## **Cervical fusion criteria**

Along with implant material, factors such as younger age, active smoking status, and the number of operated levels were independent predictors of cervical pseudoarthrosis. Given the impact of nonunion on patient-reported outcome (PRO), perioperative optimization of modifiable factors and surgical planning are essential to ensure a successful outcome <sup>1)</sup>.

Oshina et al., found 4 major criteria (I-IV) that were used to assess fusion, and except for those that did not specify fusion criteria, all articles used least 1 of the 4 or combinations of the 4. All but 2 articles that reported fusion 1- or 2-year fusion rates used the bridging trabecular bone criterion (I). The 2-year fusion rates determined using combinations including criterion I were no significantly different, but the mean fusion rate of only criterion I was the lowest in those combinations, regardless of using the minimum number of criteria. The 1-year fusion rates reported in the reviewed articles were not significantly different, but the 2-year fusion rates were (P 1/4 .048). The 1- and 2-year fusion rates reported in 29 articles had a large range from 60% to 100%. Some articles reported solid fusion rates of 100% at 3 months and others reported rates of 42% at 4 years. As expected, the fusion rates fluctuated widely. They considered that the range in reported fusion rates resulted from differences in radiographic interpretation as well as fusion level, type of implant, patient history, and surgical technique. It was difficult to decide which criteria were the most reliable, but the most highly documented criteria and the most objective radiographic assessments had the strongest support. Criterion I, visualization of bridging trabecular bone between the endplates, was the most commonly used criterion, followed by the absence of radiolucency between graft and endplate (criterion II). Both criteria are subjectively determined because there is no objective scale to measure the findings, at least on plain radiographs.

Diagnosis of pseudarthrosis after anterior cervical fusion is difficult, and often depends on the surgeon's subjective assessment because recommended radiographic criteria are lacking. A review of Oshina et al., evaluated the available evidence for confirming fusion after anterior cervical discectomy.

Articles describing assessment of anterior cervical fusion were retrieved from MEDLINE and SCOPUS. The assessment methods and fusion rates at 1 and 2 years were evaluated to identify reliable radiographical criteria.

Ten fusion criteria were described. The 4 most common were presence of bridging trabecular bone between the endplates, absence of a radiolucent gap between the graft and endplate, absence of or minimal motion between adjacent vertebral bodies on flexion-extension radiographs, and absence of or minimal motion between the spinous processes on flexion-extension radiographs. The mean fusion rates were 90.2% at 1 year and 94.7% at 2 years. The fusion rate at 2 years had significant independence (P = .048).

The most common fusion criteria, bridging trabecular bone between the endplates and absence of a radiolucent gap between the graft and endplate, are subjective. They recommend using <1 mm of motion between spinous processes on extension and flexion to confirm fusion  $^{2)}$ .

Reintjes et al performed a comprehensive PubMed search of English-language articles pertaining to

PCF and OCF in patients less than 18 years old. Of the 561 abstracts selected, 148 articles were reviewed, resulting in 60 articles that had sufficient detail to be included in the analysis. A meta-regression analysis was performed to determine if and how age, fusion technique, levels fused, fusion substrate, BMP use, postoperative bracing, and radiographic fusion criteria were related to the pooled prevalence estimates. A systematic review of the literature was performed according to the Preferred Reporting Items for Systematic Reviews and MetaAnalyses.

A total of 604 patients met the specific inclusion and exclusion criteria. The overall fusion rate was 93%, with a mean age of 9.3 years and mean follow-up of 38.7 months. A total of 539 patients had fusion with autograft (94% fusion rate) and 65 patients with allograft (80% fusion rate). Multivariate meta-regression analysis showed that higher fusion rates were associated with OCF compared with fusions that excluded the occiput (p < 0.001), with the use of autograft instead of allograft (p < 0.001), and with the use of CT to define fusion instead of plain radiography alone. The type of internal fixation, the use of BMP, patient age, and the duration of follow-up were not found to be associated with fusion rates in the multivariate analysis.

Fusion rates for PCF are high, with higher rates of fusion seen when autograft is used as the bone substrate and when the occiput is included in the fusion construct. Further study of the use of allograft as a viable alternative to autograft bone fusion is warranted because limited data are available regarding the use of allograft in combination with more rigid internal fixation techniques and osteoinductive substances, both of which may enhance fusion rates with allograft <sup>3)</sup>.

The purpose of a 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 <sup>4</sup>.

Measurement of the change in distance between spinous processes is more reproducible and accurate than the Cobb method for making the diagnosis of pseudarthrosis. The authors believe that the measurement of distances between spinous processes on lateral flexion-extension radiographs should be used as a method for evaluating radiographic fusion in patients with pseudarthrosis <sup>5)</sup>.

## **CT** fusion criteria

Would two-dimensional CT studies more accurately identify fusion following single-level anterior cervical 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 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 <sup>6</sup>.

However, even the evaluation of CT images is somewhat subjective. Several articles used a cutoff value of 50% of the space between graft and endpoint to satisfy these criteria, that is, trabecular bone bridging at least 50% of the gap or radiolucency involving less than 50%. Disappearance of the endplates of the 2 adjacent vertebral bodies might also be helpful in deciding whether fusion had been accomplished. Motion of vertebral bodies on flexionextension radiographs (criterion III) involves an upper limit of Cobb angles ranging from 0 to 5 and an upper limit for translation ranging from 0 to 3 mm. When Cobb angles were calculated, the endplates could be rotated with an apparent angle mismatch in the extension and flexion views. Kaiser et al., reported that an interspinous distance of 2 mm on dynamic radiographs was a more reliable indicator of pseudarthrosis than an angular motion of 2 using Cobb angle measurements. They recommended the use of interspinous distance rather than Cobb angles (quality of evidence class II and strength recommendation B)<sup>7)</sup>

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