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Prosthesis in Anterior Cervical Herniated Disc Approach Does Not Prevent Radiologic Adjacent Segment Degeneration

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Study Design. Retrospective analysis using data from RCTs.

Objective. This study aimed to report on the incidence of radiological adjacent segment degeneration (ASD) in patients with cervical radiculopathy due to a herniated disc that were randomized to receive cervical arthroplasty or arthrodesis.

Summary of Background Data. Cervical disc prostheses were introduced to prevent ASD in the postsurgical follow-up. However, it is still a controversial issue.

Methods. Two hundred fifty-three patients were included in two randomized, double-blinded trials comparing anterior cervical discectomy with arthroplasty (ACDA), with intervertebral cage (ACDF), or without intervertebral cage (ACD) for one-level disc herniation. Neutral lateral radiographs were obtained preoperatively, at 1- and 2-year follow-up after surgery. Radiological ASD was evaluated on X-ray and defined by a decrease in disc height and the presence of anterior osteophyte formation on both the superior and the inferior level in relation to the target level.

Results. Radiological ASD was present in 34% of patients at baseline and increased to 59% at 2-year follow-up in the arthrodesis groups (ACD and ACDF combined), and to 56% in the arthroplasty group. Progression of radiological ASD was present in 29% of patients in the arthrodesis group and in 31% of patients in the arthroplasty group for 2-year follow-up.

Conclusion. Radiological ASD occurs in a similar manner in patients who were subjected to arthrodesis in cervical radiculopathy and in patients who received arthroplasty to maintain motion. Current data tend to indicate that the advantage of cervical prosthesis in preventing radiological ASD is absent.

Key words: adjacent segment degeneration, arthroplasty, cervical discectomy.

Level of Evidence: 2

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Anterior cervical discectomy and fusion (ACDF) has been a common surgical treatment for cervical radiculopathy since it was initially described in the 1950s[1–3] and became the gold standard procedure. The procedure remained largely unchanged until the 1990s. Cages, and allograft bone were introduced to reduce the complications of harvesting autologous bone graft from the iliac crest. To decrease the prevalence of pseudarthrosis, plates were successfully introduced.[4–6] However, it was shown that arthrodesis of a motion segment caused by ACDF leads to increased mechanical load at the adjacent levels,[7] and hypothetically this can contribute to degeneration of the cervical discs at the adjacent levels (ASD). In the effort to avoid ASD in postsurgical follow-up, artificial disc (ACDA) was developed with the rationale of maintaining motion. Some researchers reported that patients treated with ACDF have higher rates of ASD than those who underwent ACDA during follow up.[8–12] However, baseline information lacked in most studies. It is highly likely that pre-existing degeneration of the cervical spine, and thus also of the levels adjacent to the operated level, continues, and that

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TABLE 1. The Classification of Adjacent Segment Degeneration (From Goffin *et al*[12])

	Disc Height	Anterior Osteophyte Formation
Normal	Same as adjacent disc	No anterior osteophyte
Mild	75–100% of normal disc	Just detectable anterior osteophyte
Moderate	50–75% of normal disc	Clear anterior osteophyte <25% of AP diameter of corresponding vertebral body
Severe	<50% of normal disc	Clear anterior osteophyte >25% of AP diameter of corresponding vertebral body

AP indicates anteroposterior.

the finding of ASD at follow-up is merely the result of pre-existent degeneration with possible additional pre-existing degeneration.

In our clinics we performed two randomized double-blind trials in which we treated patients with cervical radiculopathy with anterior discectomy. One-third of patients received a PEEK cage in the intervertebral space to restore disc height, leading to fusion of the segments (ACDF). One-third of patients did not receive an intervertebral spacer leading to fusion without restoring disc height (ACD) and one-third of patients received arthroplasty leading to preservation of motion (ACDA).

The objective of this retrospective cohort study is to compare the incidence of radiological ASD in patients who were enrolled in those two trials.

PATIENTS AND METHODS

Study Design

NECK Trial

A prospective, randomized double-blind multicenter trial among patients with cervical radiculopathy due to single-level disc herniation was conducted. Patients were randomly assigned into three groups: anterior cervical discectomy with arthroplasty (ACDA; activC, Aesculap AG, Tuttlingen, Germany), anterior cervical discectomy with fusion (ACDF; Cage standalone) and anterior cervical discectomy without fusion (ACD). The design and study protocol were published previously.[13] The protocol was approved by medical ethics committees, including an approval for randomization after anesthetic induction. All patients gave informed consent. The 2-year follow-up data revealed no differences in clinical outcomes.[14]

PROCON Trial

The trial design was a prospective, double-blind, single-center randomized study, with a three-arm parallel group. Patients were randomly allocated into three groups: ACDA (Bryan disc prosthesis, Sofamor Danek, Kerkrade, the Netherlands), ACDF (Cage standalone, DePuy Spine, Johnson and Johnson, Amersfoort, the Netherlands), and ACD. The trial was approved by medical ethics committee and all patients gave informed consent. The design and study protocol were published previously.[15] The follow-up data up to 8 years postsurgery revealed no differences in clinical outcomes.[16]

Radiographic Outcomes

Flexion-extension radiographs were obtained preoperatively and at 12 and 24 months postoperatively. The range of motion (ROM) at index level was defined as the intervertebral sagittal rotation between full flexion and extension. The ROM at index level was measured on dynamic lateral radiographs with a custom developed image analysis tool (BMGO, KU Leuven, Belgium), which has a measurement error of 0.3 degree and 0.3 mm and excellent interrater and intrarater agreement (intraclass correlation coefficient >0.75).[17] Fusion was defined as ROM less than 4 degrees.[18,19] Lateral radiographs of the cervical spine were obtained with the patients in a neutral standing position and instructed to look straight ahead, with hips and knees extended. Radiological ASD was evaluated based on the height of the adjacent level disc (4 grades) and the anterior osteophyte formation (4 grades) on X-rays according to the classification reported by Goffin *et al*[7] preoperatively, and at 12 and 24 months postoperatively (Table 1).

Radiological ASD was defined in three different ways:

1. If the patient did not have any loss of disc height and did not have osteophyte formation (*normal)*, the patient was scored as "non-ASD." All patients who had loss of disc height, or osteophyte formation, either being mild, moderate or severe, were scored as "ASD."
2. If the patient had either no or mild loss of disc height (75–100% of the adjacent level, not being the target level) or no or a mild osteophyte formation the patient was scored as "non-ASD" and all other patients with moderate or severe loss of disc height or osteophyte formation were scored as "severe ASD."
3. In order to evaluate the progression of ASD during follow-up period, the patient was judged as positive if the patient increased in ASD grading during follow-up period. For the patient who did not increase in Goffin score, the ASD progression was marked as negative.

The radiographs were independently evaluated by one senior neurosurgeon dedicated to spine surgery and a junior medical doctor educated for this purpose. If deemed necessary, a third reviewer (senior neurosurgeon) was consulted. The reviewers were blinded to the type of surgery at baseline. The reviewers were not provided with any clinical information of the included patients. Prior to

TABLE 2. Patient Demographics by Treatment Arm

	ACD	ACDF	ACDA	Total	*P* Value
Population	83	85	85	253	
Age (years, mean ± SD)	45.3 ± 6.7	45.6 ± 7.6	44.8 ± 7.7	45.2 ± 7.3	0.787
Body mass index (mean ± SD)	26.2 ± 3.8	26.6 ± 4.7	26.7 ± 4.1	26.5 ± 4.2	0.726
Sex					
Male	42	37	43	122	0.939
Female	41	48	42	131	
Smoking					
Yes	33	40	41	118	0.305
No	50	43	44	133	
Alcohol					
Yes	46	52	55	153	0.565
No	37	31	30	98	
Herniated level					
C4-C5	1	2	0	3	
C5-C6	46	39	40	125	
C6-C7	36	43	45	124	
C7-Th1	0	1	0	1	

ACD indicates anterior cervical discectomy; ACDF, anterior cervical discectomy with fusion; ACDA, anterior cervical discectomy with arthroplasty; SD, standard deviation.

the evaluation of radiographs, the reviewers met in person to evaluate and refine the definitions.

Statistical Analysis

All the data were presented as mean ± standard deviation. Baseline and follow-up characteristics of the ACD, ACDF, and ACDA treatment group were compared using analysis of variance for continuous data and chi-square test for categorical data. The patients in the ACD and ACDF groups were combined as ''arthrodesis group,'' in order to be compared with the patients in ''arthroplasty'' group (ACDA). The incidence of radiological ASD between two groups was compared using chi-square test for categorical data. Tests were two tailed, and a P value of < 0.05 was considered significant. SPSS software, version 23.0 was used for all statistical analyses (SPSS Inc, Chicago, IL).

RESULTS

In the NECK trial, 111 patients were included. Thirty-eight patients were randomly assigned to ACD, 38 patients to ACDF, and 35 patients ACDA. At baseline, X-ray data were available for 107 patients and for 98 patients at 2-year follow-up.

In the PROCON trial, 142 patients were randomized into ACD (45 patients), ACDF (47 patients) or ACDA (50 patients). At baseline, X-ray data were available for 121 patients and for 70 patients at 2-year follow-up.

Demographics

Baseline characteristics are presented in Table 2. The mean age of the study population was 45.2 years (ranging from 27 to 70 yr). There was no difference regarding baseline characteristics between treatment groups. Surgery was most frequent at levels C5-C6 and C6-C7.

Fusion Rate

If a cut-off value of 4 degrees movement was taken into consideration, it was demonstrated that 96% of patients in the ACD group (44 patients) and 86% of patients in the ACDF group (38 patients) were fused at 2 years follow-up, and that 63% of patients in the ACDA group (36 patients) maintained mobile.

Incidence of Radiological ASD (Combined Superior With Inferior Level)

Preoperatively, the incidence of ASD did not differ in the two groups: 37% in the arthrodesis group (56 patients), and 29% (22 patients) in the arthroplasty group ($P = 0.2$). One year after surgery, the incidence of ASD increased, but was still comparable in the two groups: 47% (59 patients) in the arthrodesis group, and 47% (35 patients) in arthroplasty group ($P = 0.98$). At 2-year follow-up, ASD increased to 59% of patients in the arthrodesis group (63 patients), and to 56% (34 patients) in the arthroplasty group. Likewise, there was no statistically significant difference between two groups ($P = 0.67$).

At baseline the incidence of severe ASD was comparable in the two groups: 15% (22 patients) in the arthrodesis group, and 13% (10 patients) in the arthroplasty group ($P = 0.75$). Likewise, 1 year as well as at 2-year follow-up after surgery, the incidence of ASD still did not differ in the two groups: 22% (28 patients) in the arthrodesis group, and 15% (11 patients) in the arthroplasty group ($P = 0.18$), respectively, 27% (29 patients) in the arthrodesis group, and 20% (12 patients) in the arthroplasty group ($P = 0.28$).

At 1-year follow-up, the proportion of patients with positive ASD progression did not differ in the two groups: 21% (22 patients) of patients demonstrated progression in the arthrodesis group, and 21% (13 patients) in the

arthroplasty group ($P = 0.99$). Again, at 2 years after randomization, the proportion of positive ASD progression was comparable in the two arms (29% in the arthrodesis group (27 patients), and 31% in the arthroplasty group (17 patients); $P = 0.78$).

An additional analysis in the arthroplasty group, comparing patients who maintained mobile (63%) to patients who demonstrated fusion (although they received a prosthesis (36%)), demonstrated no difference between the groups (ASD, $P = 0.384$; severe ASD, $P = 0.473$; positive ASD progression, $P = 1.0$)

Incidence of Radiological ASD (Superior and Inferior Level Respectively)

In the analysis of ASD at superior and inferior level separately, the data on the degree of ASD were demonstrated in Table 3. If ASD was evaluated by the loss of disc height, the incidence of ASD was comparable between arthrodesis and arthroplasty at baseline and at 2-year follow-up, at either superior or inferior level (Table 4). When ASD was judged by the presence of anterior osteophyte formation, a similar incidence of ASD was shown between arthrodesis and arthroplasty, both at baseline and at 2 years after surgery, either at superior level or inferior level (Table 4).

DISCUSSION

The rationale of cervical motion preservation technology has been not only maintenance of normal mobility at the index level, but also reduction of accelerated degeneration at adjacent levels. Based on a recent systematic review,[20] the previous research failed to report the incidence of radiological ASD among patients who suffered from radiculopathy exclusively. In this study, we have evaluated the degree of ASD according to the decrease of disc height and the severity of osteophyte formation on X-rays, at both superior and inferior levels. We demonstrated that there was no difference in ASD in patients who underwent cervical anterior discectomy with fusion or patients who received an artificial cervical disc, neither at superior nor inferior level.

Disc degeneration and osteophyte formation are physiological processes, and therefore, the observation of degeneration at the adjacent disc levels is not necessarily the result of adjacent segment disease. Particularly in a population with a mean age of 45, it is only the pre-existing degeneration to observe during a degenerative process.

In accordance, our study documented not only radiological ASD in follow-up, but also evaluated degeneration of the cervical spine at the adjacent levels of the target level at baseline. This type of degeneration existed in 34% of the patients at baseline. A similar result was reported previously by Coric *et al*,[8] who demonstrated that ASD was present in more than 50% of patients before undergoing ACDF or ACDA. Similarly, in the study of Hilibrand *et al*,[21] 63% of the patients who developed ASD had sign of denegation preoperatively. It is remarkable that only a minority of studies (only in six of the 31 studies that evaluated ASD in published systematic-analysis in patients with cervical

TABLE 3. Adjacent Segment Degeneration at Superior and Inferior Level

	Superior Level						Inferior Level					
	Disc Height			Osteophyte			Disc Height			Osteophyte		
	ACD	ACDF	ACDA	ACD	ACDF	ACDA	ACD	ACDF	ACDA	ACD	ACDF	ACDA
Baseline												
Normal	67 (94.4%)	72 (90%)	71 (93.4%)	52 (73.2%)	59 (73.8%)	60 (80%)	50 (90.9%)	58 (92.1%)	59 (92.2%)	44 (80%)	52 (82.5%)	54 (84.4%)
Mild	4 (5.6%)	8 (10%)	4 (5.3%)	13 (18.3%)	14 (17.5%)	8 (10.7%)	5 (9.1%)	4 (6.3%)	2 (3.1%)	6 (10.9%)	7 (11.1%)	6 (9.4%)
Moderate	0	0	0	5 (7%)	5 (6.3%)	6 (8%)	0	1 (1.6%)	3 (4.7%)	4 (7.3%)	4 (6.3%)	1 (1.6%)
Severe	0	0	1 (1.3%)	1 (1.4)	2 (2.5)	1 (1.3%)	0	0	0	1 (1.8%)	0	3 (4.7%)
1 year												
Normal	60 (92.3%)	51 (85%)	67 (90.5%)	44 (67.7%)	43 (70.5%)	51 (68.9%)	47 (87%)	41 (87.2%)	55 (87.3%)	41 (75.9%)	37 (77.1%)	47 (74.6%)
Mild	5 (7.7%)	7 (11.7%)	6 (8.1%)	14 (21.5%)	11 (18%)	17 (23%)	7 (13%)	5 (10.6%)	5 (7.9%)	5 (9.3%)	6 (12.5%)	10 (15.9%)
Moderate	0	2 (3.3%)	0	4 (6.2%)	5 (8.2%)	4 (5.4%)	0	1 (2.1%)	2 (3.2%)	6 (11.1%)	5 (10.4%)	1 (1.6%)
Severe	0	0	1 (1.4%)	3 (4.6%)	2 (3.3%)	2 (2.7%)	0	0	1 (1.6%)	2 (3.7%)	0	5 (7.9%)
2 year												
Normal	50 (89.3%)	43 (86%)	55 (91.7%)	31 (55.4%)	30 (60%)	37 (61.7%)	35 (85.4%)	37 (92.5%)	46 (88.5%)	26 (63.4%)	24 (60%)	37 (71.2%)
Mild	6 (10.7%)	5 (10%)	4 (6.7%)	15 (26.8%)	13 (26%)	17 (28.3%)	6 (14.6%)	2 (5%)	2 (3.8%)	8 (19.5%)	9 (22.5%)	8 (15.4%)
Moderate	0	2 (4%)	0	7 (12.5%)	5 (10%)	4 (6.7%)	0	1 (2.5%)	2 (3.8%)	4 (9.8%)	5 (12.5%)	3 (5.8%)
Severe	0	0	1 (1.7%)	3 (5.4%)	2 (4%)	2 (3.3%)	0	0	2 (3.8%)	3 (7.3%)	2 (5%)	4 (7.7%)

ACD indicates anterior cervical discectomy; ACDF, anterior cervical discectomy with fusion; ACDA, anterior cervical discectomy with arthroplasty.

TABLE 4. Incidence of ASD at Superior and Inferior Level

		ASD (Defined by Loss of Disc Height)			ASD (Defined by Osteophyte Formation)		
Level	**Follow-up**	**Arthrodesis**	**Arthroplasty**	***P***	**Arthrodesis**	**Arthroplasty**	***P***
Superior level	Baseline	12 (7.9%)	5 (6.6%)	0.712	40 (26.5%)	15 (20%)	0.284
	1-year	14 (11.2%)	7 (9.5%)	0.699	39 (31.0%)	23 (31.1%)	0.985
	2-year	13 (12.3%)	5 (8.3%)	0.434	45 (42.5%)	23 (38.3%)	0.604
Inferior level	Baseline	10 (8.5%)	5 (7.8%)	0.877	22 (18.6%)	10 (15.6%)	0.609
	1-year	13 (12.9%)	8 (12.7%)	0.974	24 (23.5%)	16 (25.4%)	0.786
	2-year	9 (11.1%)	6 (11.5%)	0.939	31 (38.3%)	15 (28.8%)	0.265

ASD indicates adjacent segment degeneration.

myelopathy and/or radiculopathy[20]) data on baseline ASD was reported.

It has been suggested before that the addition of a plate to affirm the cage and to further stabilize the two cervical segments may increase the risk of ASD.[22] In a recent systematic review it was discussed that the prevalence of adjacent segment degeneration in ACDF is more prevalent in articles from the US, since plating is common there, whereas in Europe ACDF without a plate is common. It was mentioned that it is an unanswered question whether adjacent segment degeneration difference between ACDA and ACDF still exists if ACDF lacks plating.[23] This question can be answered in the present study: cage standalone was used in the ACDF approach, and a comparable incidence of ASD was observed between groups.

In the 2-year follow-up period of our patients, ASD increased to 58%, irrespective of surgical treatment. It is generally presumed that the development of ASD is a slow process, and that therefore long-term follow-up periods are essential in order to properly judge the occurrence of ASD. Nevertheless, an increase of circa 20% of ASD (or 20% of patients with progression of ASD) in a group of 250 patients, within the first 2 years after surgery, without a difference between the three groups, justifies the conclusion that ASD is not prevented by the use of cervical prosthesis.

A limitation of the current study may be that evaluating ASD on x-ray will depend on the quality of the images. Another flaw is the focus on radiological ASD. Clinical ASD would be represented by invalidating radicular symptoms due to a herniated disc at the adjacent level. If these complaints would be significantly invalidating, subsequent surgery would follow. Therefore, the number of reoperations in the two groups for this diagnosis would be a suitable measure for clinical ASD. However, reoperation numbers are too small to draw meaningful conclusions in this study.

CONCLUSION

Cervical disc arthroplasty does not result in less degeneration at the adjacent levels in comparison with patients who were subjected to arthrodesis. The proclaimed advantage of implanting a prosthesis, preventing ASD, is likely to be absent.

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