

Guidelines for the performance of fusion procedures for degenerative disease of the lumbar spine. Part 4: radiographic assessment of fusion

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Recommendations

Standards. Static lumbar radiographs are not recommended as a stand-alone means to assess fusion status following lumbar arthrodesis surgery.

Guidelines. 1) Lateral flexion and extension radiography is recommended as an adjunct to determine the presence of lumbar fusion postoperatively. The lack of motion between vertebrae, in the absence of rigid instrumentation, is highly suggestive of successful fusion. 2) Technetium-99 bone scanning is not recommended as a means to assess lumbar fusion.

Options. Several radiographic techniques, including static radiography, lateral flexion–extension radiography, and/or CT scanning, often in combination, are recommended as assessment modality options for the noninvasive evaluation of symptomatic patients in whom failed lumbar fusion is suspected.

Rationale

Lumbar fusion is performed in patients with pain due to lumbar degenerative disease. An outcome measure frequently cited in studies evaluating lumbar fusion techniques is the “radiographic fusion rate;” however, radio-

graphic fusion is not consistently defined throughout the literature. The purpose of this review is to examine the literature regarding the ability of various diagnostic techniques to assess fusion status after lumbar fusion is performed to treat degenerative disease.

Search Criteria

A computerized search of the database of the National Library of Medicine between 1966 and July 2003 was conducted using the search terms “lumbar spine fusion assessment,” “lumbar spine pseudoarthrosis,” or “lumbar spine fusion outcome.” The search was restricted to references in the English language involving humans. This yielded a total of 1076 references. The titles and abstracts of each of these references were reviewed. Only papers concerned with the assessment of fusion status following arthrodesis procedures for degenerative lumbar disease were included. Additional articles were obtained from the bibliographies of the selected articles. Forty-five references were identified that provided either direct or supporting evidence relevant to the radiographic assessment of lumbar fusion status. Reports involving Class III or better medical evidence are listed in Table 1. Supportive data are provided by additional references listed in the bibliography.

Scientific Foundation

Open surgical exploration is the only method that allows direct inspection of fusion integrity. This procedure

Abbreviations used in this paper: CT = computerized tomography; NPV = negative predictive value; PPV = positive predictive value; RSA = roentgen stereophotogrammetric analysis.

is considered the gold standard of lumbar fusion assessment.^{6,7} It is, therefore, an appropriate benchmark to use in establishing the accuracy and predictive value of noninvasive radiographic studies for the assessment of fusion status following attempted lumbar fusion surgery.

Plain Radiographs (static)

Anteroposterior and lateral radiographs can demonstrate a continuous bone mass between adjacent vertebral segments following lumbar fusion. Because of their relatively low cost, widespread availability, and long history as a means of assessing fusion, plain spinal radiography remains a common method of assessment of lumbar fusion;⁶ however, the limitations of static plain radiography as a reliable test for determining the presence or absence of a solid fusion have been well documented. Brodsky, et al.,³ reported a 64% correlation between preoperative plain radiographs and surgical exploration in a retrospective study of 214 lumbar fusion exploration procedures in patients who had undergone prior posterolateral fusion. Plain radiography had an 89% sensitivity and 60% specificity for predicting solid fusion. Radiographs interpreted as demonstrating fusion had a PPV of 76%. Those predicting pseudarthrosis had an NPV of 78%. These data indicate a 0.18 likelihood ratio for a false-positive result (chance of a pseudarthrosis discovered at exploration when radiography indicates fusion), and a 2.25 likelihood ratio for a negative test result (chance of a fusion discovered at exploration when the radiography suggests pseudarthrosis).³ The medical evidence provided by this review is considered Class II for the use of plain lumbar radiography compared with open surgical exploration to assess fusion because of the authors' selection bias for open exploration.

Similarly, in a retrospective study of 75 patients, Kant and coworkers¹¹ found a positive correlation between static radiography and surgical exploration of lumbar fusion in 68% of their patients (sensitivity 85%, specificity 62%, PPV 76%, and NPV 54%). The likelihood ratio for a positive result was 0.81, and the likelihood ratio for a negative result was 2.24. Finally, in a study of 49 patients treated with posterolateral and posterior interbody fusion with internal fixation, Blumenthal and Gill¹ compared findings on anteroposterior and lateral radiographs (interpreted by two surgeons and two radiologists) with surgical exploration of the fusion mass at the time of reoperation for hardware removal. They reported a 69% agreement between the radiographic diagnosis and surgical findings. The accuracy among the four physicians interpreting the radiographs ranged from 57 to 77% (false-positive rate 42%, false-negative rate 29%). These authors concluded that plain radiography has limited accuracy and validity for the assessment of lumbar fusion. Furthermore, they noted significant intra- and interobserver variation, indicating a lack of reliability (κ 0.4–0.7). Their study provides Class I medical evidence indicating that static radiography is only accurate in determining fusion status in roughly two thirds of cases. Therefore, static anteroposterior and lateral radiographs are not recommended as a stand-alone assessment of the presence of an arthrodesis after lumbar fusion surgery for degenerative disease.

Flexion–Extension Radiography

In 1948 Cleveland, et al.,⁶ advocated the use of dynam-

ic lumbar spinal radiography rather than static radiography, for the diagnosis of pseudarthrosis following attempted lumbar fusion surgery. Other authors have also suggested that lateral lumbar flexion–extension radiography allows for appropriate assessment of fusion status.⁴ There has been disagreement, however, on the number of allowable degrees of motion at the treated (fused) levels for determining the presence or absence of successful bone fusion.¹⁶

Brodsky, et al.,³ compared the findings of lumbar flexion–extension radiography to surgical exploration in a series of 175 patients who underwent reoperation for various indications following instrumented and noninstrumented lumbar fusion. They found a 62% correlation between preoperative flexion–extension radiography and intraoperative findings at exploration (specificity 37%, sensitivity 96%, PPV 70%, and NPV 86%). Their study provides Class II medical evidence that the absence of motion on flexion–extension x-ray films is highly suggestive of a solid fusion. The occurrence of some degree of motion at the treated levels, however, does not necessarily indicate a pseudarthrosis.

Computerized Tomography Scanning

Since the introduction of CT scanning in the 1970s, this modality has been used to assess lumbar fusion. Early studies involved axial sequences alone. Brodsky, et al.,³ used 6-mm axial slice CT scans and demonstrated a 57% correlation between fusion assessment based on these scans compared with direct surgical exploration in a series of 214 operations on 175 patients. Computerized tomography scanning had a sensitivity of 63%, specificity of 86%, PPV of 72%, and an NPV of 81%. Laasonen and Soini¹² conducted a retrospective review of 20 patients who underwent CT scanning prior to surgical exploration and found an approximate 80% correlation between the CT study–based diagnosis of fusion and intraoperative diagnosis of fusion. Since the publication of these earlier studies, CT imaging technology has advanced. The use of thin-section axial sequences, improved resolution, and multiplanar imaging capability has enhanced the ability of CT scanning to assess lumbar fusion status. There have been no studies comparing these more advanced CT scanning capabilities with direct surgical exploration. Lang and colleagues¹⁴ found that the addition of thin-slice and multiplanar CT scanning resulted in a higher rate of detection of pseudarthrosis compared with plain radiography. Similarly, Chafetz, et al.,⁵ demonstrated that direct coronal CT scanning may be more sensitive than two-dimensional reconstructed coronal CT images for the detection of pseudarthrosis. Zinreich and colleagues²¹ reported that three-dimensional CT reconstruction may be more sensitive than two-dimensional CT reconstruction for the detection of pseudarthrosis. Siambanes and Mather²⁰ demonstrated that multiplanar CT imaging detected pseudarthrosis in patients who had undergone posterior lumbar interbody fusion compared with plain radiography that had suggested a solid fusion. Santos and colleagues¹⁸ examined 32 patients who underwent anterior lumbar interbody fusion with carbon fiber cages. Plain static radiographs were interpreted to demonstrate fusion at 86% of the assessed levels. Flexion–extension lumbar radiography suggested fusion rates ranging from 74 to 96% in this same group of patients, depending on the method used to analyze