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Cervical surgical techniques for the treatment of cervical spondylotic myelopathy

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Object. The objective of this systematic review was to use evidence-based medicine to compare the efficacy of different surgical techniques for the treatment of cervical spondylotic myelopathy (CSM).

Methods. The National Library of Medicine and Cochrane Database were queried using MeSH headings and keywords relevant to anterior and posterior cervical spine surgery and CSM. The guidelines group assembled an evidentiary table summarizing the quality of evidence (Classes I–III). The group formulated recommendations that contained the degree of strength based on the Scottish Intercollegiate Guidelines network. Validation was done through peer review by the Joint Guidelines Committee of the American Association of Neurological Surgeons/Congress of Neurological Surgeons.

Results. A variety of techniques have improved functional outcome after surgical treatment for CSM, including anterior cervical discectomy with fusion (ACDF), anterior cervical corpectomy with fusion (ACCF), laminoplasty, laminectomy, and laminectomy with fusion (Class III). Anterior cervical discectomy with fusion and ACCF appear to yield similar results in multilevel spine decompression for lesions at the disc level. The use of anterior plating allows for equivalent fusion rates between these techniques (Class III). If anterior fixation is not used, ACCF may provide a higher fusion rate than multilevel ACDF but also a higher graft failure rate than multilevel ACDF (Class III). Anterior cervical discectomy with fusion, ACCF, laminectomy, laminoplasty, and laminectomy with arthrodesis all provide near-term functional improvement for CSM. However, laminectomy is associated with late deterioration compared with the other types of anterior and posterior surgeries (Class III).

Conclusions. Multiple approaches exist with similar near-term improvements; however, laminectomy appears to have a late deterioration rate that may need to be considered when appropriate.
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Key Words • cervical spine • cervical spondylosis • cervical myelopathy • practice guidelines • surgical technique • treatment outcome

Recommendations

Indication: CSM. It is recommended that a variety of techniques be considered in the surgical treatment of CSM including ACDF, ACCF, laminoplasty, laminectomy, and laminectomy with fusion (quality of evidence, Class III; strength of recommendation, D).

Technique: ACDF Compared to ACCF. It is recommended that ACDF or ACCF be used in patients undergoing multilevel anterior cervical spine decompression for lesions located at the disc level. The use of anterior plate fixation allows for equivalent fusion rates between these techniques (quality of evidence, Class III; strength of recommendation, D).

If anterior fixation is not used, it is recommended that ACCF be considered before ACDF because it may provide a higher fusion rate than multilevel ACDF. It should be understood that the use of ACCF is associated with

Abbreviations used in this paper: ACCF = anterior cervical corpectomy with fusion; ACD = anterior cervical discectomy; ACDF = ACD with fusion; CSM = cervical spondylotic meylopathy; JOA = Japanese Orthopaedic Association; ROM = range of motion.

higher graft failure rates than multilevel ACDF (quality of evidence, Class III; strength of recommendation, D).

Technique: ACDF or ACD Versus Laminectomy. There is insufficient evidence to recommend ACD or ACDF over laminectomy in the near term because both approaches have produced comparable improvements in the surgical treatment of CSM; however, because of the association of laminectomy with late deterioration, ACDF or ACD should be considered for short segment decompression for CSM when technically feasible (quality of evidence, Class III; strength of recommendation, D).

Technique: ACDF Versus Laminectomy/Arthrodesis. There is insufficient evidence to recommend ACDF over laminectomy/arthrodesis because both approaches have produced comparable improvement in the surgical treatment of CSM (quality of evidence, Class III; strength of recommendation, D).

Technique: ACDF and ACCF Versus Laminoplasty. There is insufficient evidence to make a recommendation of ACDF or ACCF over laminoplasty because both approaches have produced comparable improvement in the surgical treatment of CSM (quality of evidence, Class III; strength of recommendation, D).

Technique: Laminectomy Versus Laminoplasty. There is insufficient evidence to recommend laminoplasty over laminectomy because both approaches have produced comparable improvement in the surgical treatment of CSM in the near term; however, because of the association of laminectomy with late deformity, laminoplasty should be considered when stability is an issue over time (quality of evidence, Class III; strength of recommendation, D).

Technique: Laminectomy Versus Laminectomy/Arthrodesis. There is insufficient evidence to recommend laminectomy with arthrodesis over laminectomy because both approaches have produced comparable improvement in the surgical treatment of CSM in the near term; however, because of the association of laminectomy with late deformity, laminectomy with arthrodesis should be considered when stability is an issue over time (quality of evidence, Class III; strength of recommendation, D).

Technique: Laminoplasty Versus Laminectomy/Arthrodesis. There is insufficient evidence to recommend laminoplasty over laminectomy with arthrodesis because both approaches have produced comparable improvement in the surgical treatment of CSM (quality of evidence, Class III; strength of recommendation, D).

Rationale

The purpose of this review was to use an evidence-based approach to examine the best surgical approach for the surgical treatment of CSM. Surgeons may access anterior compressive pathological entities in the cervical spine directly using either ACDF or ACCF. The surgeon may access posterior compressive lesions through laminectomy, laminoplasty, or laminectomy/arthrodesis. Furthermore, decompression of anterior lesions in the cervical spine may be undertaken using a posterior approach. The question arises whether one of these operations is superior to the other in terms of patient outcome.

Search Criteria

We completed a computerized search of the National Library of Medicine and the Cochrane Database for literature published between 1966 and 2007 using MeSH headings and keywords. Only English language citations were included. References cited in the qualifying articles were also reviewed to gather any other applicable manuscripts published between 1966 and 2006.

For ACDF and ACCF, the search headings included the following terms: "anterior cervical discectomy" and "anterior cervical corpectomy," "cervical discectomy versus corpectomy," "outcome and anterior cervical spine surgery," "fusion rate and anterior cervical spine surgery." These search terms yielded 1035 citations. The abstracts of these citations were reviewed and applicable articles (which discussed both ACDF and ACCF) were selected.

For cervical laminectomy, the MeSH subject headings of "cervical" and "surgery" limited to humans, and generated a broad base of studies (9589 references). We reviewed titles and abstracts with attention to those titles addressing clinical management. We followed the initial search with a secondary search crossing "myelopathy" with "surgery" and "cervical" and" myelopathy."

For cervical laminoplasty, we used standard search terms along with MeSH headings. A search using the subject heading "laminoplasty" yielded 381 citations. The following subject headings were combined: "laminoplasty and outcome," "laminoplasty and cervical spine," "laminoplasty and myelopathy," "laminoplasty and surgery," and "laminoplasty and cervical stenosis." These search terms yielded 155, 269, 266, 347, and 69 citations, respectively. Accounting for redundancy, 314 citations were acquired.

Other search terms included "myelopathy, cervical spine, fusion, laminectomy, laminoplasty, cervical spondylotic myelopathy, and ossification of posterior longitudinal ligament." A search using the subject heading "laminectomy" and "cervical" and "arthrodesis" yielded 345 citations. The following subject headings were combined: "laminectomy and outcome and arthrodesis" (244 citations) and "laminectomy and arthrodesis and myelopathy" (329 citations). We acquired a total of 614 citations after accounting for redundancy.

Scientific Foundation

Anterior Cervical Discectomy With Fusion Versus ACCF

For a variety of reasons, we graded all manuscripts as Class III evidence. The primary reasons were as follows: absence of a control group, nonblinded allocation of a control group, nonvalidated outcome measures, and unblinded outcome assessors. All of these flaws introduced bias into the studies described below (Table 1).

Emery et al.[7] reported on a series of 108 patients with

TABLE 1: Evidentiary summary of manuscripts examining the efficacy of multilevel ACDF versus ACCF for degenerative cervical myelopathy*

Authors & Year	Class	Description of Study	Comments
Emery et al., 1998	III	108 patients w/ CSM treated w/ anterior decompression & arthrodesis. Operative treatment was ACDF (n = 45) or ACCF (n = 55) w/ autograft. Fixation was NOT utilized. Outcome was assessed using Nurick scores. Subjective development of pain was followed. Also assessed was fusion rate using radiographs.	Nurick improved from 2.4 to 1.2 for all patients. Myelopathy outcome was similar in all groups. Pseudarthrosis developed in 16 patients (13 of these had ACDF). Pain was associated w/ development of pseudoarthrosis. No statistics given. Class III due to nonblinded allocation & nonvalidated outcome measures.
Fraser & Hartl, 2007	III	The authors reviewed studies published after 1990 in which fusion rates achieved w/ each procedure were reported for patients w/ degenerative disease at 1, 2, & 3 disc levels. The only inclusion criteria were that the series had to have had a minimum number of patients followed up over a specified period of time.	This was graded Class III since it did not follow standard techniques for systematic reviews. This study combined patients from several different case series & added them to patients allocated in clinical trials of ACDF vs ACCF. It did not grade each trial & pooled case series. This combined population was then analyzed. Appropriate inclusion & exclusion criteria were not followed. The authors did not test for heterogeneity or determine a method for pooling of results. The authors did not have inclusion criteria for studies specifically examining ACDF vs ACCF & did not exclude case series. The authors found that 2-level disc disease treated w/ either 2-level ACDF w/ plate or 1-level corpectomy w/ plate resulted in similar fusion rates (>90%). For 3-level disc disease, fusion rates for ACDF w/ plate fixation (82.5% fusion rate) were lower than for corpectomy w/ plate fixation (96.2% fusion rate) ($p = 0.03$).
Hilibrand et al., 2001	III	190 patients w/ CSM followed clinically & radiographically for ≥2 yrs. ACCF (n = 59) & ACDF (n = 131) were utilized w/ autograft. Smoking history in 55 patients (ACCF = 15, ACDF = 40). Outcomes were assessed subjectively w/ pain & daily activity. Dynamic radiographs to assess fusion at 2 yrs.	In ACDF group, fusion was 20/40 in smokers & 69/91 in nonsmokers ($p < 0.02$). In ACCF group, fusion was 14/15 in smokers & 41/44 in nonsmokers (no difference). The authors concluded that ACCF may be better for smokers. Clinical outcome was worse in smokers. Class III because of unblinded allocation & nonvalidated outcome measures.
Hilibrand et al., 2002	III	190 patients underwent anterior cervical decompression & autogenous grafting w/o internal fixation. Mean FU was 68 mos. ACDF: 98 patients w/ 2-level, 33 w/ 3-level. ACCF: 16 w/ 1-level, 21 w/ 2-level, 20 w/ 3-level, & 2 w/ 4-level. Radiographic outcome reviewed. Clinical outcomes were related to pain through Robinson's criteria.	ACCF 55/59 (93%) had solid arthrodesis compared to ACDF 87/131 (66%) ($p = 0.0002$). ACCF 6/59 (10%) graft displacement compared to ACDF 0/131 (0%) ($p < 0.0001$). More "good" & "excellent" clinical outcomes were found among patients who underwent strut-grafting (88% vs 84%), although the difference was not statistically significant (p = NS). However, patients w/ a pseudoarthrosis had significantly worse clinical outcomes ($p < 0.0001$). Class III because of bias between groups (halo use greater in ACCF group), nonblinded allocation since the study was retrospective & nonblinded radiological reporting.
Lee et al., 2007	III	348 patients who underwent ACDF (n = 121) or ACCF (n = 173) over 4-yr period. FU over 2 yrs in 310 patients. Patients were prospectively interviewed at 1, 2, 6, 12, & 24 mos regarding the presence & subjective severity of dysphagia using the dysphagia grading system defined by Bazaz et al.† Proportion analysis (chi-square or Fisher exact test), prevalence ratios, & 95% CIs were used to compare the prevalence of dysphagia w/ age, sex, type of surgery (e.g., discectomy vs corpectomy, primary vs revision), use of instrumentation, number & location of surgical levels.	Overall prevalence for dysphagia at 1, 2, 6, 12, & 24 mos was 54.0, 33.6, 18.6, 15.2, & 13.6%, respectively. The prevalence of dysphagia was found to be significantly higher in women, after revision surgery, & w/ > 2-level surgery. No statistical difference in dysphagia rates was seen between ACDF & ACCF. This study was graded Class III due to unbalanced allocation of study groups since the ACCF group had a greater proportion of surgeries >3 levels ($p < 0.01$) & the use of fixation was surgeon dependent.
Nirala et al., 2004	III	201 patients who underwent multilevel anterior cervical decompression & fusion w/o fixation using autograft. ACDF (n = 69) or ACCF (n = 132) over a 10-yr period. Radiological outcomes in followed using dynamic radiographs. Patients wore a hard cervical collar for 3 mos. Outcomes using Odom's criteria.	ACDF had 69.6% fusion rate vs ACCF 93.9% ($p = 0.0001$). Within subgroups, 2-level ACDF had 86.7% fusion vs 1-level ACCF (96.3%). 3-level ACDF had 57.6% vs 2-level ACCF (92.4%). 4-level ACDF had 50% fusion vs 3-level ACCF (91.7%). Odom's criteria (good/excellent) similar in both groups. More graft dislodgements in ACCF (3.8%) vs ACDF (1.4%). Class III due to biased allocation (more Pott's disease in ACCF) & unblinded radiographic assessment.

(continued)

TABLE 1: Evidentiary summary of manuscripts examining the efficacy of multilevel ACDF versus ACCF for degenerative cervical myelopathy* *(continued)*

Authors & Year	Class	Description of Study	Comments
Swank et al., 1997	III	Allograft tricortical iliac crest reconstruction & anterior cervical plating were studied in 64 patients (38 ACDF & 26 ACCF). The average FU was 39 mos. Hard cervical collar for 4–6 wks. Outcome assessed w/ plain radiographs. Clinical outcomes were subjective.	Non-union: ACDF 42% vs ACCF 31%. 2-level ACDF 36% vs 1-level ACCF 10%. 3 level ACDF 54% vs 2 level ACCF 44%. Class III due to biased allocation of groups (constrained plates had a higher fusion rate than dynamic; more of dynamic plates in ACDF group; retrospective nature also leads to bias; no blinding of radiographic assessors). Clinical outcomes subjective.
Wang et al., 2001	III	Anterior decompression/fusion over 2 levels w/ iliac crest & plate fixation in 52 patients (20 ACCF & 32 ACDF). Average FU was 3.6 yrs. Hard cervical collar for 6–8 wks. Outcome w/ dynamic radiographs & Odom's criteria.	Fusion rates were not statistically significant ($p = 0.385$). The clinical results of the surgeries were similar between the groups based on Odom's criteria. The addition of cervical plates to either 2-level ACDF or single-level ACCF yielded similar fusion & complication rates. 1 nonunion in ACCF group. No difference in graft collapse (1 mm in both groups) or kyphosis (1° in both groups) Odom's outcomes similar. Class III due to biased allocation & unblinded outcome assessors.

* The criteria for scoring each manuscript into a class are described in *Introduction and Methodology: Guidelines for the Surgical Management of Cervical Degenerative Disease*, which appears in this issue of the *Journal of Neurosurgery: Spine*.

† Bazaz R, Lee MJ, Yoo JU: Incidence of dysphagia after anterior cervical spine surgery: a prospective study. **Spine 27:**2453–2458, 2002.

CSM who underwent ACDF. Of this group, 45 patients had ACDF with iliac autograft without plate fixation, and 55 patients had partial ACCF with iliac autograft without plate fixation. The authors assessed fusion using dynamic radiographs. The ACDF group had a higher rate of pseudarthrosis compared to the ACCF group, and patients with pseudarthrosis had a statistically worse outcome. Overall, Nurick scores improved from 2.4 to 1.2. Because the allocation to groups was biased and the outcome measure was not formally validated, this study was graded Class III.

Fraser and Hartl[8] pooled patient populations from several retrospective series in addition to randomized trials. They analyzed a combined group of 2682 patients. This paper did not follow standard techniques for systematic reviews and was therefore graded Class III. The authors did not test for heterogeneity or determine a method for pooling results. The authors reported that 2-level disc disease treated with either 2-level ACDF plus fixation or 1-level ACCF plus fixation resulted in similar fusion rates (> 90%). For 3-level disc disease, fusion rates for ACDF with plate fixation (82.5% fusion rate) were lower than for ACCF with plate fixation (96.2% fusion rate; $p = 0.03$).

Hilibrand and colleagues[15] retrospectively reviewed a series of 190 patients. In their series, 131 patients underwent ACDF—2-level surgery in 98 patients and 3-level in 33—using autograft without fixation. Anterior cervical corpectomy with fusion was undertaken in 59 patients (16 1-level, 21 2-level, 20 3-level, and 2 4-level surgeries) using iliac or fibula strut autograft. The mean follow-up was 68 months, and dynamic radiographs were used to assess fusion. The rate of fusion was higher in patients who underwent ACCF; this result was statistically significant. Patients who underwent 2-level ACDF without fixation had lower fusion rates than those who underwent 1-level ACCF without fixation. Patients who underwent 3-level ACDF had lower fusion rates than those who underwent 2-level ACCF (again, without fixation). However, the graft extrusion rate was higher in patients who underwent ACCF than in those who underwent ACDF. This finding was statistically significant. Clinical outcomes (Robinson's criteria) were not statistically different between the groups.[15] The authors found that smokers had better fusion rates if they underwent ACCF rather than multilevel ACDF. In the absence of plate fixation, the authors recommended that smokers be preferentially treated with ACCF rather than multilevel ACDF because of the higher fusion rate with the former operation.[14]

Lee et al.[22] conducted a prospective review in patients undergoing anterior cervical fusion to determine risk factors for dysphagia. They reviewed 121 patients who underwent ACCF and 173 who had multilevel ACDF. The type of surgery performed, number of operated levels, and the use of instrumentation were chosen by the surgeon and were not standardized. The ACCF cohort had a significantly higher proportion of surgeries that spanned > 3 levels ($p < 0.01$). The authors found no statistical difference in dysphagia rates between patients who underwent ACDF versus those who underwent ACCF.

Nirala et al.[24] retrospectively reviewed 201 patients who underwent anterior cervical surgery using autograft iliac crest without fixation. In this series, 132 patients underwent ACCF and 69 patients underwent multilevel ACDF. The authors placed all patients in a hard cervical collar for 3 months. Fusion was assessed on dynamic radiographs. The overall fusion rate for multilevel ACDF was 69.6%, and 93.9% for ACCF ($p = 0.0001$). Subgroup analysis compared the fusion rate of 2-level ACDF (86.7%) with the fusion rate of a 1-level ACCF (96.3%). Further subgroup analysis compared the fusion rate of

TABLE 2: Evidentiary summary of studies examining laminectomy compared to anterior surgery for CSM*

Authors & Yr	Study Description	Data Class	Conclusions
Arnasson et al., 1987	39 patients w/ myelopathy (laminectomy 29, ACDF 5, conservative 5). Assignment to Tx group not randomized. FU 2–4 yrs w/ nonvalidated outcome measure. Results expressed as improved, unchanged, or worse.	III	Improvement in patients w/ myelopathy: laminectomy 20/29 (69 %), ACDF 1/5 (20 %), conservative 0/4 (0 %). Results were not influenced by age or duration of symptoms.
Arnold et al., 1993	70 patients w/ myelopathy (laminectomy [44] anterior fusion [19] laminectomy + fusion [7]). Assignment to Tx group not randomized. Mean FU 8 yrs; nonvalidated outcome measure. Results expressed as improved, unchanged, or worse.	III	early improvement (0–6 mos) laminectomy 34/44 (77%) ventral fusion 17/19 (90%) laminectomy & fusion 5/7 (72%) late improvement (mean 8 yrs) laminectomy 17/33 (52%) central fusion 14/19 (74%) laminectomy & fusion 5/6 (83%) Most cases of later deterioration were in the laminectomy group.
Benzel et al., 1991	75 patients w/ myelopathy: laminectomy in 18, laminectomy + DLS in 40, & anterior fusion in 17. Assignment to treatment group not randomized. FU reported as 1–2 mos using modified JOA.	III	Functional improvement (mean): laminectomy 3.1 ± 1.5 laminectomy + DLS 2.7 ± 2.0 anterior fusion 3.0 ± 2.0 All of the patients who improved substantially (≥6 points) in the laminectomy groups had normal cervical spine contours (lordosis). No instability occurred in either the laminectomy or the laminectomy plus DLS group. No benefit from dentate ligament sectioning was demonstrated.
Carol & Ducker, 1988	206 patients w/ myelopathy: laminectomy in 125, ACDF in 81, both in 10. Assignment to Tx group not randomized. FU 10 yrs. Outcome nonvalidated (reported as percentage improved).	III	improvement posterior 68 % anterior 73 % Combined not reported; no statistics presented.
Ebersold et al., 1995	Long-term FU in 84 of 100 patients w/ myelopathy: 33 ACDF, 51 laminectomy. Mean FU 7.35 yrs (range 3–9.5 yrs). Nurick scale used; anterior approach used for kyphosis & 1–3 levels.	III	immediate outcomes: laminectomy improved: 35/51 (69%) unchanged: 11/51 (22%) worse: 5/51 (9%) ACDF improved: 24/33 (73%) unchanged: 9/33 (27%) long-term outcomes: laminectomy improved: 19/51 (37%) unchanged: 13/51 (26%) worse: 19/51 (37%) ACDF: improved: 18/33 (55%) unchanged: 9/33 (27%) worse: 6/33 (18%) Duration of symptoms preoperatively related to potential deterioration. Age, severity of disease, no. of operated levels, & preop grade were not predictive of outcome.
Gregorius et al., 1976	Retrospective analysis of 55 patients w/ cervical myelopathy: laminectomy in 29 & ACDF in 26. Mean FU 85 mos. Nonvalidated outcome measure (used a 5-step disability scale). Tx choice not randomized.	III	Results not reported specifically for laminectomy patients. Statistical analysis compared those patients changing in disability score by ≥1 grade based on surgical approach. There was a significant deterioration in patients treated w/ laminectomy alone vs an anterior procedure ($p = 0.035$). The described trend of long-term deterioration in patients treated w/ laminectomy alone was concerning.

(continued)

TABLE 2: Evidentiary summary of studies examining laminectomy compared to anterior surgery for CSM* *(continued)*

Authors & Yr	Study Description	Data Class	Conclusions
Phillips, 1973	102 patients: cervical immobilization in 24, laminectomy in 24, & ACDF in 65. FU 2–10 yrs. No validated outcome measure.	III	Improved: cervical immobilization (37%), laminectomy (50%), ACDF (74%). Better results if symptoms for <1 yr in all groups.
Yonenobu et al., 1985	95 patients: laminectomy in 24, ACDF in 50, & corpectomy & fusion in 21. FU 12–157 mos. JOA used to assess outcome.	III	laminectomy 3.3, ACDF 3.3, lorpectomy 6.0 laminectomy resulted in late deterioration (>30 mos) in 29% Corpectomy for ≤3 levels had best results & were significantl($p < 0.01$). The authors recommended laminectomy for ≥4 levels.

* DLS = dentate ligament section.

3-level ACDF (57.6%) to the fusion rate of 2-level ACCF (92.4%). Also compared were the fusion rates of 4-level ACDF (50%) with the fusion rate of 3-level ACCF (91.7%). The outcome score using Odom's criteria was good or excellent in 81.1% of the ACDF group and in 87.1% of the ACCF group. There was no statistical difference in the complication rates between the groups. More graft dislodgements were noted in the ACCF group (3.8%) than in the ACDF group (1.4%), however, but this finding did not reach statistical significance. A major confounding variable in this study was the significant number of patients with Pott's disease in the ACCF compared to the ACDF group.

Swank and associates[30] retrospectively reviewed 64 patients who underwent anterior cervical surgery using tricortical iliac crest allograft with plate fixation. The authors placed patients in a hard cervical collar for 4–6 weeks. In this study, 38 patients underwent multilevel ACDF, and 26 underwent ACCF. The mean follow-up period was 39 months, and fusion was assessed on dynamic radiographs. The overall pseudarthrosis rates were 42% in the ACDF group and 31% in the ACCF group. Subgroup analysis compared the pseudarthrosis rate for 2-level ACDF (36%) with that of 1-level ACCF (10%). Further subgroup analysis compared the pseudarthrosis rate of 3-level ACDF (54%) to that of 2-level ACCF (44%). One confounding factor in the fusion assessment was the different types of anterior cervical plates; patients who received constrained plates had fusion at a higher rate than those with dynamic plates (no probability values provided). No standardized outcomes were used. The authors stated that 85% of patients in the ACCF group reported improvement in symptoms in contrast to 66% of those in the ACDF group. The authors concluded that ACCF may be preferred to ACDF because of better fusion rates.[30]

Wang et al.[33] reported a retrospective series of 52 patients. Twenty patients underwent 1-level ACCF and 32 patients underwent 2-level ACDF. The authors used iliac crest autograft and plate fixation in all cases. The mean follow-up duration was 3.6 years, and fusion was assessed on dynamic radiographs; no significant difference in fusion rates between the groups was observed. There was no difference in graft collapse or kyphosis between the groups, and the outcome assessment using Odom's criteria was not statistically different between the groups.[33]

Bryan Arthroplasty

Sekhon[28] detailed a series of 11 patients with CSM who underwent Bryan arthroplasty. The author conducted follow-up over 18 months with the Oswestry Neck Disability Index and Nurick scores. The Oswestry Neck Disability Index improved 45%, while Nurick scores improved 0.91. There was no control group. This study was scored Class III because it was a small series without control.

Anterior Surgery Versus Laminectomy

Many authors have attempted to compare laminectomy to various procedures for the surgical management of CSM. We included the studies identified that specifically included data regarding laminectomy. The comparative studies summarized below are all Class III studies and are subject to bias (Table 2). Overall, it appears that laminectomy in selected patients compares favorably to alternative strategies. Arnasson et al.[1] described 29 patients who underwent laminectomy for CSM and reported a 69% overall rate of improvement with laminectomy compared to only 20% with ACDF and 0% with conservative measures only. Age or preoperative duration of symptoms did not appear to impact results.

Arnold et al.[2] reported on 44 patients who underwent laminectomy in a nonrandomized series of 70 patients with CSM. Seven additional patients underwent laminectomy with fusion. The authors observed early improvement (within 6 months of surgery) in 77% of the patients who underwent laminectomy, and improvement was maintained at late follow-up (mean 8 years) in 52%. This was slightly less than the rates reported for anterior decompression via ACDF in 19 patients (90% with early and 74% with improvement maintained at late follow-up). Most cases of late deterioration were in the laminectomy group. The authors hypothesized that late deterioration was related to postoperative instability.

Benzel et al.[3] reported on 18 patients who underwent laminectomy, 40 patients who received laminectomy and dentate ligament section, and 17 who underwent ACDF. In this nonrandomized study, there was no difference between any of the groups with modified JOA score im-

TABLE 3: Evidentiary summary of studies examining laminoplasty or laminectomy with arthrodesis as compared to anterior surgery for CSM*

Authors & Yr	Description	Results	Class	Conclusions
Iwasaki et al., 1996	33 patients had soft cervical disc displacement. From 1984 to 1987, 17 patients underwent cervical ACF (Group A). Between 1987 and 1993, 16 patients underwent ODL (Group B).	In ACF group, mean FU 105 mos compared to 39 mos in laminoplasty. No difference was observed in recovery rates on JOA scale (Group A = 93%, JOA 15.8; Group B = 81%, JOA 16.4) Complication rate higher in Group A (18%) compared to Group B (6%).	III	The rates of recovery are not significantly different for laminoplasty vs ACF for soft disc; however, complication rates appear to be higher w/ ACF.
Wada et al., 2001	Subtotal corpectomy compared to ODL in different yrs for CSM. Corpectomy (Group A, n = 23, 2.5 levels, 15-yr FU, average age 53 yrs). Laminoplasty (n = 24, 12-yr FU, average age 56 yrs). JOA used to follow along w/ evaluation of ROM & axial pain.	JOA scores similar in Group A (7.9 to 13.4) & Group B (7.4 to 12.2). Incidence of moderate/severe axial pain greater in laminoplasty (40 vs 15%, $p < 0.05$). ROM only 29% in Group B vs Group A (49%). Higher rates of C-5 palsy & kyphosis w/ laminoplasty.	III	Both approaches clinically effective; however, increased pain & decreased ROM w/ laminoplasty along w/ an increase in C-5 palsy; corpectomy carries risk of pseudoarthrosis.
Yonenobu et al., 1992	100 patients w/ CSM of which 83 had 2-yr FU; 41 patients underwent ACF (1976-83) while 42 underwent laminoplasty ("French window").	JOA improved in both groups (44% in laminoplasty & 55% in ACF, not significant). In subset w/ canal < 12 mm, outcomes were 55% in laminoplasty & 59% in ACF. Complication rate was graft related & 29% in ACF. Laminoplasty had 7% C-5 radiculopathy.	III	Groups compared over different time periods (Class III). Results show similar clinical improvement but higher complication rates in ACF.
Edwards et al., 2002	38 patients CSM studied retrospective w/ matched cohorts Group A (13 corpectomy, <1996) & Group B (25 laminoplasty of which 13 chosen, >1996). ODL in 3 patients & T-saw in 10. FU >40 mos.	Nurick improved 1.9 to 1.0 in Group A & 2.3 to 0.8 in Group B (not significant). Pain improved to 0.5 in Group A & 1.0 in Group B (not significant); ROM reduced from 37 to 16° in Group A & 39° to 24° in Group B (not significant) w/ pseudoarthrosis; Group A had higher complication (9/1).	III	Unclear matching technique & different periods. Both corpectomy & laminoplasty reliable. Laminoplasty appears to have fewer complications.
Sakaura et al., 2005	43 patients w/ cervical disc displacement & myelopathy. Group A (ACF, n = 15/21, age 44 yrs, 1984-7). Group B (Laminoplasty, n = 18/22, age 51, 1987-94). Average FU was 15 yrs in Group A/10 yrs Group B.	Recovery rate of JOA was 71% in Group A & 70% in Group B. ROM maintained 65% in Group A & 64% in Group B. Similar late deterioration.	III	Anterior approach associated w/ higher reoperation rate due to pseudarthrosis but outcomes similar.
Kawakami et al., 2000	136 patients w/ myelopathy over 10-yr period (69 w/ disc & 67 w/ CSM). ACF in 60 (85% disc) & laminoplasty in 76 (30%) disc. AF 1–2 levels & laminoplasty 3 levels or more.	Mean recovery in JOA was 71% in disc patients; same result w/ ACF or laminoplasty. In CSM, 49% recovery w/ ACF & 58% w/ laminoplasty (not significant). Recovery rate lower in both approaches w/ kyphotic cord.	III	Comparison between multiple subgroups makes analysis difficult. However, approach does not appear to make a difference w/ respect to disc or myelopathy. Kyphotic cord negative risk factor.
Hasegawa et al., 2002	90 patients w/ CSM. Age > 70 yrs (n = 40, 27 mos FU) & < 60 (n = 50, 36-mo FU). Anterior fusion (n = 35), laminoplasty (n = 29), & laminectomy (n = 26). Comparison between technique & age group (6 groups).	No significant differences in final JOA score between groups. No significant difference in preop JOA scores between groups. Complication rate greater in older patients (15%) vs 8% in younger patients.	III	Multiple subgroups in series. However, age does not appear to be negative risk factor except for complication. Also, technique does not appear to change control of myelopathy.
Tomita et al., 1988	23 patients w/ OPLL & JOA < 12. Average age was 60 yrs & average FU 2.5 yrs. Group compared to historical controls of ACF (n = 17) & laminectomy (n = 14).	JOA improved from 8.5 to 15.25 (81%). This compared to laminectomy (72%) & ACF (63%). Radiographic analysis showed an expansion ration of 124%.	III	Laminoplasty effective when compared to anterior fusion & simple decompression but historical controls unreliable.
Yoshida et al., 1998	47 patients w/ congenital stenosis + disc displacement; 32 patients had laminoplasty (other 15 followed). Compared to ACF (n = 44) in same 8-yr period. ACF group had significantly larger AP spinal canal distance & higher preop JOA score.	JOA improvement was 68% in both groups. In patients w/ laminoplasty, disc regression seen in 75% compared to 80% of nonoperative patients (n = 15). Incidence of complications was related to fusion & higher in ACF group.	III	Class III due to mixed groups (difference in JOA & degree of stenosis). Both anterior & posterior techniques effective. Discs tend to regress.

(continued)

TABLE 3: Evidentiary summary of studies examining laminoplasty or laminectomy with arthrodesis as compared to anterior surgery for CSM* *(continued)*

Author/Yr	Description	Results	Class	Conclusions
Gonzalez-Feria & Peraita-Peraita, 1975	20 patients CSM laminectomy & either wire facet fusion or spinouts process plate 1–7 yr FU. Outcomes modified Nurick. No radiographic analysis.	Neurological improvement in 17/20 (85%). 4 patients improved 1 grade, 5 improved 2 grades, & 8 ≥ 3 grades. 2 plate failures.	III	Good neurological outcomes. No radiographic analysis.

* ODL = open-door laminoplasty.

provements of 3.1, 2.7, and 3.0 respectively. There was no impact of dentate ligament sectioning and no increase in instability noted with posterior decompression in this study. Patients who underwent laminectomy who had substantial improvement (≥ 6 points) all had normal preoperative radiographic alignment.

Carol et al.[4] reported on a total of 206 patients with CSM who received surgical treatment. In this cohort were 125 laminectomies and 81 anterior decompressions with fusion. Most patients had either one surgery or the other; however, 10 patients received circumferential surgery. The authors reported long-term follow-up (mean of 10 years) in the nonrandomized groups. The authors did not use standard outcome measures and did not provide any statistical analysis. The improvement rate of 68% for the laminectomy group was comparable to the 73% improvement rate in the anterior surgical group.[4] Ebersold et al.[5] reported outcomes in 84 patients treated surgically for CSM: 51 patients underwent laminectomy and 33 anterior decompression and fusion at 1 or 2 levels (presumably ACDF). Six-month outcomes showed improvements of 69% with laminectomy and 73% with anterior surgery. The long-term results were 37% with laminectomy and 55% with anterior surgery. The authors provided no statistical comparison to determine whether the changes were significant. The study reported that only preoperative duration of symptoms was associated with a worsened outcome. Age, severity of disease, extent of decompression, and preoperative grade were not predictive of outcome in this study.[5]

Gregorius et al.[10] retrospectively reviewed 55 patients with CSM, including 29 treated with laminectomy and 26 with ACDF. The study did not use a validated outcome measures, and treatment assignments were not randomized. There was a concerning trend of long-term late deterioration in the laminectomy alone group.

Phillips[26] reported a study of 102 patients of whom 24 were treated with a cervical collar, 24 with laminectomy, and 65 with anterior decompression (ACDF with Cloward fusion). Overall improvement rates were reported as 37, 50, and 74%, respectively. In all groups, better results were seen when symptoms were present for less than a year before surgery.

Yonenobu et al.[34] reported the outcomes in 3 treatment groups: 24 patients underwent laminectomy, 50 patients underwent anterior segmental discectomy, and 21 underwent anterior corpectomy. The laminectomy group had a similar overall improvement to the anterior segmental decompression (both had 3.3 points improvement on JOA scale). The authors reported best results when 3 segments were treated with corpectomy and recommended laminectomies for ≥ 4-segment disease. Patients who underwent laminectomy had a 29% rate of late deterioration.

Anterior Surgery Versus Laminoplasty

Three studies compared laminoplasty to ACDF in patients with 1-level disc displacement and myelopathy (Table 3).[19,27,36] In the Class III studies by Iwasaki et al.[19] and Sakaura et al.,[27] surgeons used ACDF at first and laminoplasty in a more recent period of their study. In the study of Iwasaki et al.,[19] which included 17 patients with ACDF

TABLE 4: Evidentiary summary of studies comparing the efficacy of laminectomy versus laminoplasty or laminectomy and arthrodesis for cervical degenerative myelopathy*

Authors & Yr	Description	Results	Class	Conclusions
Kaminsky et al., 2004	20 consecutive patients (age 53 yrs) w/ CSM who underwent ODL (A) compared to 22 matched controls who underwent laminectomies (B, age 54 yrs). Min FU 3 yrs w/ average 5 yrs.	Average number of levels decompressed was 4.3 in A & 4.6 in B. Nurick grade preop was 2.44 in A & 3.09 in B ($p < 0.0001$). Recovery was 2.44 to 1.48 (48.6%) in A & 3.09 to 2.50 (17.8%) in B ($p < 0.0001$). Pain level reduced in A (57% compared to 8%, $p < 0.004$); however, preop pain level significantly higher in A.	III	Class III due to historic controls & lack of similar Nurick status preop & lack of similar pain severity. Conclusion was that laminoplasty provides better results clinically at 3–5 yrs w/ less ROM, and does reduce pain.
Shiraishi et al., 2003	43 patients w/ CSM in 32 and OPLL 11 who underwent skip laminectomy (after 1998); age 69 yrs w/ 2-yr FU; Comparison to ODL in 51 patients (CSM 36 & OPLL in 15); age 67 yrs w/ 2-yr FU.	JOA recovery was 59 vs 60% w/ laminoplasty; ROM 98% preserved w/ skip vs 44% in laminoplasty; Ishiara curvature index 11.4 to 13.4 w/ skip vs 16.0 to 11.8 in laminoplasty ($p < 0.05$); atrophy was 13% in skip vs 60% in laminoplasty on T2-weighted MRIs.	III	Historical controls (Class III): however skip laminectomy reduces atrophy & reduces risk of kyphosis.
Ishida et al., 1989	Retrospective comparison: Laminectomy vs laminoplasty, 55 patients/group. Evaluation of postop radiographs & JOA scale assessment used. Mean FU 61 mos.	Laminectomy: 13 (24%) of 55 developed kyphotic deformity. Overall JOA scale score improvement 71% recovery rate (preop 7.1 to postop 13.6). With full decompression 90% recovery rate (preop 9.2 to postop 16.2). Preop motion 30%; postop motion 21%.	III	With full decompression, laminectomy & laminoplasty provided 90% recovery.
Matsunaga et al., 1999	Laminoplasty in 64, laminectomy in 37. Plain radiographs evaluated; mean FU 79 mos w/ laminectomy & 66 mos w/ laminoplasty.	Overall postop kyphosis ("Buckling-type" alignment): 34% after laminectomy 7% after laminoplasty Chi-square calculation for laminectomy vs laminoplasty is 43.2 ($p < 0.01$), indicating a significantly higher rate of postop kyphosis in the laminectomy group.	III	Laminectomy was associated with higher kyphosis rate.
Heller et al., 2001	Comparison of laminoplasty (n = 13) vs laminectomy & arthrodesis (n = 13) in CSM; originally 25 in each group but number lost. Lateral mass screws utilized. Average age 55 yrs w/ 25-mo FU.	Nurick improvement ($p > 0.05$) laminoplasty 2.3 to 1.1 fusion 2.2 to 1.5 Laminoplasty had a better Ishihara index (0.09 to 0.9). Both preserved index w/ surgery. reduction of ROM ($p < 0.002$) arthrodesis: 36 to 11 laminoplasty: 40 to 26 Complication higher w/ fusion.	III	Laminectomy & arthrodesis have similar clinical outcome but a greater loss of ROM & increased complication rate; unclear why the loss of numbers.
Perez-Lopez et al., 2001	Retrospective; laminectomy in 19 & laminectomy & fusion in 17. Nurick scale for assessment; mean FU 40 mos.	laminectomy: 0.84 Nurick score improvement 24% postop kyphosis laminectomy & fusion: 1.24 Nurick score improvement 7% postop kyphosis The observed improvement in myelopathy scores following laminectomy w/ or w/o fusion was similar. Postop kyphosis more common w/ laminectomy alone.	III	Similar functional improvement with 2 treatment arms but greater kyphosis with laminectomy alone.
Hamanishi & Tanaka, 1996	69 patients, 34 judged unstable combined w/ fusion. JOA scale used. Mean FU 3.5 yrs.	Results: no fusion, 50.8% improvement; fusion, 51.2% improvement (p = NS). The authors conclude that wide laminectomy w/ or w/o posterolateral fusion is a simple operation that can be recommended.	III	

* Abbreviation: OPLL = ossification of the posterior longitudinal ligament.

and 16 with laminoplasty, the JOA scale score recovery rates were 93 and 81%, respectively. The Sakaura et al.[27] study, which included 15 patients with ACDF and 18 with laminoplasty, showed JOA scale score recovery rates of 71 and 70%, respectively. In their Class III study, Yoshida et al.[36] compared outcomes in 32 patients who underwent laminoplasty to those in 44 who underwent ACDF. However, unlike the laminoplasty group, the ACDF group did not have superimposed congenital stenosis. The JOA scale scores were similar between groups. The reported complication rate was higher with ACDF because of graft complications.[19,36]

Six studies compared laminoplasty to ACCF for treatment of CSM.[6,12,21,31,32,35] In a Class III study, Wada et al.[32] compared subtotal corpectomy in 23 patients (2.5 levels, average age 53 years, and average 15-year follow-up) to open-door laminoplasty in 24 patients (average age 56 years, average 12-year follow-up). The JOA scale scores improved in both groups: from 7.9 to 13.4 after anterior and from 7.4 to 12.2 after posterior surgery. The incidence of moderate/severe pain was higher with laminoplasty (40 vs 15%; $p < 0.05$), and ROM was better preserved (49 vs 29%) with ACCF. In another Class III study, Yonenobu et al.[35] reported on 83 patients with CSM of whom 42 underwent French window laminoplasty while the remainder underwent ACCF. All patients completed 2 years of follow-up, and JOA scale scores improved in both groups (by 44% with laminoplasty and 55% with ACCF). Outcomes were also similar in patients with canal stenosis (< 12 mm). The rate of complications was higher with ACCF because of graft complications (29 vs 7%). Of the 6 studies above, however, not all showed a higher complication rate for the anterior approach, nor did all show better preservation of ROM with an anterior approach.

Anterior Surgery Versus Laminectomy/Arthrodesis

Gonzalez-Feria and Peraita-Peraita[9] performed a multicenter retrospective review of 525 patients with CSM treated in the Iberian Peninsula. The authors used the anterior approach in 195 patients (usually a 1- or 2-level ACDF), laminectomy in 242, a combined anterior and posterior approach in 42, and laminectomy and fusion with spinous process plate fixation in 41 patients. The plates were "crab plates" that were fixated to the first spinous process above and below the laminectomy defect. In all treatment groups, 60% of patients showed neurological improved and 6.5% deteriorated. There was an overall mortality rate of 3%. The average Nurick grade improvement was 0.9.

Comparison of results by surgical method revealed that laminectomy and posterior fusion had significantly greater rates of neurological recovery than all other types.[9] This group improved an average of 2.0 Nurick grades, whereas the mean improvement for the anterior approach was 1.2 and 0.9 for laminectomy. The average follow-up duration was not specified. This report provided Class III evidence for the efficacy of laminectomy and fusion over other techniques. However, there were many methodological problems including surgical indication bias, lack of follow-up statistics, lack of surgeon reporting of neurological outcomes, and lack of radiographic analyses.

Laminoplasty Versus Laminectomy

Laminoplasty was compared to laminectomy in 4 studies. In a Class III study, Kaminsky et al.[20] compared open-door laminoplasty in 20 patients (average age 53 years) to laminectomy in 22 patients (average age 54 years) with CSM with a 3-year follow-up period. The average number of levels decompressed was 4.3 for laminoplasty and 4.6 for laminectomy. The Nurick scores improved from 2.44 to 1.48 with laminoplasty versus 3.09 to 2.50 for laminectomy. The recovery rates, 49 versus 18%, respectively, were significantly different ($p < 0.0001$). However, the preoperative Nurick scores were also significantly worse for the laminectomy group ($p < 0.0001$).[20] In another Class III study, Shiraishi et al.[29] compared outcomes after skip laminectomy for the treatment of cervical myelopathy in 43 patients to outcomes achieved wtih open-door laminoplasty in 51 patients. The JOA scale score recovery was 59% with laminectomy compared to 60% with laminoplasty; however, the skip technique preserved ROM and increased the Ishiara index from 11.4 to 13.4 compared to laminoplasty in which it decreased from 16.0 to 11.8 ($p < 0.05$).

Ishida et al.[18] compared the results in 55 patients undergoing laminectomy to those in 55 patients undergoing laminoplasty. The authors assessed the extent of decompression. Those judged to have had "full" decompression had ~ 90% recovery rate in both groups.

Matsunaga et al.[23] compared postoperative kyphosis rates in 37 patients who underwent laminectomy to those in 64 patients who underwent laminoplasty with mean follow-up periods of 79 and 66 months, respectively. The authors reported postoperative kyphosis in 11 (34%) of 37 patients in the laminectomy group and 4 (7%) of 64 in the laminoplasty group. This report did not address functional outcome.

Laminoplasty Versus Laminectomy/Arthrodesis

Heller et al.[13] compared laminoplasty (midline and open door, in 13 patients) to laminectomy with arthrodesis (in 13 patients) in patients with CSM or ossification of the posterior longitudinal ligament. The patients averaged 55 years of age and underwent an average of 2 years of follow-up. Greater improvement in Nurick scores was observed with laminoplasty (from 2.3 to 1.1) compared to laminectomy and arthrodesis (from 2.2 to 1.5) but the trend was not significant. Not surprisingly, laminoplasty was associated with greater preservation of ROM ($p < 0.002$) (Table 4).[13]

In the study, the mean follow-up was 26 months (range 9–46 months). Patients who underwent fusion had greater kyphosis but less maximum stenosis. The authors reported no differences in postoperative axial pain scores.[13] Radiographically, the authors observed no difference in alignment between the groups, although severe kyphosis developed in 1 patient who underwent fusion. There was a significant difference in complication rates between the 2 groups, with no complications reported in the laminoplasty group. In the fusion group, 2 patients experienced neurological deterioration, a deep infection developed in 1, 5 patients had pseudarthrosis, 2 patients had

hardware failure, and adjacent degeneration developed requiring anterior cervical decompression and fusion in 1 patient. This study provided Class III evidence because of selection bias that may have occurred in developing the matched cohorts, and because of the small sample size which probably resulted in insufficient power to measure the primary outcome variables. Additionally, there was surgical selection bias because kyphotic patients were more likely to receive fusion. The data on complications were worrisome and favored laminoplasty over laminectomy and posterior fusion with plate fixation. However, authors of other similar studies did not report these complications using similar fusion techniques.[16,17]

Laminectomy Versus Laminectomy/Arthrodesis

Hamanishi and Tanaka[11] reported on 69 patients with CSM. Thirty-four were judged as "unstable" on preoperative radiographs, and these patients underwent laminectomy and fusion using onlay bone graft placement onto the lateral masses. The authors compared these patients to the remaining 35 who underwent laminectomy alone. The authors did not observe any significant difference, and noted a 51% JOA scale score improvement in both groups (51.2% vs 50.8%; p = NS) after a mean follow-up period of 3.35 years. The time from onset of symptoms or injury strongly correlated to neurological recovery in both groups. Radiographically, instability developed in 2 nonfusion patients and progressive kyphosis developed in 5. In the fusion group, instability developed in 2 patients. Kyphotic malalignment occurred in 6 (17%) of 35 patients who did not undergo fusion compared to in 4 (12%) of 34 patients with fusion. This study provided Class III evidence that fusion does not significantly improve neurological outcome. However, the 2 treatment groups were dissimilar in that the fusion group had instability or kyphosis and had worse JOA scale scores prior to treatment. Therefore, any comparison of outcomes was probably biased against the fusion group.

Perez-Lopez et al.[25] compared a cohort of 19 patients who underwent laminectomy to 17 who underwent laminectomy and fusion, finding similar improvement in Nurick scores (0.84 vs 1.24). However, there was an increase in postoperative kyphosis with in the laminectomy alone cohort (24%) compared to the laminectomy and fusion group (7%).

Summary

Current evidence (Class III) suggests that multilevel ACDF and ACCF offer equivalent treatment strategies and outcomes in the anterior surgical treatment of CSM. If fixation is not used anteriorly, ACCF may offer better fusion rates. In comparison with laminectomy, 4 of 8 Class III studies indicated better improvement with ACF, while 3 Class III studies showed equivalency. One Class III study showed better improvement with laminectomy. Only 1 study compared laminectomy with arthrodesis to ACF in a multigroup comparison. In this study, laminectomy with arthrodesis appeared to have better results.

There is no Class I or II evidence to suggest that laminoplasty is superior to other techniques for decompression. However, Class III evidence has shown equivalency in functional improvement between laminoplasty and ACF. Class III evidence is unclear regarding differences in complication rates between these techniques.

In comparing posterior techniques, there is no Class I or II evidence to suggest that laminoplasty is superior to laminectomy/arthrodesis or laminectomy alone. Class III evidence has shown equivalency between laminoplasty and laminectomy, with the results of 1 study suggesting laminoplasty to be superior. However, laminectomy may better preserve ROM. Class III evidence has shown equivalency between laminoplasty and laminectomy/arthrodesis; however, laminoplasty appears to better preserve ROM. Finally, 1 Class III study compared laminectomy to laminectomy/arthrodesis. Both treatment strategies had similar outcomes, but laminectomy was associated with a higher rate of kyphosis.

Although there is no Class I or II evidence to suggest that ACF, laminoplasty, or laminectomy and arthrodesis are superior to laminectomy for CSM, there is Level III evidence indicating that laminectomy may be associated with late deterioration. Although this may not speak completely against laminectomy as a means of treatment, especially if there are technical issues in utilizing other techniques, it does argue for consideration of other techniques in younger patients in whom late deterioration my be more likely to develop.

Key Issues

There are several well-accepted surgical techniques for treating CSM. Because of the high relative effectiveness and similarity of costs and complications after instrumented ACDF and ACCF, it may not be necessary to devote substantial resources to clinical trials designed to determine small incremental benefits of 1 technique or the other. The same holds true for posterior techniques. As new technologies are introduced, they should be compared in clinical trials. Of importance would be the development of kyphotic deformity after surgery and whether its presence or progression correlates negatively with outcome.

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