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Original Article

Efficacy of anterior cervical discectomy and fusion versus artificial cervical disc replacement for cervical degenerative disease

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Abstract: Objective: To compare the clinical efficacy of anterior cervical discectomy and fusion (ACDF) and artificial cervical disc replacement (ACDR) in the management of cervical degenerative disease in patients. Methods: Seventy-nine patients with cervical degenerative disease admitted to The First Hospital of Nanping City Affiliated to Fujian Medical University from January 2012 to December 2014 were assigned to undergo ACDF or ACDR and followed for 3 years. In the ACDF group, 24 patients were male and 19 were female, with an age range of 43 to 55 years (mean, 48.9±1.6 years). All the patients had 36 months of follow-up. In the ACDR group, 21 patients were male and 15 were female and they varied in age from 42 to 57 years (mean, 49.1±1.4 years) and were followed up for 36 months. There were no remarkable differences between the two groups in basic data, as well as imaging data at baseline. The Japanese Orthopaedic Association (JOA) score, the neck disability index (NDI), the visual analogue scale (VAS) for pain in the neck and upper-limb, the Odom scale score, the cervical spine range of motion (ROM) and the cervical curvature index were employed to assess the clinical efficacy of the surgeries in the patients. Results: Greater improvements in the JOA, VAS, and NDI scores after surgery were noted than those before surgery in the two groups ($P<0.05$), but the corresponding scores were insignificantly different between the two groups ($P>0.05$). At the final follow-up after surgery, the excellent and good rate (83.72%) of the Odom scores in the ACDF group was insignificantly different from that (88.89%) in the ACDR group ($P>0.05$). The surgical segments in the ACDF group were fully fused, but the ROM of the surgical segments in the ACDR group was 7.4±3.9, which was mildly different from than before surgery. The cervical spine ROM in the ACDF group was remarkably smaller than that of the ACDR group ($P<0.05$), and that of the ROM group before surgery ($P<0.05$). However, the ROM of the cervical spine in the ACDR group at final follow-up after surgery differed insignificantly from that before surgery ($P>0.05$). The values for the cervical curvature index were strikingly lower in the ACDF group than in ACDR group at 3, 12, 24, and 36 months after surgery. The cervical curvature index in the ACDF group at 36 months was remarkably lower than that before surgery ($P<0.05$), but the cervical curvature index in the ACDR group was insignificantly different from that before surgery ($P>0.05$). Conclusion: Among the patients with cervical degenerative disease, the clinical efficacy of ACDR was similar to that of ACDF, but ACDR was superior to ACDF in maintaining the ROM and physiological curvature of the cervical spine.

Keywords: Anterior cervical discectomy and fusion, artificial cervical disc replacement, cervical degenerative disease, efficacy comparison

Introduction

With the rapid development of society, increasingly people spend longer times bending over their desks to work or bowing their heads to play mobile phone games, cervical degenerative disease is more prevalent and has become a common and frequently-occurring clinical disease [1]. The special structure and the great range of motion (ROM) of cervical spine may affect adjacent spinal cord and nerve roots. Moreover, the vertebral arteries run along the transverse foramen and are surrounded by sympathetic nerves, so cervical lesions are detrimental to the spinal cord, nerves and vessels. The resulted signs and symptoms may influence work, life, and physical health of the patients [2]. As early as 1883, some scholars

recognized that degeneration of the cervical spine contributed to spinal stenosis and spinal cord compression. Since anterior cervical discectomy and fusion (ACDF) was introduced in the 1950s, this technology has been extensively applied in the clinical treatment of cervical degenerative disease, and has also known as the gold standard [3]. Although ACDF has greatly improved the clinical symptoms, the long-term follow-up results demonstrate the loss of normal ROM of the cervical spine in the patients after the surgery. The consequence of adjacent segment degeneration was reported by the scholars worldwide [4, 5]. In this case, anterior cervical non-fusion, namely, artificial cervical disc replacement (ACDR) was developed and has been used in clinical practice [6]. The biggest advantages of ACDR are maximum retention of ROM of the surgical segments and little influence on intervertebral space. As a result, the postoperative kinematic characteristics of the entire cervical spine are close to the preoperative physiological profile. Additionally, ACDR is associated with reduced postoperative surgical segment fusion which otherwise might result in dysfunction of the segment, centralized stress and excessive motion of adjacent segments. ACDR does not increase the stress of adjacent segments, instead it is effective in preventing the complication of accelerated degeneration due to stress changes in adjacent segments [7]. Nevertheless, few studies are focused on follow-ups regarding the safety and efficacy of ACDR [8].

Therefore, in the current study, we made 3 years of follow-up with the patients and compared the efficacy and safety of the ACDF and ACDR, in hope of providing potent evidence for the planning of the protocols in treatment of cervical degenerative disease.

Materials and methods

Patients

Between January 2012 and December 2014, a total of 79 patients with cervical degenerative disease admitted to the Department of Orthopedics in The First Hospital of Nanping City Affiliated to Fujian Medical University were recruited in this study. Among the 79 patients, 45 were male and 34 were female, with an age ranging from 42 to 57 years (mean, 49.2±1.7 years). Forty-two patients had cervical spondylotic myelopathy while 37 had cervical spondylotic radiculopathy. Patients were eligible for enrollment if they had cervical spondylotic myelopathy or radiculopathy, previous 6-week ineffective standard care before enrollment, spinal stenosis, anterior neural compression suitable for anterior approach, and provided written informed consent. Patients were ineligible for enrollment if they had undergone surgeries for cervical degenerative disease, had inflammation, deformity, or tumor in the cervical vertebrae, were required to have other concomitant surgeries, complicated with acute cervical trauma, severe osteoporosis, cervical instability, or associated with ossification of the posterior longitudinal ligaments. Patients were also excluded if they had severe disease involving in the heart, liver, or kidney, or they were unsuitable for treatment by ACDF or ACDR. This study was approved by Ethics Committee Hospital.

Methods

The enrolled patients underwent the surgeries under general anesthesia. Placed in a supine position and with a thin pillow under the shoulder, each patient stretched out the neck backward. The operative part of the patient was fully exposed by the standard Smith-Robinson method [9]. All the patients were managed by the method. After routine sterilization and draping, a transverse incision was made on the right side of the neck. After the skin incision, subcutaneous tissue and platysma were dissected layer by layer till the junction between the internal jugular sheath and the carotid sheath, where the blunt dissection was used to dissect till the prevertebral fascia, allowing the lesion segment fully exposed. Subsequently, the patients in the two groups were treated with the following different procedures.

ACDF procedure: Under the guidance of radiography, a Caspar retractor was mounted at the junction between the superior and inferior vertebral body connected with the diseased intervertebral space, and then the annulus fibrosus located in the anterior part of the intervertebral disc was cut open. The Caspar retractor was employed to distract the intervertebral space, followed by resection of all nucleus pulposus and posterior longitudinal ligaments and clearance of the posterior osteophytes and the spinal nucleus. In this manner, the compression in

this segment was completely relieved. The processed intervertebral space was implanted with Syncage-C Cage (Synthes, Sweden) and bone fragments, and then compressed to realize a chimeric fixation. After the completion of the surgery, the surgical site was visualized under radiography (Toshiba TOSHIBA, Japan). When the surgery was confirmed as satisfactory, appropriate titanium end-plates and screws were used for fixation. After that, suturing was performed. The patients were required to wear neck support for a month after surgery and allowed to ambulate 2 days after surgery.

ACDR procedure: Under the guidance of radiography, the diseased intervertebral disc and its surrounding diseased tissues were removed. After distraction of the involved intervertebral space, the midline was found out for channel grinding. The center was ground after localization. A disc-shaped grinding drill was utilized to grind and dissect the posterior border of the vertebral level, whereas a column-shaped grinding drill was used to grind and dissect the superior and inferior end-plates. The residual osteophytes and ligaments were completely scraped with a curette, and the bilateral nerve root canals were open wider. The osteophytes at the Luschka's joint were completely scraped off with the curette. After full relief of the compression, hemostasis and washing were conducted, followed by implantation of artificial intervertebral discs of the right size. After completion of the surgery, the surgical site was visualized under the radiography. When the surgery was confirmed as satisfactory, suturing was performed. The patients were required to wear neck support for 2 weeks after surgery and allowed to ambulate 2 days after the surgery.

Clinical efficacy assessment

The clinical efficacy of the surgery in the patients was evaluated using the Japanese Orthopaedic Association (JOA) score, the neck disability index (NDI), the visual analogue scale (VAS) score for pain in the neck and upper-limb, as well as the Odom scale score [10-13]. The JOA scores were assessed with the 17-point scoring criteria [14].

The NDI score consists of 10 items (each having six 0-5-point scoring criteria) and ranges from 0 to 50, with higher scores indicating more severe dysfunction or disability of performance status in patients.

On the VAS scale, 0 point indicates no pain; 1-3 indicates mild pain; 4-6 indicates tolerable pain affecting sleep; 7-10 indicates unbearable pain.

On the Odom scale, excellent efficacy indicates the clinical symptoms disappear, and the patient can work normally. Good efficacy indicates most of the clinical symptoms disappear, and the patient can go on working. Fair efficacy indicates the symptoms are relieved, but the patient cannot work normally, whereas poor efficacy indicates the symptoms are not relieved, and they affect the patient's normal work. The formula for calculation of the excellent and good rate of the Odom score in patients was as follows: Excellent and good rate = (Excellent + Good)/Total number of patients * 100%.

The values for the Cobb angles of the patients were measured according to the data from the imaging system in The First Hospital of Nanping City Affiliated to Fujian Medical University. Over the whole range of overextension to over-flexion, the Cobb angle values of the C2-C7 segments on the radiographs were measured to evaluate the ROM of the entire cervical spine. The overall curvature of the cervical spine was defined as the intersection angle formed by the inferior border of C2 segment and the inferior border of C7 segment, whereas the ROM of the entire cervical spine was defined as the changes in the overall cervical curvature in the preoperative and postoperative overextension to over-flexion of cervical spine on the radiographs [15, 16]. The measurements were utilized to evaluate the changes in the normal physiological functions of the cervical spine.

Statistical analysis

The data analyses were performed with the use of the SPSS statistical software, version 17. Continuous variables are presented as mean ± standard deviation, with independent sample t-tests for the intergroup comparisons, and paired t-tests for intragroup comparisons. Categorical variables were compared using the two-tailed chi-square tests or the two-tailed

Table 1. Basic and clinical characteristics of the patients

Variable	ACDF group (n, %)	ACDR group (n, %)	t/X^2	P
Case	43	36		
Sex			0.341	0.642
Male	24 (55.8)	21 (58.3)		
Female	19 (44.2)	15 (41.7)		
Age (year)	48.9±1.6	49.1±1.4	-0.795	0.412
Lesion subtype				
CSM	22 (51.2)	21 (58.3)	0.316	0.547
CSR	21 (48.8)	15 (41.7)	0.298	0.518
Involved segment	34.0±3.4	35.0±2.8	-0.845	0.521*
C3-4	1 (2.3)	2 (5.6)		
C4-5	12 (27.9)	10 (27.8)		
C5-6	27 (62.8)	21 (58.3)		
C6-7	3 (7.0)	3 (8.3)		
PCIDB				
JOA score	9.0±1.3	9.3±1.6	-0.842	0.678
VAS score	3.3±2.0	3.1±2.5	-0.803	0.841
NDI score	23.39±6.41	22.24±5.01	-0.741	0.652
C2-C7 angle (°)	18.5±8.1	14.5±12.1	-1.352	0.247
ROM (°)				
Surgical segment	9.2±4.9	8.1±4.2	-1.214	0.236
C2-C7	43.4±16.6	46.9±12.5	0.914	0.358

Note: *Fisher precision probability test. ACDF denotes anterior cervical discectomy and fusion, ACDR artificial cervical disc replacement, CSM cervical spondylotic myelopathy, CSR cervical spondylotic radiculopathy, JOA Japanese Orthopaedic Association, VAS visual analogue scale, NDI neck disability index, PCIDB preoperative clinical and imaging data at baseline and ROM range of motion.

Table 2. JOA scores of the patients before and after surgery

Time	ACDF group (n=43)	ACDR group (n=36)	t	P
Pre-surgery	9.3±1.6	9.0±1.3	-0.842	0.678
3 mon after surgery	14.9±1.1	15.6±1.7	0.985	0.741
12 mon	14.9±1.8	14.8±1.4	0.841	0.514
24 mon	15.3±1.2	14.4±1.7	0.548	0.301
36 mon	15.4±1.4	14.3±2.0	0.558	0.324
t	2.354	2.187		
P	0.024*	0.013*		

Note: *Comparison of the JOA scores before and 36 mon after surgery. ACDF denotes anterior cervical discectomy and fusion, ACDR artificial cervical disc replacement, and JOA Japanese Orthopaedic Association.

Fisher exact probability tests. Rank sum tests were employed for intergroup comparisons of class variables and the paired rank sum tests for intragroup comparisons. P<0.05 was deemed as significantly different.

Results

Basic and clinical characteristics of the patients

A total of 79 patients were recruited in this study. Among them, 43 patients were assigned to receive ACDF (ACDF group). There were 24 males and 19 females with an age of 43-55 years (mean, 48.9±1.6 years). Cervical spondylotic myelopathy occurred in 22 patients and cervical spondylotic radiculopathy in 21 patients. One patient had the surgical segment C3-4, 12 had the surgical segment C4-5, 27 had the surgical segment C5-6, 3 had the surgical segment C6-7; all the patients had 36 months of follow-up. The remaining 36 patients were assigned to undergo ACDR (ACDR group); 21 patients were male and 15 were female, with an age of 42-57 years (mean, 49.1±1.4 years). Cervical spondylotic myelopathy occurred in 20 patients and cervical spondylotic radiculopathy in 16 patients whereas 2 patients had the surgical segment C3-4, 10 had the surgical segment C4-5, 21 had the surgical segment C5-6, and 3 had the surgical segment C6-7. All the patients had 36 months of follow-up. The patients in the two groups were generally well-balanced in basic characteristics, as well as preoperative clinical and imaging data (P>0.05, **Table 1**).

JOA scores of the patients

The preoperative JOA scores of the patients were low in both groups, and the results of the 3 years of follow-up after treatment revealed that the JOA scores at 3, 12, 24, and 36 months after surgery were 14.9±1.1, 14.9±1.8, 15.3±1.2 and 15.4±1.4 in the ACDF group, and 15.6±1.7, 14.8±1.4, 14.4±1.7, and 14.3±2.0 in the ACDR group. The JOA scores were insignificantly different between the two groups at the same time points (P>0.05), but the scores at 36 months in the two groups differed remarkably from those before surgery (P<0.05, **Table 2**).

Table 3. VAS scores of the patients before and after surgery

Time	ACDF group (n=43)	ACDR group (n=36)	t	P
Pre-surgery	3.3±2.0	3.1±2.5	0.384	0.841
3 mon after surgery	1.8±0.6	1.4±0.6	0.698	0.401
12 mon	1.3±0.7	1.3±0.5	0.574	0.642
24 mon	1.2±0.3	1.1±0.6	0.745	0.148
36 mon	0.9±0.7	1.0±0.6	0.954	0.214
t	2.584	2.847		
P	0.002*	0.004*		

Note: *Comparison of the VAS scores before and 36 mon after surgery. ACDF denotes anterior cervical discectomy and fusion, ACDR artificial cervical disc replacement, and VAS visual analogue scale.

Table 4. NDI scores of the patients before and after surgery

Time	ACDF group (n=43)	ACDR group (n=36)	t	P
Pre-surgery	23.39±6.41	22.24±5.01	0.598	0.652
3 mon after surgery	6.81±2.71	5.51±1.72	0.987	0.124
12 mon	5.01±2.03	4.51±1.76	0.687	0.541
24 mon	3.54±1.14	3.12±1.24	0.574	0.648
36 mon	3.12±1.12	2.71±0.91	0.848	0.224
t	3.187	3.014		
P	<0.001*	<0.001*		

Note: *Comparison of the NDI scores before and 36 mon after surgery. ACDF denotes anterior cervical discectomy and fusion, ACDR artificial cervical disc replacement, and NDI neck disability index.

Table 5. Odom scores of the patients at the final follow-up after surgery (n, %)

Odom score	Excellent	Good	Fair	Poor
ACDF group (n=43)	27 (62.79)	9 (20.93)	7 (16.28)	0 (0.00)
ACDR group (n=36)	21 (58.33)	11 (30.56)	4 (11.11)	0 (0.00)
Z		-0.158		
P		0.873		

Note: ACDF denotes anterior cervical discectomy and fusion, ACDR artificial cervical disc replacement.

VAS scores of the patients

The preoperative VAS scores of the patients were high in both groups, and the results of the 3 years of follow-up after treatment indicated that the VAS scores at 3, 12, 24, and 36 months after surgery were 1.8±0.6, 1.3±0.7, 1.2±0.3, and 0.9±0.7 in the ACDF group, and 1.4±0.6, 1.3±0.5, 1.1±0.6, and 1.0±0.6 in the ACDR group. The VAS scores were insignificantly different between the two groups at the same time points (P>0.05), but the scores at 36 month in both groups differed strikingly from those before surgery (P<0.05, **Table 3**).

NDI scores of the patients

The preoperative NDI scores of the patients were higher than 20 points in both groups, and the results of the 3 years of follow-up after surgery showed that the NDI scores at 3, 12, 24, and 36 months after surgery were 6.81±2.71, 5.01±2.03, 3.54±1.14, and 3.12±1.12 in the ACDF group, and 5.51±1.72, 4.51±1.76, 3.12±1.24, and 2.71±0.91 in the ACDR group. The JOA scores differed insignificantly between the two groups at the same time points (P>0.05), but the scores at 36 months in the two groups differed significantly from those before surgery (P<0.05, **Table 4**).

Odom scores of the patients

According to the Odom scores, insignificant disparities were noted between the excellent and good rate (83.72%) of the ACDF group and that (88.89%) of the ACDR group at the final follow-up of surgery (P>0.05, **Table 5**).

ROM of surgical segments and cervical spine of the patients

The ROM of surgical segments before surgery was different insignificantly between the two groups (P> 0.05). The surgical segments of the patients in the ACDF group achieved full fusion at the final follow-up after surgery. The ROM (7.4±3.9) of surgical segments differed insignificantly from that before surgery in the ACDR group (P>0.05). There were insignificant differences in the ROM of cervical spine between the two groups before surgery (P>0.05). The ROM of cervical spine declined substantially in the ACDF group at the final follow-up, and was remarkably different from that in the ACDR group at the final follow-up, and that before surgery (P<0.05, **Table 6**).

Table 6. ROM of surgical segments and cervical spine of the patients

Variable	Case	ROM (°)			
		Surgical segment		Cervical spine	
		Pre-surgery	Final follow-up	Pre-surgery	Final follow-up
ACDF group	43	9.2±4.9	0	43.4±16.6	29.1±9.2*
ACDR group	36	8.1±4.2	7.4±3.9	46.9±12.5	39.1±14.9
t		0.941	2.957	0.863	2.456
P		0.236	0.001	0.358	0.032

Note: *Compared with that before surgery (P<0.01). ACDF denotes anterior cervical discectomy and fusion, ACDR artificial cervical disc replacement, and ROM range of motion.

Table 7. Cervical curvature index of the patients

Time	ACDF group (n=43)	ACDR group (n=36)	t	P
Pre-surgery	14.71±3.02	14.31±2.78	0.521	0.612
3 mon after surgery	10.41±2.19	13.61±1.91	-2.541	0.001
12 mon	11.91±2.98	13.78±1.86	-2.165	0.014
24 mon	12.31±2.41	13.84±1.76	-1.697	0.036
36 mon	12.82±2.29	13.91±1.59	-1.484	0.042
t	2.869	0.532		
P	0.001*	0.594*		

Note: *Comparison of the values for cervical curvature index before and 36 mon after surgery. ACDF denotes anterior cervical discectomy and fusion, ACDR artificial cervical disc replacement.

Cervical curvature index of the patients

The patients in the two groups differed insignificantly in the values for the cervical curvature index before surgery (P>0.05), whereas the values of the cervical curvature index at 3, 12, 24, and 36 months after surgery were remarkably lower in the ACDF group than in the ACDR group (all P<0.05). Moreover, the value at 36 months in the ACDF group was considerably different from that before surgery (P<0.05, **Table 7**).

Discussion

It has been half a century since ACDF was applied to treat cervical degenerative disease. Multiple clinical studies demonstrate that ACDF is effective in relief of the clinical symptoms, improvement of the neurologic functions, and enhancement of the stability of the cervical spine. ACDF has been extensively used in clinical practice, but it has the disadvantages of constraining the ROM of the surgical segment and contributing to the degeneration of adjacent segments [4, 5, 17]. Given the drawbacks of the conventional technique, ACDR came into being accordingly. ACDR is characterized by maintenance of the surgical segment mobility and normalization of the kinematics and mechanics of adjacent segments. Hence, it can not only guarantee the stability of surgical segments and recovery of the cervical curvature, but also enable the surgical segments to recover the normal ROM after surgery. In this manner, ACDR broke out the status quo of static fixation and decompression after ACDF in patients [6].

As far as the clinical symptoms are concerned, this study showed that the JOA scores after surgery in the two groups increased substantially. The scores at 36 months after surgery were greatly different from those before surgery in the same group, but differed insignificantly between the two groups. The VAS and NDI scores in both groups decreased considerably after surgery. The scores at 36 months after surgery were different from those before surgery in the same group, but differed insignificantly between the two groups. The excellent and good rate of the Odom scores at the final follow-up was 83.72% in the ACDF group and 77.78% in the ACDR group, so they were different insignificantly. As a result, the patients in the two groups were largely similar in relief of clinical symptoms. Earlier studies revealed that ACDR was superior to ACDF in the JOA scores, VAS scores, NDI scores, the ROM of the cervical spine, as well as adverse events [18, 19]. In a study with a long-term follow-up, the VAS and NDI scores of patients increased strikingly after ACDR and the rate of reoperation in adjacent segments was 21%, so the researchers argued that ACDR was safe and effective [20]. In our current study, the VAS and NDI scores were improved remarkably at 3 months after surgery in the two groups. Though greater improvements were observed in the ACDR group, the difference was insignificant (P>0.05). The VAS

and NDI scores of both groups were improved substantially over time as compared with those before surgery. Such non-synchronization was also reflected in the excellent and good rates of the Odom scores. The postoperative excellent and good rate in the ACDR group was higher than that of the ACDF group, though insignificantly ($P>0.05$). This suggests that the fact that the patients in the ACDR group could alleviate the clinical symptoms in the early stage and continue to treat for 3 years might be related to the shorter duration of neck support use and earlier exercise of cervical spine among the patients.

When it comes to the imaging improvements, fusion and smaller ROM of the surgical segments, and greater ROM of adjacent segments were found among the patients after ACDF [21]. In long-term follow-up, degeneration of adjacent segments in different degrees, disappearance of physiological curvature, and backward extrusion of cervical spine were noted in the patients with ACDF [22]. By contrast, in numerous follow-ups, fewer events of adjacent segment degeneration were observed in the patients with ACDR, and the clinical efficacy of ACDR was basically similar to that of ACDF [23-27]. In our current study, we found that at the final follow-up, the surgical segments were completely fused in patients of the ACDF group, whereas the ROM (7.4±3.9) of the surgical segments in the ACDR group differed insignificantly from that of the same group before surgery ($P>0.05$). Additionally, the ROM of the surgical segments in the ACDF group at the final follow-up dropped more strikingly when compared with those of the ACDR group both at the final follow-up and before surgery. The cervical curvature index after surgery was remarkably lower in the ACDF group than in the ACDR group, which was consistent with the results reported by Kim [28]. Moreover, according to a previous report of long-term follow-up, the improvements in the surgical segment, the adjacent segments, and the cervical curvature index in the ACDR group were greater than those in the ACDF group.

There are the following limitations in this study: no randomization was conducted to the patients in the two groups, and the sample size was small. As for the selection of surgeries, the patients should be explained in details according to their conditions. The final choice was at the discretion of the patients, hence there was a bias of selection.

In summary, for the patients with cervical degenerative disease, ACDR was similar to ACDF in clinical efficacy but superior to ACDF in maintaining the ROM and physiological curvature of the cervical spine. It was safe and reliable during follow-up.

Disclosure of conflict of interest

None.

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