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ORIGINAL ARTICLE

M. L. Swank
G. L. Lowery
A. L. Bhat
R. F. McDonough

Anterior cervical allograft arthrodesis and instrumentation: multilevel interbody grafting or strut graft reconstruction

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M. L. Swank · G. L. Lowery (✉)
A. L. Bhat · R. F. McDonough
Research Institute International,
6716-F NW 11th Place, Gainesville,
FL 32605, USA
Tel. +1-352-331 8109;
Fax +1-352-332 2119;
e-mail: rii@afn.org

Abstract This retrospective study evaluated a single surgeon's series of patients treated by multilevel cervical disc excision (two or three levels), allograft tricortical iliac crest arthrodesis, and anterior instrumentation. The objective of this retrospective study was to compare fusion success and clinical outcome between multilevel Smith-Robinson interbody grafting and tricortical iliac strut graft reconstruction, both supplemented with anterior instrumentation in the cervical spine. The incidence of nonunion for cervical discectomy and fusion varies widely depending on the number of disc levels involved, type of bone graft used, and whether the anterior grafting is supplemented with instrumentation. An alternative to multilevel interbody fusion is corpectomy and strut grafting, in which the incidence of nonunion has been reported to be 27% with autograft and 41% with allograft. Sixty-four consecutive patients who underwent allograft tricortical iliac crest reconstruction and anterior cervical plating were studied. The average follow-up was 39 months. There were 38 patients in the discectomy and interbody grafting group and 26 patients in the corpectomy and strut graft reconstruction group. Pseudoarthrosis occurred in 42% of the anterior cervical interbody fusion patients and 31% of the corpectomy patients. Nonunion in two-level interbody fusions occurred in 36% of the patients as compared to 10% for patients with one-level corpectomies; while 54% of patients with three-level interbody fusions and 44% of patients with two-level corpectomies were noted to have pseudoarthrosis. Higher percentages of nonunion were noted in multilevel interbody grafting than in corpectomy with strut grafting and when more vertebral levels were involved. These radiographic and clinical findings underscore the shortcomings of multilevel anterior cervical allograft reconstruction with plating. Corpectomy may be the preferred method when multiple disc levels are fused. In addition, anterior corpectomy affords decompression of significant osteophytes in a safer and quicker manner. In retrospective studies, there is a need for long-term follow-up before accurate statements can be made about the study population.

Key words Allograft fusions · Multilevel anterior cervical interbody fusion · Strut graft · Anterior cervical plating

Introduction

Cervical degenerative disc disease involving two or more levels can present a challenge for reconstruction. The incidence of nonunion for cervical discectomy and interbody grafting varies widely depending on the number of levels fused, the graft material used, and whether the reconstruction is supplemented with instrumentation [1–11, 13–17, 19, 20, 22, 24, 25].

An alternative to multilevel discectomy and interbody grafting is corpectomy with strut grafting. Whitecloud and LaRocca introduced this technique as an "attempt to circumvent graft failure due to compressive loading across multiple segments" [22]. Initially, fibular struts were reported to have an excellent fusion rate, but in long-term follow-up, the nonunion rate was 27% for autograft and 41% for allograft [10]. Fusion rates as high as 97% have been reported with iliac crest strut grafting [11]. However, using autologous iliac crest to reconstruct defects greater than 6 cm or more than two vertebral bodies can prove to be difficult and can result in permanent donor site morbidity for the patient.

Because of the lack of data comparing multilevel discectomy and interbody grafting with corpectomy and strut grafting, this retrospective review was undertaken to assess the clinical outcomes, incidence of radiographic nonunion, and complications associated with anterior cervical reconstruction for multilevel degenerative disease in two groups of patients: (1) patients treated with multilevel discectomy and interbody Smith-Robinson grafting, and (2) those treated with corpectomy and strut grafting. Both groups were reconstructed using allograft tricortical iliac crest bone (aseptic processing by Osteotech, Shrewsbury, N.J.) and stabilized by anterior cervical plating.

Materials and methods

Study population

Sixty-four consecutive patients with a diagnosis of cervical spondylosis underwent either a two-level or three-level discectomy. Surgical indications for multilevel discectomy and interbody Smith-Robinson grafting included soft disc herniations without significant canal compromise or osteophytosis. Patients with extensive osteophytosis and requiring significant resection of the posterior longitudinal ligament were treated with pedicle-to-pedicle subtotal corpectomy and strut grafting. Both groups were reconstructed using allograft tricortical iliac crest bone and stabilized by anterior cervical plating.

There were 27 women and 37 men in the study, with a mean age of 51 years (range: 30–78 years). Average follow-up was 39 months (range: 12–81 months). Eighteen patients (28%) had undergone prior surgical procedures. All patients were available for follow-up.

Table 1 shows the number of reconstruction procedures carried out according to the number of operative disc levels and the type of allogenic bone graft used. Table 2 gives the type of anterior cervical plating system used according to type of procedure performed and number of operative disc levels.

Table 1 Allograft reconstruction procedure (n = 64)

No. of disc levels	Interbody wedges	Tricortical strut
2	25	10
3	13	16

Table 2 Anterior cervical plating systems

Type of plate	Two disc levels		Three disc levels	
	ACIF[a]	Corpectomy[b]	ACIF	Corpectomy
Orozco (n = 27)	16	1	7	3
CSLP/Morscher (n = 25)	8	6	3	8
Orion® (n = 12)	1	3	3	5

[a] Anterior cervical interbody fusion
[b] Corpectomy and strut graft reconstruction

Clinical evaluation

Analog pain scores on a scale of 0–10 were recorded preoperatively and postoperatively for axial and appendicular pain separately. Postoperative scores were routinely recorded at 3 months, 6 months, 12 months, and yearly thereafter. Records of axial pain scores were available for 54 patients, and appendicular pain scores were available for 53 patients.

Self-assessment of benefit from surgery was also recorded for patients at each postoperative visit. Using three response categories, the patient could be (1) doing better than before surgery, (2) showing no improvement, or (3) doing worse than before surgery.

Radiographic evaluation

Preoperative and postoperative flexion-extension radiographs were reviewed for all patients. Postoperative flexion-extension films were taken at 3, 6, and 12 months, and yearly thereafter. Each radiograph was reviewed for alignment, hardware position, hardware failure, and bony fusion. Pseudoarthrosis was defined as (1) any evidence of radiolucency at the host-graft interface or (2) greater than 2 mm of motion on flexion-extension radiographs at the 6-months follow-up. Hardware failures were recorded, regardless of significance or surgical outcome (i.e., loosened screws and/or broken plates).

Surgical technique

A standard anterolateral approach to the cervical spine was performed from the left side. Discectomy was performed in a standard fashion after intraoperative fluoroscopy confirmed the appropriate levels. Using a curette, endplates were prepared so that punctate subchondral bleeding occurred; however, the structural integrity of the endplate was left intact. For multilevel interbody fusions, allograft tricortical iliac crest was fashioned into wedged Smith-Robinson grafts. For the corpectomy group, the vertebral bodies were resected, the canal was decompressed from pedicle to pedicle, and reconstruction was performed with allograft tricortical iliac crest wedged struts. All patients were then treated with an anterior plating system spanning the reconstructed levels. A Philadelphia-style orthosis was given to patients to wear while ambulating for the first 4–6 weeks after surgery.

Table 3 Radiographic nonunions

No. of disc levels	ACIF	Corpectomy
2	36%	10%
3	54%	44%

Results

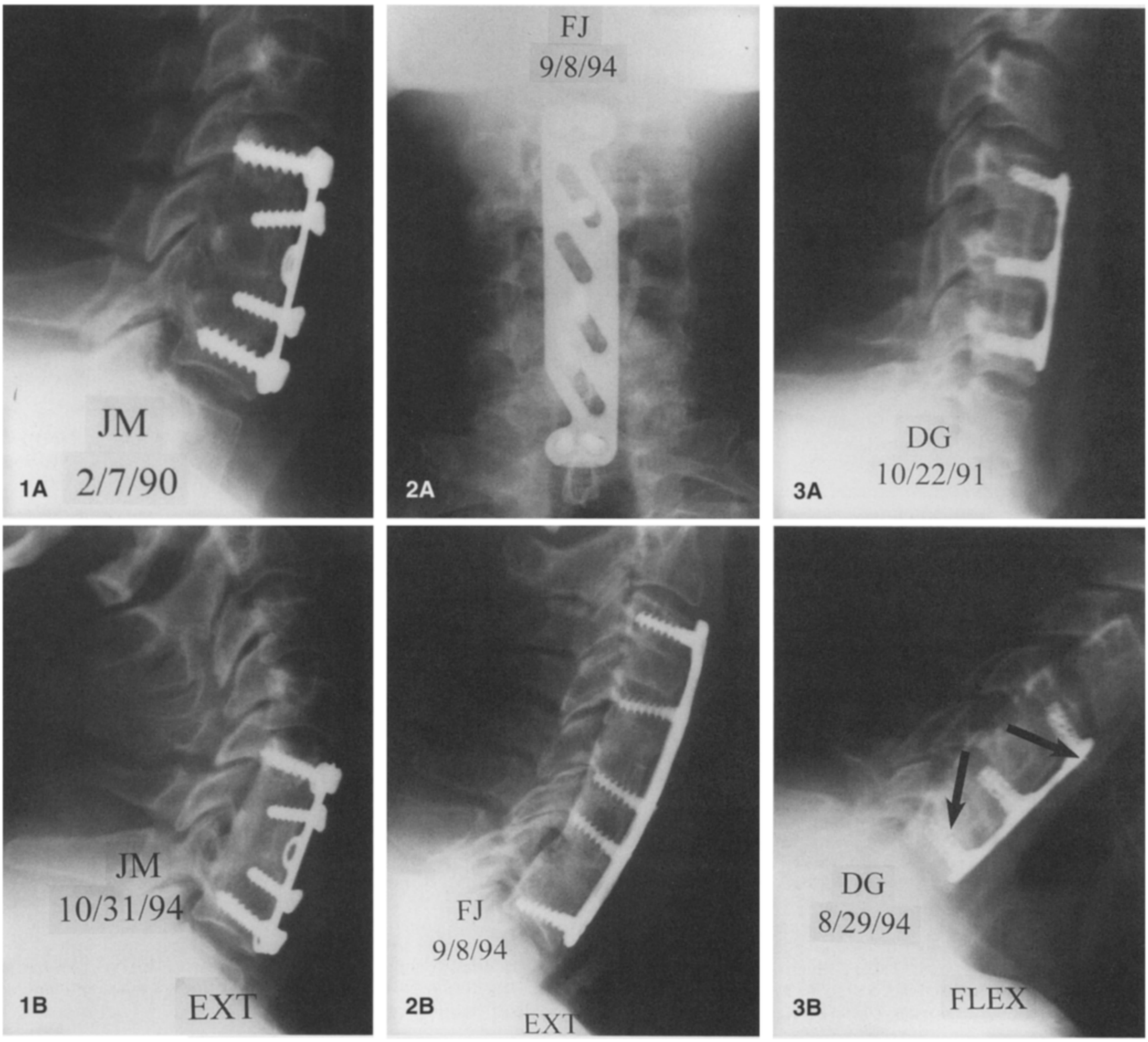
Radiographic outcome

Sixty-three percent of patients ($n = 40$) proceeded to a radiographic union. Thirty-seven percent of patients ($n = 24$) had a symptomatic pseudoarthrosis. Except for one, all of these nonunions have been confirmed upon surgical

Fig. 1 This patient underwent two-level discectomy with corpectomy, strut reconstruction, and Orozco plating. **A** Lateral radiograph 1 month after surgery. **B** Lateral extension radiograph 58 months after surgery showing clear bony incorporation of the allograft strut

Fig. 2 In this patient with a solid one-level fusion, a revision three-level anterior cervical discectomy was performed with allograft and Orion plating. **A** Anterior-posterior radiograph 13 months after surgery showing proper alignment of Orion plate. **B** Lateral extension radiograph 13 months after surgery demonstrating solid interbody fusions

Fig. 3 This patient underwent a two-level discectomy, interbody grafting, and CSLP/Morscher plating. **A** Lateral radiograph 2 weeks after surgery. **B** Lateral flexion radiograph 35 months after surgery showing a broken inferior fenestrated screw and loose superior lock screw, but the patient has the appearance of a solid fusion, and he had no symptoms. The symptoms returned after 6 months, and an anterior revision surgery was performed. Exploration revealed no risk to surrounding structures from the failed hardware and a fibrous union at C5-C6



exploration and have been revised. Table 3 compares fusion results for four subgroups. Patients with two discectomies and a one-level subtotal corpectomy of the intervening body (Fig. 1) were compared to patients having two discs removed and a two-level interbody fusion. A similar analysis was undertaken for patients whose surgery involved three disc levels (Fig. 2). In the two disc level group, nonunion occurred in 36% of the interbody patients versus 10% in the corpectomy group. When three discs were removed, the incidence of nonunion was 54% for the interbody fusion group and 44% for the corpectomy group. We also found that constrained plating systems, Orion (Sofamor Danek, Memphis, Tenn.) and CSLP, had a higher incidence of radiographic union (73% and 68%, respectively) than the nonconstrained Orozco plating system (54%).

Clinical outcome: patients' self-assessment

At the most recent follow-up, for patients who had a solid fusion and reduced pain scores, there was an average reduction of 71% and 78% in axial and appendicular pain, respectively. Seven patients with a solid fusion had a slight increase in their subjective axial pain scores, and two patients experienced an increase in appendicular pain.

The patients' self-assessment of benefit from surgery was as follows. In the corpectomy group 85% (n = 22) stated that they felt better than before surgery; 11% (n = 3) felt the same as before surgery, and 4% (n = 1) felt worse than before surgery. In contrast, 66% of interbody fusion patients (n = 25) felt better than before surgery; 8% (n = 3) felt the same as before surgery, and 26% of patients (n = 10) felt worse than before surgery. Of the patients who said they felt worse, six were found to have a nonunion and required additional surgery, one patient had disc degeneration adjacent to the solid fusion, three patients felt worse despite a solid fusion, and one patient suffers from the effects of multiple sclerosis.

Complications

Table 4 illustrates the type and incidence of hardware failure encountered with the three different anterior cervical plating systems. Hardware failure occurred in 52% (14/27) of Orozco cases, 48% (12/25) of CSLP/Morscher cases, and 25% (3/12) of Orion cases. The failure mode for Morscher screws was primarily fracture of fenestrated locked screws (no longer commercially available). The Orozco is a nonconstrained system and was prone to screw loosening and plate fracture. Likewise, the three patients who had early failures with the Orion system had an early screw design (prior to commercial market release).

Twenty-six patients (40%) were noted to have inconsequential hardware failure (Fig. 3), which by itself did not necessitate removal or revision for threat of injury to the trachea, esophagus, or neurovascular structures. Seventeen patients from this group (65%) had revision surgery, either for nonunion (n = 16) or for adjacent disc degeneration (n = 1). Nine patients (35%) demonstrated a solid fusion despite hardware failure.

Table 4 Hardware failures

Type of plate	Broken screws	Loose screws	Broken plate	Loose plate
Orozco (n = 27)	5	3	6	0
CSLP/Morscher (n = 25)	6	2	2	2
Orion® (n = 12)	2	1	0	0

Only 3 of all 64 patients (5%) had significant hardware failure that independently necessitated hardware revision; these three patients, additionally, had a pseudoarthrosis. Although these three cases had the potential for tracheoesophageal injury, such injury did not occur. One patient, 4 months after surgery, fractured a three-level allograft iliac crest strut and subsequently bent her anterior plate. Her anterior instrumentation was removed, and only the inferior portion of her graft was revised, because the superior portion of the graft demonstrated bony incorporation. Revision anterior instrumentation, posterior fusion, and posterior instrumentation were used to stabilize her spine. A second patient was noted to have one broken inferior screw and one loose inferior screw that required removal. An anterior revision with instrumentation was performed, where the inferior end of the original graft was resected and regrafted. The other patient underwent emergency intubation 2 days postoperatively for respiratory difficulty with subsequent graft and plate dislodgement of 2 mm. As a precaution against future problems, posterior fusion with plate stabilization was performed. Despite these noted complications, none of these patients suffered tracheoesophageal injury.

Of the 23 patients who had symptomatic nonunions, hardware failure was noted in 17 patients (74%). It is significant that six patients (26%) demonstrated no hardware failure despite a nonunion.

Two patients with ossification of their posterior longitudinal ligaments had a dural leak at the time of surgery that was surgically repaired without any complications and treated with a lumbar CSF diversion drain. One patient had a nonfatal pulmonary embolus that was treated with anticoagulant drugs. One patient developed hoarseness and dysphagia that resolved within 6 weeks. Another patient developed postoperative dysphagia that also resolved within 6 weeks. One patient had transient right-sided deltoid weakness that improved gradually over 10 weeks.

Twenty-nine patients (45%) had secondary procedures. Twenty-three patients (36%) were reoperated because of symptomatic pseudoarthrosis. Four patients required further surgery after degeneration of levels adjacent to a solid fusion. One patient had a revision after early hardware failure and graft dislodgement. One patient had an additional surgery for continued radicular symptoms.

Discussion

Reconstruction of the anterior cervical spine after multilevel decompression presents several technical challenges. Decompression of the stenosis can be achieved by discectomy alone provided the stenosis is limited to the disc space level. Otherwise, corpectomy must be used for more advanced pathology. Graft-related problems include obtaining an appropriately sized graft, locating a site for harvest of autograft, procuring allograft, as well as graft fragmentation, graft migration, and nonunion.

Few comparisons reporting the results of multilevel interbody fusions versus strut grafting have been published. Yonenobu et al., while using autologous iliac crest bone graft, found improved clinical outcome with corpectomy and noted a higher incidence of nonunion (45%) in multilevel interbody grafting for three levels as compared with iliac strut grafting (30%) [23]. The rate of graft dislodgement was lower in the multilevel interbody group (7%) than in the strut graft group (14%). Hanai et al. reported excellent clinical success and a 100% union rate in corpectomy and autograft strut graft reconstruction for three-level and four-level corpectomy patients [12]. Okada et al. in their series of patients reported good clinical results and a 10% graft complication rate with one dislodgement and three delayed unions, which eventually healed, although two required supplemental procedures [18].

Simmons and Bhalla obtained a higher incidence of fusion with the keystone type of graft than with the dowel type of graft [20]. They relate their success to the type of graft used, its method of seating, depth of penetration, a larger surface area, and the superior contact of the raw cancellous bone of the adjacent vertebrae with the graft. Hubach noted that nonunion rates increased as the number of levels fused increased [13]. Whitecloud and LaRocca reported on the excellent immediate and long-term stability offered by the fibular strut graft when multiple-level reconstruction is required, and particularly when extensive bone removal is needed for neural decompression [22].

Early reports of 95%–100% successful fusions have been recorded for instrumented autograft and allograft fusions [15, 21]. In our study, the incidence of nonunion for multilevel allograft interbody fusion was 42% as compared to 31% for corpectomy and allograft strut graft reconstruction. Again we would like to emphasize that this was a retrospective review of 64 consecutive patients with an average follow-up of 39 months, and all these patients were available for a follow-up (100%). Among two-level discectomy patients, more nonunions occurred in the interbody group (36%) than in the strut group (10%). As shown in Table 3, within both interbody and corpectomy groups, there was a higher probability of nonunion in three-level cases than two-level cases. Overall, the chance of nonunion increased with number of operative levels (26% for two-level surgery and 48% for three-level surgery).

Persistent pain after a reconstruction was commonly associated with a nonunion, whether or not there was hardware failure. There were 29 hardware failures, but 26 of these failures (90%) were inconsequential and not associated with tracheoesophageal or neurovascular risk. Only three patients had the potential for tracheoesophageal or neurovascular problems, yet revision treated these difficult cases without further complications. We would like to emphasize our observation that 26% of the patients with surgically confirmed nonunions demonstrated intact hardware. Therefore, lack of hardware failure cannot be used as a strict criterion for fusion. With regard to the incidence of hardware failure, the authors point to the long-term follow-up in this study, where every patient is included. By following every patient, every hardware failure and nonunion is seen, even late occurrence. None of the successes or failures have been lost in this study.

However, there are limitations to this study. Because this is a retrospective review, controlled randomized prospective groups were not possible. The plating was not homogeneous as three systems were used. The choice of anterior plate followed the market availability of the most current option in anterior cervical plating systems.

Conclusions

The purpose of this study was to review clinical and radiographic outcomes in a single surgeon's series of patients treated with either multilevel interbody allografts or structural allografts, both supplemented with anterior instrumentation. These data underscore the shortcomings of multilevel anterior cervical interbody fusion (ACIF) using allograft supplemented with anterior instrumentation. Corpectomy with strut graft reconstruction and anterior instrumentation may be the procedure of choice for multilevel cervical disease requiring excision of two or more discs. In addition, anterior corpectomy allows decompression of significant osteophytes in a safer and quicker manner. Results were more pronounced in the two-level discectomy group, favoring corpectomy and strut reconstruction over ACIF (10% nonunion vs 36% nonunion). While the overall nonunion rate in the corpectomy group is 31%, it is well within published results for strut grafting especially when compared to autograft reconstructions without instrumentation [10]. Supplementation of the reconstruction with anterior cervical plating prevented the complication of graft migration and may have increased the union rate compared to other series with allograft fibular struts. Hardware-related complications requiring a repeat procedure were found to be infrequent (5%). In retrospective studies, there is a need for long-term follow-up to make accurate statements about the involved study population.

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