

# Documenting Fusion Following Anterior Cervical Surgery: A Comparison of Roentgenogram *Versus* Two-Dimensional Computed Tomographic Findings

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**Summary:** Documentation of fusion following anterior cervical surgery may critically influence management strategies that can adversely affect outcome. Would two-dimensional CT studies more accurately identify fusion following single-level anterior corpectomy with fusion compared with radiographic studies (plain/dynamic) alone? To answer this question, two radiologists, in a “blinded” fashion, separately read both radiographic and two-dimensional CT studies obtained 3 and 6 months following 46 single-level anterior corpectomy with fusion. Single-level anterior corpectomy with fusion used nonreversed iliac crest strut autografts and dynamic ABC plates (Aesculap, Tuttlingen, Germany). Following surgery, patients were immobilized in cervicothoracic orthoses, which were discontinued when fusion was confirmed. Patients were followed an average of 3.2 years (minimum 2 years). Outcomes were measured with the Short Form-36 questionnaire administered preoperatively, and 3, 6, and 12 months postoperatively. Three months after surgery, radiographs documented fusion in 38 (83%) of 46 patients, whereas two-dimensional CTs confirmed fusion in only 23 (50%) of 46 patients. Six months postoperatively, radiographs documented fusion in 44 (96%) of 46 patients, whereas only 32 (70%) of 46 patients were solidly fused on two-dimensional CT studies. Three and 6 months following single-level anterior corpectomy with fusion, two-dimensional CT scans more accurately confirmed fusion compared with radiographs alone. **Key Words:** Single-level—Anterior cervical corpectomy—Fusion—Two-dimensional CT—Roentgenogram.

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## INTRODUCTION

Plain and dynamic roentgenograms are typically used to demonstrate fusion following anterior cervical surgery (1,2). The need to accurately document fusion following anterior cervical procedures is critical as it directs postoperative management strategies. Would two-dimensional

(2D) CT studies more accurately document fusion following single-level anterior corpectomy with fusion (ACFs) compared with roentgenograms alone? To answer this question, two radiologists in a “blinded fashion” separately read both radiographic and 2D CT studies obtained 3 and 6 months following 46 single-level ACFs. For those not fused, they were repeated 9, 12, or 15 months postoperatively until fusion or its absence provided a guide for further care. Fusions were performed using reversed iliac crest strut autografts and dynamic ABC plates (Aesculap, Tuttlingen, Germany) (3,4). Clinical outcomes were measured using the Short Form-36 (SF-36) questionnaire.

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## METHODS

### Clinical Data

One surgeon performed 46 single-level ACF (Table 1). Surgery addressed contiguous two-level disease associated with significant retrovertebral extension attributed to disc herniations, spondylosis, stenosis, and/or ossification of the posterior longitudinal ligament. Patients averaged 44 years in age and included 27 males and 19 females. Preoperatively, patients demonstrated moderate myelopathy (average Nurick Grade 3.0). Outcomes were measured using the SF-36 questionnaire administered preoperatively and 3, 6, and 12 months postoperatively. Patients were followed an average of 3.2 years (minimum 2 years).

### Operative Procedure

Single-level ACF involved partial resection/perforation of the cephalad and caudad vertebral endplates, complete removal of two discs, and the excision of the intervening vertebral body. Nonreversed iliac crest strut autografts (average 2.8 cm) were swaged into place, followed by the application of dynamic ABC plates (Aesculap, Tuttlingen, Germany). Postoperatively, patients were immobilized in hard cervicothoracic orthoses until fusion was confirmed on both radiographic (plain, dynamic) and 2D CT studies.

### Postoperative Roentgenogram and Two-dimensional CT Studies

Postoperatively, plain roentgenograms were routinely performed every 6 weeks until fusion was confirmed. Dynamic roentgenograms and 2D CT studies were obtained 3 and 6 months postoperatively to further assess fusion (Tables 2 and 3). CT examinations were performed on the Phillips MX 8000 and consisted of 1-mm contiguous axial

**TABLE 1.** *Clinical data*

Clinical parameters	46 single-level ACF
Average Age (yr)	44
(range)	(23–65)
Males	27
Females	19
Average follow-up interval (yr)	3.2
Minimum follow-up interval (yr)	2.0
Surgical procedures	
ACF C5–C7	34
ACF C4–C7	8
ACF C3–C5	3
ACF C2–C4	1
Nurick grade	
Preoperatively	3.0
Postoperatively	0.4
Average time to fusion (mo)	3.8

**TABLE 2.** *Three-month postoperative roentgenogram and 2D CT data documenting fusion or no fusion in 46 patients undergoing single-level anterior corpectomy with fusion*

Roentgenogram	CT	
	Fusion	No fusion
Fusion	23	15
No fusion	0	8

scans using separate soft tissue and bone algorithms. Reconstructed 1-mm views were also obtained in the sagittal, coronal, and oblique disc planes. For those not fused by the sixth postoperative month, both radiographic and 2D CT studies were repeated 9, 12, or 15 months postoperatively to assess the presence or absence of fusion and to guide further management. Two radiologists separately interpreted both radiographic and 2D CT studies, and were “blinded” to their own and the other radiologist’s interpretation of each patient’s examination.

### Fusion Criteria

Fusion criteria on static roentgenograms and 2D CT studies included the presence of bony trabeculation and lack of bony lucency at the graft/vertebral junction. Documentation of fusion on dynamic roentgenograms required the absence of translation and lack of motion between contiguous spinous processes (<1 mm). Patients with a fibrous union, defined by residual lucency at the graft/vertebral body interface, the lack of bony trabeculation, and absence of motion on dynamic studies were not considered fused for the purposes of this study.

## RESULTS

### Roentgenogram and Two-dimensional CT Documentation of Fusion

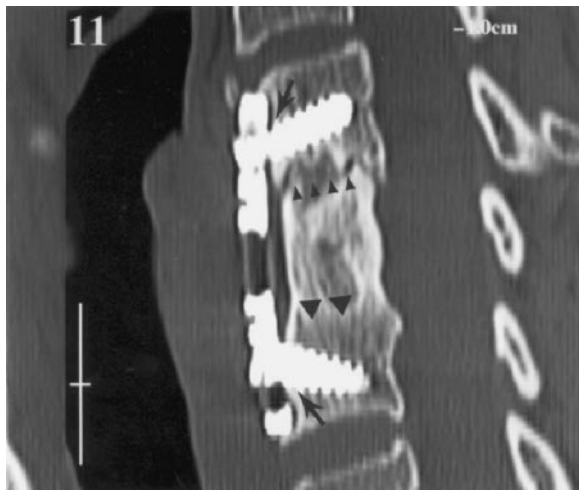
Three months following single-level ACFs, radiographic studies performed in 38 (83%) of 46 patients were interpreted as “fused” (Table 2). In comparison, only 23 (50%) of 46 2D CT examinations in the same patients were read as “fused” (Fig. 1 and 2; Table 2). By the sixth postoperative month, 44 (96%) of 46 radiographic studies,

**TABLE 3.** *Six-month postoperative roentgenogram and CT data documenting fusion or no fusion in 46 patients undergoing single-level anterior corpectomy with fusion*

Roentgenogram	CT	
	Fusion	No fusion
Fusion	32	12
No fusion	0	2



**FIG. 1.** Three months following a C4–C6 ACF performed in a 42-year-old woman, the lateral radiograph was interpreted as demonstrating caudad (single short arrow) but not cephalad (triple arrows) fusion at the respective graft/vertebral body junctions. Note the 6 mm of cephalad and caudad plate migration (single long arrows).



**FIG. 2.** The 3-month postoperative parasagittal bone-window 2D CT from the same patient (Fig. 1) confirmed caudad fusion (double arrows) but incomplete cephalad fusion (quadruple arrows). Again, 6 mm of cephalad and caudad plate migration was observed (single long arrows). By the sixth postoperative month, both radiographic and 2D CT studies confirmed fusion.

but only 32 (70%) of 46 2D CT examinations confirmed the presence of arthrodesis (Table 3). As interexaminer differences in interpretation of radiographic and 2D CT studies were minimal, varying from two for the former to four for the latter, only the average responses for the two categories are presented.

Six months postoperatively, 14 patients showed no evidence of fusion. Two patients who demonstrated inferior pseudarthroses, one at 6 and the other at 12 months postoperatively, fused following secondary posterior fusions (Fig. 3). Three patients developed cephalad (two patients) and caudad (one patient) fractures adjacent to graft/vertebral endplate junctions 8–12 months postoperatively; with bracing, all fused within 4–6 additional months. One patient developed a delayed mid-strut fracture visualized on both radiographic and 2D CT studies 6 months postoperatively. Because he failed to fuse wearing a brace for 6 months, a secondary posterior fusion was performed and he fused within 3 postoperative months (Fig. 4 and 5). Eight other patients went on to spontaneously fuse on both radiographic and 2D CT studies, 9 (2 patients), 12 months (2 patients), and 15 months (4 patients) following surgery.

**SF-36 Outcome Data**

Postoperatively, patients improved 2.6 points on the Nurick Scale, to a grade of 0.4 (mild residual radiculop-



**FIG. 3.** Six months after a 44-year-old, 300 lb. man had a dynamic plated C5–C7 ACF, plain roentgenograms and the coronal bone-window 2D CT scan documented cephalad fusion but an inferior pseudarthrosis (single arrow). Motion was also demonstrated on the dynamic radiographs. Four months following a secondary C4–T1 posterior fusion, combined radiographic and 2D CT scans confirmed both anterior and posterior fusion.



**FIG. 4.** Six months postoperatively, a 39-year-old male 2 packs/day smoker, who returned to work as a truck driver against medical advice 3 months following surgery, presented with recurrent neck pain. Plain and dynamic films, including this lateral flexion roentgenogram, showed a mid-strut fracture (double arrows). Note that at this point the extremes of the graft appeared to be fused to the cephalad and caudad vertebral endplates.

athy). Improvement on the SF-36 questionnaire between 6 and 12 months postoperatively was greatest on the Physical Function Scale (+24%), with milder improvement being seen on the Mental Health (+13%) and Social Function Scales (+6%) (Table 4).

### DISCUSSION

Anterior cervical plates reduce graft collapse and angulation rates following single-level ADF while also improving fusion rates following two-level ADF (1–10). Higher fusion rates are also frequently reported using iliac crest autograft compared with allograft substitutes (1,2). In the An et al. series (1), involving one- to two-level ADF, a 26.3% pseudarthrosis rate for autograft compared with a 46.2% frequency of pseudarthrosis using allograft plus demineralized bone matrix was encountered. Performing two-level ADF, Zdeblick and Ducker encountered a higher pseudarthrosis rate of 63% for allograft compared with 17% for autograft (2).

Many authors rely on roentgenograms (plain/dynamic) alone to confirm fusion (1,2,5,9,10). Few authors order MR and/or CT studies in addition to roentgenograms. Magnetic susceptibility artifacts on MR scans make them

less useful than CTs (3,4,6–8,11,12). Physiologic confirmation of fusion may also be obtained using single-photon emission CT (13).

In this series of patients undergoing single-level anterior corpectomy and fusion using iliac crest autografts, fusion was more accurately documented on postoperative 2D CT studies than on routine roentgenograms alone. Because critical clinical decisions are based on the precise determination of fusion following anterior cervical surgery, one should consider adding 2D CT studies, particularly in cases in which fusion is questionable, as an adjunct to routine roentgenograms. Although 2D CT examinations pose an increased financial burden, its benefits include the avoidance of further complications such as graft or plate fracture, extrusion, or pseudarthrosis resulting from the premature removal of a brace. The four delayed strut fractures were associated with trauma and may in part have been attributed to the greater compression allowed by the dynamic plate design. Three of these patients were also smokers.

### CONCLUSION

In this limited series, 3 and 6 months following 46 single-level ACFs, 2D CT studies more accurately documented the presence of fusion as compared with roent-



**FIG. 5.** The 6-month postoperative coronal bone-window 2D CT study in the same patient demonstrated fusion at the cephalad and caudad endplates but also confirmed the presence of a mid-strut fracture (double arrows). As dynamic studies showed no gross instability and the patient wished to avoid secondary surgery, he wore a CTO orthosis for the next 6 months. Ultimately, when the fracture failed to heal, a secondary C3–T1 PWF was performed. Three months later, the anterior fracture site (double arrows) fused while posterior fusion also occurred.

TABLE 4. SF-36 outcome data

Short form-36	Physical function	Role-physical	Bodily pain	General health	Vitality	Social function	Role-emotional	Mental health
Before surgery	46	9	26	51	39	48	52	59
3 months after surgery	34	6	40	66	39	38	41	64
6 months after surgery	49	25	66	90	57	65	62	68
1 year after surgery	73	25	66	90	57	71	50	81

genograms (plain, dynamic) alone. To help avoid further complications and to provide additional therapeutic options, both surgical and nonsurgical, the addition of 2D CTs should be considered as an adjunct to roentgenograms in documenting postoperative fusion in selected patients.

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