Sagittal Segmental Alignment as Predictor of Adjacent-Level Degeneration After a Cloward Procedure

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Abstract

Background The Cloward anterior interbody fusion is commonly performed for cervical disc herniation or spondylosis. In followup studies, various authors have noted clinically relevant adjacent-level degeneration. However, factors associated with adjacent-level degeneration are not well known.

Questions/purposes We asked whether the postoperative sagittal segmental alignment of the fused vertebrae could be used as a predictor of adjacent-level degeneration.

Methods We retrospectively studied 107 patients, aged 35 to 55 years, with one-level cervical disc disease between C4 and C7 operated on from 1985 to 1995 by discectomy and one-level anterior cervical fusion according to the Cloward procedure. In standard radiographs of the cervical spine in lateral view, the alignment of the involved intervertebral space (sagittal segmental alignment) and the sagittal alignment of the cervical spine were measured and the adjacent-level degeneration was assessed using the

Kellgren and Lawrence criteria. The minimum followup was 10 years (mean, 16 years; range, 10–23 years).

Results Preoperatively, mean sagittal segmental alignment was $0.6^\circ \pm 2.0^\circ$ and sagittal alignment of the cervical spine was $17.0^\circ \pm 4.9^\circ$. At last followup, the mean sagittal segmental alignment was $1.8^\circ \pm 4.1^\circ$ and mean sagittal alignment of the cervical spine was $19.7^\circ \pm 6.6^\circ$. Adjacent-level degeneration was present in 60% of cases with postoperative sagittal segmental alignment of 0° or less and in 27% of cases with postoperative sagittal segmental alignment of more than 0° .

Conclusions To prevent adjacent-level degeneration, we recommend proper lordotic sagittal segmental alignment when anterior interbody fusion of the cervical spine is indicated.

Level of Evidence Level II, prognostic study. See Guidelines for Authors for a complete description of levels of evidence.

Each author certifies that he or she has no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.

Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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Introduction

Cervical disc herniation and cervical spondylosis of one segment are frequently observed in clinical practice; they can produce axial neck pain, cervical radiculopathy, or cervical myelopathy and can be an important disabling condition [5, 43]. Surgery is indicated when nonoperative treatment fails or there is worsening of radiculopathy and/or myelopathy [28, 36]. Several procedures have been described for treatment of disc herniation and cervical spondylosis including anterior decompression, laminectomy, laminoplasty, instrumented anterior and posterior fusion by plates or screws [2–4, 6, 7, 10, 16, 17, 19, 22, 24, 29, 34, 38, 40, 45, 50]. The anterior decompression of the spinal cord and interbody fusion of the affected level were

first described by Robinson and Smith in 1955 [44] and by Cloward in 1958 [11, 12].

These techniques are still used [1, 3, 6, 13, 46, 52]. With the Cloward procedure, the fusion is performed by a cylindrical bicortical iliac graft driven into the involved intervertebral space, restoring the intervertebral space and decompressing the foramina to resolve the neurologic symptoms and signs [15, 46, 48, 51] (Fig. 1). This technique is reportedly associated with overall rates of satisfaction ranging from 70% to 99% depending on type of grading scale [8, 12, 34, 36, 41, 46]. When one cervical segment is fused, the adjacent cervical levels provide compensatory motion, thus increasing the mechanical stress of these sites [9, 18, 20, 25, 33, 39]. Degenerative changes in intervertebral spaces adjacent to the fused segment can present in 10% to 89% of operated patients at long-term followup [23, 26, 33, 37, 52]. Several authors have reported progression of adjacent degeneration relates to a number of factors: large ranges of movements, individual predisposition, life habits, increased stress on the disc space of the adjacent level degeneration, reduction of the disc nutrition because of the increased stress on the end plates, increased motion transferred to fewer remaining motion segment, and instability [1, 18, 23, 30, 33, 37]. Cervical alignment in the sagittal and frontal planes is also likely important [23, 30, 37, 49].

To confirm these reports, we determined whether (1) the surgery restored the lordotic alignment of the operated segment; (2) the postoperative sagittal segmental alignment of the fused vertebrae (SSA) and the sagittal alignment of the cervical spine (SACS) predicted adjacent-level degeneration at a minimum followup of 10 years; (3) the postoperative SSA of the fused vertebrae and SACS were maintained at the last followup; and (4) there was a relation

between the level of fusion and degeneration of the adjacent level.

Patients and Methods

We retrospectively reviewed the records of 143 patients with one-level cervical disc disease between C4 and C7 operated on from 1985 to 1995 by discectomy and one-level anterior cervical fusion using the operative technique described by Cloward [11] and meeting the following criteria: (1) age between 35 and 55 years; (2) a single-level disc herniation between C4 and C7 operated on by the Cloward procedure; and (3) no preoperative degeneration of the adjacent levels evident on radiographs (Grade 0 and 1 in the scale described by Kellgren and Lawrence [31]). During the study period, we performed the Cloward procedure at a single level in 271 patients. We excluded 128 patients with one of the following: (1) posttraumatic cervical disc herniation and spondylosis; (2) history of rheumatic disease; (3) diabetes; (4) arthritis; (5) neurodegenerative and inflammatory diseases; (6) age older than 65 years at last followup; and (7) incomplete preoperative and postoperative cervical AP and lateral radiographs in which all the vertebral bodies between C2 and C7 were visible. These exclusions left 143 patients; of these, 36 were lost to followup before a minimum of 10 years leaving 107 patients for final review. There were 14 females and 93 males. The average ($\pm$ SD) age was 46 ± 7 years. The C4–C5 level was involved in 46 cases, the C5–C6 level in 34 cases, and the C6–C7 level in 27 cases. All patients reported intractable neck pain for at least 12 weeks, refractory to nonoperative treatment, and pain associated with radiculopathy and/or myelopathy during a period of

Fig. 1A–C Images illustrate the case of a 46-year-old man with one-level (C5–C6) disc disease. (A) A preoperative radiograph in the lateral view shows a kyphotic alignment of the cervical spine and of the C5–C6 segment and absence of degeneration in adjacent levels. (B) A postoperative radiograph shows the bone graft inserted that restored the lordotic sagittal segmental alignment of the fused vertebrae (SSA). (C) A 15-year followup radiograph on a lateral view shows complete remodeling of the grafts with no evident signs of adjacent-level degeneration.

less than 12 weeks. No patients were recalled specifically for this study; all data were obtained from medical records and radiographs. The minimum followup was 10 years (median, 16 years; range, 10–23 years).

In preoperative, postoperative, and followup standard radiographs of the cervical spine in lateral view, at neutral position of the cervical spine, three of the authors not involved in surgery (SP, DL, MTM) measured the SSA and the SACS. Each of the three observers independently evaluated each radiograph, and in case of differing opinion among the three observers, a combined assessment was performed and agreement was reached. SSA and SACS were measured in degrees [30]. SSA was measured as the angle between the line parallel to the upper border of the vertebral body proximal to the disc space involved and the line parallel to the lower border of the underlying vertebral body [30] (Fig. 2A). This value is positive in the case of lordotic alignment and negative in the case of kyphotic alignment. SACS angle was calculated according to a graphic equivalent of the method by Katsuura et al. [30] and measured as the angle between the line parallel to the upper border of the C2 vertebral body and the line parallel to the lower border of the C7 vertebral body (Fig. 2B). SACS describes the alignment of the whole cervical segment, and this value is positive in the case of lordotic alignment. Radiographic evidence of adjacent-level degeneration was based on the parameters described by Kellgren and Lawrence [31]: Grade 0 indicates a definite absence of radiographic degenerative changes; Grade 1 indicates a doubtful presence of degeneration; Grade 2 indicates degeneration is definitely present though of minimal severity; Grade 3 indicates moderate degeneration;

and Grade 4 indicates severe degeneration. Kellgren and Lawrence [31] considered formation of osteophytes, peri-articular ossicles, cartilage narrowing with subchondral bone sclerosis, pseudocystic areas, and altered bone shape as evidence of degeneration.

Three surgeons (PGM, AF, SG) performed all surgery. All procedures were performed under general anesthesia with the patient lying in the supine position. The first surgical time consisted of harvesting a bicortical iliac autograft from the anterior iliac crest. Then, an anterior, oblique, usually left neck skin incision was performed. The trachea and the esophagus were retracted medially, whereas the sternocleidomastoid muscle and the neurovascular bundle were retracted laterally. An intraoperative C-arm control confirmed the involved intervertebral level. After performing a complete discectomy to reach the posterior longitudinal ligament, the autograft was driven into the intervertebral space. Hemostasis was obtained. The wound was closed with interrupted absorbable stitches and the skin with silk stitches. A small rubber drain was placed for the first 24 hours. A thin gauze dressing was placed.

Immediately after surgery, all patients were fitted with a semirigid cervical collar and were instructed to wear it continuously for 2 months, after which it was removed. Patients were allowed out of bed the day after surgery. We instituted no physiotherapy. Patients were discharged 3 to 5 days after surgery, as their symptoms permitted.

All patients were checked by two of us (SG, CF) in outpatient facilities at 2 weeks, then at 2, 6, and 12 months after surgery, and at last available followup. Standard radiographs of the cervical spine in two views at neutral position of the cervical spine were performed.

Fig. 2A–B Illustrations show the (A) sagittal segmental alignment of the fused vertebrae (SSA) and (B) sagittal alignment of the cervical spine (SACS) angles measured on the lateral radiograph of a cervical segment; SSA was measured as the angle between the line parallel to the upper border of the vertebral body proximal to the disc space involved and the line parallel to the lower border of the underlying vertebral body. SACS was measured as the angle between the line parallel to the upper border of the C2 vertebral body and the line parallel to the lower border of the C7 vertebral body.

To evaluate whether the surgical technique was able to restore the lordotic alignment of the operated segment, the SSA angle was measured in postoperative radiographs of the cervical spine in lateral view and compared with the preoperative SSA angle. The relation between the preoperative and postoperative SSA angles was performed by using Wilcoxon matched-pairs test because the SSA angle did not have a normal distribution. To evaluate whether the postoperative SSA of the fused vertebrae and SACS could be predictors of adjacent-level degeneration, we divided patients into two groups: Group A included patients whose postoperative SSA was neutral or kyphotic ($\text{SSA} \leq 0^\circ$), whereas Group B included patients who had a lordotic postoperative SSA ($\text{SSA} > 0^\circ$). We compared the rate of adjacent-level degeneration in Group A (kyphotic SSA) and Group B (lordotic SSA) by using the chi square test. We evaluated the degeneration rate in the level adjacent to the fusion according to the parameters described by Kellgren and Lawrence [31]. We evaluated the correlation

between SSA angles, SACS angles, and the degeneration rate in the adjacent levels using logistic regression and Spearman's rho, which permit correlations between continuous variables and dichotomous variables to be made. Using logistic regression, which suggests whether a continuous variable predicts a dichotomous variable, we determined whether the SSA angle predicted the occurrence of degeneration in adjacent levels. To evaluate whether the postoperative SSA of the fused vertebrae and SACS were maintained at the last followup, we compared the last followup values with the postoperative values by using a Wilcoxon matched-pairs test for SSA angle and chi square test for SACS angle because SACS angle had a normal distribution. To evaluate whether there was a relation between the level of fusion and degeneration of the adjacent level, we used the chi square test. All continuous data were expressed as mean $\pm$ SD. Data analysis was performed using SPSS[®] software Version 9.0 (SPSS Inc, Chicago, IL).

Fig. 3 A graph shows sagittal segmental alignment of the fused vertebrae (SSA) values measured preoperatively, postoperatively, and at last followup. Box = distribution; vertical bars = SD; horizontal bar = arithmetic average. SSA increased ($p < 0.001$) from preoperatively to postoperatively, and there was no difference ($p = 0.861$) between the SSA measured postoperatively and at last followup.

Results

The technique restored the lordotic SSA in 66 of 107 patients (62%) (Fig. 3). The SSA angle increased ($p < 0.001$) from a preoperative value of $0.6^\circ \pm 2.0^\circ$ to a postoperative value of $1.9^\circ \pm 4.2^\circ$ (Table 1). The postoperative SSA was 0° or less in 41 patients (Group A) and greater than 0° in 66 patients (Group B). In Group A, the postoperative SSA was $-3.0^\circ \pm 1.2^\circ$, whereas in Group B, it was $5.0^\circ \pm 1.9^\circ$.

At last followup, adjacent-level degeneration was present in 40% of patients in the whole series (Table 2). In particular, adjacent-level degeneration occurred more frequently (odds ratio [OR], 2.236; $p < 0.001$) in Group A than in Group B: 61% versus 27%, respectively (Fig. 4). Increase of postoperative SSA correlated with ($r = -0.428$; $p < 0.001$) adjacent-level degeneration and increase of SSA at the last followup correlated with ($r = -0.432$; $p < 0.001$) adjacent-level degeneration (Fig. 5). The logistic regression for postoperative SSA and

Table 1. SSA and SACS angles

Variable	Preoperative		Postoperative		Followup		Postoperative				Followup			
	SSA		SSA		SSA		SSA		SACS		SSA		SACS	
							A	B	A	B	A	B	A	B
Number of patients	107	107	107	107	107	107	41	66	41	66	41	66	41	66
Average	0.6	17.0	1.9	21.0	1.8	19.7	-3.0	5.0	15.9	24.3	-2.8	4.8	14.0	23.5
SD	2.0	4.9	4.2	6.2	4.1	6.6	1.2	1.9	3.8	5.1	1.2	2.3	6.0	7.0

SSA = sagittal segmental alignment of the fused vertebrae; SACS = sagittal alignment of the cervical spine.

adjacent-level degeneration found an OR of 0.788 (95% confidence interval, 0.708–0.877; $p < 0.001$), and $+2.0^\circ$ was the cutoff value of postoperative SSA predicting adjacent-level degeneration (Fig. 6). Considering the whole series, 64 patients (60%) had no adjacent-level degeneration, 18 with a SSA of less than 2.0° and 46 with a SSA of greater than 2.0° , whereas 43 patients (40%) had adjacent-level degeneration, 30 with a SSA of less than 2.0° and 13 with a SSA of greater than 2.0° . We found no correlation between the postoperative SACS and adjacent-level degeneration and between the last followup SACS and adjacent-level degeneration. Considering the whole series of 43 patients who had adjacent-level degeneration, 16 had a caudal adjacent-level degeneration, 15 had a cephalad adjacent-level degeneration, and 12 had both.

The postoperative SSA of the fused vertebrae was maintained at the last followup. The SSA angles measured postoperatively ($1.9^\circ \pm 4.2^\circ$) and at last followup ($1.8^\circ \pm 4.1^\circ$) were similar ($p = 0.861$) (Fig. 3). The SACS angles measured postoperatively ($21.0^\circ \pm 6.2^\circ$) and at last followup ($19.7^\circ \pm 6.6^\circ$) were also similar ($p = 0.639$).

Adjacent-level degeneration was present in 20 patients (43%) who underwent C4–C5 fusion, in 13 patients (39%) who underwent C5–C6 fusion, and in 10 patients (37%)

who underwent C6–C7 fusion (Table 3). We found no correlation between level of fusion and adjacent-level degeneration.

Discussion

Surgical treatment of cervical disc herniation or spondylosis is common when nonoperative treatment fails. The Cloward procedure is an excellent technique for the treatment of myelopathy or nerve root compression at one segment [35]. Complications encountered using this

Fig. 5 A graph shows the relation between the sagittal segmental alignment of the fused vertebrae (SSA) and the grade of adjacent-level degeneration. Box = distribution; vertical bars = SD; horizontal bar = arithmetic average; horizontal line = point where SSA equals 0° for separating patients into the two groups (Group A: $SAA \leq 0^\circ$; Group B: $SAA > 0^\circ$). A kyphotic SSA angle was correlated with a higher rate of adjacent-level degeneration.

Table 2. Grade of adjacent level degeneration in the two groups

Patients	Grade of adjacent level degeneration				
	0	1	2	3	4
Number of patients in Group A	7	9	14	8	3
Number of patients in Group B	29	19	15	3	0
Total number of patients	64		43		
Percentage of patients	60		40		

Fig. 4 A graph shows the number of patients in Groups A and B sharing Grades 0 to 4 of adjacent-level degeneration according to the Kellgren–Lawrence classification.

technique include nonunion, collapse of the implant producing segmental kyphotic deformity, and donor site morbidity [14, 21, 30, 31, 47]. Moreover, radiographic degeneration of the disc spaces adjacent to one-level anterior cervical fusion seems to be a frequent finding at long-term followup [23, 30, 32, 42]. Hilibrand et al. [23] observed a prevalence of symptomatic adjacent-level degeneration after anterior cervical arthrodesis of 12% at 5 years and of 19% at 10 years with an average annual incidence of 3%. Interestingly, they noted a lower risk of symptomatic adjacent-level degeneration after multilevel fusion than that after single-level fusion; however, they did not analyze the possible correlation between adjacent-level degeneration and sagittal alignment of the fused levels or of the cervical spine. Katsuura et al. [30], at a mean 10-year followup after anterior cervical fusion, reported an

incidence of adjacent-level degeneration up to 50%. However, it is unclear what promotes these radiographic changes and how they relate to clinical symptoms [1, 25–27, 37, 51]. Cervical disc degeneration could represent the natural history of age-linked degenerative changes [5, 43]. In this study, we determined whether the restored the lordotic alignment of the operated segment, whether the postoperative SSA of the fused vertebrae and SACS predicted adjacent-level degeneration at a minimum followup of 10 years, whether the postoperative SSA of the fused vertebrae was maintained at the last followup, and whether there was a relation between level of fusion and adjacent-level degeneration.

There are some limitations to this study. The first, and perhaps the main, limitation of this study relates to the selection of patients; we excluded patients who at the last followup were 65 years old or older because of the difficulty in distinguishing between degeneration that is age-related and degeneration related to the fusion itself. However, based on the data, we believe the sample we have included in the study is heterogeneous enough to provide a reliable assessment of the outcome in the general population. Second, the radiographic assessments are prone to some interobserver variability. Three of the observers were not directly involved in the treatment and we believe those radiographic assessments are less subject to bias. Third, we performed the measurements on radiographs, which is not as reliable as CT and MRI. Fourth, we only studied radiographic and not clinical outcomes, but radiographic degeneration is not always related to clinical symptoms.

Martins and Colonel [36] reported the Cloward procedure restored the lordotic alignment in 84% of their cases. The kyphotic alignment of the cervical spine and of the fused vertebrae is a commonly reported complication after the Cloward procedure. In a review of the extensive literature on the Cloward procedure, Chauten et al. [8] reported a rate of kyphotic alignment of 20%. Vavruch et al. [51] reported an increase of SSA at 1-year followup after the Cloward procedure. We observed an increase in SSA angle comparing the preoperative ($0.6^\circ \pm 2.0^\circ$) and postoperative ($1.9^\circ \pm 4.2^\circ$) values. In particular, the surgical technique

Fig. 6 A graph shows sagittal segmental alignment of the fused vertebrae (SSA) values in patients without adjacent-level degeneration and in patients with adjacent-level degeneration. Box = distribution; vertical bars = SD; horizontal bar = arithmetic average; horizontal line = the SSA cutoff. The major part of patients presenting no adjacent-level degeneration had a SSA of greater than 2° , and the major part of patients presenting adjacent-level degeneration had a SSA of less than 2° . Thus, $+2.0^\circ$ was the cutoff value of postoperative SSA predicting adjacent-level degeneration.

Table 3. Adjacent-level degeneration rate

Fused level	Total number of patients	Adjacent-level degeneration	No adjacent-level degeneration	Group A			Group B		
				Patients	Adjacent-level degeneration	No adjacent-level degeneration	Patients	Adjacent-level degeneration	No adjacent-level degeneration
C4–C5	46	20 (44%)	26 (56%)	20	11 (55%)	9 (45%)	26	9 (35%)	17 (65%)
C5–C6	34	13 (38%)	21 (62%)	11	8 (73%)	3 (27%)	23	5 (22%)	18 (78%)
C6–C7	27	10 (37%)	17 (63%)	10	6 (60%)	4 (40%)	17	4 (23.5%)	13 (76.5%)
Total	107			41	25 (61%)	16 (39%)	66	18 (27%)	48 (73%)

we used was able to restore lordotic SSA in 66 of 107 patients (62%).

As suggested by some authors [1, 30, 37, 51], preservation or restoration of the physiological sagittal alignment could represent a protective factor against the development of adjacent-level degeneration. In a kinematic analysis study, Miyazaki et al. [37] demonstrated the changes in the sagittal alignment of the cervical spine affect the kinematics and the contribution of each segment to the whole cervical spine mobility, and consequently the authors assumed these changes may cause abnormal load distribution promoting degenerative changes. Nevertheless, no clear correlation between loss of cervical lordosis and promotion of degenerative changes was demonstrated. Although they found no evidence that a localized malalignment or kyphosis of the cervical spine related to neurologic recovery, Baba et al. [1], suggested maintaining the physiological lordosis when performing cervical spine surgery. Vavruch et al. [51] asserted cervical kyphosis could be disadvantageous in the long term because of increasing degenerative changes at adjacent levels. Katsura et al. [30] observed a higher incidence of degenerative changes in adjacent levels in patients with a postoperative kyphotic alignment of the spine than in ones with lordotic alignment. We found an OR of 0.788 between postoperative SSA and adjacent-level degeneration, suggesting a lordotic SSA angle can be considered a protective factor against adjacent-level degeneration. In particular, for each positive degree of SSA angle, there was a 20% reduced risk of adjacent-level degeneration. Therefore, we observed kyphotic postoperative SSA was related to adjacent-level degeneration and $+2.0^\circ$ was the cutoff value of postoperative SSA predicting adjacent-level degeneration (Fig. 6).

Cloward [15] reported a low rate (1%) of graft resorption. However, Vavruch et al. [51] reported an increase of kyphotic alignment of SSA angle after the Cloward procedure at 2 years' followup, ascribing this result to the collapse of the graft. We found no differences between the postoperative SSA angle ($1.9^\circ \pm 4.2^\circ$) with the SSA angle measured at the last followup ($1.8^\circ \pm 4.1^\circ$). No changes in the SSA angle suggest there was little graft resorption without collapse.

Hilibrand et al. [23] reported a higher relative risk to develop adjacent-level degeneration at the interspace between the fifth and sixth and between the sixth and seventh cervical vertebrae and a lower relative risk between the second and third cervical vertebrae and at the cervicothoracic interspace. We found no correlation between the level of fusion (C4–C5, C5–C6, C6–C7) and the rate of adjacent-level degeneration; we suspect the difference in these findings is because proper alignment of the fused vertebrae is more important than the level of

fusion in determining the likelihood of adjacent-level degeneration.

Anterior fusion of the cervical spine using the Cloward procedure is a reasonable technique for the treatment of cervical disc herniation. To prevent adjacent-level degeneration, we recommend establishing a lordotic SSA.

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