SURGICAL TREATMENT OF CERVICAL SPONDYLOTIC MYELOPATHY

Predictive Factors Affecting Outcome After Cervical Laminoplasty

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Study Design. Systematic review.

Objective. To determine whether various preoperative factors affect patient outcome after cervical laminoplasty for cervical spondylotic myelopathy (CSM) and/or ossification of posterior longitudinal ligament (OPLL).

Summary of Background Data. Cervical laminoplasty is a procedure designed to decompress the spinal cord by enlarging the spinal canal while preserving the lamina. Prior research has identified a variety of potential predictive factors that might affect outcomes after this procedure.

Methods. A systematic search of multiple major medical reference databases was conducted to identify studies explicitly designed to evaluate the effect of preoperative factors on patient outcome after cervical laminoplasty for CSM or OPLL. Studies specifically designed to evaluate potential predictive factors and their associations with outcome were included. Only cohort studies that used multivariate analysis, enrolled at least 20 patients, and adjusted for age as a potential confounding variable were included. JOA (Japanese Orthopaedic Association), modified JOA, and JOACMEQ-L (JOA Cervical Myelopathy Evaluation Questionnaire

lower extremity function section) scores were the main outcome measures. Clinical recommendations and consensus statements were made through a modified Delphi approach by applying the GRADE (Grading of Recommendation Assessment, Development and Evaluation)/AHRQ (Agency for Healthcare Research and Quality) criteria.

Results. The search strategy yielded 433 citations, of which 1 prospective and 11 retrospective cohort studies met our inclusion criteria. Overall, the strength of evidence from the 12 studies is low or insufficient for most of the predictive factors. Increased age was not associated with poorer JOA outcomes for patients with CSM, but there is insufficient evidence to make a conclusion for patients with OPLL. Increased severity of disease and a longer duration of symptoms might be associated with JOA outcomes for patients with CSM. Hill-shaped lesions might be associated with poorer JOA outcomes for patients with OPLL. There is insufficient evidence to permit conclusions regarding other predictive factors.

Conclusion. Overall, the strength of evidence for all of the predictive factors was insufficient or low. Given that cervical myelopathy due to CSM tends to be progressive and that increased severity of myelopathy and duration of symptoms might be associated with poorer outcomes after cervical laminoplasty for CSM, it is preferable to perform laminoplasty in patients with CSM earlier rather than waiting for symptoms to get worse. Further research is needed to more clearly identify predictive factors that affect outcomes after cervical laminoplasty because there were relatively few studies identified that used multivariate analyses to control for confounding factors and many of these studies did not provide a detailed description of the multivariate analyses or the magnitude of effect estimates.

Evidence-Based Clinical Recommendations.

Recommendation 1. For patients with CSM, increased age is not a strong predictor of clinical neurological outcomes after laminoplasty; therefore, age by itself should not preclude cervical laminoplasty for CSM.

Overall Strength of Evidence. Low

Strength of Recommendation. Strong

Recommendation 2. For patients with CSM, increased severity of disease and a longer duration of symptoms might be associated with poorer clinical neurological outcomes after laminoplasty; therefore, we recommend that patients be informed about this.

Overall Strength of Evidence. Low

Strength of Recommendation. Strong

Summary Statements. For patients with OPLL, hill-shaped lesions might be associated with poorer clinical neurological outcomes after laminoplasty; therefore, surgeons might consider potential benefits and risks of alternative or additional surgery.

Key words: cervical laminoplasty, JOA, mJOA, cervical spondylotic myelopathy, ossification of posterior longitudinal ligament, CSM, OPLL.

Cervical laminoplasty is a procedure designed to decompress the spinal cord by enlarging the spinal canal while preserving the lamina. Since the invention of this procedure in Japan, its use has spread throughout the world and has gained increasing usage among spine surgeons. Commensurate with the increase in experience with this technique, the literature on laminoplasty has become extensive. This literature includes refinements of indications for laminoplasty, analysis of complications of laminoplasty, and outcomes of laminoplasty in both the short and long terms for the treatment of cervical spondylotic myelopathy (CSM) and ossification of the posterior longitudinal ligament (OPLL). Previous research has identified a variety of potential prognostic indicators that may affect outcomes after cervical laminoplasty, including age of patient, presence of diabetes, severity of preoperative myelopathy, severity of preoperative axial pain, length of preoperative symptoms, presence and/or degree of OPLL, shape of OPLL lesion, degree of stenosis, number of levels with compression, type of preoperative stenosis, alignment of the cervical spine, the presence of T2 and/or T1 signal change on magnetic resonance imaging (MRI), and preoperative sagittal alignment. This report systematically evaluates whether these preoperative factors affect patient outcome after cervical laminoplasty for CSM and/or OPLL. Outcomes of interest include JOA/mJOA ([modified] Japanese Orthopaedic Association) scores, Nurick scores, NDI (Neck Disability Index) scores, pain, and/or reoperation.

MATERIALS AND METHODS

Electronic Literature Search

A systematic search of PubMed/MEDLINE, the Cochrane Collaboration Library, and Google Scholar for literature published through October 22, 2012, was conducted. Only studies in humans, written in English, and containing abstracts were considered for inclusion. The focus was on identification of studies explicitly designed to evaluate the effect of preoperative factors on patient outcome after cervical laminoplasty for cervical myelopathy (CSM and OPLL). Details of the inclusion and exclusion criteria are given in Table 1. Terms specific to CSM are as follows: cervical spondylotic myelopathy OR cervical myelopathy OR (cervical AND myelopathy) OR Ossification of Posterior Longitudinal Ligament[MeSH] OR Ossification of Posterior Longitudinal Ligament. They were combined with terms specifying the cervical spine (Cervical OR Cervical Vertebrae[MeSH]) and those related

to treatment or surgery (Laminoplasty OR laminoplast* OR laminaplast*). Studies specifically designed to evaluate potential predictive factors and their associations with outcomes were sought. The search was limited to cohort studies that used multivariate analysis and that enrolled at least 20 patients. Furthermore, to evaluate the highest quality studies, we included only those studies that adjusted for preoperative JOA score and age as potential confounding variables.

Case reports, meeting abstracts/proceedings, white papers, and editorials were excluded. Table 1 provides additional information on inclusion/exclusion criteria. We also hand-searched key references to identify any additional studies that were not found by our systematic literature search.

Data Extraction

The following demographic information was abstracted from each study: population, condition, details of the intervention, and follow-up information. Outcomes abstracted focused on those outcomes listed in our inclusion table (Table 1), namely, myelopathy scores (*i.e.*, JOA/mJOA or Nurick scores), patient-reported pain outcomes (including NDI scores), and reoperation rates. Details of the multivariate analysis, including dependent and independent variables, odds ratios (ORs), 95% confidence intervals (CIs), and *P* values, were abstracted. All predictive factors in each study's multivariate analysis are included in the results tables. The interpretation of results includes adjustment (holding factors constant) for all of the predictive factors evaluated for each particular study.

Study Quality and Overall Strength of Body of Literature

Class of evidence (CoE) ratings were assigned to each included article independently by 2 reviewers (A.R., R.H.), using criteria set by *The Journal of Bone and Joint Surgery*[1] for prognostic studies and modified to delineate criteria associated with methodological quality and risk of bias based on recommendations made by the Agency for Healthcare Research and Quality.[2,3] The appraisal system used in this article accounts for features of methodological quality and important sources of bias by combining epidemiological principles with characteristics of study design to determine the CoE and are consistent with those used in previous focus issues.[4] See the Supplemental Digital Content material (available at http://links.lww.com/BRS/A825) for details on individual study ratings.

After individual article evaluation, the strength of the overall body of evidence with respect to each outcome was determined on the basis of precepts outlined by the Grades of Recommendation Assessment, Development and Evaluation (GRADE) Working Group[5,6] and recommendations made by the Agency for Healthcare Research and Quality (AHRQ).[2,3] Qualitative analysis is performed considering AHRQ-required and additional domains.[7] The initial strength of the overall body of evidence was considered "high" if the majority of the studies were class I or II and "low" if the majority of the studies were class III or IV. Criteria for downgrading published evidence 1 or 2 levels included the following: (1) inconsistency of results, (2) indirectness of evidence, (3)

TABLE 1. Summary of Inclusion and Exclusion Criteria

	Inclusion	Exclusion
Patient	Adult patients who have undergone laminoplasty for cervical myelopathy, including • CSM • OPLL	• Patients <18 yr of age • Tumor • Trauma • Infection • Deformity
Predictive factors	Predictive factors of interest included but were not limited to • Age of patient • Presence of diabetes • Severity of preoperative myelopathy (defined as preoperative JOA or mJOA score) • Severity of preoperative axial pain • Length of preoperative symptoms • Presence and/or degree OPLL* • Shape of OPLL lesion • Degree of preoperative stenosis (defined as the spinal canal diameter) • Number of levels with compression • Type of preoperative stenosis • Preoperative alignment of the cervical spine (defined as lordosis, normal alignment, or kyphosis) • Presence of T2 and/or T1 signal change on MRI • Preoperative sagittal alignment	
Outcome	• JOA/mJOA score, or • Nurick score, or • NDI score, or • Pain, or • Reoperation	• Radiographical outcomes • Infection • Neurological complications • Nonunions • Kyphosis
Study design	• Cohort studies specifically designed to evaluate predictive factors using multivariate analysis to explore associations between risk factors and outcome(s)	• Studies in which multivariate analysis is not used • Studies in which the effect of age is not adjusted for by multivariate analysis • Studies with <80% of the population with a diagnosis of CSM or OPLL • Studies with >20 patients • Case reports • Animal or biomechanical studies

We accepted the diagnosis of OPLL versus CSM as reported in each study.

imprecision of the effect estimates (*e.g.*, wide CIs), or (4) non–*a priori* statement of subgroup analyses. Alternatively, the body of evidence could be upgraded 1 or 2 levels on the basis of the following factors: (1) large magnitude of effect or (2) dose-response gradient. The final overall strength of the body of literature expresses our confidence in the estimate of effect and the impact that further research may have on the results. An overall strength of "high" means we have high confidence that the evidence reflects the true effect. Further research is very unlikely to change our confidence in the estimate of effect. The overall strength of "moderate" means we have moderate confidence that the evidence reflects the true effect. Further research may change our confidence in

both the estimate of effect and the estimate. A grade of "low" means we have low confidence that the evidence reflects the true effect. Further research is likely to change the confidence in the estimate of effect and likely to change the estimate. Finally, a grade of "insufficient" means that evidence either is unavailable or does not permit a conclusion. The Supplemental Digital Content (available at http://links.lww.com/BRS/A825) contains the details of how we arrived at the strength of evidence for each key question.

Data Analysis
When the data were available, we reported ORs, 95% CIs, and *P* values. ORs greater than 1.0 suggest increased risk of

a poor recovery (poor improvement of JOA or mJOA score) for a given predictor; values less than 1 suggest decreased risk. For the studies that reported ORs for predictors of a good recovery, the OR was recalculated for a poor recovery by taking the inverse of the OR and revising the description of the results to reflect prediction of a poor recovery for consistency. For studies that did not report effect measures, we reported *P* values if available or the significance of the predictive factor as described by the study authors. Some studies reporting a JOA outcome score performed a linear regression analysis.[8–12]

Outcome Measures Reported

The most common outcome measures used included the following:

- JOA score: evaluation of the neurological function of patients with cervical myelopathy; range of score 0 to 17, with a lower score indicating a poor outcome.
- JOACMEQ-L (Japanese Orthopedic Association Cervical Myelopathy Evaluation Questionnaire, lower extremity function section of JOACMEQ): used to evaluate cervical compression myelopathy; range of score 0 to 100, with lower score indicating a poor outcome.
- JOA recovery rate = 100 × (postoperative JOA score − preoperative JOA score)/(17 − preoperative JOA score).
- Motor function score of lower extremity portion of JOA: range of score 0 to 4, with a lower score indicating a poor outcome.

Clinical Recommendations and Consensus Statements

Clinical recommendations or consensus statements were made through a modified Delphi approach by applying the GRADE/AHRQ criteria that imparts a deliberate separation between the strength of the evidence (*i.e.*, high, moderate, low, or insufficient) from the strength of the recommendation. When appropriate, recommendations or statements "for" or "against" were given "strong" or "weak" designations based on the quality of the evidence, the balance of benefits/harms, and values and patient preferences. In some instances, costs may have been considered. A more thorough description of this process can be found in the focus issue Methods article.

RESULTS

Study Selection

The search strategy yielded 433 potentially relevant citations; of these, 373 were excluded on the basis of title and/or abstract and 60 were selected for full-text review (Figure 1). An additional 48 were excluded on the basis of full-text review for the following reasons: the study did not control for potential confounding factors using multivariate analysis (38 studies), study participants did not receive laminoplasty treatment (7 studies), results were not reported clearly or sufficiently enough to ascertain whether a multivariate analysis was performed (2 studies),[13,14] or outcomes of interest were not reported (1 study). Details of the excluded articles can be
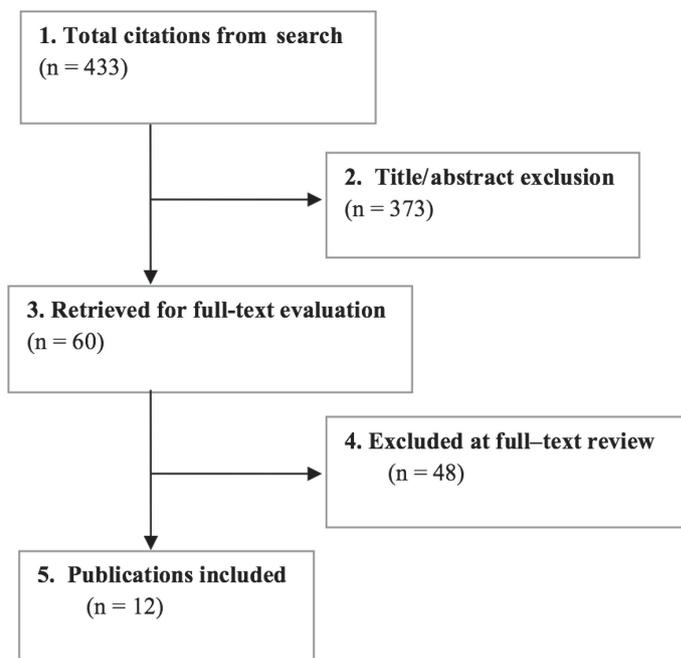

Figure 1. Flowchart showing result of literature search.

found in the Supplemental Digital Content material (available at http://links.lww.com/BRS/A825).

Twelve studies were selected for inclusion and are summarized in this report (see Table 2 and Supplemental Digital Content Table 1, available at http://links.lww.com/BRS/A825, for detailed information). Five studies included a population of at least 80% patients with CSM,[11,15–18] 4 studies included only patients with OPLL,[8,9,19,20] 2 studies included both patients with CSM and patients with OPLL,[10,12,21] and 1 study included patients with CSM and patients with OPLL but evaluated them separately.[12] Mean patient ages ranged from 43.8 to 77 years, and males comprised 30% to 79% of the study populations. Mean follow-up times ranged from 1 to 12.2 years. All studies used laminoplasty, and although the specific approaches varied (see Supplemental Digital Content Table 1, available at http://links.lww.com/BRS/A825, for details), the studies can be aggregated into 2 French-door studies and 9 open-door studies. All included studies evaluated whether the predictive factors of interest influence outcome as measured by the JOA or mJOA score and controlled for any potentially confounding effects that age and preoperative severity of myelopathy may have on outcomes. None of the studies identified for inclusion evaluated the effect that these potential factors had on other outcomes of interest, including Nurick scores, NDI scores, pain, or reoperation. After methodological review, 1 prospective cohort study[15] and 4 retrospective cohort studies[9–11,16] were graded CoE II, indicating a moderately low risk of bias, and 7 retrospective studies[8,12,17–21] received a CoE III grade, indicating that they were at moderately high risk of bias. Further details, including additional predictive factors that were reported but not discussed later, are available in Supplemental Digital Content Tables 2–4 (available at http://links.lww.com/BRS/A825).

TABLE 2. Characteristics of Studies Evaluating Potential Predictive Factors Affecting Outcomes After Laminoplasty for Cervical Myelopathy

Author (Year)	Population	Follow-up Duration (% Followed)	Outcomes Evaluated	Predictive Factors Evaluated
Studies with at least 80% of patient population with CSM				
Nakashima et al[15] (2012) Prospective cohort CoE: II	• N = 101 • CSM: 86% • OPLL: 14%	>1 yr (range NR) (79% f/u)	• JOA RR • JOAC-MEQ-L	• Age
				• Male sex
				• Duration of symptoms
				• Step test ≥14.5
				• Preoperative JOACMEQ-L score
				• Signal change on MRI
				• C2–C7 angle
				• C7 plumb line
Naruse et al[16] (2009) Retrospective cohort CoE: II	• N = 101 • CSM caused by • Spondylosis: 70% • OPLL: 18% • Disc herniation: 12%	Mean 1.1 ± 0.3 yr (range: NR) (97% f/u)	• JOA RR	• Age
				• Preoperative JOA score
				• Spinal cord floating from anterior elements on ultrasonogram
Suda et al[17] (2003)† Retrospective cohort CoE: III	• N = 154† • CSM	5 yr (range: 2–13 yr) (74% f/u)	• JOA RR	• Age
				• Sex
				• Preoperative JOA score
				• Signal change on MRI
				• Local kyphosis angle
				• Number of enlarged laminae
				• Overall cervical alignment (C2–C7 angle)
Tanaka et al[11] (1999) Retrospective cohort CoE: II	• N = 47 • CSM	0.9 yr (range: 0.4–3 yr) (100% f/u)	• JOA score • JOA lower extremity score	• Age
				• Preoperative JOA score
				• Preoperative motor function score of lower extremities
				• Duration of lower extremity disability
				• Duration of symptoms
Wada et al[18] (1999) Retrospective cohort CoE: III	• N = 50 • CSM	2.9 yr (range: 2–4 yr) (67% f/u)	• JOA RR	• Age at surgery
				• Duration of symptoms
				• Severity of myelopathy
				• Anteroposterior canal diameter at maximum compression
				• Transverse area of spinal cord at maximum compression
				• Signal changes on T2-weighted MRI
				• Number of blocks on myelogram

(Continued)

TABLE 2. (*Continued*)				
Author (Year)	**Population**	**Follow-up Duration (% Followed)**	**Outcomes Evaluated**	**Predictive Factors Evaluated**
Studies with only patients with OPLL				
Fujimura et al[19] Retrospective cohort CoE: III	• N = 55 • OPLL	6.7 ± 2.7 yr (range: 5.3–12.5 yr) (% f/u NR)	• JOA RR	• Age at time of surgery
				• Duration of myelopathy
				• Progression of ossification
				• Degree of spinal canal expansion
Iwasaki et al[8] Retrospective cohort CoE: II	• N = 66 • OPLL	10.2 yr (range: 5–20 yr) (80% f/u)	• JOA RR • JOA score	• Age at operation
				• Preoperative JOA score
				• Hill-shaped ossification
				• Postoperative change in cervical alignment
				• Occupying ratio of OPLL
				• Space available for the spinal cord
Iwasaki et al[8] (2002)* Retrospective cohort CoE: III	• N = 64 • OPLL	12.2 yr (range: NR) (% f/u NR)	• mJOA score	• Age at operation
				• Preoperative JOA score
				• Type of OPLL
				• Occupying ratio of OPLL
				• Space available for the spinal cord
				• Postoperative change in cervical alignment
				• Postoperative radiographical fusion of motion segments
Wang et al[20] (2010)† Retrospective cohort CoE: III	• N = 102† • OPLL	1.2 yr (range: 1–1.5 yr) (57% f/u)	• mJOA RR	• Age
				• Duration of disease
				• Preoperative JOA score
				• Babinski sign
				• Ankle clonus
				• Signal intensity ratio (low, intermediate, high)
Studies with both patients with CSM and patients with OPLL				
Kim et al[21] (2008) Retrospective cohort CoE: III	• N = 87 • Cervical myelopathy (CSM or OPLL, details NR)	≥2 yr (% f/u NR)	• JOA RR	• Age
				• Presence of diabetes
				• Presence of diabetes and older age
				• Presence of diabetes and smoking
				• Duration of symptoms
				• Preoperative JOA score
				• Signal change on MRI
Morio et al[10] (2001) Retrospective cohort CoE: II	• N = 73 • CSM: 58%	3.4 yr (range: 0.5–10 yr) (100% f/u)	• JOA RR • JOA score	• Age
				• Duration of symptoms

(*Continued*)

TABLE 2. (Continued)				
Author (Year)	**Population**	**Follow-up Duration (% Followed)**	**Outcomes Evaluated**	**Predictive Factors Evaluated**
	• OPLL: 42%			• Severity of myelopathy (preoperative JOA score)
				• Transverse area of spinal cord at site responsible for cervical myelopathy
				• Preoperative signal intensity
Uchida et al[12] (2005) Retrospective cohort CoE: III	• CSM: N = 45 • OPLL: N = 47	8.3 yr (range: 1.0–12.8 yr) (% f/u NR)	• JOA score	• Age at surgery
				• Preoperative JOA score
				• Type of OPLL
				• Type of myelopathy (Crandall and Batzdorff)
				• Spinal cord evoked potentials type
				• Level of compression
				• Rate of flattening of the cord
				• Increased transverse area of the cord
				• Spinal canal narrowing (preoperative CT)
				• Postoperative expansion rate of spinal canal
				• Radiological abnormality

JOA score: evaluation of the neurological function of patients with cervical myelopathy; range of score 0 to 17, with a lower score indicating a poor outcome. Motor function score of lower extremity portion of JOA: range of score 0 to 4, with a lower score indicating a poor outcome. mJOA score: similar to JOA score, with additional section for shoulder and elbow: points can be subtracted on the basis of the manual muscle test of the deltoid or biceps muscle; range of score 0 to 17, with a lower score indicating a poor outcome. JOACMEQ-L: used to evaluate cervical compression myelopathy; range of scores 0 to 100, with lower score indicating a poor outcome.

It is likely that these studies have overlapping patient populations, although the extent of the overlap cannot be determined.

†Demographic characteristics presented for 114 patients with available follow-up (Suda et al[17]) or 58 patients with f/u >12 months (Wang et al[20]).

CoE indicates class of evidence; CSM, cervical spondylotic myelopathy; CT, computed tomography; f/u, follow-up; JOA, Japanese Orthopedic Association; JOACMEQ-L, Japanese Orthopedic Association Cervical Myelopathy Evaluation Questionnaire lower extremity function section; JOA RR, JOA recovery rate; mJOA: modified JOA; MRI, magnetic resonance imaging; NR, not reported; OPLL, ossification of the posterior longitudinal ligament.

Sociodemographic Characteristics and Comorbidities

Age

All 12 studies investigated the role of age in laminoplasty outcomes in univariate and/or multivariate analyses (Table 3). Of the studies in which the majority of patients had CSM, 4 of 6 studies found that age was not significantly associated with laminoplasty outcomes in univariate analysis and thus did not further evaluate its effects using multivariate analyses.[11,16–18] One study found that age of at least 60 years correlated with decreased JOA scores on multivariate analysis; however, the statistical significance of this outcome was not clear and the partial correlation coefficient value was not high enough to meet the study's criteria for entering age into a multiple regression analysis.[12] In a multivariate analysis, 1 study of patients with CSM found that older patients were slightly more likely to have a poor recovery (<50% recovery rate) than younger patients (OR: 1.05; 95% CI: 1.00–1.11; $P = 0.04$), although the effect was marginally significant.[15] In contrast, the same study found that age was

not a predictor of postoperative JOACMEQ-L scores on univariate analysis.[15]

In studies that included only patients with OPLL, there were conflicting results for the effect of age on poor recovery. Two of the 5 studies reported that older age was a statistically significant predictor of a lower JOA recovery rate on multivariate analysis. Fujimura et al[19] found that older patients were significantly more likely to be at risk for a lower recovery rate ($P < 0.0001$) and a significant decrease in recovery rate between the 1- and 5-year follow-ups ($P < 0.0001$) than younger patients. Wang et al[20] reported that older age increased the risk of a lower JOA recovery rate on multiple linear regression analysis; however, the P value was not reported. In addition, one study found that age of at least 60 years was associated with lower JOA scores according to multivariate analysis; however, the statistical significance of this outcome was not reported.[12] In contrast, 2 studies found that age was not significantly associated with lower postoperative JOA scores: $P = 0.064$ (Iwasaki et al[9]) and $P = 0.1866$ (Iwasaki et al[8]).

TABLE 3. Older Age as a Predictive Factor and Its Association With JOA Score or Recovery Rate After Laminoplasty for All Studies

Author (Year) CoE	Length f/u	Outcome	Predictive Factors Evaluated	Effect Estimates: Odds Ratio (95% Confidence Interval), *P*	
				Univariate Analysis	Multivariate Analysis
Studies with ≥80% patients with CSM					
Nakashima et al[15] (2012)* CoE: II	>1 yr (range: NR)	JOA RR <50%	Older age	*P* = 0.011	1.05 (1.00–1.11), *P* = 0.04
		JOACMEQ-L "ineffective"†	Older age	*P* = 0.28	Not tested‡
Naruse et al[16] (2009) CoE: II	1 yr	JOA RR <50%	Older age	*P* = 0.76	Not tested‡
Suda et al[17] (2003) CoE: III	5 (2–13) yr	JOA RR <50%	Older age	*P* ≥ 0.05	Not tested‡
Tanaka et al[11] (1999) CoE: II	11 (5–36) mo	Postoperative JOA score	Older age	*P* ≥ 0.05	Not tested
		Postoperative JOA LES score	Older age	*P* ≥ 0.05	Not tested
Wada et al[18] (1999) CoE: III	35.1 (24.4–48.3) mo	Negative JOA RR	Older age	*P* ≥ 0.05	Not tested
Uchida et al[12] (2005) CoE: III	8.3 yr (mean)	Decreased JOA score	Age at operation	NR	Older age correlated with decreased JOA score but *P* value NR (and statistical significance unclear)
Studies with only patients with OPLL					
Wang et al[20] (2010) CoE: III	14.5 (12–18) mo	mJOA RR	Older age	NR	Older age associated with decreased JOA RR (*P* value NR)
Iwasaki et al[9] (2007)§ CoE: II	10.2 (5–20) yr	JOA score (at final f/u)	Older age	*P* ≥ 0.05	Not tested
		JOA score (at the time of maximum recovery)	Older age	NR	*P* = 0.19
Iwasaki et al[8] (2002) CoE: III	12.2 yr (mean)	JOA score	Older age	NR	*P* = 0.064
Fujimura et al[19] (1998) CoE: III	80.3 ± 32.6 mo	Decreased JOA RR¶	Older age	*P* < 0.05	*P* < 0.0001 between 1 and 5 yr
		JOA RR	Older age	NR	*P* < 0.0001 at 5 yr
Uchida et al[12] (2005) CoE: III	8.3 yr (mean)	Decreased JOA score	Age at operation	NR	Older age (≥60 yr) correlated with decreased JOA score but *P* value NR (and statistical significance unclear)
Studies with both patients with CSM and patients with OPLL					
Kim et al[21] (2008)‖ CoE: III	2 yr	JOA RR <50%	Older age	*P* < 0.05	Not tested

(Continued)

TABLE 3. (Continued)

Author (Year) CoE	Length f/u	Outcome	Predictive Factors Evaluated	Effect Estimates: Odds Ratio (95% Confidence Interval), P	
				Univariate Analysis	Multivariate Analysis
Morio et al[10] (2001)‖ CoE: II	3.4 yr (mean)	Lower JOA RR	Older age	P < 0.05	P = 0.0002
		Decreased JOA score	Older age	P < 0.05	P < 0.0001

*Study reported performing a multivariate logistic analysis with resulting HR effect estimates. We report these estimates as odds ratios because that is the appropriate measure for a logistic analysis (Nakashima et al[15]).

†Ineffective result using JOACMEQ-L defined as satisfying at least 1 of the following conditions: (1) the post-treatment score was not higher than the pretreatment score by ≥20 points, and (2) the pretreatment score was >90 points and the post-treatment score was <90 points (Nakashima et al[15]).

‡Factors entered into multivariate analysis only if the P value from univariate analysis was P < 0.20 (Nakashima et al[15]); P < 0.05 (Naruse et al[16]); and P < 0.1 (Suda et al[17]).

§Six patients who developed symptoms of thoracic myelopathy or lumbar spinal canal stenosis were excluded from the multivariate analysis (Iwasaki et al[9]).

¶Significant decrease in recovery rate; significance not defined (Fujimura et al[19]).

‖Population comprised 58% CSM and 42% OPLL (Morio et al[10]) or not reported (Kim et al[21]).

CoE indicates class of evidence; f/u, follow-up; JOA, Japanese Orthopedic Association; JOACMEQ, Japanese Orthopedic Association Cervical Myelopathy Evaluation Questionnaire; JOACMEQ-L, JOACMEQ lower extremity function section; JOA LES, JOA lower extremity score; JOA RR, JOA recovery rate = 100 × (postoperative JOA score − preoperative JOA score)/(17 − preoperative JOA score); mJOA, modified JOA score; NR: not reported.

These 2 studies that included both patients with CSM and patients with OPLL found that age was significantly associated with outcome. One study found that older age significantly increased the risk of a lower recovery rate and lower postoperative JOA score ($P < 0.0002$ and $P = 0.0001$, respectively) on multivariate analysis.[10] A second study reported that older age was a significant predictor of a JOA recovery rate of less than 50% on univariate analyses but did not evaluate age using multivariate analysis.[21]

Diabetes
In a study of both patients with CSM and patients with OPLL undergoing laminoplasty, Kim et al[21] found that diabetic patients had almost 3 times the risk of a poor neurological recovery (<50% recovery rate) than patients without diabetes (OR: 2.92; 95% CI: 1.32–6.12; $P = 0.01$). The same study also found an increased risk for a poor recovery in diabetic patients of older age (OR: 2.21; 95% CI: 1.15–4.23; $P = 0.04$) or who smoked (OR: 4.01; 95% CI: 1.89–8.32; $P = 0.02$) (see Supplemental Digital Content Table 4, available at http://links.lww.com/BRS/A825).

CSM and Characteristics

Severity of Preoperative Myelopathy (Preoperative JOA Score)
Ten studies investigated the role of the preoperative JOA score in laminoplasty outcomes in univariate and/or multivariate analyses (Table 4). Of the 6 studies comprising only patients with CSM, the results were inconsistent. Three studies evaluated the preoperative JOA score in multivariate analyses and found that this factor was significantly associated with outcome.[11,12,16] Naruse et al[16] found that patients with a low preoperative JOA score were significantly more likely to have a less than 50% recovery rate than patients with a

high preoperative JOA score (OR: 1.65; 95% CI: 1.20–2.25; $P = 0.0019$). Tanaka et al[11] reported that a lower preoperative JOA score significantly increased the risk of a lower postoperative JOA score ($P < 0.0001$). The same study also found that a lower preoperative lower extremity JOA score significantly increased the risk of a lower postoperative lower extremity JOA score ($P < 0.0001$). Uchida et al[12] found that a preoperative JOA score of less than 7 points in patients with CSM was significantly associated with a decreased postoperative JOA score ($P = 0.0329$) in multivariate analysis. One study found that preoperative JOA score was significantly associated with poor outcome by univariate analysis (OR: 0.76; 95% CI: 0.64–0.91; $P < 0.01$), but the factor was not included in the stepwise multivariate analysis.[17] Two studies found that the preoperative JOA score was not significantly associated with laminoplasty outcomes in univariate analysis and did not further evaluate its effects using multivariate analyses.[15,17,18]

Of the 4 studies evaluating this predictive factor in which the majority of patients had OPLL, all found that a lower preoperative JOA score was significantly associated with poorer outcomes in multivariate analysis.[8,9,12,20] Two studies reported that a lower preoperative JOA score increased the risk of a lower postoperative JOA score: $P = 0.0001$ (Iwasaki et al[8]), $P = 0.0015$ at the final follow-up, and $P = 0.0003$ at the follow-up with the maximum JOA score.[9] A third study reported that a lower preoperative JOA score was a predictor of a lower recovery rate (P value not reported).[20] Finally, the fourth study found that a preoperative JOA score of less than 7 points was significantly associated with a lower postoperative JOA score ($P = 0.0375$).[12]

In a study that included both patients with CSM and patients with OPLL, Morio et al[10] reported that a lower preoperative JOA score significantly increased the risk of a lower postoperative JOA score ($P < 0.0001$).

TABLE 4. Preoperative JOA Score as a Predictive Factor and Its Association With JOA Score or Recovery Rate After Laminoplasty for All Studies

Author (Year) CoE	Length f/u	Outcome	Predictive Factors Evaluated	Effect Estimates: Odds Ratio (95% Confidence Interval), P	
				Univariate Analysis	Multivariate Analysis
Studies with ≥80% patients with CSM					
Nakashima et al[15] (2012) CoE: II	>1 yr (range: NR)	JOA RR <50%	Preoperative JOA score	*P* = 0.36	Not tested*
		JOACMEQ-L "ineffective"†	Preoperative JOA score	*P* = 0.89	Not tested*
Naruse et al[16] (2009) CoE: II	1 yr	JOA RR <50%	Lower preoperative JOA score	*P* = 0.0093	1.65 (1.20–2.25), *P* = 0.0019*
Suda et al[17] (2003) CoE: III	5 (2–13) yr	JOA RR <50%	Preoperative JOA score	*P* < 0.01	Not tested*
Tanaka et al[11] (1999) CoE: II	11 (5–36) mo	Postoperative JOA score	Preoperative JOA score	NR	*P* < 0.0001
		Postoperative JOA LES score	Preoperative JOA LES score	NR	*P* < 0.0001
Wada et al[18] (1999) CoE: III	35.1 (24.4–48.3) mo	Negative JOA RR	Preoperative JOA score	*P* ≥ 0.05	Not tested
Uchida et al[12] (2005) CoE: III	8.3 yr (mean)	Decreased JOA score	Lower preoperative JOA score (<7 points)	NR	*P* = 0.0329
Studies with only patients with OPLL					
Wang et al[20] (2010) CoE: III	14.5 (12–18) mo	mJOA RR	Lower preoperative JOA score	NR	Associated with decreased JOA RR (*P* value NR)
Iwasaki et al[9] (2007)‡ CoE: II	10.2 (5–20) yr	JOA score (at final f/u)	Preoperative JOA score	NR	*P* = 0.0015
		JOA score (at time of maximum recovery)	Preoperative JOA score	NR	*P* = 0.0003
Iwasaki et al[8] (2002) CoE: III	12.2 yr (mean)	JOA score	Lower preoperative JOA score	NR	*P* = 0.0001
Uchida et al[12] (2005) CoE: III	8.3 yr (mean)	Decreased JOA score	Lower preoperative JOA score (<7 points)	NR	*P* = 0.0375
Studies with both patients with CSM and patients with OPLL					
Morio et al[10] (2001)§ CoE: II	3.4 yr (mean)	Decreased JOA score	Lower preoperative JOA score	*P* < .0001	*P* < 0.0001

*Factors entered into multivariate analysis only if the P value from univariate analysis was as follows: P < 0.20 (Nakashima et al[15]); P < 0.05 (Naruse et al[16]); and P < 0.1 (Suda et al[17]).

†Ineffective result using JOACMEQ-L defined as satisfying at least 1 of the following conditions: (1) the post-treatment score was not higher than the pretreatment score by ≥20 points, and (2) the pretreatment score was >90 points and the post-treatment score was <90 points (Nakashima et al[15]).

‡Six patients who developed symptoms of thoracic myelopathy or lumbar spinal canal stenosis were excluded from the multivariate analysis (Iwasaki et al[9]).

§Population comprised 58% CSM and 42% OPLL (Morio et al[10]).

CoE indicates class of evidence; f/u: follow-up; JOA, Japanese Orthopedic Association; JOACMEQ, Japanese Orthopedic Association Cervical Myelopathy Evaluation Questionnaire; JOACMEQ-L, JOACMEQ lower extremity function section; JOA LES, JOA lower extremity score; JOA RR, JOA recovery rate = 100 × (postoperative JOA score − preoperative JOA score)/(17 − preoperative JOA score); mJOA, modified JOA score; NR, not reported.

Duration of Preoperative Symptoms/Disease/Myelopathy

Six studies evaluated whether duration of symptoms affected laminoplasty outcomes, using univariate and/or multivariate analyses (Table 5). Of the 3 studies of patients with CSM, all 3 found that patients with a longer duration of symptoms were at a higher risk for a recovery rate of less than 50% or a lower postoperative JOA score.[11,15,18] Nakashima et al[15] found that patients with a longer duration of symptoms were slightly more likely to have a recovery rate of less than 50% than patients with a shorter duration of symptoms (OR: 1.19; 95% CI: 1.03–1.37; *P* = 0.016). In contrast, this study also found that the duration of symptoms was not significantly

TABLE 5. Longer Duration of Symptoms, Disease, or Myelopathy as a Predictive Factor and Its Association With JOA Score or Recovery Rate After Laminoplasty for All Studies

Author (Year) CoE	Length f/u	Outcome	Predictive Factors Evaluated	Effect Estimates: Odds Ratio (95% Confidence Interval), P	
				Univariate Analysis	Multivariate Analysis
Studies with ≥80% patients with CSM					
Nakashima et al[15] (2012)* CoE: II	> 1 yr (range: NR)	JOA RR <50%	Longer duration of symptoms	$P = 0.029$	1.19 (1.03 – 1.37), $P = 0.016$
		JOACMEQ-L "ineffective"†	Longer duration of symptoms	$P = 0.54$	Not tested‡
Tanaka et al[11] (1999) CoE: II	11 (5–36) mo	Postoperative JOA score	Longer duration of symptoms	NR	$P < 0.0001$ (longer duration lowers JOA score)
		Postoperative JOA LES score	Longer duration of lower extremity disability	NR	$P < 0.0001$ (longer duration lowers JOA LES score)
Wada et al[18] (1999) CoE: III	35.1 (24.4–48.3) mo	Negative JOA RR	Longer duration of symptoms	NR	$P < 0.05$
Studies with only patients with OPLL					
Wang et al[20] (2010) CoE: III	14.5 (12–18) mo	mJOA RR	Longer duration of disease	NR	Associated with decreased JOA RR (P value NR)
Fujimura et al[19] (1998) CoE: III	80.3 ± 32.6 mo	JOA RR	Longer duration of myelopathy	NR	$P < 0.0001$ at 1, 3, and 5 yr
Studies with both patients with CSM and patients with OPLL					
Morio et al[10] (2001)§ CoE: II	3.4 yr (mean)	Lower JOA RR	Longer duration of symptoms	$P < 0.05$	$P = 0.0002$
		Decreased JOA score	Longer duration of symptoms		$P < 0.0001$

*Study reported performing a multivariate logistic analysis with resulting HR effect estimates. We report these estimates as odds ratios because that is the appropriate measure for a logistic analysis (Nakashima et al[15]).

†Ineffective result using JOACMEQ-L defined as satisfying at least 1 of the following conditions: (1) the post-treatment score was not higher than the pretreatment score by ≥20 points, and (2) the pretreatment score was >90 points and the post-treatment score was <90 points (Nakashima et al[15]).

‡Factors entered into multivariate analysis only if the P value from univariate analysis was $P < 0.20$ (Nakashima et al[15]).

§Population comprised 58% CSM and 42% OPLL (Morio et al[10]).

CoE indicates class of evidence; f/u, follow-up; JOA, Japanese Orthopedic Association; JOACMEQ, Japanese Orthopedic Association Cervical Myelopathy Evaluation Questionnaire; JOACMEQ-L, JOACMEQ lower extremity function section; JOA LES, JOA lower extremity score; JOA RR, JOA recovery rate = 100 × (postoperative JOA score − preoperative JOA score)/(17 − preoperative JOA score); mJOA, modified JOA score; NR, not reported.

associated with an ineffective result using the JOACMEQ-L score on univariate analysis and thus did not further evaluate its effects in a multivariate analysis. Tanaka et al[11] reported that a longer duration of symptoms and lower extremity disability significantly increased the risk of a lower postoperative JOA score and a JOA motor function score of lower extremity ($P < 0.0001$ for both factors). Similarly, Wada et al[18] found that a longer duration of symptoms significantly increased the risk of a lower recovery rate ($P < 0.05$).

Of the 2 studies in which the majority of patients had OPLL, both reported that an increased duration of preoperative symptoms in laminoplasty outcomes was significantly associated with poorer outcomes, using univariate and/or multivariate analyses.[19,20] Fujimura et al[19] reported that a longer duration of myelopathy significantly increased the risk of a lower recovery rate in multivariate analysis ($P < 0.0001$ at 1-, 3-, and 5-yr follow-up). Wang et al[20] reported that a longer duration of disease is the best combination of predictors of a lower recovery rate in a multivariate analysis (P value not reported).

In a study that included both patients with CSM and patients with OPLL, Morio et al[10] found that a longer

TABLE 6. Increased Severity/Degree of Stenosis as a Predictive Factor and Its Association With JOA Score or Recovery Rate After Laminoplasty for All Studies

Author (Year) CoE	Length f/u	Outcome	Predictive Factors Evaluated	Effect Estimates: Odds Ratio (95% Confidence Interval), *P*	
				Univariate Analysis	Multivariate Analysis
Studies with ≥80% patients with CSM					
Wada et al[18] (1999) CoE: III	35.1 (24.4–48.3) mo	Negative JOA RR	Decreased AP canal diameter at maximum compression (mm)	NR	*P* < 0.05
			Decreased transverse area of spinal cord at maximum compression	NR	*P* < 0.05
Uchida et al[12] (2005)* CoE: III	8.3 yr (mean)	Decreased JOA score	Rate of flattening of the cord <50%	NR	*P* = 0.0116
			Spinal canal stenosis	NR	*P* ≥ 0.05
Studies with only patients with OPLL					
Uchida et al[12] (2005) CoE: III	8.3 yr (mean)	Decreased JOA score	Rate of flattening of the cord <30%	NR	*P* = 0.0434
			Spinal canal narrowing ≥40% (preoperative CT)	NR	*P* ≥ 0.05
Iwasaki et al[8] (2002) CoE: III	12.2 yr (mean)	JOA score	Space available for spinal cord	NR	*P* ≥ 0.05

*Spinal canal stenosis defined as canal diameter <12 mm in the sagittal plane on radiograph (Uchida et al[12]).

AP indicates anteroposterior; CoE, class of evidence; CT, computed tomography; f/u, follow-up; JOA, Japanese Orthopedic Association; JOACMEQ, Japanese Orthopedic Association Cervical Myelopathy Evaluation Questionnaire; JOACMEQ-L, JOACMEQ lower extremity function section; JOA LES, JOA lower extremity score; JOA RR, JOA recovery rate = 100 × (postoperative JOA score − preoperative JOA score)/(17 − preoperative JOA score); mJOA, modified JOA score; NR, not reported

duration of symptoms significantly increased the risk of a lower recovery rate and a postoperative JOA score in a multivariate analysis (*P* = 0.0002 and *P* < 0.0001, respectively).

Shape of OPLL Lesion
One study in which the majority of patients had OPLL evaluated the role of OPLL lesion shape in laminoplasty outcomes in univariate and/or multivariate analyses.[9] Iwasaki et al[9] found that hill-shaped lesions significantly increased the risk of a lower recovery rate (*P* < 0.0001 at the final follow-up and *P* < 0.0001 at the time of maximum recovery) and a lower JOA score (*P* < 0.0001 at the final follow-up and *P* < 0.0001 at the time of maximum recovery) than plateau-shaped lesions based on the OPLL classification system of Iwasaki.[22] The author defined hill-shaped ossifications as demonstrating a massive beak-shaped ossification localized to certain levels (see Supplemental Digital Content Table 3, available at http://links.lww.com/BRS/A825).

Degree or Severity of Stenosis
Three studies evaluated whether severity of stenosis affected laminoplasty outcomes (Table 6). Overall, results from the 2 studies in which the majority of patients had CSM suggested that increased preoperative stenosis is predictive of poorer outcomes in univariate and/or multivariate analyses. Wada

et al[18] found that stenosis (as measured by 2 methods) significantly increased the risk of a negative postoperative recovery rate (*P* < 0.05 for both measures of stenosis). This study defined stenosis as a decrease in anteroposterior canal diameter at maximum compression (measured on radiograph) or the transverse area of the spinal cord at maximum compression (measured on computed tomographic [CT] myelography). Uchida et al[12] also used 2 measures of stenosis to investigate its role as a potential predictor of the postoperative JOA score. This study found that less than 50% flattening of the spinal cord on MRI in patients with spondylosis significantly increased the risk of a lower JOA score (*P* = 0.0116); however, spinal canal stenosis defined as a canal diameter of less than 12 mm in the sagittal plane on radiograph was not significantly associated with a lower JOA score in patients with spondylosis (*P* > 0.05).

In studies that included only patients with OPLL, there were conflicting results in the 2 studies that evaluated the role of the degree of stenosis on laminoplasty outcomes in univariate and/or multivariate analyses.[9,12] Iwasaki et al[8] reported that the space available for the spinal cord was not significantly associated with the postoperative JOA score (*P* > 0.05). Uchida et al[12] reported that a narrowing rate of less than 40% at the most affected segment on the preoperative CT scan did not increase the risk of a lower JOA

score in patients with OPLL in multivariate analysis ($P > 0.05$), but, in contrast, reported that less than 30% flattening on the preoperative MRI significantly increased the probability of a poor long-term outcome in multivariate analysis ($P = 0.0434$).

No studies comprising both CSM and OPLL studies evaluated stenosis as a predictive factor for laminoplasty outcomes.

Number of Levels With Compression
Only one study investigated the effect of the number of levels with compression on laminoplasty outcomes in univariate and/or multivariate analyses. Uchida et al[12] found that involvement at 3 or more levels significantly increased the risk of a lower JOA score for both patients with spondylosis and patients with OPLL ($P = 0.0293$ and $P = 0.0029$, respectively) (see Supplemental Digital Content Tables 2 and 3, available at http://links.lww.com/BRS/A825).

Radiographical/Neurological Characteristics

Presence of Preoperative Kyphosis
One study of patients with CSM investigated preoperative cervical alignment as a predictor for laminoplasty outcomes in univariate and/or multivariate analyses. Suda et al[17] found that patients with local kyphosis (angle $>5°$) had a slightly increased risk of a less than 50% recovery rate than patients without local kyphosis (OR: 1.21; 95% CI: 1.08–1.36; $P < 0.01$) (see Supplemental Digital Content Table 2, available at http://links.lww.com/BRS/A825).[17]

Presence of T2 and/or T1 Signal Change on MRI
T1 and T2 signal changes on MRI were variously defined by the 6 studies that evaluated them as a potential predictive factor, so caution must be exercised in the interpretation of the results (Table 7). The studies evaluated either only T2 signal changes or concurrent T1 and T2 signal changes.

Only T2 Changes
In studies that included only patients with CSM, 2 studies reported that a T2 signal intensity change had no effect on laminoplasty outcomes in univariate and/or multivariate analyses. Nakashima et al[15] measured spinal cord signal intensity changes on T2-weighted MRI in the sagittal and axial planes and reported percent change of signal intensity. This study found that T2 signal intensity changes in patients with CSM did not significantly increase the risk of an ineffective result measured by the JOACMEQ-L score ($P = 0.98$; refer to Table 3 for the definition of an ineffective result).[15] This same study also found that a T2 signal intensity change was not significantly associated with a recovery rate of less than 50% in a univariate analysis and thus did not further evaluate its effects using multivariate analyses. Wada et al[18] also found that a T2 signal intensity change was not significantly associated with a negative recovery rate in a univariate analysis ($P > 0.05$) and did not further evaluate its effects in a multivariate analysis.

One study comprising patients with OPLL evaluated the role of T2 signal intensity change on laminoplasty outcomes

in univariate and/or multivariate analyses. Wang et al[20] used sagittal T2-weighted MRI and reported the signal intensity ratio between areas of compressed spinal cord and normal spinal cord at the C7–T1 disc level and found that an increased signal intensity ratio with positive pyramidal signs was associated with a lower recovery rate (P value not reported).

Concurrent T1 and T2 Changes
In a study that included only patients with CSM, Suda et al[17] measured preoperative signal intensity changes on T1- and T2-weighted MRI in the sagittal and axial planes and reported the presence or absence of these changes. This study found that patients with a signal intensity change on MRI had a 4 times higher risk of a recovery rate of less than 50% than patients with CSM with no signal intensity change (OR: 4.10; 95% CI: 1.51–11.12; $P < 0.01$).[17] However, the wide CI for the OR suggests great variability in the effect estimate and casts doubt as to the certainty of the estimate. In considering both preoperative kyphosis and signal intensity changes, Suda et al[17] also reported that the maximum local kyphosis angle leading to a good outcome was within 13° without a signal intensity change and within 5° with a signal intensity change.

These two studies including both patients with CSM and patients with OPLL found that concurrent T1 and T2 signal intensity changes were significantly associated with poorer laminoplasty outcomes in univariate and/or multivariate analyses. Kim et al[21] defined a signal intensity change as being present when there was an increased signal on T2 with an accompanying decreased signal on T1 and found that patients with a signal intensity change were almost 4 times more likely to have a recovery rate of less than 50% than patients without a signal intensity change in multivariate analysis (OR = 3.53; 95% CI: 1.67–5.95; $P = 0.01$). Morio et al[10] defined 3 patterns of signal intensity changes on T1-weighted/T2-weighted MRI, normal/normal, normal/high, and low/high, and found that the low-intensity signal changes on T1-weighted sequences significantly increased the risk of a lower recovery rate ($P = 0.0002$) and a lower postoperative JOA score ($P < 0.0001$) in multivariate analyses.

Evidence Summary
Results are summarized in Table 8, and evidence summaries may be found in Table 9. The overall strength of the evidence for increased age, severity of disease, and a longer duration of symptoms as risk factors in patients with CSM is "low," that is, there is a low confidence that the evidence reflects the true effect, and further research is both likely to change the confidence in the estimate of effect and likely to change the estimate. The overall strength of evidence for severity/degree of stenosis, number of levels with compression, local kyphosis, and signal intensity change/ratio as risk factors in patients with CSM is "insufficient," that is, the available evidence does not permit a conclusion.

The overall strength of the evidence for OPLL lesion type as a risk factor in patients with OPLL is "low," that is, there is a low confidence that the evidence reflects the true effect, and further research is both likely to change the confidence in the

TABLE 7. Signal Intensity Change on MRI as a Predictive Factor and Its Association With JOA Score or Recovery Rate After Laminoplasty for All Studies

Author (Year) CoE	Length f/u	Outcome	Predictive Factors Evaluated	Effect Estimates: Odds Ratio (95% Confidence Interval) *P*	
				Univariate Analysis	Multivariate Analysis
Studies with ≥80% patients with CSM					
Studies evaluating only T2 changes					
Nakashima et al[15] (2012)* CoE: II	>1 yr (range: NR)	JOA RR <50%	T2 signal intensity change (MRI)	*P* = 0.69	Not tested†
		JOACMEQ-L "ineffective"‡	T2 signal intensity change (MRI)	*P* = 0.164	2.56 (0.85–7.69), *P* = 0.98
Wada et al[18] (1999) CoE: III	35.1 (24.4–48.3) mo	Negative JOA RR	Presence of T2 signal changes on MRI	*P* ≥ 0.05	Not tested
Studies evaluating concurrent T1 and T2 changes					
Suda et al[17] (2003) CoE: III	5 (2–13) yr	JOA RR <50%	T1 and T2 signal intensity change (MRI)	*P* < 0.05	4.10 (1.51–11.12), *P* < 0.01
Studies with only patients with OPLL					
Studies evaluating only T2 changes					
Wang et al[20] (2010)§ CoE: III	14.5 (12–18) mo	mJOA RR	T2 signal intensity ratio	NR	Associated with decreased JOA RR (*P* value NR)
Studies with both patients with CSM and patients with OPLL					
Studies evaluating concurrent T1 and T2 changes					
Kim et al[21] (2008)¶ CoE: III	2 yr	JOA RR <50%	T1 and T2 signal change on MRI	*P* < 0.05	3.53 (1.67–5.95), *P* = 0.01
Morio et al[10] (2001)¶ CoE: II	3.4 yr (mean)	Lower JOA RR	T1 and T2 signal intensity change pattern	NR	*P* = 0.0002
		Decreased JOA score	T1 and T2 signal intensity change pattern	NR	*P* < 0.0001

*Study reported performing a multivariate logistic analysis with resulting HR effect estimates. We report these estimates as odds ratios because that is the appropriate measure for a logistic analysis (Nakashima et al[15]).

†Factors entered into multivariate analysis only if the P value from univariate analysis was: P < 0.20 (Nakashima et al[15]).

‡Ineffective result using JOACMEQ-L defined as satisfying at least 1 of the following conditions: (1) the post-treatment score was not higher than the pretreatment score by ≥20 points, and (2) the pretreatment score was >90 points and the post-treatment score was <90 points (Nakashima et al[15]).

§Signal intensity ratio categorized as: low (<1.396), intermediate (≤1.396 and <1.689), and high (≥1.689) (Wang et al[20]).

¶Population comprised 58% CSM and 42% OPLL (Morio et al[10]) or not reported (Kim et al[21]).

CoE indicates class of evidence; f/u, follow-up; JOA, Japanese Orthopedic Association; JOACMEQ, Japanese Orthopedic Association Cervical Myelopathy Evaluation Questionnaire, JOACMEQ-L, JOACMEQ lower extremity function section; JOA LES, JOA lower extremity score; JOA RR, JOA recovery rate = 100 × (postoperative JOA score − preoperative JOA score)/(17 − preoperative JOA score); mJOA, modified JOA score; MRI, magnetic resonance imaging; NR, not reported; OPLL.

estimate of effect and likely to change the estimate. The overall strength of evidence for increased age, severity of disease, a longer duration of symptoms, severity/degree of stenosis, number of levels with compression, and signal intensity change/ratio as risk factors in patients with OPLL is "insufficient," that is, the available evidence does not permit a conclusion.

The overall strength of the evidence for increased age, severity of disease, and a longer duration of symptoms as

risk factors in a mixed population of patients with CSM and OPLL is "low," that is, there is a low confidence that the evidence reflects the true effect, and further research is both likely to change the confidence in the estimate of effect and likely to change the estimate. The overall strength of evidence for signal intensity change/ratio and diabetes and/or smoking or older age as risk factors in a mixed population of both patients with CSM and patients with OPLL is

TABLE 8. Summary of Predictive Factors Significantly Associated With a Poor Recovery as Measured by JOA Score or Recovery Rate After Laminoplasty

Predictive Factors	Studies With ≥80% Patients With CSM						Studies With Only Patients With OPLL					Studies With Both Patients With CSM and Patients With OPLL	
	CoE: II			CoE: III			CoE: II	CoE: III				CoE: II	CoE: III
	Nakashima et al[15] (2012)	Naruse et al[16] (2009)	Tanaka et al[11] (1999)	Suda et al[17] (2003)	Wada et al[18] (1999)	Uchida et al[12] (2005)	Iwasaki et al[9] (2007)	Fujimura et al[19] (1998)	Iwasaki et al[8] (2002)	Wang et al[20] (2010)	Uchida et al[12] (2005)	Morio et al[10] (2001)	Kim et al[21] (2008)
Sociodemographic characteristics and comorbidities													
Older age	Mixed results*	NS	NS†	NS†	NS†	→ (p-NR)	NS†	→	NS	↓ (p-NR)	→ (p-NR)	→	↓†
Diabetes													→
Diabetes and age													→
Diabetes and smoking													→
CSM and diagnostic characteristics													
Severity of disease: lower preoperative JOA score or motor function score of lower extremities	NS†	→	→	↓†	NS†	→	→		→	↓ (p-NR)	→	→	
Longer duration of symptoms/myelopathy/disease or lower extremity disability	Mixed results		→		→			→		↓ (p-NR)			
Hill-shaped OPLL lesion							→						
Increased severity/degree of stenosis‡					→	Mixed results			NS		Mixed results		
≥3 levels with compression						→					→		
Radiographical/neurological characteristics													
Local kyphosis (angle >5°)				→									
Signal intensity change/ratio/change pattern	NS†			→	NS†					↓ (p-NR)		→	→

*Mixed results: The study analyzed more than 1 relevant outcome, and the predictive factor was statistically associated with one outcome but not with the other.

†Tested only by univariate analysis.

‡Increase severity/degree of stenosis defined as the rate of flattening of cord (Uchida et al[12]), canal diameter <12 mm in sagittal plane (Uchida et al[12]), decreased anteroposterior canal diameter at maximum compression (Wada et al[18]), space available for spinal cord (Iwasaki et al[8]), or decreased transverse area of spinal cord at maximum compression (Wada et al[18]).

Blank cell indicates factor was not evaluated; CoE, class of evidence; CSM, cervical spondylotic myelopathy; JOA, Japanese Orthopedic Association; NS, factor is not statistically predictive of poor recovery by univariate or multivariate analysis; OPLL, ossification of posterior longitudinal ligament; p-NR, P value not reported; ↓, factor is significantly predictive of a poor recovery.

TABLE 9. Strength of Evidence Summary

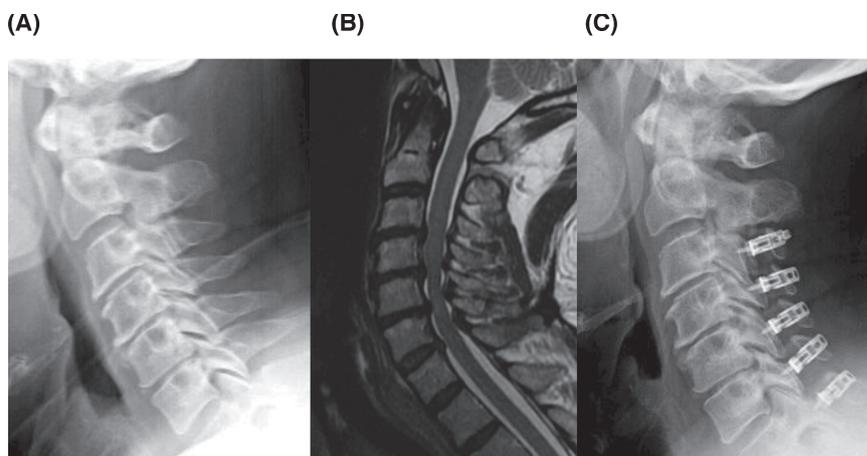|	Strength of Evidence	Conclusions/Comments	Baseline	UPGRADE (Classes)	DOWNGRADE (Classes)
In adult patients with cervical myelopathy, how do preoperative factors affect patient outcome after cervical laminoplasty?					
Sociodemographic factors and comorbidities					
Studies with ≥80% patients with CSM					
Increased age	Low	Age is not a significant predictor of JOA outcome based on data from 6 studies. Specifically, age is not associated with JOA RR <50% (2 of 3 studies), negative JOA RR (1 study), or postoperative JOA score (1 of 2 studies). However, one study found that older patients were slightly more likely to have a recovery rate <50%.	High		(1) Inconsistency of results (1) Indirectness of evidence*
Studies with only patients with OPLL					
Increased age	Insufficient	We are unable to draw a conclusion as to whether older age may be associated with lower JOA RRs based on insufficient strength of evidence from 5 studies. In these studies, age was associated with lower JOA RR in 2 studies and postoperative JOA score in 1 study according to multivariate analysis but was not predictive of postoperative JOA scores in 2 studies. However, we have very little confidence that these results reflect the true effect estimate.	Low		(1) Inconsistency of results
Studies with both patients with CSM and patients with OPLL					
Increased age	Low	Age is a significant predictor of JOA outcome based on data from 2 studies. Specifically, older age was a significant predictor of a JOA RR of <50% (1 study) and with lower JOA RRs (1 of 2 studies).	Low		
Diabetes (and/ or smoking or older age)	Insufficient	We are unable to draw a conclusion as to whether diabetes, either alone or in association with older age or smoking, may be associated with JOA RRs of <50% based on insufficient strength of evidence from 1 study. In this study, diabetes, diabetes and older age, and diabetes and smoking were associated with a poor recovery according to multivariate analysis. However, we have very little confidence that these results reflect the true effect estimate and wide confidence intervals indicate imprecision of the effect estimates.	Low		(1) Imprecision of estimates
CSM and diagnostic factors					
Studies with ≥80% patients with CSM					
Severity of disease	Low	Severity of disease, as measured by preoperative JOA score, may be associated with lower JOA RRs based on data from 6 studies. Specifically, preoperative JOA score was a significant predictor of a decreased JOA score (1 study), JOA RR of <50% (1 study), and the postoperative JOA score (1 study) in multivariate analyses. One study found this factor to be a significant predictor in univariate analysis, but it was not tested in a multivariate analysis (1 study). In contrast, this factor was not significantly predictive of a poor outcome (2 studies) in univariate analyses.	High		(1) Indirectness of evidence* (1) Inconsistency of results
Longer duration of symptoms	Low	Longer duration of symptoms is significantly associated with poorer outcomes based on data from 3 studies. Specifically, it was associated with JOA RR of <50% (1 study), postoperative JOA and JOA LES scores (1 study), and negative JOA RR (1 study). In contrast, this factor was not predictive of an "ineffective" JOACMEQ-L outcome (1 study).	High		(1) Indirectness of evidence* (1) Inconsistency of results

(Continued)

TABLE 9. (Continued)

	Strength of Evidence	Conclusions/Comments	Baseline	UPGRADE (Classes)	DOWNGRADE (Classes)
Severity/degree of stenosis	Insufficient	We are unable to draw a conclusion as to whether severity/degree of stenosis may be associated with poor JOA outcome based on insufficient strength of evidence from 2 studies.	Low		(1) Inconsistency of results
		Two measures of stenosis were associated with a negative JOA RR in 1 study, but only 1 of 2 measures of stenosis in the second study were associated with a decreased JOA score. However, we have very little confidence that these results reflect the true effect estimate.			(1) Imprecision of estimates
Number of levels with compression	Insufficient	We are unable to draw a conclusion as to whether compression of ≥3 levels may be associated with lower JOA score based on insufficient strength of evidence from 1 study. In this study, involvement at ≥3 levels significantly increased the risk of a lower JOA score. However, we have very little confidence that this result reflects the true effect estimate.	Low		(1) Imprecision of estimates
Studies with only patients with OPLL					
Severity of disease	Insufficient	We are unable to draw a conclusion as to whether severity of disease, as measured by preoperative JOA score, may be associated with lower JOA scores or recovery rates based on insufficient strength of evidence from 4 studies. In these studies, a lower preoperative JOA score was associated with a lower postoperative JOA score at the final follow-up or follow-up with maximum JOA score in 2 studies, a lower JOA RR in 1 study, and a decreased JOA postoperative JOA score in 1 study. However, we have very little confidence that these results reflect the true effect estimate.	Low		(1) Indirectness of evidence*
Longer duration of symptoms	Insufficient	We are unable to draw a conclusion as to whether longer duration of symptoms may be associated with lower JOA RRs based on insufficient strength of evidence from 2 studies. In both of these studies, a longer duration of symptoms was associated with lower JOA RR in 2 studies according to multivariate analysis. However, we have very little confidence that these results reflect the true effect estimate.	Low		(1) Indirectness of evidence*
OPLL lesion type	Low	Hill-shaped OPLL lesions are a significant predictor of JOA outcome based on data from 1 study. Specifically, this factor is a significant predictor of both JOA score and JOA RR at the final follow-up and at the time of maximum recovery.	High		(1) Indirectness of evidence* (1) Imprecision of estimates
Severity/degree of stenosis	Insufficient	We are unable to draw a conclusion as to whether severity/degree of stenosis may be associated with lower JOA scores based on insufficient strength of evidence from 2 studies. One study found no association between a measure of stenosis (space available for spinal cord) and JOA score, whereas the other study reported 1 of 2 measures of stenosis (<30% flattening on preoperative MRI) associated with lower JOA scores. However, we have very little confidence that these results reflect the true effect estimate.	Low		(1) Inconsistency of results
Number of levels with compression	Insufficient	We are unable to draw a conclusion as to whether compression of ≥3 levels may be associated with lower JOA score based on insufficient strength of evidence from 1 study. In this study, involvement at ≥3 levels significantly increased the risk of a lower JOA score. However, we have very little confidence that these results reflect the true effect estimate.	Low		(1) Imprecision of estimates
Studies with both patients with CSM and patients with OPLL					
Severity of disease	Low	One study found severity of disease to be a significant predictor of lower postoperative JOA score.	High		(1) Indirectness of evidence* (1) Imprecision of estimates

(Continued)

TABLE 9. (Continued)

	Strength of Evidence	Conclusions/Comments	Baseline	UPGRADE (Classes)	DOWNGRADE (Classes)
Longer duration of symptoms	Low	One study found that a longer duration of symptoms was a significant predictor of a lower postoperative JOA score.	High		(1) Indirectness of evidence* (1) Imprecision of estimates
Radiographical/neurological factors					
Studies with ≥80% patients with CSM					
Local kyphosis	Insufficient	We are unable to draw a conclusion as to whether local kyphosis angle >5° may be associated with a JOA RR of <50% based on insufficient strength of evidence from 1 study. In this study, a local kyphosis angle of >5° was associated with JOA RR of <50% according to multivariate analysis. However, we have very little confidence that these results reflect the true effect estimate.	Low		(1) Imprecision of estimates
Signal intensity change/ratio	Insufficient	We are unable to draw a conclusion as to whether T2 and/or T1 signal changes on MRI may be associated with poor outcome based on insufficient strength of evidence from 3 studies. T2 signal intensity changes were not significantly associated with an ineffective result or JOA RR of <50% in 1 study, or with a negative recovery rate in 1 study. In contrast, concurrent T1 and T2 changes were associated with a recovery rate of <50% in the third study; a wide confidence interval suggests great variability for the effect estimate. However, we have very little confidence that these results reflect the true effect estimate.	Low		(1) Inconsistency of results (1) Indirectness of evidence*
Studies with only patients with OPLL					
Signal intensity change/ratio	Insufficient	We are unable to draw a conclusion as to whether T2 and/or T1 signal changes on MRI RRs based on insufficient strength of evidence from 1 study. In this study, an increased T2 signal intensity ratio with positive pyramidal signs was associated with a lower JOA RR. However, we have very little confidence that these results reflect the true effect estimate.	Low		(1) Imprecision of estimates (1) Indirectness of evidence*
Studies with both patients with CSM and patients with OPLL					
Signal intensity change/ratio	Insufficient	We are unable to draw a conclusion as to whether T2 and/or T1 signal changes on MRI may be associated with lower JOA RRs or decreased JOA scores based on insufficient strength of evidence from 2 studies.	Low	No	(1) Indirectness of evidence*
		Concurrent T1 and T2 changes were associated with JOA RR of <50% (1 study), a lower JOA RR (1 study), and a decreased JOA score (1 study). However, we have very little confidence that these results reflect the true effect estimate.			

Baseline quality: High = Majority of articles level I/II. Low = Majority of articles levels III/IV.
UPGRADE: Large magnitude of effect (1 or 2 classes); dose-response gradient (1 class).
DOWNGRADE: Inconsistency of results (1 or 2 classes); indirectness of evidence (1 or 2 classes); imprecision of effect estimates (1 or 2 classes).
*The following factors provide indirect evidence in that they are surrogate measures that may or may not reflect changes in an outcome important to patients: increased age, severity of disease as measured by JOA score or JOA RR, longer duration of symptoms, OPLL lesion type, and signal intensity change/ratio.
CSM indicates cervical spondylotic myelopathy; JOA, Japanese Orthopedic Association; JOACMEQ-L, Japanese Orthopedic Association Cervical Myelopathy Evaluation Questionnaire lower extremity function section; JOA LES, JOA lower extremity score; JOA RR, JOA recovery rate; MRI, magnetic resonance imaging; OPLL, ossification of posterior longitudinal ligament.

Figure 2. Successful laminoplasty case: 62-year-old male with multilevel cervical stenotic myelopathy and with a lordotic spine underwent C3–C7 laminoplasty with open-door technique with laminoplasty plates. Postoperatively, the patient has no neck pain, preserved motion, normal alignment, and excellent resolution of myelopathic symptoms. **A**, Preoperative lateral radiograph. **B**, Preoperative mid-sagittal magnetic resonance image. **C**, Postoperative lateral radiograph.

"insufficient," that is, the available evidence does not permit a conclusion.

Further details are available in Table 9.

DISCUSSION

Overall, reporting of the multivariate analyses for the studies was poor; many studies did not state explicitly the variables included in the multivariate regression models or how the final regression model was selected. This, combined with the failure of authors to describe the magnitude of effect estimates adequately, makes it difficult both to assess the overall strength of evidence across studies and to draw meaningful conclusions for some predictive factors. In this report, the OR is liberally interpreted to be an estimate of relative risk; however, because the prevalence of a poor outcome was not reported in most studies reporting ORs, the OR may overestimate the relative risk and caution should be exercised in interpreting the risk of a poor outcome. Wide CIs suggest greater variability in effect estimates and call into question the certainty of the effect estimate.
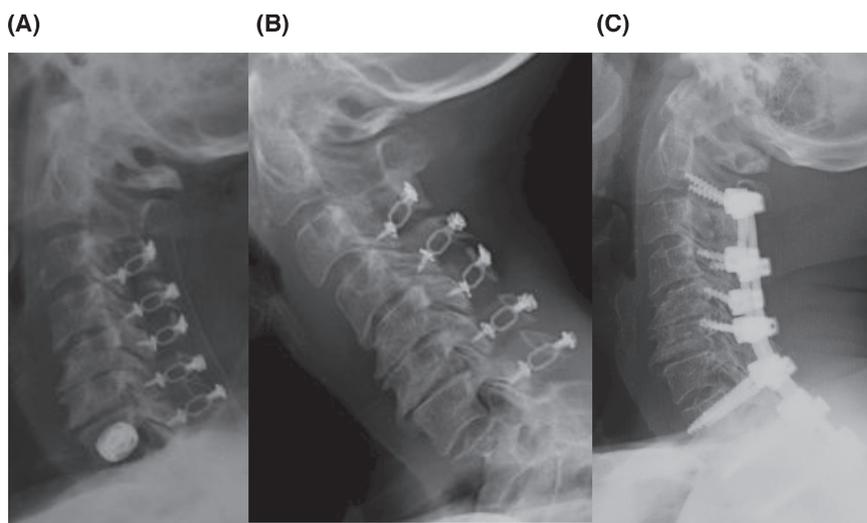
The varying definitions of outcome across studies and failure in some studies to define thresholds for improved or worse scores precluded the pooling of data and made meaningful synthesis challenging. None of the authors provided a definition

of a clinically meaningful improvement for any outcome. One author group[15] reported performing a logistic regression yet reported an HR (assumed to be a hazard ratio). We reported the OR, which is the appropriate measure from a logistic regression.

It is not surprising that preoperative (baseline) JOA scores are associated with the JOA outcome measures. The formula for calculating the JOA recovery rate includes the preoperative JOA score, which adjusts for, or takes into account, the preoperative baseline JOA score. Some of the factors were considered indirect measures because it is not clear to what extent they may have a direct influence on the outcome(s) of interest and how they may influence patient counseling or clinical decision making. Such factors include lesion type/configuration, changes in magnetic resonance signal, and increased age. Factors such as symptom intensity and duration may be subjective.

With regard to age as a risk factor, 5 of the studies assessed it as a potential factor, but because a univariate association was not found, it was not included in final multivariate models. In multivariate analyses, 1 study found that age and diabetes together were significant predictors of a poor recovery, 3 studies found that age alone was a significant predictor of a poor recovery, and 3 studies found that age did not increase the risk of a poor recovery. Study sample size and/or degree

Figure 3. Failed laminoplasty case: 58-year-old petite female with multilevel cervical spondylitic myelopathy had laminoplasty C3–C7 for multilevel disease. She did well for 3 months but began complaining of difficulty holding up her head, especially toward the end of the day. Despite physical therapy for strengthening, her alignment wand neck pain worsened to an intolerable level. Two years after the index procedure, she had a C2–T3 posterior fusion. This improved her alignment and resolved her neck pain completely. **A**, Lateral radiograph after index procedure. **B**, Lateral radiograph 2 years after the index procedure. **C**, Lateral radiograph after posterior fusion.

of variation in age in some studies may have influenced the ability to detect a statistical association.

We have included illustrative cases of a successful laminoplasty (Figure 2A–C) and a failed laminoplasty (Figure 3A–C).

Evidence-Based Clinical Recommendations.

Recommendation 1. For CSM patients, increased age is not a strong predictor of clinical neurological outcomes following laminoplasty, therefore age by itself should not preclude cervical laminoplasty for CSM.

Overall Strength of Evidence. Low

Strength of Recommendation. Strong

Recommendation 2. For CSM patients, increased severity of disease and longer duration of symptoms might be associated with poorer clinical neurological outcomes following laminoplasty, therefore we recommend that patients be informed about this.

Overall Strength of Evidence. Low

Strength of Recommendation. Strong

Summary Statements. For OPLL patients, Hill-shaped lesions might be associated with poorer clinical neurological outcomes following laminoplasty therefore surgeons might consider potential benefits and risks of alternative or additional surgery.

➤ Key Points

- ❑ A systematic search of the literature identified 12 studies with at least 20 patients; 3 studies that used multivariate analysis to analyze predictive factors for outcomes after cervical laminoplasty for the treatment of CSM or OPLL.

- ❑ For patients with CSM, increased age was not associated with a poorer clinical outcome, but for patients with OPLL, there is insufficient evidence to arrive at a conclusion.

- ❑ For patients with CSM, increased severity of disease and a longer duration of symptoms might be associated with worse clinical outcome.

- ❑ For patients with OPLL, hill-shaped lesions might be associated with poorer clinical outcomes.

Acknowledgments

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