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Integrated Outcome Assessment After Anterior Cervical Discectomy and Fusion

Myelocompression But Not Adjacent Instability Affect Patient-Reported Quality of Life and Cervical Spine Symptoms

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Study Design. The authors conducted a cross-sectional study.

Objective. Integrated assessment of adjacent instability (AI), myelocompression (MC), magnetic resonance imaging (MRI) signs of myelopathy (MRISM), physician-assessed clinical signs and symptoms, including clinical signs of myelopathy (CSM), patients' self-reported symptoms and quality of life after anterior cervical discectomy and fusion (ACDF).

Materials and Methods. Fifty-four patients who had ACDF between 1986 and 1995 received MRI scans, conventional and flexion/extension radiographs to assess myelocompression, MRISM, fusion, and AI. Clinical outcome was assessed using signs and symptoms based on selected items of Odom's criteria, Oswestry low back pain disability questionnaire, and the neck disability index. Patients reported their quality of life (QL) on a standardized instrument (Profiles of QL of Chronically Ill [PLC]) and by a specific validated Cervical Spine Symptom Scale (CSSS).

Results. Myelocompression was found more frequently than expected (24%). MRISM were seen in 2 patients (4%). One of the 2 patients developed CSM. Fusion was achieved in 94% (with kyphosis in 17%). AI was found in 30%. However, only myelocompression but not AI was associated with statistically significant decreases in most QL scores (*i.e.*, everyday capabilities, positive mood) and high cervical spine symptom burden (all P's < 0.05).

Conclusions. The study results underline the need for a better understanding of the biomechanical changes in the adjacent unfused segments. Consensus is needed on postoperative follow-up guidelines, including pain management strategies. Future studies on the outcome of ACDF will profit from an integrated outcome approach, including assessments based on imaging, physicians, and patients.

Key words: anterior fusion, cervical spine, myelocompression, myelopathy, adjacent instability, quality of life. **Spine 2004;29:2501–2509**

The most common surgical procedure to treat cervical degenerative disc disease is *a*nterior *c*ervical *d*iscectomy with (ACDF) or without *f*usion (ACD) of the 2 vertebral bodies. If no bony fusion is desired, the previous disc space can be reestablished using methacrylates.[1–4] Bone fusion instead can generally be achieved with allograft bone,[5–11] autograft bone,[5,8,12–15] osteoconductive biopolymers,[16,17] or the implantation of a fusion cage[18–20] into the intervertebral disc space. Generally, degenerative disc diseases can be operated with posterior, anterior, or combined procedures.[21] However, in the majority, the anterior approaches are used as a result of the associated options of disc removal and/or the removal of the retrospondylophytes and the uncinate processes, the anatomic structures mainly responsible for radiculopathy and myelopathy. The most common ACDF procedures using autograft bone were first described by Smith and Robinson and Cloward.[22,23]

Although cervical discectomies with and without cervical fusions are accepted procedures to treat degenerated cervical discs with radiculopathy, it is essential to monitor the long-term outcome. The question arises which outcome parameters should be used to evaluate treatment success or failure. Traditionally, spine surgeons have almost exclusively relied on imaging techniques and physician-assessed parameters in evaluating operative outcome. However, the medical field is witnessing a paradigm shift, and patient-based outcomes such as quality of life or satisfaction with care are increasingly being included in clinical studies.[24,25] We advocate for an integrated outcome assessment that covers objective imaging measures, physician-assessed clinical criteria, and patient reported quality of life.[26] Therefore, the purpose of this study was to assess the outcome of patients who had undergone ACDF using this integrated outcome concept.

Materials and Methods

Study Design. This was a cross-sectional study with 1 point of measurement.

Basic patient and treatment data (type of operation, medical history) were taken from the medical chart (retrolective data collection).[27] Data related to current health status (clinical investigation), operative results (magnetic resonance imaging [MRI], radiographic analysis), and patient self-reported symptoms were newly collected according to a study protocol (prolective data collection[27]).

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Table 1. Patient Characteristics

Age at time of operation (years; median, range)	46 (29–64)
Sex	
M	30
F	24
Occupation at time of operation	
Yes	53
No	1
Height (median, range)	171 cm (150–191)
Weight (median, range)	71 kg (48–105)
Follow-up time (years; median, range)	7 y (3–12)

Patient Sample. All patients who had undergone anterior cervical discectomies and fusions (ACDF) between 1986 and 1995 and were willing to subject themselves to the complete assessment procedure (MRI scan, conventional and flexion/extension radiographs, clinical evaluation quality of life plus cervical spine scale questionnaire) were included in this study. Patient characteristics are summarized in Table 1. The median follow-up time was 7 years (range, 3–12 years) after operation.

Operation: Indication and Technique. Indication for the operative procedure was based on 2 criteria: 1) the clinical evidence of radiculopathy, cervicobrachialgia with radicular pain or cervical myelopathy, and 2) radiographic evidence of either a cervical disc herniation or retrospondylophytes or spondylophytes at the uncinate process. The preoperative radiographic evaluation consisted of an anterior–posterior cervical radiograph laterally and either a computed tomography–myelography or an MRI in all patients. Thus, at the site of the subsequently performed ACDF, all patients had a diagnosis of cervical radiculopathy, myelopathy, or myeloradiculopathy and a radiologic diagnosis of herniated disc, posterior osteophyte, or cervical stenosis causing foraminal narrowing or spinal cord compression. All patients were also evaluated for numerous diseases that also might cause *headache and suboccipital pain* such as vascular dysregulation, *i.e.*, resulting from cluster headache, migraine, insufficiency of basilar or vertebral artery, or which can cause *neck–shoulder–arm pain* such as any shoulder disease or a nerve root lesion resulting from other causes than degenerative changes such as tumor, arachnoiditis, or herpes or any plexus lesion or peripheral nerve lesion resulting from any cause. All operations were performed in a single center by 4 different surgeons all using the same operative fusion technique without instrumentation. Our operative procedure was a modified Smith Robinson technique[23] with an anteromedial approach. The patient was placed supine without traction. A longitudinal incision anterior to the sternocleidomastoid was used. Curettes and rongeurs were used to remove the disc material. If the longitudinal ligament was perforated, further decompression was undertaken. Diamond burrs of different diameters were used to remove retrospondylophytes. For the subsequent fusion, iliac bone autografts were inserted. Further data collection in respect to the operative site and technique included number and level of the operative segments, removal of retrospondylophytes and spondylophytes at the uncinate processes (Table 2).

Study Procedure in the Single Patient. Patients were contacted by telephone and asked to participate in the study. On the day of the investigation, patients received first a cervical MRI scan, then underwent radiographic examination, then followed by the clinical investigation. Finally, patients filled out the quality-of-life questionnaire (Profiles of Quality of Life of Chronically Ill [PLC][28]) and the Cervical Spine Symptom Scale (CSSS[29]). The whole procedure lasted approximately 3 hours.

Table 2. Operation Criteria and Technique

No. of segments	
1	39
2	14
3	1
Segment level*	
C3/4	1
C4/5	3
C5/6	32
C6/7	32
C7/D1	2
Disc removal	70
Retrospondylophyte removal	26
Uncinate process removal	17
Autograft transplantation	70

* Including multisegmental operations.

Magnetic Resonance Image Evaluation. A cervical MRI scan (Siemens Magnetom Expert, Erlangen, Germany) was performed to assess the localization of myelocompression, myelopathy, disc protrusion, and disc herniation. Images were acquired by sagittal and transverse spin echo (SE, T1), sagittal turbo spin echo (TSE, T2), and transverse gradient echo (FL2D, T2) sequences. All images were acquired and displayed using adapted matrices from 130 to 240 $\times$ 256. A sagittal scout view, T2-weighted turbo spin echo (TSE) sequence (TR 5000/TE 112/AC 2) was followed by T1-weighted sagittal spin echo (SE) sequence (TR 440/TE 15/AC 3), transverse T1-weighted SE-sequence (TR 500/TE 15/AC 3), and transverse gradient echo (GE, FL2D) sequence (TR 585/TE 18/AC 3). MRI signs of myelopathy were defined as high signal foci of the spinal cord in T2-weighted images resulting from edema with or without a focal dimensional change of the spinal cord in T1-weighted images. Myelocompression was defined as positive when the following 2 criteria were met:

Criterion 1: Focal disappearance of the subarachnoid space.

Criterion 2: The sagittal diameter of the spinal cord was reduced by more than one third in comparison to the arithmetic mean of the sagittal diameters of up to 3 of the adjacent proximal and distal segments that did not demonstrate focal disappearance of the subarachnoid space (Figure 1).

Radiographic Evaluation. All patients received conventional (anterior–posterior, lateral) and functional (flexion/extension) radiographs to assess fusion, fusion alignment, and adjacent instability. Fusion was defined when a continuous trabecular architecture between the former end plates of the fused vertebrae and no signs of instability as defined subsequently were present. The alignment of the fused segment was defined as lordotic or kyphotic based on the angle of the tangents on the ground and end plate cranially and caudally to the operated site. Adjacent instability was defined by a modification of the White and Panjabi recommendation taking into account the results of the anthropometric study of Gilad et al. on sagittal radiographic measurements,[30–32] *i.e.*, the sagittal plane translation was equal to or more than 25% of the sagittal diameter of the adjacent vertebra.

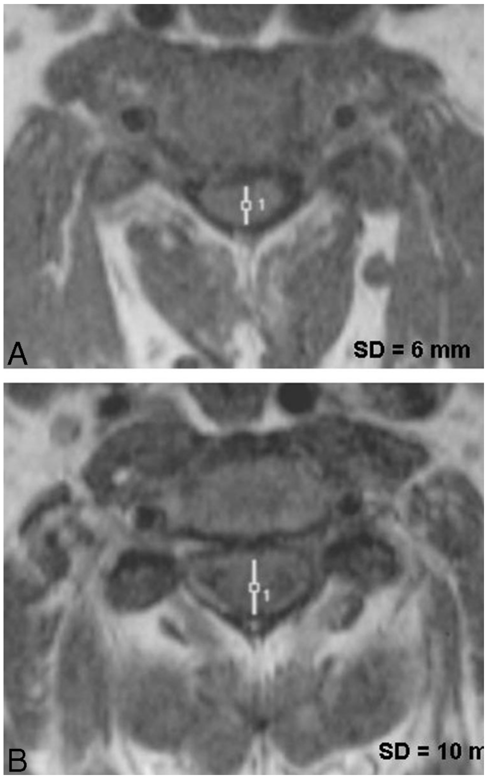

Figure 1. Example of T1 axial images to illustrate how sagittal diameter measurements were performed. **A,** myelocompression was defined as positive because focal disappearance of the subarachnoid space at the segment proximal to the fusion segment was present and the sagittal diameter was reduced by more than one third (6 mm) in comparison to the arithmetic mean of up to 3 proximal and distal segments that did not demonstrate focal disappearance. **B,** myelocompression was defined as negative because there was no focal disappearance of the subarachnoid space. This segment was used as a reference segment with a measured sagittal diameter of 10 mm.

Clinical Assessment by the Physician. Assessments were performed by 1 single investigating physician not identical with the surgeon. The documentation form included selected items of standard scores (Odom's criteria,[33] Oswestry low back pain disability questionnaire,[34] neck disability index[35]) tapping into pain characteristics (radicular, nonradicular, permanent, nonpermanent), impaired range of motion, paresis, sensitivity change, reflex status, and signs of cervical myelopathy.

Patient Self-Reported Quality-of-Life Cervical Spine Symptoms

Selection of a Standardized Quality-of-Life Instrument: Profiles of Quality of Life of the Chronically Ill. Quality-of-life assessment in clinical trial is best accomplished by means of a modular approach, that is using a standardized quality-of-life instrument in combination with a symptom-specific scale for the patient sample of interest. We considered several standardized instruments (SF-36, FACT, EORTC, PLC[36–38]) and decided to use the PLC,[28] primarily because it was designed for chronically ill patients and, unlike other instruments, it does not only tap into impairments of quality of life, but also covers positive issues. We reasoned that cervical spine patients with chronic symptoms would experience a loss of positive experiences and that therefore this instrument would be sensitive to detect such differences.

The PLC is a 40-item instrument, all items to be answered on 5-point Likert scales (0 = not at all, 5 = very well/very strong). The items represent the following domains:

Scale 1—Everyday capabilities (item example: "carrying out physically strenuous work")

Scale 2—Ability to enjoy ("enjoying something or being pleased about something")

Scale 3—Positive mood ("in good mood and optimist")

Scale 4—Negative mood ("anxious and worried")

Scale 5—Sociability ("undertaking something together with others")

Scale 6—Sense of belonging ("belonging to a circle of family or friends")

The PLC has been rigorously tested regarding psychometric properties (reliability, validity, sensitivity). An English translation and a Spanish version[39] are available. Norm data collected in a representative sample of over 2000 German inhabitants have been reported.[40] Symptom scales designed to accompany the PLC are available for hypertension, chronic heart disease, epilepsy, knee injuries, and also cervical spine symptoms (see subsequently).

Cervical Spine Symptom Scale. When this investigation was planned, a standardized scale to assess cervical spine specific symptoms was not available in German.[41,42] For this reason, we developed such a scale before beginning with this study.[43] (Meanwhile, a standardized scale is available but was validated only in 14 cervical spine patients.[41]). The framing of the questionnaire (introductory remarks, timeframe), the wording of the symptoms and of response scales followed the lead of the standardized quality-of-life questionnaire PLC.[28] In an earlier publication, we showed that the CSSS has convincing psychometric properties (reliability, validity, sensitivity) and is able to discriminate very well between persons with high and low symptom burden.[29] Internal consistencies of the scales are very high, ranging between Cronbach's alpha = .88 to .95 in different samples. This justifies the computation of an overall symptom score. The entire scale is depicted in the Appendix (available for viewing on ArticlePlus).

Statistical Procedures. Descriptive statistics (frequencies, mean, median, ranges) were used to present patient characteristics, operative techniques, and basic results of the imaging procedures. Before/after differences in the occurrence (present/absent) of clinical signs and symptoms were calculated with the McNemar test.

Quality-of-life scores were computed according to the PLC manual.[28] The univariate influence of adjacent instability (present/absent) and myelocompression (present/absent) on patients' self-reported quality of life (PLC) and cervical spine symptoms (CSSS) were calculated by independent *t* tests. These analyses were supplemented by multiple regression analyses entering a broader set of variables simultaneously (age, gender, time since operation burden, adjacent instability, myelocompression). PLC quality-of-life scores were compared with German norm data by computing t-statistics and effect sizes.[37] Effect sizes indicate clinical significance (rather than statistical significance) and by convention are interpreted as small (0.2), moderate (0.5), or large (>0.8).[44] The statistical analyses were

Table 3. Results of MRI Scan

Variables	Localization	Results
Compression of myelon	None	41
	Yes	13
	With MRI signal indicating myelopathy	2
	Without MRI signal indicating myelopathy	11
	Yes (respective to operated segment)	
	Proximal	5
	Distal	5
	Proximal and distal	3
Origin of myelon compression	Anterior	13
	By disc herniation	6*
	By spondylophyte	10*
	Posterior	0

* The counts of disc herniations and spondylophytes are 16 rather than 13 because of the three cases with proximal and distal myelocompression.

Table 4. Results of Radiographic Evaluation

Imaging Procedure	Variables	Localization	Results
Conventional radiograph cervical spine (AP and lateral)	Fusion	Yes	51
		No	3
Functional lateral radiograph cervical spine (flexion/extension)	Adjacent instability	None	37
		Proximal segment	13
		Distal segment	2
		Proximal and distal segment	1
		Missing	1

made in an attempt to detect a pattern of clinical and patient-based outcomes that would characterize patients with overall postoperative long-term success or failure. The test of an overall null hypothesis (*i.e.*, there is no difference between groups on any given list of characteristics) was not at the core of these analyses and therefore, Bonferroni adjustment was not applied.[45] All analyses were performed using the statistical computer package SPSS.[46]

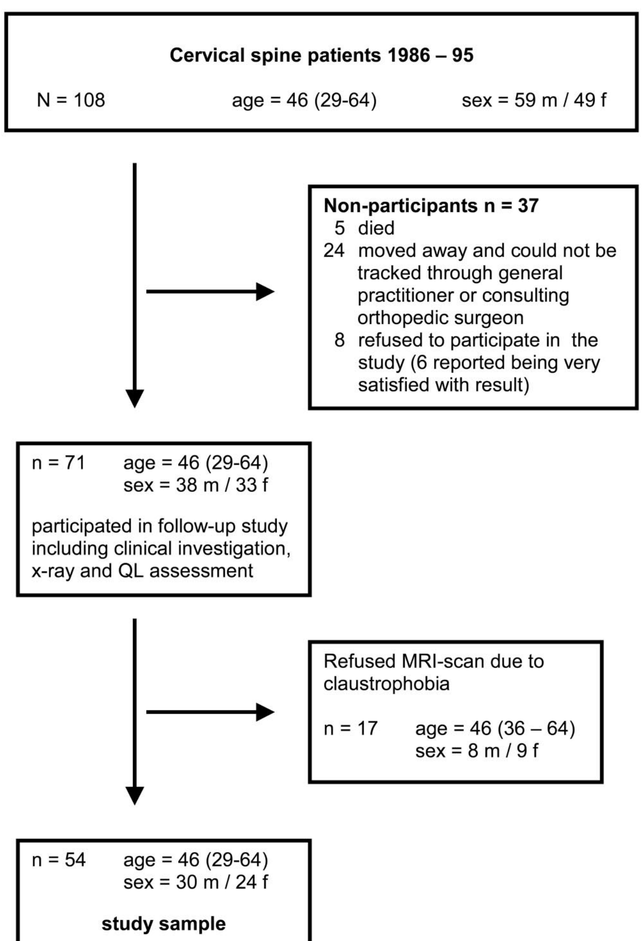

Figure 2. Trial profile.

Results

Operative Complications

Early surgery-related postoperative complications were wound hematoma/hemorrhage at graft donor site in 1 patient, graft displacement of less than one third of the initial contact area in 1 patient, and temporary unilateral recurrent laryngeal nerve lesion in 2 patients.

Magnetic Resonance Image Evaluation

The MRI revealed an adjacent myelocompression in 13 of 54 patients (24%), with the main compression originating anteriorly in all. The location was proximally in 5 patients, distally in 5, and both proximally and distally in 3. Myelocompression was caused by disc herniations in 6 cases and by spondylophytes in 10 cases (Table 3). Of these 13 patients, 2 had additional MRI signal changes indicating a myelopathy. One of the 2 patients also developed clinical signs of myelopathy. Clinical signs of myelopathy were not present before surgery (Figure 3).

Furthermore, the MRI revealed in all adjacent cervical segments a total of 56 disc protrusions of which 36 were proximally and 20 distally. Nine disc herniations were found, 7 in the proximal and 2 in the distal segments. Before surgery on the MRI scan or CT scan, none of these patients had signs of myelocompression at the levels adjacent to the ACDF site.

Radiographic Evaluation

A fusion was achieved in 51 (94%) patients (Table 4). However, 9 (17%) patients did demonstrate a kyphotic malalignment. The flexion/extension radiographs displayed in 16 (30%) adjacent instabilities of which 13 were located at the proximal, 2 at the distal, and 1 at both segments.

Clinical Assessment

Before surgery, all 54 (100%) patients experienced pain. Forty-five (83%) patients had permanent and 9 (17%)

Table 5. Clinical Signs and Symptoms Before and After Operation

	Before	After
Pain (present)	54	13
Pain (permanent)	45	0
Pain (radicular)	49	9
Pain medication	50	10
Impaired range of motion	49	36
Paresis (yes)	33	9
Sensitivity change	50	25
Reflex status (pathological)	36	7

Note: All before/after differences are statistically significant ($P < .001$, McNemar test).

patients nonpermanent pain (Table 5). Forty-nine (91%) patients had radicular and 5 (9%) patients nonradicular pain. Fifty (93%) patients used pain medication. An impaired range of cervical motion was found in 49 (91%) patients. Neurologic deficits consisted of muscle weakness/paresis in 33 (61%) patients, sensitivity changes in 50 (93%) patients, and pathologic reflexes in 36 (67%) patients. Clinical signs of myelopathy were seen in 2 (4%) patients.

After surgery, all patients were judged to be free of permanent pain. Nevertheless, from a clinical standpoint, 13 (24%) patients were assessed to have pain episodes, 9 (17%) remained with radicular pain characteristics, and 10 patients (19%) still used pain medication. An impaired range of cervical motion was found in 36 (67%) patients. Neurologic deficits consisted of persistent muscle weakness/paresis in 9 (17%) patients, persistent sensitivity changes in 25 (46%) patients, and a persistent pathologic reflex status in 7 (13%) patients. Six (11%) patients demonstrated clinical signs of cervical myelopathy.

All preoperative–postoperative differences were significant at the $P < 0.001$ level (McNemar test).

Patient Self-Reported Quality of Life and Cervical Spine Symptoms

The Effect of Adjacent Instability and Myelocompression on Patients' Quality of Life

Patients with and without radiographic signs of adjacent instability were compared regarding their responses to the quality-of-life questionnaire PLC[28] and the CSSS.[29] Table 6 shows that the only significant difference related to the negative mood scale in the sense that those patients with adjacent instability have less favorable values.

In the same manner, patients with and without myelocompression were being compared. Significant differences were detected for all quality-of-life scales except sense of belonging. Patients with myelocompression had lower quality of life and a higher cervical spine symptom burden.

It is noteworthy that myelocompression and adjacent instability were not unrelated, but that 8 patients had both signs of myelocompression and adjacent instability. Furthermore, it appeared possible that other factors such as age or gender affect patients' quality of life and symptom burden.[37] Therefore, we performed multiple regression analyses using the quality-of-life scores and the CSSS as dependent variables. The predictor variables age, gender, and time since operation, myelocompression, and adjacent instability were entered into the regression equation simultaneously.

Myelocompression was the only predictor variable that yielded significant beta weights in the case of 6 of 7 quality-of-life symptom scores (Table 7). It is also noteworthy that myelocompression *versus* nonmyelocompression patients before surgery did not differ regarding

Table 6. Effects of Adjacent Instability and Myelocompression on Quality of Life and Cervical Spine Symptoms

	No Adjacent Instability (n = 37)		Adjacent Instability (n = 16)			No Myelocompression (n = 41)		Myelocompression (n = 13)		
	M	SD	M	SD	t	M	SD	M	SD	t
Scale 1 Everyday capabilities	2,57	0,81	2,23	0,75	1,41	2,66	0,76	1,91	0,63	3,19†
Scale 2 Ability to enjoy	2,82	0,55	2,52	0,69	1,73	2,87	0,61	2,35	0,45	2,88†
Scale 3 Positive mood	2,35	0,73	2,12	0,87	1,02	2,43	0,73	1,82	0,73	2,64†
Scale 4 Negative mood	3,27	0,64	2,86	0,72	2,09*	3,35	0,56	2,58	0,75	3,99‡
Scale 5 Sociability	2,95	0,64	2,67	0,70	1,42	2,98	0,62	2,51	0,68	2,29*
Scale 6 Sense of belonging	3,15	0,66	3,02	0,70	0,64	3,15	0,66	2,98	0,70	0,78
Cervical spine symptoms	0,96	0,77	1,14	0,84	0,73	0,89	0,69	1,39	0,96	2,06*

Scale 1 to Scale 6: Range of means (M) 0 (lowest well being) to 4 (highest well being). Cervical spine symptom scale: Range of means 0 (lowest symptom burden) to 4 (highest symptom burden).
* $P < 0.05$, † $P < 0.01$, ‡ $P < 0.001$
SD = standard deviation, t = t-statistic.

Table 7. Multiple Regression Analyses

	R	beta
Scale 1		
Everyday capabilities	0,50*	−0,40†
Scale 2		
Ability to enjoy	0,47*	−0,37†
Scale 3		
Positive mood	0,41	−0,34*
Scale 4		
Negative mood	0,51*	−0,42†
Scale 5		
Sociability	0,43	−0,32*
Scale 6		
Sense of belonging	0,21	−0,12
Cervical spine symptoms	0,35	−0,31*

* $P < 0.05$, † $P < 0.01$.
R relates to the multiple regression coefficient resulting from a multiple regression analysis with the predictors age, gender and time since operation, adjacent instability, and myelocompression. Beta is the standardized beta weight of the predictor variable myelocompression (no = 0, yes = 1)

height ($P = 0.28$), weight ($P = 0.31$), age ($P = 0.84$), range of motion ($P = 0.41$), and paresis ($P = 0.49$).

Comparison With Population-Based Norm Data

Comparisons with norm data based on a representative sample of the German population are depicted in Table 8. Differences were expressed with the conventional t-statistics but also with the effect size, expressing the clinical meaningfulness of the differences.[37]

The overall sample of cervical spine patients (n = 54) differed from the norm data with regard to the scales everyday capabilities (lower values for cervical spine patients, $P < 0.05$) and sociability (higher values for cervical spine patients, $P < 0.05$). In both cases, the effect sizes were small.

Comparing the subsample of patients with adjacent instability (n = 16) with the norm data showed 1 significant difference, namely, with regard to everyday capabilities (lower values for cervical spine patients, $P < 0.05$; moderate effect size).

However, striking differences with regard to 4 of the 6 quality-of-life scores were detected when comparing the subsample of patients with myelocompression (n = 13) with the norm data; in all cases, the patients evidenced lower values. Particularly strong were the differences with regard to everyday capabilities ($P < 0.001$) and positive mood ($P < 0.01$), which were statistically reliable and clinically meaningful (high effect sizes).

Clinically Assessed Pain

As detailed previously, pain was also assessed in the clinical assessment using selected items of Odom's criteria and the Oswestry low back pain disability questionnaire. This pain score had no relation to myelocompression or adjacent instability (P values 0.53 and 0.79, respectively), whereas the correlation with our cervical symptom scale CSSS was significant, r = .53 ($P < 0.001$).

■ Discussion

The goal of this study was to assess the postoperative clinical outcome in an integrated manner, including both conventional clinical criteria, cervical MRI scans, cervical anterior–posterior, lateral, and functional radiographs, clinical assessment by the physician as well as patient self-reported quality of life and cervical spine symptoms. A total of 54 patients have been analyzed in the present study, and the sample represents 50% of a larger cohort of 108 patients operated in a 10-year period. A possible objection therefore is that of a patient selection bias in the sense of omitting particularly ill patients, thus downsizing the clinical problem under investigation. We kept track of all operated patients and care-

Table 8. Profiles of Quality of Life With Chronic Disease: Comparing German Norm Data With Cervical Spine Patients

	German Norm Data (n = 1273)		Cervical Spine Patients (n = 54)				Adjacent Instability (n = 16)				Myelo-compression (n = 13)			
	M	SD	M	SD	t	ES	M	SD	t	ES	M	SD	t	ES
Scale 1 Everyday capabilities	2,70	0,62	2,48	0,80	2,52*	0,28§	2,23	0,75	3,01†	0,68¶	1,91	0,63	4,57‡	1,26‖
Scale 2 Ability to enjoy	2,67	0,62	2,75	0,61	0,93	0,13	2,52	0,69	0,87	0,23§	2,35	0,45	2,54*	0,59¶
Scale 3 Positive mood	2,41	0,70	2,28	0,77	1,33	0,18	2,12	0,87	1,64	0,37§	1,82	0,73	3,02†	0,82‖
Scale 4 Negative mood	3,06	0,75	3,16	0,69	0,96	0,14	2,86	0,72	1,06	0,27§	2,58	0,75	2,29*	0,64¶
Scale 5 Sociability	2,61	0,68	2,86	0,66	2,65†	0,37§	2,67	0,70	0,35	0,08	2,51	0,68	0,53	0,15
Scale 6 Sense of belonging	2,98	0,69	3,11	0,66	1,36	0,19	3,02	0,70	0,23	0,05	2,98	0,70	0	0

t and ES refer to the comparison of the German norm data with the respective group of patients.
* $p < 0.05$, † $p < 0.01$, ‡ $p < 0.001$.
§ small (0,2 to 0,5), ¶ medium (0,5 to 0,8), ‖ strong (> 0,8) effect size.
M = Mean, SD = standard deviation, t = t-statistic, ES = effect size.

Figure 3. Eight-year postoperative cervical magnetic resonance image of a 62-year-old male patient with ACDF procedure C5–C7. **A,** multisegmental adjacent disc degenerations (C3/4, C4/5, and C7/Th1) can be seen. At C7/Th1, a myelocompression with intramedullar signal change in the T2-weighted image can be seen. Retropondylophytes have developed and osteoarthritic hypertrophies of the facet joints are prominent. **B,** at C7/Th1, a subligamentary disc herniation with partial cranial sequestration and myelocompression is detectable. This patient developed clinical signs of cervical myelopathy.

fully documented reasons for not participating in the study (Figure 2). The study sample is practically identical to the larger cohort regarding the basic characteristics age and gender ratio. Furthermore, 6 patients who refused to participate in the study mentioned that they were very satisfied with the treatment result. Furthermore, the present analyses revealed complication rates that were identical or even slightly higher than reported in the literature. Therefore, the existence of a systematic patient selection bias in the sense of underestimating the clinical problem seems unlikely. Nevertheless, we acknowledge that the generalizability of the present results would profit greatly from replications in other samples.

The clinical and radiographic results are first discussed in light of the literature. The rate related to the early complications of surgical technique such as wound hematoma/hemorrhage at the graft donor site, autograft displacement, temporary lesion of recurrent laryngeal nerve is within the range that has been described by other authors using this technique[8,21,47–54] Although it had been shown before that both myelocompression and adjacent instability were able to affect the clinical outcome,[55–58] little is known about the long-term complications, particularly myelocompression and myelopathy, as diagnosed by MRI. This study demonstrated an unexpectedly high rate (24%) of myelocompression. This myelocompression was never located directly at the operated site, but was always found adjacent (5 proximally, 5 distally, 3 proximally and distally).

Wu et al.[59] reviewed fast spin echo (FSE) MR images of disc herniations and spondylosis in patients after cervical surgery with an average follow-up time of 3 years. They concluded that ACDF causes acceleration of the degenerative changes at the fused level and at the level below and above the fused segment. Although they found that the prevalence of disc herniation, below and above the fused level, was not significantly different from the control group, they expected that in a longer follow up, the disc herniations would occur with increasing frequency. The high rate of disc herniations (17%) in this study after a median follow-up time of 7 years (range, 3–12 years) supports Wu's hypothesis. Biomechanically, this can be explained by the increased mechanical stress transfer to the adjacent proximal and distal segments leading to adjacent instability.[55] Indeed the flexion/extension radiographs in this study revealed adjacent instabilities in 30% of the cases. The proximal *versus* distal ratio of this instability was 13:2. Although there is a theoretical magnification error in lateral radiographs,[60] this should not affect the adjacent instability criteria set for this patient sample because this was based on angle measurements and on the magnification independent criteria of Panjabi.

The fusion rates given by several authors[8,14,21,47–54,61] range from 75% (multisegmental fusion without plate) to 98% (single fusion with plate). In our study, a fusion was achieved in 94%. However, 9 (17%) of those patients demonstrated a kyphotic malalignment. Recently, Katsuura[62] investigated a patient sample comparable to ours and reported kyphotic malalignment in 19% and sigmoid malalignment in 10%. Although the prevalence of kyphotic malalignment in the 2 studies is similar, we—in contrast—did not find a higher prevalence of adjacent instability in our kyphotic malaligned subgroup.

Comparing the results of the postoperative MRI with the preoperative MRI or CT-myelographies, an interesting finding was that none of the patients had evidence of myelocompression at the motion segment before surgery, which eventually became the area of compression at follow up. It appears that the preoperative radiologic assessment had no predictive value in which patients would develop myelocompression.

The other important objective of this study was to investigate the effect of myelocompression and adjacent instability on patient self-reported outcomes. This study revealed the important new finding that myelocompression, but not adjacent instability, led to a decrease in quality of life and an increase in symptom burden as assessed with the CSSS. Certainly, this effect warrants replication in additional studies.

It would be interesting to see if our findings can be replicated with other generic questionnaires such as the SF-36 or disease-specific scales such as the North American Spine Society Instrument.[42] Quite generally, the relationship between conceptual clinical variables (in this case "myelocompression," "quality of life," and "cervical symptom burden") is regarded as strong when the relation holds stable across a variety of different, yet comparable, means of measurements.[63] It has to be pointed out that the relation between myelocompression and pain did not occur regarding physician-based clinical pain judgment but only when patients filled in a multidimensional quality-of-life and symptom questionnaire. This striking finding underlines the need that classic imaging-based assessments and physician-determined clinical scores should be supplemented by symptom and quality-of-life assessments expressed by the patients themselves.[25,26,64–68]

Conclusions

The present study revealed an unexpectedly high long-term postoperative myelocompression rate that became apparent in magnetic resonance imaging scans and in low levels of quality of life and high cervical spine symptom burden.

The results of this study underline the need for a better understanding of the biomechanical changes (particularly strain distribution and motion) in the adjacent non-unfused segments to permit the development of more physiological operative solutions.

A consensus on follow-up guidelines of ACDF patients is needed, including an agreement on the implication of postoperative MRI scans and pain management treatment for patients who still suffer from symptoms. For comparison studies (*i.e.*, different fusion techniques or disc replacements) as well as follow-up studies, we recommend the use of an integrated outcome approach, including imaging-based, physician-based, and patient-based assessments.

Key Points

- In this cross-sectional study an analysis of myelocompression, myelopathy, adjacent instability, physician-assessed clinical signs and symptoms and patient's self-reported symptoms and quality of life after anterior cervical discectomy and fusion (ACDF) was performed.
- Myelocompression but not adjacent instability was associated with strong statistically significant decreases in quality of life and high cervical spine symptom burden.

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