Acta Orthop. Belg., 2006, **72**, 342-346

ORIGINAL STUDY

Prospective assessment of cervical fusion status : plain radiographs versus CT-scan

Avraam PLOUMIS, Amir MEHBOD, Timothy GARVEY, Thomas GILBERT, Ensor TRANSFELDT, Kirkham WOOD

From the Twin Cities Spine Center, Minneapolis, Minnesota, USA and the Center for Diagnostic Imaging, Edina, Minnesota, USA

The purpose of this prospective study was to compare the pseudarthrosis rate after anterior cervical fusion, estimated either with static and dynamic plain radiographs or with two-dimensional CT-scans.

There is a plethora of radiographic tools and criteria used to determine pseudarthrosis after cervical spine fusion. However, it is not known to which extent these tools correlate with each other.

Forty-seven adult patients were enrolled in this study, about one year after surgery. Four independent blinded observers evaluated the roentgenological data. CT assessment led to higher pseudarthrosis rates than plain radiographs : 13 to 31% according to CT ; 2 to 16% according to plain radiographs. The difference averaged 11%. Consistency between reviewers was higher with CT (average agreement : 89% ; range 82%-96%) than with plain radiographs (average agreement : 81% ; range : 76% to 87%).

The need to accurately document pseudarthrosis is critical as it helps direct the postoperative management of the patient. The present study stresses the value of computed tomography. However, surgical exploration continues to be the gold standard.

Keywords : cervical spine ; fusion ; fusion status ; CT-scan.

INTRODUCTION

Various disorders of the cervical spine are treated successfully with discectomy and fusion. Although developing a solid fusion is not the only factor in obtaining a successful clinical outcome, many series report superior clinical results when a solid arthrodesis has been obtained (*1, 2, 4, 7, 8, 12, 14, 15, 17, 19*).

The pseudarthrosis rate is known to be affected by the number of operative levels (*1, 2, 6, 8, 13, 17*), the type of graft used (*13, 18*) and the surgical technique (*2, 3, 7*). On the other hand, the type of instrumentation, the type of graft and the patient's size may interfere with the quality of the images for the interpretation of the fusion status and thus affect its accuracy. Also the criteria used to determine pseudarthrosis play an important role (*16*).

Persistent pain after cervical fusion necessitates an accurate determination of the fusion status, but this is not always easy. Also research projects would benefit from a clear definition of fusion status. Indeed, if the methodology for determining the fusion status is not correct, the findings of the study are valueless.

■ Avraam Ploumis, MD, PhD, Spine Fellow.
■ Amir Mehbod, MD, Spine Surgeon.
■ Timothy Garvey, MD, Spine Surgeon.
■ Ensor Transfeldt, MD, Spine Surgeon.
■ Kirkham Wood, MD, Spine Surgeon.
Twin Cities Spine Center, Minneapolis, Minnesota, USA.
■ Thomas Gilbert, MD, MPP, Radiologist.
Center for Diagnostic Imaging, Edina, Minnesota, USA.
Correspondence : Avraam Ploumis, MD, Twin Cities Spine Center, 913 E. 26th Street, Minneapolis, MN 55404.
E-mail : AAMehbod@tcspine.com.

No benefits or funds were received in support of this study

Of course, the true gold standard is the finding of motion and lack of bony union at surgical exploration, but this is not feasible for most research projects and it is of no use in preoperative decision making. The radiographic criteria which have been mentioned in the literature include lack of bridging trabeculae between vertebral body and bone graft, according to plain radiographs or computed tomography, and motion between the spinous processes or change in the Cobb angle on flexion-extension radiographs (*5, 9-11, 15, 19*). Yet, the accuracy of the diagnostic methods used to detect pseudarthrosis in the cervical spine has been poorly documented until recently (*5, 9*).

The purpose of this study was to prospectively compare the pseudarthrosis rates estimated either with static and dynamic plain roentgenograms, or with two-dimensional CT-scans. The hypothesis was that two-dimensional CT-scans would more accurately document pseudarthrosis following all types of cervical fusion.

MATERIALS AND METHODS

Forty-seven consecutive patients, aged 29 to 78 (average : 49), who had undergone a cervical fusion approximately one year (9 months to 15 months) before, were solicited via letter to enrol in the study. They were not selected according to symptoms or clinical status, so that the series consisted of a mix of patients with and without clinical symptoms of pseudarthrosis. Patients with congenital anomalies, tumours or infections were excluded from the study. Patients who agreed to participate were required to complete an informed consent form approved by the local institutional review board (IRB).

There were 21 (44%) males and 26 (56%) females. Two-thirds (67%) of the patients were non-smokers. Most patients (45 : 96%) had an anterior only fusion, while the remaining patients underwent an anterior-posterior fusion. A single level fusion was performed in 15 patients, a two level fusion in 12, a three level fusion in 14, a four level fusion in 4, a five level fusion in one and a six level fusion in one.

Plain radiographs, including static AP, static lateral, and lateral flexion-extension views, were obtained, using standardised methods, at one institution. Patients were placed in an upright position for all films. The central ray was focused on the body of C4, from a distance of 72 inches (183 cm), for all views. For the AP position, the patient's neck was extended enough to prevent superimposition of the mandible. For the lateral view, the patient was positioned to assure a true lateral view. The flexion and extension views were taken from a true lateral position with patient-exerted flexion or extension. The patient was told to bend the head down, with the neck only, and draw the chin as close as possible to the chest for the flexion view. On extension, the patient was told to elevate the chin as much as possible, with the neck only, to a position of extreme extension.

All CT-scans were obtained at one facility, using one of several GE Lightspeed Systems, within one month after the plain radiographs. The axial CT sections were made at 1.5 mm intervals with curved coronal and sagittal reconstruction. A standard protocol was followed.

Four reviewers, including two spine surgeons, one radiologist and one spine fellow, evaluated the plain films and the CT-scans in a random, blinded order. Evaluation of radiographs and evaluation of CT-scans were separated by at least two weeks for each reviewer. Each fusion level was checked, and read as *fused*, *not fused* or *indeterminate*. A level was interpreted as *fused*, on plain radiographs, when bridging trabeculae were seen, and a change of less than 2 mm in inter-spinous process distance and absence of motion on flexion/extension radiographs. A level was interpreted as *not fused*, on plain radiographs, when there were no bridging trabeculae, and/or more than 2 mm interwspinous process motion on dynamic flexion-extension radiographs. The term *indeterminate* was used when there was neither clear evidence of fusion nor clear evidence of pseudarthrosis. A level was considered as *fused* on the CT-scan when there were bridging trabeculae.

Inter-observer consistency (within the same diagnostic tool) and intra-observer consistency (across the two diagnostic tools) were determined by calculating the percent of levels on which agreement existed. If a level was read as *indeterminate* on plain radiographs and *fused* on CT, this was considered a *non-match*.

RESULTS

Fusion status (tables I and II)

Plain radiographs (table I) : the percentage of levels assessed as *fused* varied by observer and ranged from 70% to 88% (average : 81%). The number of levels deemed *indeterminate* ranged from 1% to 14% across the readers (average : 8%).

Table I. — Plain radiographs : fusion status evaluation, by observer

Observer	Fused	Not Fused	Indeterminate
Spine fellow	76%	16%	8%
Spine surgeon 1	70%	15%	14%
Spine surgeon 2	88%	11%	1%
Radiologist	88%	2%	10%
Average	81%	11%	8%

Table II. — CT-scan : fusion status evaluation, by observer

Observer	Fused	Not Fused	Indeterminate
Spine fellow	69%	31%	0%
Spine surgeon 1	66%	23%	10%
Spine surgeon 2	79%	21%	0%
Radiologist	79%	13%	8%
Average	74%	22%	5%

Computerised tomography (table II) : the percentage of levels assessed as *fused* ranged from 66 to 79% (average : 74%). All 4 reviewers indicated higher pseudarthrosis rates when studying CT-scans (13% to 31%, on an average 22%, according to CT-scans ; only 2% to 16%, on an average 11%, according to plain radiographs). The mean difference was 11%. Similarly, computerised tomography led to less *indeterminate* levels ; two observers did not use this term at all, and the remaining two used it in only 8 and 10% of the cases.

Interestingly, as well for plain radiographs as for CT-scan, the spine fellow indicated the highest pseudarthrosis rate while the radiologist indicated the lowest pseudarthrosis rate.

Inter-observer consistency (tables III and IV)

In a general sense, consistency between readers was relatively high. It was higher with CT (average agreement : 89% ; range : 82 to 96) than with plain radiographs (average agreement : 81% ; range : 76 to 87). In other words, two readers had, on an average, an 89% chance of reading any given level exactly the same when using CT-scans, and an 81% chance when using plain radiographs.

Intra-observer consistency (table V)

The percentage of levels, read the same on both plain radiographs and CT-scan by the same observer, ranged from 64% (spine fellow) to 85% (spine surgeon 2). The most common inconsistency within an observer was to read a level as *fused* on plain radiographs and *not fused* on CT. This was true for all 4 readers. Conversely, all readers also had some levels that were deemed *not fused* on plain radiographs and *fused* on CT.

Table III. — Plain radiographs : inter-observer consistency in %

	Spine fellow	Spine surgeon 1	Spine surgeon 2	Radiologist
Spine surgeon 1	76%			
Spine surgeon 2	77%	81%		
Radiologist	83%	81%	87%	
Average : 81%				

Table IV. — CT-scan : inter-observer consistency in %

	Spine fellow	Spine surgeon 1	Spine surgeon 2	Radiologist
Spine surgeon 1	92%			
Spine surgeon 2	82%	91%		
Radiologist	82%	96%	94%	
Average : 89%				

Table V. — Plain radiographs compared to CT-scan : intra-observer consistency in %

Spine fellow	64%
Spine surgeon 1	72%
Spine surgeon 2	85%
Radiologist	74%
Average	74%

DISCUSSION

Radiographic assessment of fusion remains an important aspect of the determination of success of cervical spinal fusion. Although pseudarthrosis does not preclude the possibility of a good or excellent clinical outcome, it has been associated with a higher rate of clinical failure and may be associated with late deformity, neurologic symptoms and pain.

Riew (*16*) recommended using the criteria set by Robinson and Smith to determine the radiographic fusion status : absence of motion on flexion/extension radiographs and presence of bridging trabeculae across the fused levels of the cervical spine. Riew (*16*) proposed to use these universal criteria in order to improve comparability between studies. Recently, two publications compared different radiographic techniques in assessment of cervical spine fusion. Cannada *et al* (*5*) retrospectively compared the accuracy of two radiographic techniques in identifying pseudarthrosis after anterior cervical discectomy and fusion. In the spinous process technique, pseudarthrosis was defined as a change of more than 2 mm in inter-spinous process distance from flexion to extension on dynamic lateral radiographs. In the second, the Cobb angle technique, pseudarthrosis was defined as a change of more than 2 degrees on dynamic radiographs. They found that the inter-observer consistency for the spinous process technique and the Cobb angle technique was 0.77 and 0.28 respectively ; thus the first technique was the most accurate.

Epstein *et al* (*9*) compared the pseudarthrosis rates established with dynamic lateral roentgenograms and with computed tomography. As to dynamic lateral views, fusion was defined as less than 1mm of inter-spinous process motion. As to computerised tomography, fusion supposed the presence of bridging trabeculae and lack of lucency at the graft-vertebral junction. The fusion rate was apparently higher with plain radiographs than with CT, at 3 months (83% versus 50%) and at 6 months (96% versus 70%). In other words, CT-scan was a more severe judge. This was in line with the current study, although the latter focused on a more heterogeneous population, and in a later stage (one year postoperatively).

The authors now use computerised tomography to determine the presence of pseudarthrosis when plain radiographs are inconclusive while the patient has persistent symptoms. Very often, pseudarthroses are seen on CT-scan, although invisible on plain radiographs.

The authors feel that the current study yields sufficient support for this philosophy. Admittedly, the “true” fusion status was not known : it would have required a surgical exploration. But it was striking that all observers indicated fewer levels as *indeterminate* when using CT. Furthermore, CT revealed pseudarthrosis twice as often as plain radiographs (22% versus 11%). Finally, the inter-observer consistency was 89% for CT versus 81% for plain radiographs.

On the other hand, inter-observer and intra-observer variability in assessing fusion status was seen with both plain radiographs and CT imaging. Also the relatively frequent use of the term *indeterminate* indicates that evaluation of fusion status is often a complex evaluation. These findings suggest that comparison of fusion rates across studies should be made with caution. Study results should be carefully examined to obtain a clear idea about the definition of fusion status and quality of the roentgenological examination. A simple yes-no answer, as is most often required in research projects, may be inadequate.

CONCLUSION

The need to accurately document pseudarthrosis after cervical fusion is critical, as it helps direct the postoperative management of the patient. The present study underlines the value of computed

tomography. Of course, surgical exploration is the gold standard, but it requires a re-operation. Prospective studies, which correlate CT findings with surgical findings at re-operation, would allow to determine the sensitivity and specificity of this diagnostic tool.

REFERENCES

1. **Bohlman HH, Emery SE, Goodfellow DB, Jones PK.** Robinson anterior cervical discectomy and arthrodesis for cervical radiculopathy. Long-term follow-up of one hundred and twenty-two patients. *J Bone Joint Surg* 1993 ; 75-A : 1298-1307.
2. **Bolesta MJ, Rechtine GR 2nd, Chrin AM.** Three- and four-level anterior cervical discectomy and fusion with plate fixation : a prospective study. *Spine* 2000 ; 25 : 2040-2044 ; discussion 2045-2046.
3. **Brodke DS, Zdeblick TA.** Modified Smith-Robinson procedure for anterior cervical discectomy and fusion. *Spine* 1992 ; 17 : S427-430.
4. **Brodsky AE, Khalil MA, Sassard WR, Newman BP.** Repair of symptomatic pseudoarthrosis of anterior cervical fusion. Posterior versus anterior repair. *Spine* 1992 ; 17 : 1137-1143.
5. **Cannada LK, Scherping SC, Yoo JU *et al.*** Pseudoarthrosis of the cervical spine : a comparison of radiographic diagnostic measures. *Spine* 2003 ; 28 : 46-51.
6. **Cauthen JC, Kinard RE, Vogler JB *et al.*** Outcome analysis of noninstrumented anterior cervical discectomy and interbody fusion in 348 patients. *Spine* 1998 ; 23 : 188-192.
7. **Emery SE, Bolesta MJ, Banks MA, Jones PK.** Robinson anterior cervical fusion comparison of the standard and modified techniques. *Spine* 1994 ; 19 : 660-663.
8. **Emery SE, Fisher JR, Bohlman HH.** Three-level anterior cervical discectomy and fusion : radiographic and clinical results. *Spine* 1997 ; 22 : 2622-2624 ; discussion 2625.
9. **Epstein NE, Silvergleide RS.** Documenting fusion following anterior cervical surgery : a comparison of roentgenogram versus two-dimensional computed tomographic findings. *J Spinal Disord Tech* 2003 ; 16 : 243-247.
10. **Farey ID, McAfee PC, Davis RF, Long DM.** Pseudarthrosis of the cervical spine after anterior arthrodesis. Treatment by posterior nerve-root decompression, stabilization, and arthrodesis. *J Bone Joint Surg* 1990 ; 72-A : 1171-1177.
11. **Hilibrand AS, Dina TS.** The use of diagnostic imaging to assess spinal arthrodesis. *Orthop Clin North Am* 1998 ; 29 : 591-601.
12. **Lowery GL, Swank ML, McDonough RF.** Surgical revision for failed anterior cervical fusions. Articular pillar plating or anterior revision ? *Spine* 1995 ; 20 : 2436-2441.
13. **Martin GJ Jr, Haid RW Jr, MacMillan M *et al.*** Anterior cervical discectomy with freeze-dried fibula allograft. Overview of 317 cases and literature review. *Spine* 1999 ; 24 : 852-858 ; discussion 858-859.
14. **Newman M.** The outcome of pseudarthrosis after cervical anterior fusion. *Spine* 1993 ; 18 : 2380-2382.
15. **Phillips FM, Carlson G, Emery SE, Bohlman HH.** Anterior cervical pseudarthrosis. Natural history and treatment. *Spine* 1997 ; 22 : 1585-1589.
16. **Riew K.** Assessment of cervical fusions : the limitations of plain radiographs in the clinical setting. American Academy of Orthopedic Surgeons, San Francisco, CA, 2001.
17. **Swank ML, Lowery GL, Bhat AL, McDonough RF.** Anterior cervical allograft arthrodesis and instrumentation : multilevel interbody grafting or strut graft reconstruction. *Eur Spine J* 1997 ; 6 : 138-143.
18. **Zdeblick TA, Ducker TB.** The use of freeze-dried allograft bone for anterior cervical fusions. *Spine* 1991 ; 16 : 726-729.
19. **Zdeblick TA, Hughes SS, Riew KD, Bohlman HH.** Failed anterior cervical discectomy and arthrodesis. Analysis and treatment of thirty-five patients. *J Bone Joint Surg* 1997 ; 79-A : 523-532.