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The Spine Journal 2 (2002) 408–414

THE SPINE JOURNAL

Comparing outcomes of anterior cervical discectomy and fusion in workman's versus non–workman's compensation population

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Received 20 February 2002; accepted 30 July 2002

Abstract

Background context: Anterior cervical discectomy and fusion (ACDF) is an accepted surgical procedure to treat degenerative conditions, including disc herniations and spinal stenosis. The literature on lumbar spine surgery reports that patients with a workman's compensation claim have less successful clinical results. Regarding the cervical spine, however, different conclusions have been drawn.

Purpose: The purpose of this study was to directly compare the functional outcomes of ACDF in patients with and without a workman's compensation claim and to determine whether a compensation claim adversely affected the clinical outcome.

Study design: This is a retrospective study examining the long-term results of ACDF in the workman's and non–workman's compensation populations.

Patient sample: Eighty consecutive patients undergoing ACDF were retrospectively analyzed. The patients were divided into two groups: 30 patients in Group 1 (workman's compensation) and 50 patients in Group 2 (non–workman's compensation). The average age of Group 1 was 45 years (range, 31 to 57) and Group 2 was 45 years (range, 30 to 79). The patients were followed for an average length of 4 years (range, 2 to 7 years).

Outcome measures: We evaluated the surgical results using a functional outcome scoring system (Odom's Criteria), visual analog scale and a radiographic grading scale. The questionnaire was independently administered in a standard question-answer format at the 1-year follow-up. Statistical analyses was performed using a Levene's test.

Methods: All surgeries were performed by the same attending physician. A left-sided approach and Smith-Robinson fusion technique with autograft or allograft without instrumentation was used in all cases. A hard cervical orthosis was used postoperatively for 8 weeks. Radiographic examination including lateral flexion and extension views were obtained at a minimum of 12 months postoperatively. Furthermore, radiographic analysis was performed each subsequent postoperative year. The radiographs were analyzed by two independent physicians in a blind fashion for evidence of radiographic fusion.

Results: At follow-up no discernible difference was noted for functional outcomes. Eighty-three percent of patients in Group 1 and 90% of patients in Group 2 noted excellent or good results. This was not statistically significant ($p=.280$). In Group 1, 97% of patients returned to work at an average of 18 weeks, whereas 98% of patients in Group 2 returned to work at an average of 10 weeks postoperatively. Upon radiographic evaluation, 64% of patients in Group 1 were determined to have a solid fusion (Grade 3). The fusion rate in Group 2 was 72%. This was not statistically significant. However, the fusion rate among smokers was 50%, and among nonsmokers it was 80%. This was statistically significant ($p=.001$).

Conclusions: Workman's compensation claims did not adversely affect the functional outcome of ACDF. It should be noted that a significant increase in pseudarthroses was noted with the smoking

FDA device/drug status: not applicable.

Nothing of value received from a commercial entity related to this research.

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PII: S1529-9430(02)00441-2

population. Patient selection is a critical factor in determining functional outcome, with 83% good to excellent results if the pathology, clinical presentation and radiographic findings correlate

Keywords: Anterior cervical discectomy and fusion; Workman's compensation; Surgical outcome

Introduction

Anterior cervical discectomy and fusion (ACDF) is an accepted surgical procedure to treat degenerative conditions, including disc herniations and spinal stenosis. Excellent and good results have been reported in 63% to 94% of patients [1–15]. The literature on lumbar spine surgery reports that patients with a workman's compensation claim have less successful clinical results [12,16–25]. Regarding the cervical spine, however, different conclusions have been drawn [4,5,14,26]. The purpose of this study was to directly compare the functional outcomes of ACDF in patients with and without a workman's compensation claim and determine whether a compensation claim adversely affected the clinical outcome.

Materials and methods

Eighty consecutive patients undergoing ACDF were retrospectively analyzed (1990 to 1997). Thirty workman's compensation (Group 1) and 50 non–workman's compensation (Group 2) patients were followed for 2 to 7 years with a mean of 4.0 years (Table 1). Surgical indications were myelopathy or radiculopathy recalcitrant to conservative treatment for at least 2 months secondary to a hemiated nucleus pulposus or spondylosis/stenosis. Conservative treatment included nonsteroidal anti-inflammatory medications and physical therapy in all patients and occasional epidural steroid injections. The preoperative work-up included a detailed history and physical examination, plain radiographs and cervical spine magnetic resonance imaging (MRI), myelogram/computed tomography scan or both. All surgeries were performed by the same attending physician. Prophylactic antibiotics were administered 30 to 60 minutes preoperatively and for 24 hours postoperatively. A left-sided approach and Smith-Robinson fusion technique with autograft or allograft without instrumentation were used in all cases. The decision to use autogenous iliac crest or iliac crest allograft was based on the patient's preference. A hard cervical orthosis was used for postoperative immobilization for 8 weeks.

Table 1
Patient demographics

	Group 1	Group 2
Patients (n)	30	50
Gender	22 male (73%)	21 male (42%)
	8 female (27%)	29 female (58%)
Age (years)	Average 45 (31–57)	Average 45 (30–79)
Diagnoses		
Herniated nucleus pulposus	27 (90%)	35 (70%)
Spondylosis/stenosis	3 (10%)	15 (30%)
Myelopathy	0 (0%)	5 (10%)
Radiculopathy	30 (100%)	45 (90%)
Fusion levels (n)		
One	28 (93%)	29 (58%)
Two	2 (7%)	19 (38%)
Three	0 (0%)	2 (4%)
Bone graft type		
Autograft	27 (90%)	40 (80%)
Allograft	3 (10%)	10 (20%)

The two groups were similar in demographics. Group 1, the workman's compensation population, included 30 patients. There were 22 men (73%) and 8 women (27%) with a mean age of 44 years (range, 31 to 57 years). Twenty seven (90%) patients were diagnosed with a herniated nucleus pulposus and 3 (10%) with stenosis. Thirty patients (100%) presented with radiculopathy and none (0%) with myelopathy. Autograft was used in 27 (90%) patients and allograft in 3 (10%). Twenty eight (93%) single-level, 2 (7%) two-level and 0 (0%) three-level fusions were performed. Sixteen (53%) patients had a history of tobacco use.

Group 2, the non–workman's compensation population, consisted of 50 patients. There were 21 men (42%) and 29 women (58%) with an average of 45 years (range, 30 to 79). Thirty-five patients (70%) were diagnosed with a herniated nucleus pulposus and 15 (30%) with stenosis. Five patients (10%) presented with myelopathy and 45 (90%) with radiculopathy. Autograft was used in 40 patients (80%) and allograft in 10 (20%). There were 29 (58%) single-level, 19 (38%) two-level and 2 (4%) three-level fusions. Fourteen patients (28%) had a history of tobacco use.

After informed consent, a chart review, radiographic evaluation and functional outcome questionnaire were completed. Radiographs, including lateral flexion and extension (F/E) views were obtained at a minimum of 12 months postoperatively and analyzed by two independent physicians in a blind fashion for fusion grading. Radiographs were also obtained after each subsequent postoperative year. Grade 1 represented an obvious pseudarthrosis with motion on F/E views. Grade 2 represented a possible pseudarthrosis with no motion on F/E views but a visible cleft at one or both graft–end plate surfaces. Grade 3 represented a solid fusion with no motion on F/E views and bony trabeculae crossing the graft–end plate surfaces [31] (Table 2).

Functional outcome was assessed by a questionnaire (Odom's Criteria) and evaluated symptom relief, return to work and medication usage. There were four clinical cate-

Table 2
Radiographic evaluation

Grade	Findings
Grade I	Obvious pseudarthrosis with motion on F/E views
Grade II	Possible pseudarthrosis with no motion on F/E views but a visible cleft at one or both graft–end plate surfaces
Grade III	Solid fusion with no motion on F/E views and bony trabeculae crossing graft–end plate surfaces

F/E = flexion and extension.

gories: excellent (complete symptom relief, return to full duty work, no pain medications); good (improved symptoms, return to work with some restrictions, no pain medications); fair (improved symptoms, return to light duty, regular pain medications); poor (no symptom improvement, failure to return to work, regular pain medications). Inquiry was also made as to whether the patient made the correct decision to have undergone surgery (Fig. 1).

Statistical analyses were performed using the Levene's test.

Results

Functional outcomes

In Group 1, 15 patients (50%) reported an excellent outcome, 10 (33%) good, 4 (13%) fair and 1 (4%) poor. Hence, 83% excellent and good and 17% fair and poor outcomes were obtained. In Group 2, 30 (60%) excellent, 15 (30%) good, 4 (8%) fair and 1 (2%) poor outcomes were reported. Hence, 90% of patients reported an excellent or good result with only 10% a fair or poor outcome. There was no statistically significant difference between the two groups ($p=.280$; Fig. 2). Twenty-eight patients (93%) in Group 1 and 49 patients (98%) in Group 2 believed surgery was a correct decision for a total satisfaction rate of 96% (77 of 80).

In Group 1 29 patients (97%) returned to work and 1 (3%) did not. Twenty-one (70%) returned without restrictions and 8 (27%) to modified duty. In Group 2 49 patients (98%) returned to work and 1 (2%) did not. Forty (80%) returned to full duty and 9 (18%) to modified positions. Group 1 patients returned to work on an average of 18 weeks (range, 6 to 30 weeks) postoperatively. Patients in Group 2 returned to work on an average of 10 weeks (range, 1 to 26 weeks) postoperatively.

Radiographic evaluation

In Group 1, 19 patients (64%) had a solid fusion (Grade 3), 8 (26%) a possible pseudarthrosis (Grade II) and 3 (10%) a pseudarthrosis (Grade 1). Therefore, 36% were defined to have a pseudarthrosis (Grades 1 and 2). In Group 2, 36 (72%) had a solid fusion (Grade 3), 10 (20%) a possible pseudarthrosis (Grade 2) and 4 (8%) a pseudarthrosis (Grade

Excellent	Complete symptom relief, return to full-duty work, no pain medications
Good	Improved symptoms, return to work with some restriction, no pain medications
Fair	Improved symptoms, return to light duty work, regular pain medications
Poor	No symptom improvement, failure to return to work, regular pain medications

Do you think you to	Yes
made the right choice	No
To have surgery?	Maybe

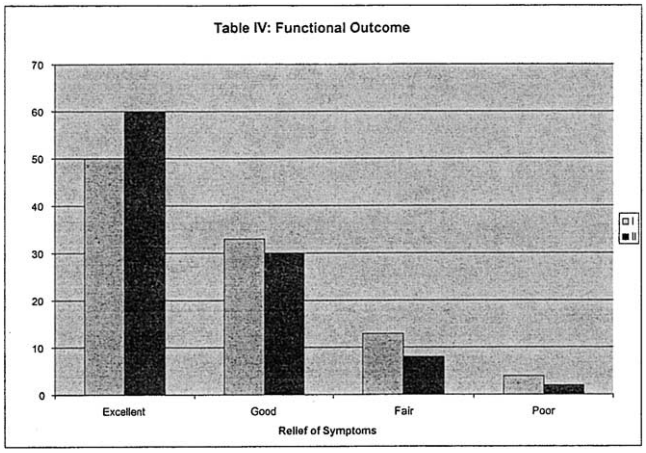
How would you rate your Neck Pain now from none (1) to worst (10)? (Please circle)

1 2 3 4 5 6 7 8 9 10 Before Surgery
1 2 3 4 5 6 7 8 9 10 After Surgery

How would you rate your Arm Pain now from none (1) to worst (10)? (Please circle)

1 2 3 4 5 6 7 8 9 10 Before Surgery
1 2 3 4 5 6 7 8 9 10 After Surgery

Table 3. The functional outcomes assessment used to evaluate the patients postoperatively.



	Group I	Group II
Excellent	15(50%)	30(60%)
Good	10(33%)	15(30%)
Fair	4(13%)	4(8%)
Poor	1(4%)	1(2%)

Fig. 1. The functional outcomes results for both comparison groups (workman's compensation versus non–workman's compensation).

1). A total pseudarthrosis rate of 14 (28%) occurred (Grades 1 and 2). There was no statistically significant difference between the two groups (p=.490; Fig. 3).

Risk factors for the development of a pseudarthrosis were investigated. Tobacco usage was recorded. There were 30 smokers (38%) and 50 nonsmokers (62%). Fusion (Grade 3) occurred in 40 (80%) nonsmokers and 15 smokers (50%). Pseudarthrosis (Grades 1 and 2) resulted in 10 nonsmokers (20%) and 15 smokers (50%). This was found to be statistically significant (p=.001).

Complications

There were no (0%) intraoperative complications. In Group 1, 2 patients (7%) reported iliac crest site donor pain and 1 (3%) transient dysphagia that resolved in 1 week. In Group 2, 3 patients (6%) reported iliac crest site donor pain and there was 1 urinary tract infection (2%). The overall complication rate for all patients was 7 (8.8%). There were no cases of increased neurological deficit, death, deep vein thrombosis, pulmonary embolus, myocardial infarction, cerebral vascular accident or injuries to the trachea, esophagus, recurrent laryngeal nerve or vascular structures. The average intraoperative blood loss was 50 cc with a range of 30 to 200 cc. The range of hospitalization was 1 to 6 days with an average of 1.9 days. Four (5%) reoperations were performed. All four patients had symptomatic pseudarthroses and underwent posterior cervical fusions.

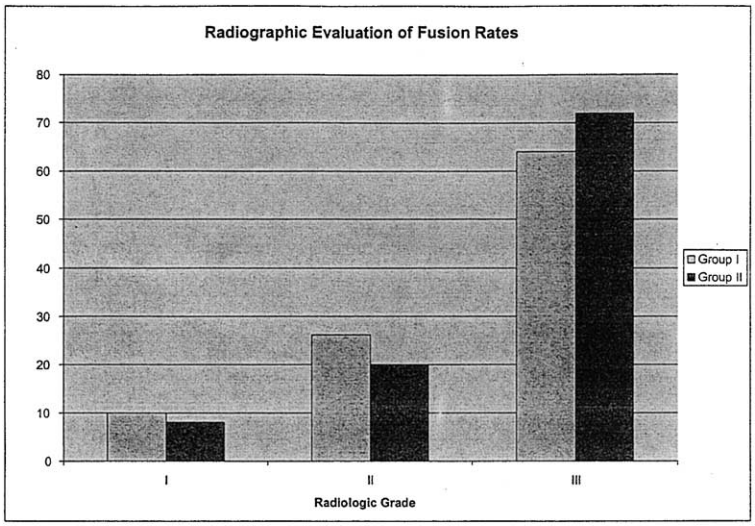
Discussion

Anterior cervical discectomy and fusion is an accepted surgical procedure for the treatment of cervical radiculopathy and myelopathy. The literature reports 63% to 94% good to excellent results in various series [3,5–8,10–12,14,15,32,33]. Robinson et al. [13] obtained 46% excellent and 27% good results in 1962. Gore and Sepic [9] reported complete pain relief in 78% and improvement in an additional 18% in 146 patients. Bohlman et al. [4] reported 90% excellent and good results in a 6-year follow-up study of 122 patients. In our series of 80 patients, when combining Groups 1 and 2, 45 (56%) excellent, 25 (31%) good, 8 (10%) fair and 2 (3%) poor results were obtained. Seventy-seven patients (96%) believed surgery was advantageous and the correct decision. These results are similar to other series and support the efficacy of ACDF in treating cervical radiculopathy and myelopathy.

Workman's compensation claims and litigation have been shown to adversely affect the clinical outcome of patients undergoing lumbar spine surgery [16,18–20,23]. Hanley and Levy [21] reported only a 39% success rate in workman's compensation patients as opposed to 83% successful results in non–workman's compensation patients treated surgically for isthmic lumbosacral spondylolisthesis. Carpenter et al. [34] documented poorer outcomes for pseudarthrosis repair of lumbar fusions in workman's compensation patients. Waddell et al. [30] reported that worker's compensation patients had poorer results with repeat lumbar spine surgery. Young et al. [24] concluded that workman's compensation claims contributed to less favorable outcomes for surgically treated lumbar disc hemiations.

Conclusions have varied regarding the effect of a workman's compensation claim on the outcomes of cervical spine surgery. Tribus et al. [29] reported that a compensation claim negatively affected the clinical outcome in patients having undergone surgical repair of a failed anterior arthrodesis. Snyder and Bemhardt [35] inferred less favorable results in worker's compensation patients after anterior cervical fractional interspace decompression. Davis [26] concluded that a compensation claim adversely affected the clinical results for posterior foraminotomies for soft cervical disc hemiations. White et al. [14], however, reported comparable results for compensation patients who underwent ACDF. Brodke and Zdeblick [5] noted that worker's compensation patients did not have poorer outcomes after ACDF. Bohlman et al. [4] found that a claim did not seem to be associated with postoperative pain after ACDF. Kaptain et al. [28] reported 84% good results in a military population after anterior or posterior decompressions and concluded that economic compensation did not lead to less favorable results.

In our series, in Group 1 (workman's compensation), 50% excellent, 33% good, 13% fair and 4% poor results were obtained. Therefore, 83% excellent and good and 17% fair and poor outcomes occurred. In Group 2, (non–workman's compensation) 60% excellent, 30% good, 8% fair and 2% poor outcomes resulted. Ninety percent excellent and good and 10% fair and poor outcomes were achieved. No statistically significant difference in functional outcome



Radiologic Grade	Group I	Group II
I	3(10%)	4(8%)
II	8(26%)	10(20%)
III	19(64%)	36(72%)

Fig. 2. The results of the radiographic evaluation based on the An and Simpson [31] criteria for analysis of fusion success (workman's compensation versus non–workman's compensation).

between the two groups was noted (p=.280). Interestingly, although Groups 1 and 2 had 17% and 10% fair and poor outcomes, respectively, 93% of patients in Group 1 and 98% of patients in Group 2 believed surgery was a correct decision. This may represent the strict parameters used in our functional outcome categories as opposed to the patients' perceived satisfaction alone.

Upon review of our data, Group 1 patients returned to work on an average of 18 weeks (range, 6 to 30 weeks) postoperatively compared with 10 weeks (range, 1 to 26 weeks) for patients in Group 2. Ninety-seven (29 of 30) of Group 1 patients returned to gainful employment with 27% (8 of 30) requiring modified duty. In Group 2, 98% (49 of 50) of patients returned to work with 18% (9 of 50) requiring restrictions. We believe that the longer time to return to work and the higher percentage of modified duty positions in Group 1 may be the result of the fact that 29 of 30 (97%) were manual laborers as opposed to 30 of 50 (60%) in Group 2. A more useful endpoint in assessing the ultimate outcome of ACDFs in the two groups may be the return to work and not necessarily the average time to return to work. If this criteria is used, then both groups have similar outcomes from the operation.

In our opinion, patient selection is critical in the surgical decision-making process and in the ultimate outcome. Strict indications were used. The patient's clinical symptoms, physical examination and radiographic diagnostics had to correlate. Boden et al. [36] discussed the importance of correlating MRI findings with clinical symptoms after reporting 19% major abnormalities on cervical spine MRI scans in 63 asymptomatic individuals. We adhere to this principle strictly and believe that the treatment of symptomatic pathology is most important in obtaining a successful clinical outcome, regardless of workman's compensation status.

The rate of pseudarthrosis in ACDF has been reported in the literature to vary from 4% to 42% [3–12,32,37,38]. In our series, the pseudarthrosis rate was 32% for the entire population of 80 patients. When comparing Group 1 with Group 2, the pseudarthrosis rate was 36% and 28%, respectively, and the difference was not statistically significant (p=.490). We believe that our high pseudarthrosis rate may be the result of the strict radiographic criteria used to define a fusion. Only Grade 3, in which no motion was observed on lateral F/E radiographs and bony trabeculae crossed the graft–end plate junctions, was defined as a fusion. Both Grade 1, motion on lateral F/E radiographs, and Grade 2, no motion on lateral F/E radiographs but lack of bony trabeculae crossing the graft–end plate junctions, were considered a pseudarthrosis.

Risk factors for the development of pseudarthroses in cervical arthrodeses include the use of allograft bone and multiple levels. Zdeblick and Ducker [38] reported that in two-level anterior cervical fusions, freeze-dried allograft resulted in only 38% unions versus 83% with autogenous iliac crest bone graft. Fernyhough et al. [39] noted a 41% pseudarthrosis rate with allograft fibula, as opposed to 27% with autograft fibula, in 126 patients having undergone multiple level cervical fusions. Connolly et al. [6] documented a 40%

nonunion rate in three-level fusions compared with 15% in single- and two-level arthrodeses. Bohlman et al. [4] reported a pseudarthrosis rate of 11% in single-level and 27% in two- and three-level fusions. Emery et al. [8] had a 42% pseudarthrosis rate in multilevel fusions and 0% in single-level arthrodeses. In our series, only 16% of patients (13 of 80) had allograft. Likewise, only 29% (23 of 80) had a multilevel procedure. These population numbers were deemed to be too small to comment on.

In our series, smoking was a statistically significant risk factor for nonunion, with a rate of 50% (15 of 30) in smokers and 20% (15 of 50) in non smokers ($p=.001$). The literature is mixed regarding cervical spinal fusions in smokers. Most recently, Hilibrand et al. [40] noted a significant decrease in fusion rates in patients who underwent a multilevel discectomy and interbody grafting. However, there was no increased rate of pseudarthroses in those patients who underwent a multilevel corpectomy with autologous strut grafting. In the series of Brodke and Zdeblick [5], 22 patients were smokers and the pseudarthrosis rate did not differ from nonsmokers. Bohlman et al. [4] reported that smoking did not have an adverse outcome on postoperative pain. Blumenthal et al. [41] recorded an 83% fusion rate in nonsmokers as compared with 63% in smokers who underwent lumbar anterior interbody fusions. Hanley and Levy [21] reported an increased rate of nonunion in fusions for isthmic lumbosacral spondylolisthesis. Brown et al. [42] demonstrated a 40% pseudarthrosis rate in smokers versus 8% in nonsmokers in two-level lumbar fusions. Zdeblick [25] also noted lower lumbar fusion rates in smokers. Daftari et al. [43], in a rabbit lumbar fusion model, proposed that the inhibition of revascularization of cancellous grafts by nicotine may be the mechanism by which smoking adversely affects fusions. Based on the literature and our finding, we now supplement anterior cervical fusions with instrumentation in patients with a history of smoking.

The authors believe there are criticisms of this study. This study was not a prospective randomized investigation. The retrospective nature of review may limit and lessen the significance of the results. The Odom's criteria for assessing the results of cervical spine surgery, which is commonly used in other series, may not be as valid as other modem outcome instruments. We decided to use the Odom's functional outcome assessment for symptom relief and modify it to include parameters on returning to work. Although Odom's criteria do not address return-to-work issues in detail, it provides both clinical outcome and return-to-work rates information.

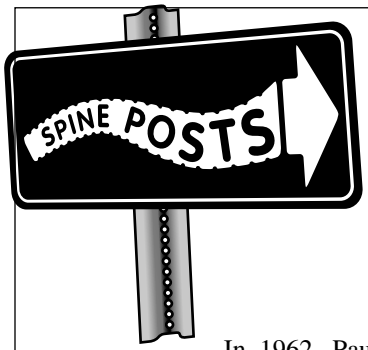
Conclusion

Anterior cervical discectomy and fusion is an accepted procedure for patients presenting with cervical myelopathy or persistent radiculopathy that is refractory to conservative treatment. Workman's compensation claims did not adversely affect the functional outcome of ACDF in patients, because there was no statistical significance between workman's and non–workman's compensation populations. It should be noted that a significant increase in pseudoarthroses was noted with the smoking population. Patient selection is a critical factor in determining functional outcome, with 83% good to excellent results if the pathology, clinical presentation and radiographic findings correlate.

References

[1] Abitol JJ, Garfm SR. Surgical management of cervical disc disease: anterior cervical fusion. Sem Spine Surg 1989;1(4):233–8.
[2] Bernard TN, Whitecloud TS. Cervical spondylotic myelopathy and myeloradiculopathy: anterior decompression and stabilization with autologous fibula strut graft. Clin Orthop 1987;221:149–60.
[3] Bohlman HH. Cervical spondylosis with moderate to severe myelopathy Spine 1977;2:151–62.
[4] Bohlman HH, Emery SE, Goodfellow DB, Jones PK. Robinson anterior cervical discectomy and arthrodesis for cervical radiculopathy. J Bone Joint Surg 1993;75:1298–307.
[5] Brodke DS, Zdeblick TA. Modified Smith-Robinson procedure for anterior cervical discectomy and fusion. Spine 1992;17(suppl):S427–30.
[6] Connolly ES, Seymour RJ, Adams JE. Clinical evaluation of anterior cervical fusions for degenerative cervical disc disease. J Neurosurg 1965;23:431–7.
[7] DePalma A, Rothman RH, Lewinnek G, Carole S. Anterior interbody fusion for severe cervical disc degeneration. Surg Gynel Obstet 1972; 134:755–8.
[8] Emery SE, Bohlman HH, Bolesta MJ, Jones PK. Anterior cervical decompression and arthrodesis for the treatment of cervical spondylotic myelopathy: two to seventeen year follow-up. J Bone Joint Surg 1998;80:941–51.
[9] Gore DR, Sepic SB. Anterior cervical fusion for degenerated or protruded discs: a review of one hundred forty-six patients. Spine 1984; 9:667–71.
[10] Herkowitz PIN. The surgical management of cervical spondylotic radiculopathy and myelopathy. Clin Orthop 1989;239:94–108.
[11] Herkowitz HN. A comparison of anterior cervical fusion, cervical laminectomy and cervical laminoplasty for the surgical management of multiple level spondylotic radiculopathy. Spine 1998;13:774–80.
[12] Riley LH, Robinson RA, Johnson KA, Walker DK. The results of anterior interbody fusion of the cervical spine. J Neurosurg 1969;30:127–33.
[13] Robinson RA, Walker AE, Ferlic DC, Wieking DK. The results of anterior interbody fusion of the cervical spine. J Bone Joint Surg 1962;44:1569–87.
[14] White AA, Southwick WD, DePonte RJ, Gainor SW, Hardy R. Relief of pain by anterior cervical spine fusion for spondylosis: a report of sixty-five cases. J Bone Joint Surg 1973;55A:525–54.
[15] Whitecloud TS, Seago RA. Cervical discogenic syndrome: results of operative intervention in patients with positive discography. Spine 1987;12:313–5.
[16] Bigos SI, Spengler DM, Martin NA, et al. Back injuries in industry; a retrospective study III, employee related factors. Spine 1986;11:252–6.
[17] Bossons CR, Levy J, Sutterlem CE. Reconstructive spinal surgery: assessment of outcome. South Med J 1996;89:1045–52.
[18] Franklin G, Haug J, Heyer N, McKeefrey S, Picciano J. Outcome of lumbar fusion in Washington state worker's compensation. Spine 1994;17:1897–904.
[19] Greenough C, Fraser R. The effects of compensation on recovery from low back injury Spine 1989;14:947–55.
[20] Greenwood J, McGuire TH, Kimbell F. A study of the causes of failure in the hemiated intervertebral disc operation. An analysis of sixty-seven reoperated cases. J Neurol 1952;9:15–20.
[21] Hanley EN, Levy JA. Surgical treatment of isthmic spondylolisthesis: analysis of variables influencing results. Spine 1989;14:48–50.

[22] Junge A, Dvorak J, Ahrens S. Predictors of bad and good outcomes of lumbar disc surgery. A prospective clinical study with recommendations for screening to avoid bad outcomes. Spine 1995;20:460–8.
[23] Lehmann TR, Brand RA. Disability in the patient with low back pain. Orthop Clin North Am 1982;13:559–68.
[24] Young JN, Shaffrey CI, Laws ER, Lovell LR. Lumbar disc surgery in a fixed compensation population: a model for the influence of secondary gain on surgical outcome. Surg Neurol 1997;48:552–7.
[25] Zdeblick TA. A prospective randomized study of lumbar fusion: preliminary results. Spine 1993;18:983–91.
[26] Davis RA. A long-term outcome study of 170 surgically treated patiaents with compressive cervical radiculopathy. Surg Neurol 1996;46:523–30.
[27] Henderson CM, Hennessy RG, Shuey HM, Shackelford EG. Posterior-lateral foraminotomy as an exclusive operative technique for cervical radiculopathy: a review of 846 consecutively operated cases. Neurosurgery 1983;13:504–12.
[28] Kaptain GJ, Shaffrey CI, Alden TD, Young JN, Laws ER, Whitehill R. Secondary gain influences the outcome of lumbar but not cervical disc surgery. Surg Neurol 1999,52:217–23.
[29] Tribus CB, Corteen DP, Zdeblick TA. The efficacy of anterior cervical plating in the management of symptomatic pseudarthrosis of the cervical spine. Spine 1999;24:860–4.
[30] Waddell G, Kummel EG, Lotto WN, Graham JD, Hall H, McCulloch JA. Failed lumbar disc surgery and repeat surgery following industrial injuries. J Bone Joint Surg 1979;61A:201–7.
[31] An HS, Simpson JM. A prospective comparison of the standard and reverse Robinson cervical grafting techniques: radiographic and clinical analyses. J Spinal Dis 2000;13(5):369–73.
[32] Martin GJ, Haid RW, MacMillan M, Rodts GE, Berkman R. Anterior cervical discectomy with freeze-dried fibula allograft. Overview of 317 cases and literature review. Spine 1999;24(9):852–8.
[33] Sambrook PN, MacGregor AJ, Spector TD. Genetic influences on cervical and lumbar disc degeneration: a magnetic resonance imaging study in twins. Arthritis Rheum 1999;42(2):366–72.
[34] Carpenter CT, Dietz JW, Leung KYK, Hanscom DA, Wagner TA. Repair of a pseudarthrosis of the lumbar spine: a functional outcome study. J Bone Joint Surg 1996;78:712–20.
[35] Synder GM, Bemhardt M. Anterior cervical fractional interspace decompression for treatment of cervical radiculopathy. A review of the first 66 cases. Clin Orthop 1989;246:92–9.
[36] Boden SD, McCowin PR, Davis DO, Dina TS, Mark AS, Wiesel S. Abnormal magnetic-resonance scans of the cervical spine in asymptomatic patients. J Bone Joint Surg 1990;72:1178–84.
[37] Brown MD, Malinin TI, Davis PB. A roentgenographic evaluation of frozen allografts versus autografts in anterior cervical spine fusions. Clin Orthop 1976;119:231–6.
[38] Zdeblick TA, Ducker TB. The use of freeze-dried allograft for anterior cervical fusions. Spine 1991;16:726–9.
[39] Fernyhough JC, White JI, LaRocca H. Fusion rates in multilevel cervical spondylosis I comparing allograft fibula with autograft fibula in 126 patients. Spine 1991;16(suppl):S561–4.
[40] Hilibrand AS, Fye MA, Emery SE, Palumbo MA, Bohlman HH. Impact of smoking on the outcome of anterior cervical arthrodesis with interbody or strut-grafting. J Bone Joint Surg 2001;83A(5):668–73.
[41] Blumenthal SL, Baker J, Dossett A, Selby DK. The role of anterior lumbar fusion for internal disc disruption. Spine 1988;13:566–9.
[42] Brown CW, Orme TJ, Richardson HD. The rate of pseudarthrosis (surgical nonunion) in patients who are smokers and patients who are nonsmokers: a comparison study. Spine 1986;11:942–3.
[43] Daftan TK, Whitesides TE, Heller JG, Goodrich AC, McCarey BE, Hutton WC. Nicotine on the revascularization of bone graft: an experimental study in rabbits. Spine 1994;19:904–11.



Forty Years Ago in Spine . . .

In 1962, Paul Harrington of Houston, Texas, published his results of correction of deformity and fixation of the scoliotic spine by means of ratcheted rods and hook attachments [1,2]. He based the sites selected for attachment on testing of the various possibilities. Harrington's publication ushered in an era of effective correction and stabilization of scoliosis by internal fixation and away from awkward external devices, such as turnbuckle casts. Although designed for scoliosis correction and stabilization, the method was used also for trauma and spondylolisthesis. The technique was widely accepted and applied to a variety of spinal disorders, although various deficiencies, outlined 20 years later by Gertzbein [3], with regard to fracture care, stimulated modifications and development of alternative devices.

References

[1] Harrington PR. Treatment of scoliosis. Correction and internal fixation by spine instrumentation. J Bone Joint Surg (Am) 1962;44A:591–610.
[2] Harrington PR. The history and development of Harrington instrumentation. Clin Orthop Rel Res 1973; 93:110–2.
[3] Gertzbein SD, MacMichael D, Tile M. Harrington instrumentation as a method of fixation in fractures of the spine: a critical analysis of deficiencies. J Bone Joint Surg (Am) 1982;64:526–9.