Motion preservation in cervical prosthesis surgery: Implications for adjacent segment degeneration

Yang, X.

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Chapter 6

The Association of Cervical Sagittal Alignment with Adjacent Segment Degeneration

Xiaoyu Yang MD, MSc[1], Ronald H.M.A. Bartels MD, PhD[2], Roland Donk[3], Mark P. Arts MD, PhD[4], Caroline G.M. Goedmakers[1], Carmen L.A. Vleggeert-Lankamp MD, PhD[1]

[1]Department of Neurosurgery, Leiden University Medical Centre, Leiden, The Netherlands

[2]Department of Neurosurgery, Radboud University Medical Centre, Nijmegen, The Netherlands

[3]Department of Orthopaedic Surgery, Via Sana Clinics, Mill, The Netherlands

[4]Department of Neurosurgery, Haaglanden Medical Centre, The Hague, The Netherlands

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ABSTRACT

Objective

Cervical spine surgery may affect sagittal alignment parameters and induce accelerated degeneration of the cervical spine. Cervical sagittal alignment parameters of surgical patients will be correlated with radiological adjacent segment degeneration (ASD) and with clinical outcome parameters.

Methods

Patients were analysed from two randomized, double-blinded trials comparing anterior cervical discectomy with arthroplasty, with intervertebral cage, and without intervertebral cage. C2-C7 lordosis, T1 slope, C2-C7 sagittal vertical axis and the occipito-cervical inclination (OCI) were determined as cervical sagittal alignment parameters. Radiological ASD was scored by the combination of decrease in disc height and anterior osteophyte formation. Neck disability index (NDI), physical component summary (PCS) and mental component summary (MCS) of 36-Item Short Form Health Survey were evaluated as clinical outcomes.

Results

The cervical sagittal alignment parameters were comparable between the three treatment groups, both at baseline and at two-year follow-up. Irrespective of surgical method, C2-C7 lordosis was found to increase from 11 to 13 degrees, but the other parameters remained stable during follow-up. Only the OCI was demonstrated to be associated with the presence and positive progression of radiological ASD, both at baseline and at two-year follow-up. NDI, PCS and MCS were demonstrated not to be correlated to cervical sagittal alignment. Likewise, a correlation with the value or change of the OCI was absent.

Conclusions

OCI, an important factor to maintain horizontal gaze, was demonstrated to be associated with radiological ASD, suggesting that the occipito-cervical angle influences accelerated cervical degeneration. Since OCI did not change after surgery, degeneration of the cervical spine may be predicted by the value of OCI.

INTRODUCTION

The cervical spine has a crucial role in compensating a distorted global spinal balance. In order to maintain horizontal gaze, the cervical spine will compensate[1]. Regularly, global sagittal imbalance is only present in a very mild form, and subsequently, cervical compensation is only minor. However, even minor cervical spine balance compensation mechanisms may cause accelerated degeneration of the cervical spine segments (ASD). Surgical interventions that possibly interfere with sagittal alignment, like anterior discectomy, may influence ASD, irrespective of the presence of preoperative sagittal imbalance of the whole spine.

In order to quantify cervical spine sagittal alignment, several radiographic parameters have been proposed, including C2-C7 lordosis, C2-C7 sagittal vertical axis (SVA) and T1 slope[2,3]. It has to be realised though that these parameters also importantly influence each other[4,5].

Furthermore, occipito-cervical inclination (OCI), defining the occipito-cervical angle, independent of the occipito-cervical distance, is an important sagittal alignment parameter, since it represents the stress on the cervical spine to maintain horizontal gaze[6]. To the best of our knowledge, no study correlated this parameter with cervical ASD previously.

Anterior cervical discectomy and fusion (ACDF) has been a common surgical treatment for cervical radiculopathy since it was initially described in the 1950s[7,8] and became the gold standard procedure. Recently, artificial disc implantation (ACDA) has been proposed to maintain disc height, restore cervical motion and avoid neck pain and disability in post-surgical follow-up[9]. Limited studies have described the cervical sagittal alignment after ACDA in comparison with ACDF and reported contradictory results. Kim et al.[10] reported that ACDA maintained the cervical sagittal alignment well in comparison to ACDF, but other researchers disputed this advantage and found that the alignment of the cervical spine is unaltered irrespective of the anterior cervical discectomy procedure performed[11,12]. Most studies, however, only focused on comparing the cervical curvature between ACDF and ACDA, and the other sagittal alignment parameters were rarely investigated.

In the current study, sagittal alignment parameters of the cervical spine are evaluated in patients from two randomized double-blind trials on patients treated by anterior cervical discectomy with or without interbody fusion and arthroplasty for cervical radiculopathy at baseline and at two-year follow-up. The parameters and the changes in sagittal alignment were correlated with the incidence and progression of radiological ASD and to clinical outcomes.

METHODS

Study design

NECK trial

A prospective, randomized double-blind multicentre 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 (ACD). The protocol was approved by medical ethics committees, including an approval for randomization after anaesthetic induction. All patients gave informed consent.

The design and study protocol were published previously[13]. The two-year follow-up data revealed no differences in clinical outcomes[14].

PROCON trial

The trial design was a prospective, double blind, single-centre 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 the medical ethics committee. All patients gave informed consent.

The design and study protocol were published previously[15]. The follow-up data up to eight years post-surgery revealed no differences in clinical outcomes[16].

Radiological evaluation

Lateral x-rays of the cervical spine were obtained with the patients in a standing position and instructed to look straight ahead, with hips and knees extended, in order to obtain a neutral position of the head.

Sagittal alignment parameters

Cervical sagittal alignment parameters were measured preoperatively and two years postoperatively (Figure 1):

- C2-7 lordosis: the angle as measured between the lines drawn parallel to the caudal endplate of C2 and C7.
- C2-7 SVA: distance between a plumb line from the centre of the C2 vertebra to the plumb line from the centre of C7 vertebra.
- T1 slope: since the superior endplate of T1 vertebra is invisible for most patients, C7 slope was measured as the angle between the superior endplate of C7 and a horizontal reference line. Subsequently, this angle was converted to the T1 slope using the formula: T1 slope= (C7 slope+0.54)/ 0.88[17].

- OCI: the angle formed by the line connecting the posterior vertical border of the C4 vertebral body and McGregor's line[6].

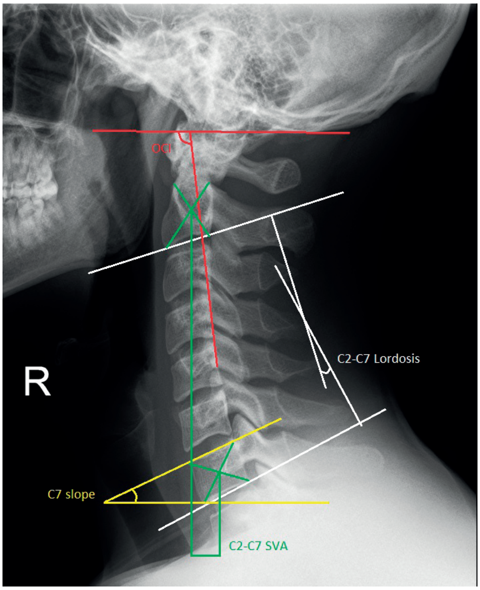

Figure 1 Radiographic evaluation of cervical sagittal alignment parameters

The changes of sagittal parameters after surgery, with reference to the baseline values, were investigated as well.

In the ACD group, the disc height decreased from the pre- to the post-operative situation. This might therefore influence the sagittal alignment parameters. Additionally, for this group specifically, the disc height was correlated to the baseline and two-year follow-up alignment parameters as well.

Adjacent segment degeneration

ASD was defined based on the height of an adjacent level disc and the anterior osteophyte formation on x-rays according to the classification reported by Goffin et al.[18] preoperatively and 24 months post-operatively (Table 1). Since there are no strict criteria to define ASD, evaluation of ASD was performed with three different methods. Firstly, only if neither the superior nor inferior adjacent level demonstrated loss of disc height or anterior osteophyte formation, the patient was graded as 'non-ASD'; all other patients were graded as 'ASD'. Secondly, in a separate analysis, 'mild-ASD' was scored if patients had 'no' or 'minor' ASD changes in both the superior and inferior adjacent levels, and 'ASD' was defined to be present if the classification was 'moderate' or 'severe' loss of disc height or anterior osteophyte formation in either the superior or inferior level. Thirdly, ASD was evaluated by progression of adjacent level degeneration: 'ASD progression' was marked as positive or negative for patients that did or did not increase in Goffin score during follow up.

Table 1 The classification of adjacent segment degeneration

	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: Anteroposterior

Clinical outcomes

Neck disability index (NDI) is a 10-item questionnaire on three different aspects: pain intensity, daily work-related activities and nonwork-related activities. Each item is scored from 0 to 5 and the total score ranges from 0 (best score) to 50 (worst score). This 50 points score was converted to a percentage (50 points=100%). The NDI is a modification of the Oswestry Low Back Pain Index and has been shown to be reliable and valid for patients with cervical pathology[19]. The physical component summary (PCS) and mental component summary (MCS) are derived from the 36-Item Short Form Health Survey and are summary scores for, respectively, the Physical Quality of Life and the Mental Quality of Life. The PCS and MCS range from 0 to 100, with higher scores representing better self-reported health.

Statistical analysis

All the data were presented as mean ± standard deviation. Paired *t*-test was used to compare the changes of sagittal alignment parameters between baseline to two-year follow-up data. Logistic regression analysis was used to determine the correlation between the sagittal balance parameters at baseline with the presence and progression of ASD. Likewise, logistic regression analysis was used to determine the correlation between the changes in sagittal balance parameters during the two-year follow-up time. Linear regression analysis was used to correlate the disc height and cervical sagittal alignment parameters at baseline and at two-year follow-up in the ACD group. Linear regression analysis was also performed to correlate the clinical outcome data with the sagittal balance parameters at two-year follow-up in all groups. The correlations between sagittal alignment parameters were analysed using the Pearson correlation coefficient.

A P value of < 0.05 was considered significant. SPSS software, version 23.0, was used for all statistical analyses (SPSS, Inc., Chicago, IL, USA).

RESULTS

In the current study, 253 patients were included and randomly assigned to ACD (83 patients), ACDF (85 patients) or ACDA (85 patients). At baseline, x-ray data were available for 228 patients and for 168 patients at two-year follow-up.

Demographics

Baseline characteristics are presented in Table 2. The mean age of the study population was 45.2 ± 7.3 years, ranging from 27 to 70 years. There was no difference regarding baseline characteristics between treatment groups. Surgery was most frequently at levels C5-C6 and C6-C7.

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: Anterior cervical discectomy
ACDF: Anterior cervical discectomy with fusion,
ACDA: Anterior cervical discectomy with arthroplasty
SD: Standard deviation

Characteristics of cervical sagittal alignment in subgroups

Table 3 demonstrates the characteristics of the cervical sagittal alignment parameters in the different treatment arms. No differences were found regarding sagittal alignment parameters between the three surgical groups neither at baseline nor at two-year follow-up (P>0.05). Additionally, it was found that the cervical alignment parameters did not change significantly comparing baseline to post-operative values, with the exception of C2-C7 lordosis in the ACDF group (P=0.048). Irrespective of the surgical method, only C2-C7 lordosis was found to change (increase) significantly over two years (from 11.3 to 13.1 degrees, P=0.023). The other three parameters (OCI, C2-C7 SVA and T1 slope) did not change with a statistical significance. Notably, the angle or sloped could be minimally negatively or minimally positively deviating.

Table 3 Characteristics of sagittal alignment parameters in subgroups

	Lordosis	SVA	T1 slope	OCI
Baseline				
ACD (63)	12.6±9.6	21.9±12.9	28.1±10.3	105.7±9.1
ACDF (69)	9.5±8.6	23.5±11.2	30.1±8.4	104.6±9.5
ACDA (69)	12.1±9.0	22.1±10.8	30.6±9.0	104.7±8.7
P value	0.117	0.684	0.272	0.803
2-year follow-up				
ACD (48)	13.5±9.8	21.0±11.2	30.7±10.1	106.4±8.4
ACDF (48)	11.8±11.1	24.1±10.5	33.1±8.7	106.9±10.5
ACDA (57)	13.6±10.5	21.9±11.9	30.6±10.0	105.1±11.3
P value	0.634	0.376	0.349	0.663

SVA: Sagittal vertical axis
OCI: Occipito-cervical inclination
ACD: Anterior cervical discectomy
ACDF: Anterior cervical discectomy with fusion
ACDA: Anterior cervical discectomy with arthroplasty

Correlation between disc height and cervical sagittal alignment

In the ACD group, there was no correlation between the disc height of the target level and cervical sagittal alignment at baseline (P>0.05). Likewise, this correlation was absent at two-year follow-up (P>0.05). There was a decrease in disc height, but this did not impact overall balance.

Adjacent segment degeneration

Preoperatively, the incidence of ASD did not differ in the three groups: 38% in the ACD group (27 patients), 36% (29 patients) in the ACDF group, and 29% (22 patients) in the ACDA group (P=0.428). At two-year follow-up, ASD increased to 63% of patients in the ACD group (35 patients), and 55% (28 patients) in the ACDF group, and to 56% (34 patients) in the ACDA group. Likewise, between three groups, there was no statistically significant difference (P=0.674).

If ASD was considered to be scored as 'ASD' only if disc degeneration and/or presence of osteophytes was moderate or severe, the incidence of ASD was still comparable in the three treatment arms at baseline: 16% in the ACD group, 14% in the ACDF group, and 13% in the ACDA group (P=0.905). And likewise, two years after surgery, the incidence of ASD did not differ between three groups (29% in the ACD group, 26% in the ACDF group and 20% in the ACDA group; P=0.522).

Furthermore, the progression of ASD was also investigated, comparing follow-up to baseline data. At two years after surgery, the proportion of positive ASD progression was comparable in the three treatment arms (33% in the ACD group, 25% in the ACDF group and 31% in the ACDA group; P=0.693).

Correlation between cervical sagittal alignment and radiological adjacent segment degeneration

In order to study the relationship between cervical sagittal alignment parameters and ASD, subjects were dichotomized according to the presence and progression of radiological ASD, irrespective of the surgical method. The average values of sagittal alignment parameters of subjects with and without ASD are shown in Table 4.

Table 4 Cervical sagittal alignment parameters with the presence and progression of adjacent segment degeneration

	ASD	Non-ASD	P value	ASD	Mild-ASD	P value	ASD positive progression	ASD negative progression	P value
Baseline									
Lordosis	10.8±9.4	11.6±9.0	0.568	12.7±9.5	11.1±9.1	0.412	-	-	-
SVA	22.7±12.4	22.5±11.3	0.884	25.8±11.3	22.1±11.6	0.122	-	-	-
T1 slope	29.8±8.8	29.5±9.5	0.879	32.1±8.7	29.2±9.3	0.144	-	-	-
OCI	107.7±9.0	103.7±8.9	0.007*	108.7±8.0	104.4±9.1	0.040*	-	-	-
2-year follow-up									
Lordosis	11.5±10.2	14.8±10.5	0.054	10.8±9.3	13.7±10.7	0.130	11.2±9.6	14.7±11.0	0.085
SVA	23.2±11.1	21.1±11.5	0.270	24.8±11.8	21.5±11.0	0.118	23.2±11.5	21.4±11.3	0.423
T1 slope	31.0±9.7	32.1±9.6	0.492	31.3±8.9	31.5±9.9	0.898	29.7±8.1	32.5±10.1	0.139
OCI	109.0±10.1	102.1±8.9	<0.001*	112.9±9.3	103.6±9.3	<0.001*	109.1±11.3	104.5±9.7	0.020*

* P<0.05
ASD: Adjacent segment degeneration
SVA: Sagittal vertical axis
OCI: Occipito-cervical inclination

At baseline, a higher OCI value was significantly correlated to the presence of ASD (OR, 1.05; 95% CI, 1.01-1.09; P=0.009). If patients were dichotomized into mild ASD and ASD, the result was similar (OR, 1.05; 95% CI, 1.00-1.11; P=0.044). C2-C7 lordosis, C2-C7 SVA and T1 slope failed to show a correlation with ASD (Table 5).

At two-year follow-up, again, OCI with higher value was correlated with the presence of ASD (OR, 1.08; 95% CI, 1.04-1.13; P<0.001). If patients were dichotomized into mild ASD and ASD, the correlation between higher OCI and ASD was detected as well (OR, 1.11; 95% CI, 1.06-1.16; P<0.001). Patients with higher OCI value were likewise correlated to the positive progression of ASD (OR, 1.05; 95% CI, 1.01-1.09; P=0.023) (Table 6).

Table 5 Factors associated with presence of adjacent segment degeneration at baseline

Factors	Comparison	non-ASD vs. ASD			mild ASD vs. ASD		
		OR	95% CI	P value	OR	95% CI	P value
Lordosis	Per additional degree	0.99	0.96-1.02	0.566	1.02	0.98-1.06	0.411
SVA	Per additional mm	1.00	0.98-1.02	0.883	1.03	1.00-1.06	0.124
OCI	Per additional degree	1.05	1.01-1.09	0.009*	1.05	1.00-1.11	0.044*
T1 slope	Per additional degree	1.00	0.97-1.04	0.879	1.03	0.99-1.08	0.145

* P<0.05
ASD: Adjacent segment degeneration
OR: Odds ratio
CI: Confidence interval
SVA: Sagittal vertical axis
OCI: Occipito-cervical inclination

Table 6 Factors associated with presence and progression of adjacent segment degeneration at two-year follow-up

Factors	Comparison	non-ASD vs. ASD			mild ASD vs. ASD			ASD negative progression vs. ASD positive progression		
		OR	95% CI	P value	OR	95% CI	P value	OR	95% CI	P value
Lordosis	Per additional degree	0.97	0.94-1.00	0.057	0.97	0.93-1.01	0.133	0.97	0.93-1.01	0.089
SVA	Per additional mm	1.02	0.99-1.05	0.269	1.03	0.99-1.06	0.120	1.01	0.98-1.05	0.421
OCI	Per additional degree	1.08	1.04-1.13	<0.001*	1.11	1.06-1.16	<0.001*	1.05	1.01-1.09	0.023*
T1 slope	Per additional degree	0.99	0.96-1.02	0.490	1.00	0.96-1.04	0.897	0.97	0.93-1.01	0.14

* P<0.05
ASD: Adjacent segment degeneration
OR: Odds ratio
CI: Confidence interval
SVA: Sagittal vertical axis
OCI: Occipito-cervical inclination

As stated above, no significant changes in mean OCI values existed between baseline and two-year follow-up. On an individual level, changes were small for the vast majority of patients, but considerate for a minority of patients (Figure 2). However, no correlation was demonstrated between the change in OCI value and the progression of ASD. Neither was there a correlation between the change in sagittal balance parameter and progression of ASD for the other parameters (Table 7).

Characteristics of clinical outcomes

The clinical outcomes represented by NDI, PCS and MCS were comparable between the three treatment groups, both at baseline and at two-year follow-up (Table 8). Therefore, the clinical outcomes were studied irrespective of surgical methods. At baseline, the mean NDI was 39.7 ± 15.4, mean PCS was 43.3 ± 13.5 and mean MCS was 59.1 ± 21.5. At two years

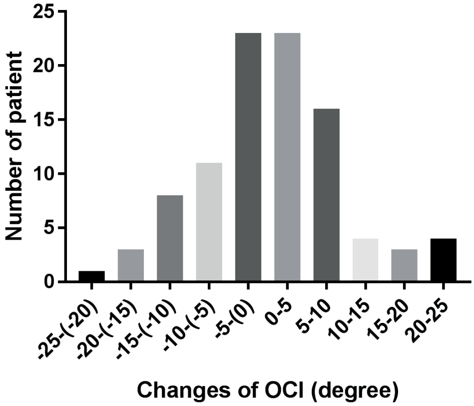

Figure 2 Patient frequency of changes of OCI during two year after surgery

Table 7 The change of sagittal alignment parameter associated with progression of adjacent segment degeneration at two-year follow-up

Association between factors and ASD	Comparison	Univariate analysis		
		OR	95% CI	P value
Lordosis changes	Per additional degree	1.02	0.95-1.08	0.618
SVA changes	Per additional mm	1.01	0.95-1.08	0.711
OCI changes	Per additional degree	1.07	0.99-1.16	0.103
T1 slope changes	Per additional degree	1.02	0.93-1.13	0.618

ASD: Adjacent segment degeneration
OR: Odds ratio
CI: Confidence interval
SVA: Sagittal vertical axis
OCI: Occipito-cervical inclinatio

after surgery, the NDI decreased to 16.4 ± 17.1. PCS and MCS increased to 73.9 ± 23.6 and 77.6 ± 21.8, respectively.

Correlation between cervical sagittal alignment and clinical outcomes

At two-year follow-up, the values of C2-C7 lordosis, C2-C7 SVA, OCI and T1 slope failed to correlate with clinical conditions, and neither was there a correlation of clinical outcome to the changes of these parameters (P>0.05).

Correlation between cervical sagittal alignments

SVA was significantly correlated with T1 slope (0.45-0.54, P<0.01) and OCI (0.20-0.37, P<0.01). C2-C7 lordosis was correlated with T1 slope as well (0.40-0.55, P<0.01) (Table 9).

Table 8 Characteristics of clinical outcome

	NDI	PCS	MCS
Baseline			
ACD	39.1 ± 15.3	42.4 ± 13.3	60.7 ± 20.2
ACDF	38.9 ± 14.2	44.7 ± 12.2	59.7 ± 21.0
ACDA	41.1 ± 16.5	42.9 ± 14.0	57.3 ± 23.2
P value	0.589	0.591	0.639
2-year follow-up			
ACD	16.3 ± 14.4	70.7 ± 23.0	74.4 ± 22.9
ACDF	16.0 ± 16.9	76.7 ± 21.5	81.6 ± 19.2
ACDA	16.9 ± 19.6	73.9 ± 25.8	76.5 ± 22.8
P value	0.963	0.497	0.262

NDI: Neck disability index
PCS: Physical-component summary
MCS: Mental-component summary
ACD: Anterior cervical discectomy
ACDF: Anterior cervical discectomy with fusion
ACDA: Anterior cervical discectomy with arthroplasty

Table 9 Correlation between sagittal alignment parameters

	Lordosis	SVA	T1 Slope	OCI
Baseline				
Lordosis	-	-0.11	0.40**	-0.01
SVA	-	-	0.45**	0.20**
T1 Slope	-	-	-	0.01
OCI	-	-	-	-
1 year				
Lordosis	-	0.03	0.55**	0.05
SVA	-	-	0.54**	0.35**
T1 Slope	-	-	-	0.16*
OCI	-	-	-	-
2 years				
Lordosis	-	0.03	0.53**	0.20*
SVA	-	-	0.53**	0.37**
T1 Slope	-	-	-	0.04
OCI	-	-	-	-

SVA: Sagittal vertical axis
OCI: Occipito-cervical inclinatio*
Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)

DISCUSSION

Cervical sagittal alignment was demonstrated not to be affected by anterior discectomy at two-years follow-up after surgery. The alleged superiority of maintaining cervical alignment in arthroplasty was not established. The occipito-cervical angle, being crucial in maintaining horizontal gaze, was identified as an important factor associated with radiological ASD.

OCI is a relatively new radiological parameter of the angle between the occiput and the cervical spine proposed by Yoon et al.[6]. In this study, it is first applied to investigate the relationship with radiological ASD and clinical outcomes in patients with cervical disc degeneration. Wu et al.[20] reported before that the occipito-C2 angle was correlated with post-operative ASD in a patient group who underwent occipitoaxial spondylodesis. Theoretically, the occipito-cervical angle is dictated by horizontal gaze, and if this angle is imbalanced, it may well lead to compensation of subaxial cervical curvature, which will eventually lead to accelerated degeneration of the cervical spine[21]. This could explain the strong correlation of OCI with ASD detected in this study.

Remarkably, the OCI angle did not change after surgery, although there was significantly more ASD in patients with a higher OCI. Therefore, the result of this study suggests that accelerated degeneration of the cervical spine is dictated by the OCI angle. Thus, accelerated degeneration of the cervical (subaxial) spine can be predicted if the OCI is known. Ideally, a cut-off point of the OCI would be available. ASD is determined in this study in three ways, and therefore three different values are available: for non-ASD, an angle of 102 to 104 degrees was measured, and for ASD angles, varying between 108 and 113 degrees were observed (Table 4). Future studies are needed to confirm and determine cut-off values. Moreover, long-term follow-up studies are needed to study whether ASD or subaxial degeneration continues during longer follow-up or that it stabilizes.

In the current study, no correlation between clinical outcome and sagittal balance parameters could be demonstrated. The C2-C7 SVA and T1 slope did not change in follow-up of surgery, the C2-C7 lordosis only increased minimally, and they did not demonstrate a correlation with ASD. Therefore, an absence of correlation to the clinical outcome is not surprising. However, previous studies did demonstrate an association between sagittal alignment parameters to the quality of life[1,22]. Tang et al.[23] found that the C2-C7 SVA was negatively correlated with PCS and positively correlated with NDI scores after multilevel cervical posterior fusion. Hyun et al.[24] found that C2-C7 SVA greater than 43.5 mm was corresponded to severe NDI (>25). Nevertheless, Jeon et al.[3] and Kwon et al.[25], who compared similar radiographic parameters with NDI and visual analogue scale, reported that no cervical sagittal alignment parameters were significantly correlated with clinical outcomes after ACDF surgery with three levels and two levels, respectively, which are consistent with our results. It has to be noted though that these authors described different surgical approaches. Tang et al.[23] and Hyun et al.[24] reported on patients with posterior cervical fusion surgery. Jeon et al.[3] and Kwon et al.[25] reported on multilevel anterior fusion surgery of the cervical spine and demonstrated threshold values for C2-C7 SVA of 40 mm[23] and 43.5 mm[24] in contrast to the values that we reported in the majority of patients (mean value: 20.6-22.5 mm).

A limitation of this study is that we have analysed radiographic parameters with a follow-up of only two years after surgery. In contrast to our results other research groups did demonstrate a lower occurrence of ASD in ACDA compared with ACDF with longer follow-up periods[26-30]. These articles, however, had a high or intermediate risk of bias, and estimates of effect were not sufficiently described. Therefore, the level of evidence that ASD occurs more often in ACDF than in ACDA is low[31]. Moreover, a recent study with low risk of bias demonstrated that the presence of both clinical ASD and radiological ASD was similar in the ACDA and ACDF at five-year follow-up[32]. It is thus debatable whether ASD will demonstrate differences between the three groups upon longer follow-up periods. However, in our opinion, the current data on ASD, demonstrating a gradual increase of ASD in all three groups, makes this rather unlikely.

CONCLUSIONS

The choice of the intervertebral device in anterior cervical discectomy surgery does not influence cervical sagittal alignment. OCI was demonstrated to be an important factor associated with radiological ASD, suggesting that occipito-cervical alignment influences accelerated cervical degeneration. The correlation between cervical sagittal alignment parameters and clinical outcome is absent.

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