

OUTCOMES

Anterior Cervical Discectomy and Fusion Outcomes over 10 Years

A Prospective Study

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Study Design. Prospective cohort study with >10-year follow-up.

Objective. To assess the long-term, >10-year clinical outcomes of anterior cervical discectomy and fusion (ACDF) and to compare outcomes based on primary diagnosis of disc herniation, stenosis or advanced degenerative disc disease (DDD), number of levels treated, and preexisting adjacent level degeneration.

Summary of Background Data. ACDF is a proven treatment for patients with stenosis and disc herniation and results in significantly improved short- and intermediate-term outcomes. Motion preservation treatments may result in improved long-term outcomes but need to be compared to long-term ACDF outcomes reference.

Methods. Patients who had disc herniation, stenosis, and DDD and underwent ACDF with or without decompression were prospectively enrolled and followed for a minimum of 10 years with outcome assessment at various intervals. All 159 consecutive patients had autogenous tricortical iliac crest bone graft and plate instrumentation used. Outcomes included visual analog scale for neck and arm pain, pain drawing, Oswestry Disability Index, and self-assessment of procedure success. Preoperative adjacent-level disc degeneration, pseudarthrosis, and secondary operations were analyzed.

Results. For all diagnostic groups, significant outcomes improvement was seen at all follow-up periods for all scales relative to preoperative scores. Outcomes were not related to age, gender, number of levels treated, and minimally to preexisting degeneration at the adjacent level. The use of narcotic pain medication decreased substantially. Neurological deficits almost all resolved. Patient self-reported success ranged

from 85% to 95%. Over the long term, additional surgery for pseudarthrosis (10%) occurred in the early follow-up period, and for adjacent segment degeneration (21%), which occurred linearly during the >10-year follow-up period.

Conclusion. ACDF leads to significantly improved outcomes for all primary diagnoses and was sustained for >10 years' follow-up. Secondary surgeries were performed for pseudarthrosis repair and for symptomatic adjacent-level degeneration.

Key words: ACDF, cervical, degenerative disc disease, disc herniation, fusion, outcomes, pseudarthrosis, stenosis.

Level of Evidence: 2

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Anterior cervical discectomy and fusion (ACDF) with or without decompression is a well-established surgical treatment for spine patients with the appropriate indications. Multiple studies have uniformly documented the success of ACDF at short- and medium-term follow-up, and at long-term follow-up in retrospective.^{1–11} However, long-term prospective outcomes studies are very few.¹² Long-term follow-up studies are of interest not only relative to the outcomes at the level of the index surgery but to understand the secondary effects such as at the adjacent level. It is well known that the levels adjacent to a fusion may become symptomatic and that some patients will require additional surgery. The indications for ACDF are for patients with herniated nucleus pulposus (HNP), chronic (or hard disc) herniations, stenosis (either foraminal with nerve root compression or central with spinal cord compression, or both), or even axial neck pain.¹³ The vast majority of these patients will undergo nonoperative treatment before an ACDF, typically with pharmacological or physical therapy and/or chiropractic, passive and active modalities, spinal steroid injections, or even alternative treatments. The timing of treatment after initial presentation to the spinal surgeon often depends on the severity of symptoms and/or neurological deficit or potential of neurological deficit.

The objective of the present study was to prospectively document clinical outcomes of consecutive ACDF patients, using patient-based self-assessment instruments, during a

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The device(s)/drug(s) is/are FDA-approved or approved by corresponding national agency for this indication.

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TABLE 1. Patient Group Characteristics.

Diagnosis	HNP	Stenosis	DDD	All
Female (%)	46	60	85	64
Age, years	43.0 ± 8.4	52.3 ± 9.8	44.1 ± 8.2	46.4 ± 9.7
Number of levels treated	1.3 ± 0.5	2.1 ± 0.7	1.7 ± 0.8	1.7 ± 0.7
Duration of symptoms	0.8 ± 0.8	3.0 ± 3.9	4.8 ± 5.3	2.9 ± 4.2
Adjacent disc degeneration (% preop)	37	71	64	57
Concomitant low back pain (%)	44	67	76	63
Smokers (%)	33	37	60	43
Worker Compensation, litigation case (%)	33	19	38	30

Values are mean ± standard deviation. DDD indicates degenerative disc disease; HNP, herniated nucleus pulposus.

minimum 10-year follow-up. In addition to assessing the durability of the outcomes, additional objectives were to identify secondary surgery rate and compare the outcomes between three major diagnostic categories: HNP, stenosis, and predominantly axial pain owing to cervical degenerative disc disease (DDD). Subanalyses were also performed for smokers *versus* nonsmokers, single *versus* multi-level (two- and three-level) surgery, work-compensation (WC) patients *versus* non-WC patients, and the possible effect of preexisting degeneration at the level adjacent to the index surgery.

METHODS

The present prospective study approved by the institutional review board relates to outcomes for ACDF surgery with or without concomitant decompression. Entry criteria were age between 18 and 65 years, less than 20° of scoliosis or kyphosis, and imaging findings consistent with clinical findings. Patients were eligible if they had a previous posterior decompression but were excluded if they had previous cervical spine fusion surgery. Patients were also excluded if they had advanced stenosis with myelopathy that necessitated corpectomy or laminoplasty. All patients underwent nonoperative treatment, including physical therapy, pharmacological treatment, and spinal steroid injections. Patients in whom nonoperative treatment failed were consecutively enrolled and treated between January 1 1996 and December 31, 2003. All patients had preoperative MRI and physical examination consistent with their cervical spine condition and gave consent to participate. The surgical procedure required that all patients have tricortical iliac autograft and rigid plate instrumentation used to optimize fusion success rate.^{14–23} Additionally, all patients had their iliac bone graft donor site reconstructed to lessen donor site pain.²⁴ All patients had their procedure performed in a similar technique by a single surgeon. Patient demographics categorization to three primary diagnoses of herniated nucleus pulposus (HNP), stenosis, and DDD are summarized in Table 1. Demographics included age, sex, duration of preoperative symptoms, smoking status, worker's

compensation status, and occupation. Additionally, the presence on preoperative MRI of disc degeneration adjacent to the index surgical level was assessed as it may influence postoperative ACDF outcomes.²⁵ Neurological assessments of upper-extremity weakness (manual resistance on 0–5 scale with 0 being flaccid and 5 normal strength) and sensory deficits (to light touch) were analyzed. Deep tendon reflexes, gait, and pathological reflexes were also examined.

Multiple outcomes questionnaires were administered to patients preoperatively and at multiple postoperative intervals for >10 years. Outcomes were measured using a neck and arm pain visual analog scale (VAS, 0–100, with 100 being the most severe pain), pain drawings, and Oswestry Disability Scale (ODI, 0–100 with 100 indicating severe disability). Note that at the inception of this prospective study, the NDI was not validated, and ODI had precedence.^{2,26–31} Additional assessment included the use of pain medication and patient's self-assessment of treatment success (Do you consider your surgery to have been successful? Would you undergo this treatment again under similar circumstances? Would you recommend this procedure to others with similar symptoms and spine problems?). Concurrent low back was also assessed, as it may affect outcomes instrument results.³² Patients completed a separate set of outcomes to distinguish neck *versus* low back complaints.

Cervical spine radiographs were obtained at 8 to 12 months postoperatively that assessed for trabeculation across the fused disc space and motion on flexion-extension films. Fusion was considered solid if there was continuous trabeculation and no >1 mm splaying of the tips of the spinous processes of the fused level on flexion/extension films. Computed tomography scans, thin cut, were obtained in all patients who did not fulfill both of these requirements to further assess for fusion status.

Statistical analysis evaluated changes from preprocedure in the parameters of neck pain VAS and arm pain VAS scores, pain drawing scores, and ODI scores. These were summarized and assessed for differences by selected subgroups using analysis of variance. Statistical significance

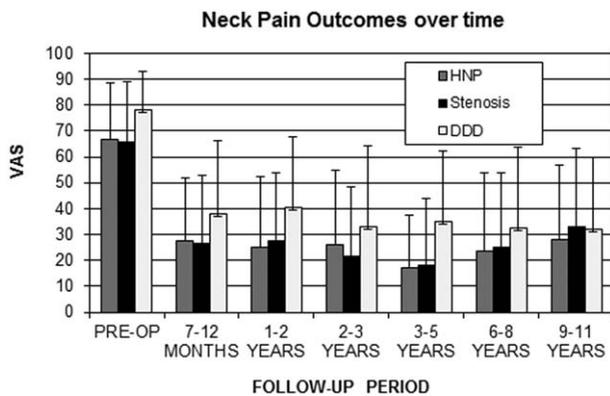


Figure 1. Neck pain VAS changes over time for three primary diagnoses, mean \pm standard deviation. DDD indicates degenerative disc disease; HNP, herniated nucleus pulposus; VAS, visual analog scale.

was determined at the nominal 0.05 level. No adjustments for multiplicity were made.

RESULTS

During the enrollment period, 159 consecutive patients fit the inclusion criteria and had a minimum 10-year follow-up. ACDF was performed in 90 single-level cases and in 69 multilevel cases. The primary diagnosis were HNP ($n = 52$), stenosis ($n = 52$), and DDD ($n = 55$). The mean (\pm standard deviation) postoperative follow-up period was 10.9 (± 1.4) years, yet some patients were lost to follow-up. Specifically, by 2-year follow-up, two patients were deceased; by 3-year follow-up, a total of two patients were deceased and two lost; by 5 years, a total of three were deceased and two lost to follow-up; by 8 years, a total of eight patients were deceased and five lost, and two declined to participate; and by 11-year follow-up, a total of 12 patients were deceased, 11 lost, and three declined to participate. All deceased patients had died of reasons unrelated to their surgery or any spinal condition.

The HNP group had the shortest duration of symptoms, the least number of levels treated, and the lowest rate of concomitant low back pain. The stenosis group was the oldest and had the greatest number of levels treated. The DDD group had a greater proportion of females and the longest duration of symptoms. Additionally, the number of patients with degeneration identified on cervical MRI scans in addition to the index level are identified (see Table 1). Many patients had shoulder conditions or low back pain, which maybe confounding factor in cervical spine outcomes assessment.

Neurological improvement was noted in all groups, specifically and correlated to imaging studies. In the HNP group, 6% had spondylitic central stenosis and 25% had central stenosis owing to the HNP, but only 8% presented with myelopathic findings (none severe). This group also had 29% with spondylitic foraminal stenosis and 63% with HNP narrowing the foramin, and in total 90% of patients had radiculopathy. The radiculopathy presented as altered deep tendon reflexes in 58%; 77% had preoperative weakness, and all resolved after surgery; 62% had preoperative

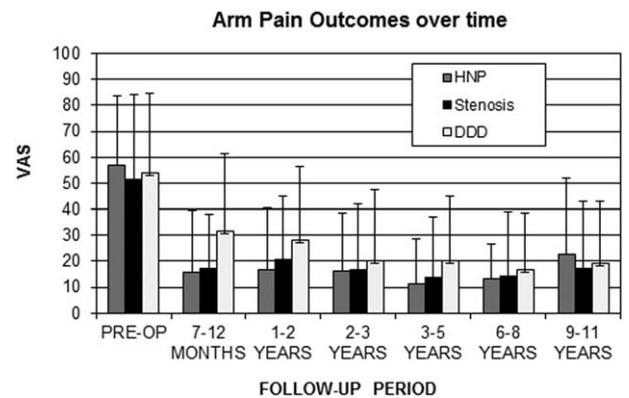


Figure 2. Arm pain VAS changes over time for three primary diagnoses, mean \pm standard deviation. DDD indicates degenerative disc disease; HNP, herniated nucleus pulposus; VAS, visual analog scale.

sensory deficit, and all but one patient had normal sensation postoperatively.

In the stenosis group, 65% had spondylitic central stenosis and 31% presented with myelopathic findings (none severe). This group also had 94% with foraminal stenosis of which 73% had radiculopathy and included 25% with altered deep tendon reflexes; 46% had preoperative weakness, and all resolved; 67% had preoperative sensory deficit, and all but one patient had normal sensation postoperatively,

In the DDD group, 35% of patients had a central disc herniation that effaced or slightly indented the cord and 7% had mild spondylitic central stenosis of which none had myelopathic findings and only one patient had a radiculopathy. Of the patients with posterior annular tears or central HNP, 16% had mild weakness (5-/5) and 27% had mildly altered sensory changes. Foraminal stenosis was present in 18% and 4% had preoperative weakness (mild, 5-/5, in both cases), and 27% had preoperative sensory deficit. Weakness resolved in all patients and all but two patients had normal sensation examination postoperatively.

Patient self-reported outcomes found significant improvement at all follow-up periods for all scales relative to preoperative scores ($P < 0.0001$; Figures 1–4). The HNP, stenosis, DDD groups all had similar improvement for VAS neck and arm pain at all postoperative follow-up periods, and small changes over the postoperative periods were not statistically significant. The HNP had significantly greater improvement in ODI compared to the stenosis and DDD groups during the initial 3-year postoperative follow-up periods. At late follow-up periods, there was an insignificant worsening of disability scores. The use of narcotic pain medication decreased substantially, but many patients still used nonsteroidal anti-inflammatory medications for long term (Table 2). Patient self-report of surgical success ranged from 85% to 95% (Table 3).

Age, sex, and the number of levels treated were unrelated to outcomes. Non-worker's compensation patients had greater improvement relative to worker's compensation

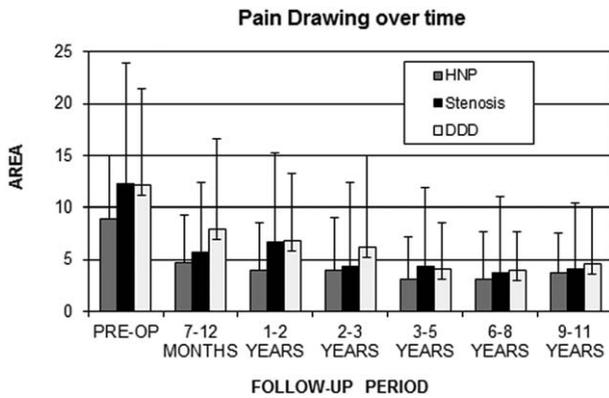


Figure 3. Pain drawing changes over time for three primary diagnoses, mean ± standard deviation. DDD indicates degenerative disc disease; HNP, herniated nucleus pulposus.

patients during the first 5 postoperative years for all outcomes scales, but this was not statistically significant. All patients in all groups returned to their preoperative occupation.

Patients with pseudarthroses, 12% of total, had significantly less improvement in all outcomes scales during the first 3 postoperative years for VAS neck and arm pain and ODI relative to those with solid fusion. Smokers had significantly less improvement in outcomes in the initial 2-year follow-up periods for VAS neck and arm pain and ODI relative to nonsmokers ($P=0.04$). Among smokers, 16% (11/67) developed a pseudarthrosis, whereas for

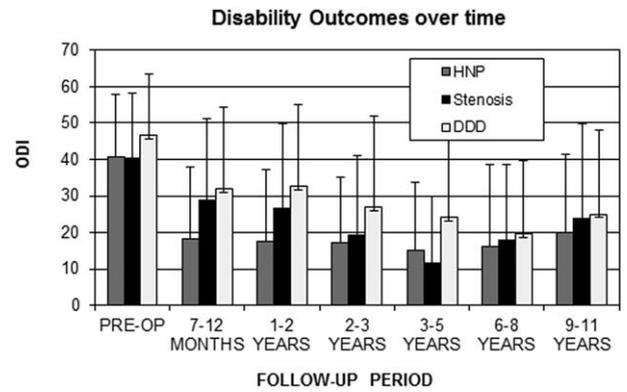


Figure 4. Disability changes over time for single-level and multilevel conditions, mean ± standard deviation. DDD indicates degenerative disc disease; HNP, herniated nucleus pulposus; ODI, Oswestry Disability Index.

nonsmokers, 8% (7 of 90) developed a pseudarthrosis. No statistically significant relationship was found between pseudarthrosis and smoking ($P=0.13$). The lack of statistically significant difference was most likely because of the small number of subjects with pseudarthrosis ($n=18$). The number of levels treated revealed a rate of pseudarthrosis for single-level (16%), which was higher than for multilevel cases (8%) (Table 4).

Patients with preexisting adjacent disc degeneration had significantly less VAS neck and arm pain improvement during the follow-up periods relative to those who did not ($P=0.01$ and $P=0.015$ respectively). However,

	Narcotics	NSAIDs	None
Preoperative	53%	43%	3%
7- to 12-mo follow-up	29%	36%	33%
1- to 2-y follow-up	19%	47%	32%
2- to 3-y follow-up	17%	38%	45%
3- to 5-y follow-up	17%	40%	48%
6- to 8-y follow-up	22%	46%	38%
9- to 11-y follow-up	26%	40%	40%

NSAIDs indicates nonsteroidal anti-inflammatory drugs.

	Overall, do you consider your treatment to have been successful?	Would you undergo this treatment again under similar conditions?	Would you recommend to others with symptoms and spine problems to have this?
7 to 12-mo follow-up	95%	95%	95%
1- to 2-y follow-up	91%	91%	94%
2- to 3-y follow-up	94%	95%	98%
3- to 5-y follow-up	90%	92%	92%
6- to 8-y follow-up	88%	88%	91%
9- to 11-y follow-up	85%	85%	90%

TABLE 4. ACDF Levels

	Single Level	2-level	3-level*
Number of Patients	69	66	24
Age, y, mean \pm SD	44.0 \pm 9.7	43.0 \pm 8.4	43.0 \pm 8.4
Female	58%	70%	67%
Smokers	48%	41%	38%
Pseudarthrosis	16%	9%	4%
Adj level fusion	28%	18%	13%
HNP	51%	24%	4%
Stenosis	15%	41%	63%
DDD	34%	35%	33%

ACDF indicates anterior cervical discectomy and fusion; DDD, degenerative disc disease; HNP, herniated nucleus pulposus; SD, standard deviation.

*Includes two patients who had four levels.

the VAS difference was ≤ 1.0 and thus not clinically significant.

Over the long term, 46 (29%) of the patients had additional surgery. Secondary surgeries for pseudarthrosis were 10% (Figure 5). Another reason for additional procedures was progressive adjacent-segment degenerative conditions either above or below the patient's index ACDF. ACDF extension surgery occurred progressively throughout the follow-up periods. Three patients had both a pseudarthrosis, which was repaired, and subsequently, the adjacent level treated surgically. The rate for surgical treatment of adjacent conditions was 21% at the 10-year follow-up and was linearly related ($r^2 = 0.98$; Figure 6) to time after the index ACDF surgery. The true rate of adjacent-segment surgery may be slightly higher, as it was unknown how many of the patients lost to follow-up may have had secondary surgery. If one assumes that all patients who were lost to follow-up or deceased had adjacent-segment surgery, the rate would have been 31% at final 12-year follow-up period (Figure 6). The number of levels fused at the index ACDF was related to secondary adjacent-level surgery: 28% of single level cases, 18% of two-level cases, and 13% of three-level cases had adjacent-level ACDF, Table 4. The rate of adjacent-segment surgery was more common in women; of those who had adjacent surgery, 76% were female; compared to those who did not have adjacent-level surgery of which 61% were female. However, adjacent-level surgery was not related to patient age and was similar for those with

preexisting adjacent degeneration; it was 22% at 10-year follow-up, compared to those who had normal adjacent discs at the index surgery and had an adjacent surgery rate of 21%. Subanalysis found that if at the time of index ACDF three or more untreated adjacent levels revealed degeneration, it indicated a two-fold increased rate of developing symptoms that then had adjacent-segment surgery. The number of patients in this study was small and thus, overall, preexisting adjacent-segment degeneration was not a risk factor for needing additional surgery at an adjacent level. On the basis of number of patients in the present study, smoking was also not related to adjacent-level secondary surgery.

DISCUSSION

This study found improvement in all three major diagnostic groups. All groups improved their outcomes scores, which were clinically significant as the improvement was greater than established minimum clinically important difference.³³⁻³⁵ Greater improvement for the HNP and stenosis groups was seen relative to the DDD group. Favorable outcomes were sustained during a 10-year follow-up period, which agrees with a previous prospective long-term report.¹² As expected, neurological deficits of radiculopathy and myelopathy all resolved except for mild residual sensory alterations in 3%.

Specifically, for the HNP group, the improved outcomes were similar to those in previous studies. One previous

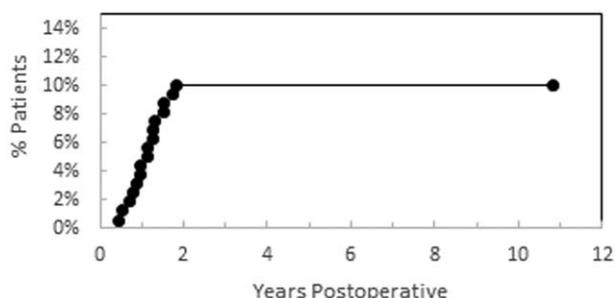


Figure 5. Cumulative secondary surgery for pseudarthrosis repair over time.

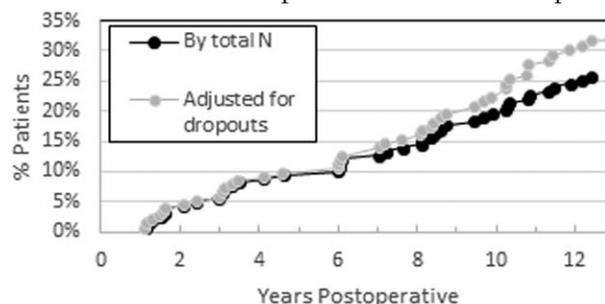


Figure 6. Cumulative secondary surgery for adjacent segment degeneration over time with rate for study patients, and worse case presumption if all lost patients required adjacent segment surgery.

report found VAS neck pain decreased from 6.7 to 3.2; VAS arm pain decreased from 5.1 to 2.3; and ODI improved by 20%.² Another study of HNP and stenosis patients also found VAS neck pain lessened from 6.5 to 2.5 and VAS arm pain from 6.1 to 1.8, results similar to those in the present study.³⁶

Preoperative axial neck pain was greatest in the DDD group, which reflects the greater degree of failed conservative care in this patient group who did not have a neurological deficit indication for surgery. The improved long-term outcomes in this group demonstrate that axial neck pain secondary to DDD may be treated successfully with ACDF in selected patients. In the present study, the VAS pain diminished from 7.8 to 3.3, and ODI improvement was comparable to two previous reports that also reported VAS improvement of 8.3 and 8.4 to 4.1 and 3.8, respectively.^{28,30,31}

A number of patient and surgical factors related to outcomes were analyzed. The number of levels treated, age, and sex were unrelated to outcomes, similar to a recent study,³⁷ although a previous study found greater pain improvement in single- compared to multilevel ACDF.³⁸ Smokers had less outcomes improvement, which agrees with results in previous studies.^{1,39,40} In the present study, however, this adverse effect occurred only during the first 2 postoperative years. Previous studies have shown worse outcomes or no effect related to worker's compensation status.^{41,42} The present study found that WC patients exhibited less improved outcomes, but this was not significant. The pseudarthrosis rate was 12% and was within the range of previous reports.^{12,18} Pseudarthrosis was more common in patients who were smokers; this has been previously reported.^{1,39,42} Our pseudarthrosis rate was greater for single-level cases, 16%, than for multilevel cases, 8%, which was unexpected given that intuitively and previous reports found increased pseudarthrosis rates with greater number of fused levels using non-instrumented techniques.^{1,5,43} Possibly, strongly encouraging postoperative brace compliance in the multilevel cases may have been a factor in their lower pseudarthrosis rates in the present study. Patients with pseudarthrosis and worse results have been previously reported.^{14,44} Our patients with pseudarthrosis had worse outcomes during the first 3 postoperative years; this time period coincided with the period during which pseudarthrosis repairs were performed. After pseudarthrosis repairs (all went on to become solid), the outcomes scores were similar to those of patients with a solid-index ACDF.

Although no unintended reoperations occurred, secondary surgeries were performed. Secondary surgeries include pseudarthrosis repair and for treatment of adjacent-segment conditions refractory to nonoperative treatment. Pseudarthrosis repair was performed in 16 of 159 patients (10%) in the present study and was most often treated within the first 2 years after their index surgery. Another reason for secondary surgery is treatment related to adjacent-segment degeneration. With aging, degeneration of the cervical spine occurs, affecting all levels but predominantly at C56 and C67.^{45,46} Adjacent-segment degeneration, typically levels in

addition to C56 and C67, is a well-known entity that may progress over time after ACDF.⁴⁷⁻⁵¹ The adjacent level may become symptomatic and even require additional surgery with adjacent-segment secondary surgery in the range of 6% to 17% at 5- to 8-year follow-up.^{5,10,48,52-54} Long-term studies have found rates of 7% to 16% at 10- to 21-year follow-up.^{7,55} Other studies have extrapolated their data to conclude rates of 2.4% per year with estimated 10-year prevalence of approximately 20% to 25%.⁵⁶⁻⁵⁸ Adjacent-segment surgery rates of the present long-term study of >21% compare favorably with these previous reports. The present study found that patient age was not related to adjacent-segment surgery, and this finding has been demonstrated in previous studies.^{48,58} However, female sex was found to be related to increased rate of adjacent-level surgery and confirmed this finding of previous studies.^{48,58} Greater number of levels fused at the index surgery was found to result in a lower rate of adjacent-level surgery in the present study, and this agrees with some previous studies, although this finding has not been uniform.^{56,58,59} The present study also did not support that symptomatic adjacent-segment degeneration leading to secondary surgery was more common in cases where the level adjacent to the index level had preexisting degeneration, which was consistent with one prior study.⁴⁸ The present study did find that cases wherein three or more adjacent levels (or a global degeneration) were identified seemed to result in a greater rate of secondary surgery. Patient self-report of "surgical success" (Table 3) remained high despite the 2+% per year increase in secondary surgeries. The questions posed to the patients were in regard to their surgery but did not discriminate between their index surgery or revision surgery (if they had a secondary surgery). This apparent discrepancy between success rate and secondary surgery rate may be interpreted that patients who had a successful secondary surgery would give a positive response which hence prevented the expected decline in surgery success rate over time.

The presumed reason for adjacent-segment degenerative conditions is, in part, stress on the adjacent segments after an ACDF and inherent age-related degeneration of these levels. Cervical spine arthroplasty (disc replacement) is now available on a limited basis and may have the potential to decrease symptomatic adjacent-segment degeneration and need for secondary surgery.^{60,61} However, the stability of these devices is imperfect, and some have migrated or subsided. Others have resulted in kyphosis malalignment or found to have heterotopic bone formation. They are well suited for HNP but not always stenosis patients, and the optimal device has yet to be developed. The author's opinion is that cervical disc replacement will not replace ACDF for all cases. The author foresees that a common scenario, already performed outside the United States, will be to perform disc replacement at the level adjacent to an existing ACDF for the treatment of adjacent-segment DDD or be used in a "hybrid" procedure in which one of multiple levels is treated with a disc replacement and the other levels are treated with traditional ACDF.

In summary, ACDF has a high degree of long-term success when used for the appropriate indications. HNP, stenosis, and DDD diagnostic groups can all expect improved outcomes lasting a decade. Long-term studies are important for patients that they may expect sustained improvement and for clinicians and payors that adjacent-segment surgery rates remain linear over the long-term. Long-term data are useful for actuaries and others in predicting future health care costs. Adjacent-segment conditions progress over time. The prevention and treatment of this condition require ongoing research and development.

➤ Key Points

- ❑ ACDF has a high degree of success when used for the appropriate indications.
- ❑ HNP, stenosis, and DDD diagnostic groups can all expect improved outcomes lasting a decade.
- ❑ Secondary surgery rate for pseudarthrosis repair was 10%, and for adjacent segment conditions was 21% during the 10-year follow-up period.

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