used for 3 days, preventing postoperative infections. Analgesic drugs were used if the patient had a severe pain within 3 days after the operation.

Therapeutic evaluation

The following indexes were evaluated before the operation, 2 weeks after the operation, 3 months after the operation, 1 year after the operation, and 3 years after the operation:

Visual analogue scores (VAS): A 10 cm horizontal line was drawn on paper, with 0 on one end and 10 on the other. Patients marked pain scores on the line according to the degree of pain. Higher scores indicate more severe pain.

Japanese Orthopedic Association (JOA) scores [12, 13]: There are 17 points in this score. Higher scores indicate better spinal functional recovery.

Neck disability index (NDI) scores [14, 15]: There are 10 items with 50 points. Higher scores indicate more severe dysfunction.

Cervical curvature index (CCI): Straight distance A from the posterior lower angle of C2 to the posterior lower angle of C7 was measured on X-ray lateral images as a denominator. Vertical distances between the posterior inferior angle of C3, C4, C5, and C6 to posterior lower angle of C2 and C7 were recorded as a1, a2, a3, and a4, respectively. CCI = (a1 + a2 + a3 + a4)/A * 100%.

Range of motion (ROM) [16]: ROM includes the sum of angles between the superior endplate on the upper vertebral body and the inferior endplate on the inferior vertebral body of the operative segment via X-rays of cervical hyperflexion and hyperextension. When ROM < 3°, it is obviously lost. ROM was compared before and after the operation, determining the effects of surgery on cervical spine mobility.

Satisfactory Rate of Odom's criteria: Overall curative effects of the patients were evaluated during the follow-up period, divided into 4 grades. Excellent: Complete remission of all preoperative symptoms; Good: Preoperative symptoms were obviously relieved and daily activities and work were not affected; Fair: Preoperative symptoms were partially relieved, but daily activities were significantly limited; Poor: No change or a deterioration of preoperative symptoms. Satisfactory rate of Odom's criteria = Odom's Standard excellent and good cases/Total number * 100%.

Adjacent Segment Degeneration Rate (ASD): Intervertebral disc degeneration, herniation, spinal stenosis, spondylolisthesis, or instability with or without symptoms in adjacent segments indicate degeneration of adjacent segments.

Ectopic Ossification [17]: Appearance of bone tissue in soft tissues can be judged by the patient's positive and lateral X-rays. These can be divided into 5 grades, according to severity: Grade 0: No ossification; Grade I: Ossification has not entered into the intervertebral space; Grade II: Ossification has entered the intervertebral space; Grade III: Further aggravation of ossification may affect intervertebral space activity; Grade IV: A bone bridge has been formed with segmental mobility < 3°.

Re-operation rates: This refers to the probability of re-operations in the two groups of patients during the observation period: (number of re-operation/number of observers) * 100%. When the cervical vertebra was completely inactivat-

Table 1. Comparison of general materials

	Group A (n = 30)	Group B (n = 30)	P
Sex			0.657
Male	18	20	
Female	12	10	
Age (year)	48.5 ± 4.6	46.8 ± 6.0	0.474
Operative segment			0.386
C3-C4	4	3	
C4-C5	3	6	
C5-C6	12	9	
C6-C7	11	12	

Note: Group A, artificial disc replacement group; group B, anterior cervical discectomy and fusion group.

ed and mobility was less than 3°, it was necessary to re-operate. ACDF or ACDR was adopted according to patient choice and specific conditions.

Statistical analysis

SPSS17.0 software was used for data analysis. Measurement data are expressed as $\bar{x}$ ± sd. Independent sample t-tests were used for comparisons between groups. Paired sample t-tests were used for intra-group comparisons. Enumeration data are expressed as χ^2. $P < 0.05$ indicates statistical significance.

Results

Comparison of general materials of the subjects

There were no significant differences in age, sex, and operative segments between the two groups (all $P > 0.05$). See **Table 1**.

Comparison of operations between the two groups

There were no significant differences in operation times and hospitalization times between the two groups (both $P > 0.05$). Blood loss in group B was significantly higher than that in group A ($P < 0.05$). See **Table 2**.

Comparison of VAS, JOA, and NID scores between the two groups

There were no differences in preoperative scores between the two groups (all $P > 0.05$). VAS, JOA, and NDI scores were improved after the operation in both groups (all $P < 0.05$). VAS, JOA, and NDI scores of the two groups at 3 months, 1 year, and 3 years after the operation were improved, compared with those at 2 weeks after the operation (all $P < 0.05$). There were no significant differences in VAS, JOA, and NDI scores at 3 months, 1 year, and 3 years after the operation (all $P > 0.05$). See **Tables 3-5**.

Comparison of CCI and ROM between the two groups

Levels of CCI and ROM after the operation in group A were significantly higher than those before the operation (both $P < 0.05$). Levels of CCI and ROM in group B were significantly lower than those before the operation (both $P < 0.05$). See **Figures 1**, **2**.

Comparison of satisfactory rates of Odom's, ASD, heterotopic ossification, and re-operation rates between the two groups

There were no significant differences in satisfactory rates of Odom's criteria in the two groups (all $P > 0.05$). ASD and incidence rates of re-operations in group B were significantly higher (all $P < 0.05$). Rates of heterotopic ossification in group A were also significantly higher (all $P < 0.05$). See **Tables 6-8**.

Discussion

Since the development of ACDF, it has gradually developed into the classical method of treatment of cervical spondylosis. However, more and more problems have been found with this method. One study confirmed that cervical fusion after ACDF can significantly affect the motion of the cervical spine, even if cervical mobility will be completely lost and need for a second operation. This can significantly affect patient quality of life [18]. Therefore, the appearance of an artificial intervertebral disc provides a new method of treating cervical spondylosis. The current study examined the efficacy of ACDR with traditional ACDF, as surgical methods for cervical spondylotic myelopathy.

According to present results, there were no significant differences between CDR and ACDF in operative times and hospitalization times. However, blood loss of ACDR was significantly less than that in ACDF. Blood loss has an impor-

Table 2. Comparison of the operation between the two groups

	Group A	Group B	P
Operation time (min)	128.54 ± 32.31	132.67 ± 29.82	0.546
Blood loss (mL)	236.76 ± 41.95	328.88 ± 46.17	0.021
Hospitalization time (d)	10.75 ± 3.31	11.23 ± 3.08	0.757

Note: Group A, artificial disc replacement group; group B, anterior cervical discectomy and fusion group.

Table 3. Comparison of VAS scores between the two groups

	Group A	Group B	t	P
Before operation	7.54 ± 1.44	7.33 ± 1.61	5.773	0.643
2 weeks after operation	3.12 ± 0.87***	3.54 ± 0.53***	6.358	0.497
3 months after operation	1.27 ± 0.31$^{\#,***}$	1.44 ± 0.28$^{\#,***}$	4.553	0.783
1 year after operation	1.36 ± 0.26$^{\#,***}$	1.33 ± 0.38$^{\#,***}$	5.587	0.618
3 years after operation	1.29 ± 0.41$^{\#,***}$	1.31 ± 0.37$^{\#,***}$	4.525	0.796

Note: VAS, visual analogue score; group A, artificial disc replacement group; group B, anterior cervical discectomy and fusion group. Compared with 2 weeks after the operation, $^{\#}P < 0.05$; compared with before the operation, $^{***}P < 0.001$.

Table 4. Comparison of JOA scores between the two groups

	Group A	Group B	t/χ^2	P
Before operation	7.38 ± 2.41	7.49 ± 2.39	5.653	0.685
2 weeks after operation	11.66 ± 1.98**	11.23 ± 1.64**	4.543	0.734
3 months after operation	15.23 ± 0.85$^{\#\#,***}$	14.98 ± 1.12$^{\#,***}$	3.654	0.796
1 year after operation	14.76 ± 1.23$^{\#,***}$	15.11 ± 0.68$^{\#\#,***}$	6.346	0.528
3 years after operation	15.42 ± 0.46$^{\#\#,***}$	14.59 ± 1.22$^{\#,***}$	5.355	0.691

Note: JOA, Japanese Orthopedic Association; group A, artificial disc replacement group; group B, anterior cervical discectomy and fusion group. Compared with 2 weeks after the operation, $^{\#}P < 0.05$; Compared with 2 weeks after the operation, $^{\#\#}P < 0.01$; compared with before operation, $^{**}P < 0.01$; compared with before the operation, $^{***}P < 0.001$.

Table 5. Comparison of NID scores between the two groups

	Group A	Group B	t/χ^2	P
Before operation	38.63 ± 5.77	37.47 ± 6.86	4.142	0.754
2 weeks after operation	24.56 ± 4.18**	26.22 ± 4.27**	5.235	0.681
3 months after operation	7.23 ± 3.19$^{\#\#\#,***}$	8.35 ± 3.07$^{\#\#,***}$	4.654	0.718
1 year after operation	6.96 ± 3.21$^{\#\#\#,***}$	7.28 ± 2.53$^{\#\#\#,***}$	5.483	0.669
3 years after operation	7.11 ± 3.73$^{\#\#,***}$	6.89 ± 2.53$^{\#\#\#,***}$	6.245	0.514

Note: NDI, neck disability index; group A, artificial disc replacement group; group B, anterior cervical discectomy and fusion group. Compared with 2 weeks after the operation, $^{\#\#}P < 0.01$; Compared with 2 weeks after the operation, $^{\#\#\#}P < 0.001$; compared with before the operation, $^{**}P < 0.01$; compared with before the operation, $^{***}P < 0.001$.

tant effect on the recovery and prognosis, especially in elderly or infirm patients. An increase of blood loss during the operation will significantly affect hemodynamic changes and lead to fluctuation of blood pressure during the operation. This will affect the prognosis of the patients. Therefore, blood loss should be reduced as much as possible. ACDR is superior to ACDF in this respect. There are many criteria used in evaluating the curative effects of cervical spondylosis surgery. Several representative indicators were selected for the current study. VAS, JOA, and NID scores of the two surgical methods were improved after the operation compared, with scores before the operation. There were no significant differences in satisfactory rates of Odom's criteria between the two groups after the operation, indicating no significant differences in the improvement of pain and the recovery of spinal cord function between the two kinds of surgical methods. Results showed that ACDR could produce the same therapeutic effect as ACDF. According to results, CCI and ROM were significantly decreased and incidence of ASD was significantly increased after ACDF. There were 8 patients that needed to undergo secondary surgeries during the follow-up period of three years. After ACDR, CCI and ROM were slightly higher than those before operation. Incidence of ASD was only 10% after 3 years. This method could retain or even improve cervical spine movement, improving the quality of life of the patients. ACDR was obviously superior to ACDF. After 3 years of follow-ups for 30 patients, no displacement, sinking, or rejection of artificial intervertebral discs occurred. However, one of the most important postoperative complications after ACDR is ectopic ossification. The pathogenesis of heterotopic ossification is complex. Thus far, there are no definite conclusions. Some studi-

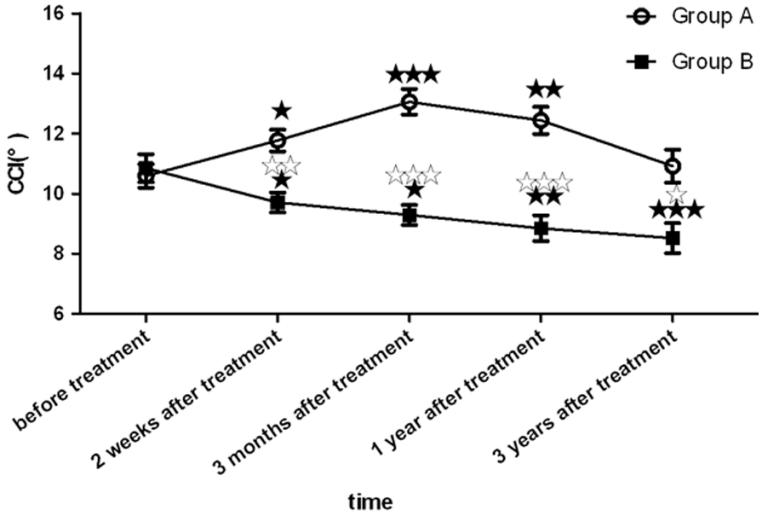

Figure 1. Comparison of CCI between the two groups. CCI, cervical curvature index; group A, artificial disc replacement group; group B, anterior cervical discectomy and fusion group. Compared with before the operation, ★P < 0.05; compared with before the operation, ★★P < 0.01; compared with before the operation, ★★★P < 0.001; compared with group A, ☆P < 0.05; compared with group A, ☆☆P < 0.01; compared with group A, ☆☆☆P < 0.001.

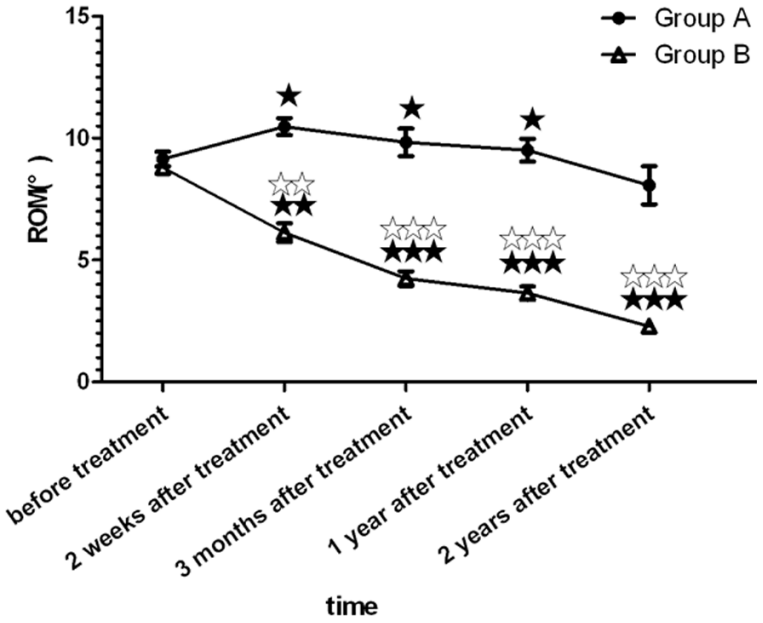

Figure 2. Comparison of ROM between the two groups. ROM, range of motion; group A, artificial disc replacement group; group B, anterior cervical discectomy and fusion group. Compared with before the operation, ★P < 0.05; compared with before the operation, ★★P < 0.01; compared with before the operation, ★★★P < 0.001; compared with group A, ☆☆P < 0.01; compared with group A, ☆☆☆P < 0.001.

es have suggested that it is related to incomplete removal of osteophytes, unsuitable prosthesis, unclean bone fragments, incomplete suction of bleeding during the operation, or inflammation of surrounding muscles caused by intraoperative traction [19, 20]. Ectopic ossification may be characterized by joint swelling and pain in the early stages, limited movement, or even a complete loss of activity in the late stages. This may result in the need for a second operation [21]. Present results showed that the heterotopic ossification rate in the ACDR group was significantly higher than that in the ACDF group. In one case, a complete osseous bridge was formed and cervical movement was almost completely lost, requiring a second operation. Although a small part of the remaining patients developed heterotopic ossification, it did not affect normal life and did not require a second surgery. However, some studies have confirmed that the rate of heterotopic ossification after artificial cervical disc replacement can reach as high as 60% [22, 23]. Studies have shown that incidence rates of heterotopic ossification with different types of prostheses are also different. Bryan prostheses have the lowest incidence of heterotopic ossification, with a 3-year incidence of about 22% [24, 25]. This study confirmed that the heterotopic ossification rate of Bryan prosthesis was 43.3%. However, because study times were short and the numbers of cases were few, the accuracy of incidence should be further investigated.

In conclusion, although the rate of heterotopic ossification of ACDR was significantly higher, incidence of re-operations was only 3.3%. This rate was significantly lower than that of ACDF. There were no other significant differences between ACDR and ACDF. Thus, both are

Table 6. Comparison of satisfactory rates of Odom's criteria between the two groups (%)

	Group A	Group B	t/χ^2	P
2 weeks after operation	79.6	76.7	4.567	0.857
3 months after operation	86.5	83.3	5.644	0.685
1 year after operation	91.8	93.6	4.268	0.884
3 years after operation	97.4	96.7	6.246	0.613

Note: Group A, artificial disc replacement group; group B, anterior cervical discectomy and fusion group.

Table 7. Comparison of ASD rates between the two groups

	Group A	Group B	t/χ^2	P
2 weeks after operation	0	0		
3 months after operation	0	3.3	16.378	0.03
1 year after operation	6.7	20	35.535	< 0.001
3 years after operation	10	30	38.543	< 0.001

Note: ASD, adjacent segmental degeneration; Group A, artificial disc replacement group; group B, anterior cervical discectomy and fusion group.

Table 8. Comparison of re-operation rates and heterotopic ossification between the two groups

	Group A	Group B	t/χ^2	P
Re-operation rate (%)	3.3	26.7	32.648	< 0.001
Heterotopic ossification (n)				
Grade 0	17	27		
Grade I	6	2		
Grade II	3	1		
Grade III	3	0		
Grade IV	1	0		
Heterotopic ossification rate (%)	43.33	10.00	34.322	< 0.001

Note: Group A, artificial disc replacement group; group B, anterior cervical discectomy and fusion group.

good surgical methods for treatment of cervical spondylotic myelopathy. Complications, including ectopic ossification, should be avoided by fine operation and proper prosthesis. The current study examined the curative effects of ACDR in cervical spondylotic myelopathy. Present results, however, were unable to confirm whether ACDR can achieve the same effects in other types of cervical spondylosis.

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Disclosure of conflict of interest

None.

Address correspondence to: Qingjiang Pang, Department of Orthopedics, Hwa Mei Hospital, University of Chinese Academy of Sciences, No.41 Xibei Street, Haishu District, Ningbo 315010, Zhejiang Province, China. Tel: +86-0574-83870248; Fax: +86-0574-83870248; E-mail: pangqingjiang2yf@163.com

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