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# Cervical laminoplasty for the treatment of cervical degenerative myelopathy

**Paul G. Matz, M.D.,[1] Paul A. Anderson, M.D.,[2] Michael W. Groff, M.D.,[3] Robert F. Heary, M.D.,[4] Langston T. Holly, M.D.,[5] Michael G. Kaiser, M.D.,[6] Praveen V. Mummaneni, M.D.,[7] Timothy C. Ryken, M.D.,[8] Tanvir F. Choudhri, M.D.,[9] Edward J. Vresilovic, M.D., Ph.D.,[10] and Daniel K. Resnick, M.D.[11]**

*[1]Division of Neurological Surgery, University of Alabama, Birmingham, Alabama; Departments of [2]Orthopaedic Surgery and [11]Neurological Surgery, University of Wisconsin, Madison, Wisconsin; [3]Department of Neurosurgery, Harvard Medical School and Beth Israel Deaconess Medical Center, Boston, Massachusetts; [4]Department of Neurosurgery, University of Medicine and Dentistry of New Jersey—New Jersey Medical School, Newark, New Jersey; [5]Division of Neurosurgery, David Geffen School of Medicine, University of California at Los Angeles, California; [6]Department of Neurological Surgery, Neurological Institute, Columbia University, New York, New York; [7]Department of Neurosurgery, University of California at San Francisco, California; [8]Department of Neurosurgery, University of Iowa Hospitals and Clinics, Iowa City, Iowa; [9]Department of Neurosurgery, Mount Sinai School of Medicine, New York, New York; and [10]Department of Orthopaedic Surgery, Milton S. Hershey Medical Center, Pennsylvania State College of Medicine, Hershey, Pennsylvania*

*Object*. The objective of this systematic review was to use evidence-based medicine to examine the efficacy of cervical laminoplasty in 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 cervical laminoplasty and CSM. Abstracts were reviewed and studies meeting the inclusion criteria were selected. The guidelines group assembled an evidentiary table summarizing the quality of evidence (Classes I–III). Disagreements regarding the level of evidence were resolved through an expert consensus conference. 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 and Congress of Neurological Surgeons.

*Results*. Cervical laminoplasty has improved functional outcome in the setting of CSM or ossification of the posterior longitudinal ligament. Using the Japanese Orthopaedic Association scale score, ~ 55–60% average recovery rate has been observed (Class III). The functional improvement observed after laminoplasty may be limited by duration of symptoms, severity of stenosis, severity of myelopathy, and poorly controlled diabetes as negative risk factors (Class II). There is conflicting evidence regarding age, with 1 study citing it as a negative risk factor, and another not demonstrating this result.

*Conclusions*. Cervical laminoplasty is recommended for the treatment of CSM or ossification of the posterior longitudinal ligament (Class III). *(DOI: 10.3171/2009.1.SPINE08726)*

**Key Words** • **cervical spine** • **cervical spondylosis** • **laminoplasty** • **myelopathy** • **practice guidelines** • **treatment outcome**

## Recommendations

*Indications: Cervical Spondylotic Myelopathy and OPLL*. Cervical laminoplasty is recommended in the treatment of myelopathy in the setting of CSM or OPLL. Using the JOA scale, ~ 55–60% recovery rate is anticipated (quality of evidence, Class III; strength of recommendation, D). The functional improvement observed after laminoplasty may be limited by duration of symptoms, severity of stenosis, severity of myelopathy, and poorly controlled diabetes as risk factors. There is conflicting evidence regarding age with 1 study citing age as a risk factor, and another not demonstrating this result (quality of evidence Class II).

*Technique: Cervical Laminoplasty*. Cervical laminoplasty is recommended in the treatment of myelopathy in the setting of CSM or OPLL. However, outcomes from laminoplasty are equivalent to those achieved with ACF

*Abbreviations used in this paper:* ACDF = anterior cervical discectomy and fusion; ACF = anterior cervical fusion; CSM = cervical spondylotic myelopathy; EMG = electromyography; JOA = Japanese Orthopaedic Association; OPLL = ossification of the posterior longitudinal ligament; ROM = range of motion.

and laminectomy with arthrodesis. Evidence is unclear regarding differences in complication rates between these techniques (quality of evidence, Class III; strength of recommendation, D).

*Timing*. There is insufficient evidence to make a recommendation regarding timing of surgery.

## Rationale

The purpose of this review is to examine questions regarding the efficacy of laminoplasty using an evidence-based approach. Cervical laminoplasty was described in the 1970s as an alternative to laminectomy in patients with myelopathy.[10] The impetus for laminoplasty was the desire to decompress long segments while avoiding postlaminectomy membrane formation and/or kyphotic deformity.[10] The authors of multiple reports have demonstrated that laminoplasty increases canal diameter.[23,28] However, this increase in canal diameter appears to be at the expense of pain and diminished ROM.[4,21,30,31,33,36,39,43]

Different approaches to laminoplasty include the open-door, the midline "French-window," and the Z-plasty techniques.[10,31] Each of these techniques permits expansion of the canal while providing a dorsal laminar cover. Specific questions regarding laminoplasty include its effectiveness in improving myelopathy, its efficacy compared to other techniques for decompression, and its complication rate. Other issues include diminished ROM, pain, and preoperative predictors of clinical outcome in patients undergoing this approach.

## Search Criteria

We performed a computerized search of the National Library of Medicine database and the Cochrane database of the literature published between 1966 and 2007. We used standard keywords 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. We selected only citations in English, and reviewed the titles and abstracts. Additional references were culled from the reference lists of the remaining articles.

Among the studies reviewed, 46 dealt with cervical laminoplasty and outcome, including functional outcome and ROM (Table 1). These studies also assessed complication rates, pain, and prognostic factors. Sixteen of these studies compared laminoplasty to a different surgical approach. One article was a meta-analysis review of laminoplasty. The remaining studies examined functional improvement, especially myelopathy, using the JOA scale.

## Scientific Foundation

Clinicians have used laminoplasty to treat cervical myelopathy primarily resulting from CSM or OPLL. Quantitative outcome measures for cervical myelopathy are many. Most studies used the JOA and Nurick scales.[5,29] The JOA scale is a reliable, valid, and responsive measure. Although more traditional, the Nurick scale has not been studied in as great detail.

## Effectiveness

Multiple studies have demonstrated the effectiveness of laminoplasty within a group of patients. Using the JOA outcome scale, the average recovery for patients was 55–65%.[4,10,12,21,25,28,31,33,36,38] None of these studies used a nonoperated control group.[31] Accordingly, the data supporting their conclusions is Class III. In the short term, Kihara et al.[21] reported on 151 patients with myelopathy (average age of 62 years, mean symptom duration 31 months), 132 with CSM, and 19 with OPLL. Surgeries were completed over a 7-month period. The mean JOA scale score increased from 8.1 to 15.2 at the 1-year follow-up examination ($p < 0.01$). Multiple other Class III studies corroborated this type of short-term improvement.[31]

Suda et al.[38] reported on 154 patients with CSM over an 18-year span who underwent French-window laminoplasty. Follow-up was possible in 114 patients (mean age 60 years), for an average of 5 years. The JOA scale score improved from 9.9 to 14.0 (60% improvement) in this series. To assess outcomes over a longer period of time, Seichi et al.[36] reviewed 60 patients (mean age 54.5 years; 35 with OPLL and 25 with CSM) who underwent French-window laminoplasty with 10 years of follow-up. In the OPLL group, the JOA scale score increased from 8.6 to 12.1; similar increases were seen in the patients with CSM (improvement from 8.3 to 12.0). Late clinical worsening was observed in 11 patients (7 with OPLL and 4 with CSM). Several other Class III studies corroborated clinical improvement maintained over 5[30,33] and 10 years.[13,18,43] However, in their study, Ogawa and colleagues[30] noted functional decline as evidenced by lower JOA scale scores 5 years after laminoplasty.

## Prognosis

Any discussion regarding efficacy should be tempered by a discussion of prognosis because there likely exist patients who are not going to benefit. Conventional wisdom would argue that increasing age would be a risk factor, but laminoplasty studies have produced conflicting results. The authors of some studies have reported age to be a risk factor,[18,23,35,45] while others did not come to the same conclusions.[6,17,40,45,46] Kohno et al.[23] examined 22 patients (mean age 60 years) with myelopathy (CSM in 12 and OPLL in 5) who underwent French-window laminoplasty and participated in follow-up for 5 years. The average JOA scale score recovery was 51% of the maximum. The authors stratified their results into good (> 50% recovery) and fair (< 50% recovery). The average age in the good recovery group was 56 years, compared to 64 years in the fair recovery group ($p < 0.05$). This study was rated Class II for prognosis because the patients were all eligible for and underwent the same treatment.

In their study of 61 consecutive patients, Handa et al.[6] reported results indicating that increased age was not a risk factor. Patients were stratified into those older than 70 years of age (22 patients, mean age 74 years) and those younger (39 patients, mean age 57 years). Postoperative evaluation at 1 year after open-door laminoplasty revealed recovery rates of 59% in the younger and 62% in older group. This study was graded Class II because patients were studied as a cohort and all were eligible for the same treatment. Yamazaki et al.[46] took a different approach in their study of 64 patients with CSM who underwent French-window laminoplasty. The authors stratified groups into those younger than 65 years (29 patients with a mean age of 53 years) and those older (35 patients with a mean age of 79 years). Evaluation took place over 3.5 years. In the younger group, the JOA scale score improved from 14.8 to 15.8 (62% recovery). In the older group, the JOA scale score improved from 12.0 to 14.6 (59% recovery). There was a significant difference between final JOA scale scores (15.8 vs 14.6; $p < 0.05$) but not recovery (62 vs 59%; $p = 0.758$). This study was rated Class III because the starting JOA scale score in the younger group was significantly higher than in the older group. This bias invalidated the comparison.

Less controversial were evaluation of duration and severity of symptoms. The studies undertaken by Yamazaki et al.[46] (rated Class III) and Handa et al.[6] (rated Class II) examined severity (mean transverse area at maximum compression and canal diameter) and duration of symptoms. Both groups found that symptom durations longer than 12 months portended a better outcome in elderly patients. Yamazaki and colleagues[46] also concluded that a smaller mean transverse area negatively affected all patients; however, in the study by Handa et al.,[6] more severe stenosis impaired outcome only in elderly patients.

Three Class II studies associated lower JOA scale scores with a worse outcome. In the study of Handa et al.,[6] outcome relative to preoperative JOA scale scores was evaluated in the young and the elderly. A JOA scale score < 12 was associated with a worse outcome, but only in patients younger than 70 years of age. Iwasaki et al.[13] studied 92 patients with OPLL who underwent open-door laminoplasty over an 8-year period. Only 64 patients were evaluated because the minimum follow-up was 10 years (25 patients died and 3 were lost to follow-up). Although the JOA scale score improved from 8.9 to 13.8, a low JOA scale score carried a strong negative prognosis ($p < 0.0001$). The patients who died also had a mean preoperative JOA scale score of 6.9—confirming the poor prognosis associated with severe myelopathy.[13] Kamizono et al.[15] reviewed 301 patients with OPLL who underwent open-door laminoplasty (mean age 58 years, 8-year follow-up period). The pre- and postoperative JOA scale scores were evaluated along with symptom duration and exertion required by the patient's job. A JOA scale score < 9, either pre- or postoperatively, was negatively associated with return-to-work, as was the extent of exertion required by the job. Duration did not affect return-to-work. This study was evaluated as Class II for prognosis.

The authors of 2 Class II studies dealt with specific prognostic issues. Kawaguchi et al.[19] studied 18 patients with CSM and OPLL who had diabetes mellitus (mean age 66 years), and underwent open-door laminoplasty. These authors compared these 18 patients with 34 patients in a control group who underwent the same therapy but did not have diabetes mellitus. Recovery for both groups was the same according to the JOA scale score (12.6 with diabetes and 13.3 without; $p = 0.25$). Within the diabetes group, the authors observed a negative correlation between JOA scale score and hemoglobin bA1c levels ($r = -0.61$, $p < 0.03$). This study was graded as Class II for prognosis. Baba et al.[1] examined posterior cord migration in 55 patients who underwent open-door laminoplasty. The authors used an index that examined the distance from the anterior spinal canal (posterior surface of the vertebral body) to the center of the spinal cord. Using this system, the authors reported an average shift of 55.3% relative to baseline in patients whose JOA scale scores improved > 50%, and an average shift of 27.7% relative to baseline in patients whose JOA scale scores improved < 50%. Matsuyama et al.[27] reported on 44 patients with cervical myelopathy (26 with CSM and 18 with OPLL) who underwent laminoplasty. The authors measured the cross-sectional area, sagittal diameter, and transverse diameter of the spinal cord prior to surgery, immediately afterward, and 1 month postoperatively. They correlated results with JOA scale scores. Increased cross-sectional area was considered "expansion." The authors found that gradual expansion (over the course of 1 month) was associated with a 68.4% recovery rate, while a 32.6% recovery rate was seen without gradual expansion. This study was graded Class III because observers were not necessarily blinded to preoperative JOA scale scores, and the uncertainty regarding selection bias as to who was chosen for surgery.

Wada et al.[44] discussed a series of 50 patients with CSM who underwent laminoplasty. This was part of an initial series of 85 patients. Ten patients were excluded and another 25 did not undergo postoperative imaging. These authors found that a transverse cord area < 40 $mm^2$, a long duration of symptoms, and a poor anteroposterior canal ratio correlated with poor outcome. Less predictive were patient age and presence of a poor preoperative JOA scale score. Importantly, multisegmental hyperintensity on T2-weighted images correlated strongly with a poor outcome ($p < 0.01$). This study was graded Class III due to nonblinded outcome assessment and the loss of 25 patients from the series.

### Range of Motion and Pain

Laminoplasty has been associated with an aggregate loss of ROM.[4,21,30,31,33,36,43] However, diminished ROM has not always signified poor outcome. In the Class III study of Kihara et al.[21] described above, 151 patients (132 with CSM and 19 with OPLL) underwent open-door laminoplasty over a 7-month period. As stated, the mean JOA scale score improved significantly in this cohort. Simultaneously, ROM decreased from 36.9 to 29.1° ($p < 0.01$). Saruhashi and colleagues reviewed 30 patients who underwent French-window laminoplasty for CSM.[33] Patients were followed up for 5 years, and JOA scale scores

**TABLE 1: Evidentiary summary of studies regarding treatment outcome and laminoplasty for cervical degenerative myelopathy***

| Authors & Year | Description | Results | Class | Conclusions |
|---|---|---|---|---|
| Iwasaki et al., 1996 | 33 patients w/ soft cervical disc displacement. From 1984–1987, 17 patients underwent cervical ACF (Group A). Between 1987–1993, 16 patients underwent ODL (Group B). | In ACF group, mean FU 105 mos vs 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%) vs 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. |
| Hirabayashi & Satomi, 1988 | Technique of ODL described in 90 patients w/ avg FU of 3 yrs; 55 patients w/ OPLL & 35 w/ CSM. | 55 patients had OPLL while 35 had CSM. Only general criteria used for FU. Generally good results. | III | ODL can be used effectively. |
| Saruhashi et al., 1999 | 30 patients underwent FWL for CSM; avg FU of 5 yrs. Evaluation by JOA scale score & cervical angle. | The avg JOA increased from 8.8 to 11.9; the improvement score was 36.6 ± 21.5% ($p < 0.001$). Patients divided into 2 groups (deteriorated alignment (decreased 12.5°) & preserved (increase 1.1°); no change in clinical outcome. | III | FWL is clinically effective; however, deterioration of alignment may develop but is not associated w/ clinical worsening. Grade III for small series & poorly described enrollment. |
| Kihara et al., 2005 | 151 patients over 7 mos underwent ODL w/ hydroxyapatite spacers. Mean age 62 yrs w/ duration of symptoms avg 31 mos. | 132 patients w/ degeneration & 19 w/ ossification of ligaments. Mean JOA increase from 8.1 to 15.2 at 1 yr ($p < 0.01$) but ROM diminished from 36.9° to 29.1° at same time ($p < 0.01$). | III | Technique effective for clinical improvement; however, ROM is diminished but not clinically deleterious. |
| Edwards et al., 2000 | 18 patient series of T-saw laminoplasties (split) for cervical spondylosis. Avg age was 54 yrs w/ mean FU of 24 mos. Evaluation by Nurick scale, Robinson pain scale, cervical ROM on plain radiography, MRI. | Nurick scale improved from 2.7 to 0.9 ($p < 0.002$), Robinson pain from 2.0 to 0.9 ($p < 0.002$); cervical ROM decreased from 37° to 23° ($p < 0.05$); 1 C-5 palsy resulted. MRI only in 5 patients. | III | Laminoplasty reduces pain & improves function but limited ROM. Pavlov ratio may be increased ($p < 0.001$) on plain radiographs. |
| Seichi et al., 2001 | 60 patients underwent FDL. OPLL in 35 & CSM in 25 w/ 10-yr FU. Assessment made of long-term decline & JOA score & ROM. | OPLL: JOA increased from 8.6 to 12.1 over 10 yrs while ROM decreased from 36 to 8°.<br>CSM: JOA increased from 8.3 to 12.0 in same interval w/ ROM reduced from 47° to 13°.<br>OPLL group had 7 worse while CSM had 4 worse. | III | Laminoplasty has good long-term improvement despite diminished ROM in both OPLL & CSM. However, worsening may occur in ~20% w/ athetoid palsy worse. |
| Wada et al., 2001 | Subtotal corpectomy vs ODL in different yrs for CSM. Corpectomy (Group A, n = 23, 2.5 levels, 15-yr FU, avg age 53 yrs). Laminoplasty (n = 24, 12-yr FU, avg age 56 yrs). JOA used to follow along w/ evaluation of ROM & axial pain. | JOA scores changes similar in A (7.9 to 13.4) & 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, increase pain & decreased ROM w/ laminoplasty & increase in C-5 palsy; corpectomy carries risk of pseudarthrosis. |
| Suda et al., 2003 | 154 CSM patients over 18 yrs; FU in 114 patients. Avg age 60 yrs, mean FU 5 yrs. FWL avg 5 levels. | JOA improved 9.9 to 14 (60%) improvement. 86 patients >50% (good) & 28 patients <50% (poor). C2–7 angle (lordosis vs kyphosis, $p < 0.05$ predictive), local kyphosis ($p < 0.05$ predictive for poor), ISI increased in poor group ($p < 0.05$). | III | General improvement w/ laminoplasty. However, kyphosis & ISI associated w/ poor outcome. Heterogeneity in description of kyphosis (sometimes loss of lordosis & others, truly kyphosis). |
| Kawaguchi et al., 2003[17] | 106 patients over 18-yr period w/ CSM. ODL but FU in 89 patients only. Group A (n = 20, >70 yrs) & Group B (n = 69, <70 yrs). Avg FU 3.3 yrs. | Avg preop JOA in Group A, 6.0 & in Group B, 8.9 ($p < 0.001$). Matched groups w/ similar JOA (n = 20 each) compared. No difference in recovery (45% elderly vs 58% young, $p = 0.13$). | III | Class III due to post-hoc matching. Age does not appear to affect outcome. However, a higher rate of postop listhesis in elderly (70% vs 13%). No difference in ROM or diameter. |
| Morimoto et al., 1997 | 20 patients w/ OPLL underwent FWL over 10-yr period. Avg age 51 yrs w/ 3-yr FU. Assessment using JOA & CT scans. | JOA improved from 7.9 to 14.1 w/ 42% increase in canal size & 96% fusion rate. | III | Laminoplasty effective over 3 yrs clinically & radiographically. |

*(continued)*

**TABLE 1: Evidentiary summary of studies regarding treatment outcome and laminoplasty for cervical degenerative myelopathy* *(continued)***

| Authors & Year | Description | Results | Class | Conclusions |
|---|---|---|---|---|
| Lee et al., 1997 | 25 patient series of ODL for CSM over 4-yr period. Avg age was 60 yrs w/ duration 1.5 yrs. | Nurick grade improved from 2.76 to 1.80 ($p < 0.05$, t-test). Gait & numbness improved subjectively in 80%. SC/VB ratio improved 38% ($p < 0.05$). | III | Over 2.5 yrs, laminoplasty is effective. Clinical improvements correlate w/ increased canal diameter. |
| Ogawa, et al., 2004 | 139 patients underwent ODL for OPLL over 14-yr period. 72 patients had min 5-yr FU (9.5-yr avg). Symptom duration was 3.5 yrs. | JOA scores improved from 9.2 to 14.2 at 3 yrs & maintained through 5 (63% recovery) but diminished after 5 yrs. Limited ROM & C-5 paralysis occurred in 7%. | III | Clinical improvement in laminoplasty w/ reduction after 5 yrs. Moderate incidence of C-5 palsy. |
| Ratliff & Cooper, 2003 | Meta-analysis of 71 clinical series w/ 2580 patients; JOA outcome used in 41 series. Several techniques included ODL, Z-plasty, & FWL. | No Class II studies for outcome. When JOA score used, recovery rate was 55%. Postop alignment was worse in 35% w/ 10% kyphosis. ROM diminished by 50%. C-5 radiculopathy in 8%. | III | Laminoplasty series tend to show improvement at expense of ROM & alignment. Technique does not appear to matter. Issue of C-5 radiculopathy. |
| Baba et al., 1996 | 55 patients (38 CSM & 17 OPLL) underwent ODL (age 64 yrs, avg FU 2.4 yrs w/ range 1–4.2 yrs). Evaluation of posterior cord shift. | Posterior cord migration correlated w/ improvement in JOA (significant). Posterior shift 55.3 in patients who had JOA recovery >50% ($n = 37$) & 22.7 in patients ($n = 18$) w/ JOA recovery <50% ($p < 0.02$, chi-square test). | II | Clinical improvement correlates w/ improved JOA scale score significantly. |
| Matsuyama, et al., 1995 | 44 patients (26 CSM & 18 OPLL) underwent laminoplasty (age 58 yrs). Evaluation w/ CT myelography to determine cross-sectional area, sagittal diameter, & transverse diameter preoperatively, postoperatively, & at 1 mo postop. Outcome using JOA scale. | Gradual spinal cord expansion at 1 mo was associated w/ 68.4% recovery rate while the absence of gradual expansion was associated w/ a 32.6% recovery rate. | III | Gradual expansion is associated w/ a better recovery rate. This study was graded Class III b/c it was not evident whether observers were blinded to JOA scores & whether the intrarater reliability was tested. |
| Yamazaki et al., 2003 | 64 CSM patients underwent FWL over 18 mos; 29 patients <65 yrs (Group A, 53 yrs, male preponderance) & 35 patients >65 yrs (Group B, 79 yrs, female preponderance). 3.5-yr FU. | JOA: Group A, 14.8→15.8 (62% recovery); Group B, 12.0→14.6 (59% recovery). Recovery not significantly different but pre- & postop JOA scale scores differed. Mean transverse are at maximum compression predicted outcome in both groups; duration predicted outcome in Group B. | III | Age does not appear to affect recovery after laminoplasty; prognosis related to severity of stenosis & also duration (in elderly). Case mix may be skewed by sex difference. Class III b/c of different starting JOA scales created bias. |
| Tanaka et al., 1999 | 47 patients of 64 reviewed w/ CSM who underwent FWL. Avg age 77 yrs. Avg no. of operated levels was 4.5. Avg 11-mo FU. | Stratification into age groups 65–75, 76–79, & >80 years. Avg JOA score improved from 7.6 to 9.6 (20% recovery) w/ no significant difference between groups. However, duration of gait problems over 3 mos or hand dysfunction longer than 1 yr has worse recovery in 26 patients. | III | Laminoplasty appears to be age indifferent. In a random subgroup, duration of symptoms seems to be a negative correlate for hand function & gait. |
| Kamizono et al., 2003 | 301 patients w/ myelopathy from OPLL studied after ODL. Avg age 58 w/ 8-yr FU. Assessment of return to work (full, partial, none). | Pre- & postop JOA scores <9, 9–12, >12 correlated w/ return to work. 53% returned to work but correlation to heavier labor. | II prognosis | Return-to-work correlated w/ higher JOA scores & sedentary labor. |
| Satomi et al., 2001 | 206 patients w/ avg age of 57 yrs. OPLL in 106 & CSM in 98. Prognosis studied in 80 patients w/ 5-yr FU min. Technique of ODL w/ or w/o spacers. | Complication rate 10.8% w/ 7.8% weakness. Closure of laminae 1.5%. Recovery & age (76% <60 vs 41% >60, $p < 0.001$). Recovery & duration (79% <1 yr vs 53% >1 yr, $p = 0.003$); sagittal diameter or preop JOA not significant. | III | Class III due to subgroup selection of cohort. Age of patient & duration of symptoms affect prognosis. |

*(continued)*

**TABLE 1: Evidentiary summary of studies regarding treatment outcome and laminoplasty for cervical degenerative myelopathy* *(continued)***

| Authors & Year | Description | Results | Class | Conclusions |
|---|---|---|---|---|
| Kohno et al., 1997 | 22 patients w/ myelopathy (CSM 12, OPLL 5, combined 5) treated w/ FWL over 4 yrs. Avg age 60 yrs; FU 5 yrs. | Avg recovery was 51% JOA. Stratified into good (>50% & fair <50%). Age significantly different in groups (good 56 yrs vs fair 64 yrs, $p < 0.05$). ISI on MRI less frequently seen in good (18% vs 82%). Area of spinal canal increased more in good group ($p < 0.05$). | III efficacy, II prognosis | Age may affect conclusion. Age appears to be negative factor for outcome along w/ area of diameter. ISI more frequent in poor outcome. |
| Wang et al., 2004 | 204 patients w/ CSM underwent ODL over 15 yrs. Avg age 63 & avg FU 16 mos. | Nurick scores improved in 62%; age >75 yrs did not appear to affect outcome. | III | Laminoplasty effective for CSM over short term. |
| Kawaguchi et al., 2003[18] | 126 patients w/ myelopathy (CSM = 57, OPLL = 69). ODL. Avg age 60 yrs w/ 13.2-yr FU. However, FU available in only 73 b/c 42 patients died & 11 were lost to FU. | JOA recovery rates were significantly better w/ age 65% (<60 yrs) & 49% (>60 yrs). If starting JOA score <8, no correlation w/ outcome (51 vs 59% JOA >8). Cervical angle decreased from 13.5 to 4.8° but canal diameter larger. | III | Laminoplasty effective over 10-yr period but is associated w/ kyphosis. Age appears to be prognostic, severity of myelopathy does not appear to be a prognostic factor. Significant numbers lost to death which skews conclusions. |
| Iwasaki et al., 2002 | 92 patients w/ OPLL underwent ODL over 8-yr period; 64 pts in series since 25 died & 3 lost to FU. Avg age 56 yrs w/ min FU 10 yrs. | JOA improved from 8.9 to 13.8; expired patients had preop JOA 6.9. Recovery was 60% at 3–10 yrs but reduced to 54% after 10 yrs. Age at op had negative trend ($p = 0.064$) & low JOA score had strong negative trend ($p < 0.0001$). Kyphosis in 8% & C-5 radiculopathy in 5% postop. | II, prognosis | Laminoplasty may be effective but severity of JOA score is negative risk factor. After 10 yrs, clinical improvement declines. |
| Handa et al., 2002 | 61 consecutive patients w/ CSM. Stratified into elderly (age >70 yrs, mean 74; n = 22) & young (age <70 yrs, mean 57; n = 39). ODL over 9-yr period w/ 12 mos FU. | Elderly had mean recovery of 59% while young had mean recovery of 62% (difference not significant). In elderly, outcome related to duration of symptoms (>12 mos) & severity of stenosis. In young, JOA score <12 negative risk factor. | III efficacy, II prognosis | No difference in outcome age over 70 vs younger. Class III for predictive factors: no uniform predictive factor. Duration & severity of stenosis in elderly & JOA score in young. |
| Kawaguchi et al., 2000[19] | 18 patients w/ CSM/OPLL w/ DM (age 66 yrs, 3-yr FU) vs 34 historical controls w/o DM (age 65 yrs, 4.7-yr FU). | Recovery 55% w/ DM & 61% w/o DM based on JOA; however, negative correlation between JOA & HgbA1c ($r = 0.61$, $p < 0.03$). | II prognosis | Comparison between DM & non-DM Class III due to historical controls; however, DM appears not to affect outcome. However, poorly controlled DM negatively affects outcome. |
| Kaminsky et al., 2004 | 20 consecutive patients (avg age 53 yrs) w/ CSM underwent ODL (A) vs 22 matched controls who underwent laminectomies (B, avg age 54 yrs). Min FU 3 yrs, avg 5 yrs. | Avg no. of levels decompressed was 4.3 in A, & 4.6 in B. Nurick preop was 2.44 in A & 3.09 in B ($p < 0.0001$). Recovery was 2.44→1.48 (48.6%) in A & 3.09 →2.50 (17.8%) in B ($p < 0.0001$). Pain level reduced in A (57% vs 8%, $p < 0.004$); however, preop pain level significantly higher in A. | III | Class III due to historic controls & lack of similar preop Nurick status & lack of similar pain severity. Conclusion was that laminoplasty provides better results clinically at 3–5 yrs w/ less ROM. It reduces pain. |
| Kawaguchi et al., 2003[16] | 28 patients w/ CSM underwent modified laminoplasty (alternating spacers w/ no bone on hinge, 1997–2000) vs 28 historical controls who underwent ODL (1982–96); modified (age 62.7 yrs; FU 2.4y); ODL (60.4 yrs, 2.8-yr FU). | ROM in modified preserved 71% vs 48% in controls ($p < 0.02$); levels fused in former 0.8 vs 2.1 in latter ($p < 0.0001$). | III | Class III for historical controls; modified technique preserves ROM. |

*(continued)*

**TABLE 1: Evidentiary summary of studies regarding treatment outcome and laminoplasty for cervical degenerative myelopathy* *(continued)***

| Authors & Year | Description | Results | Class | Conclusions |
|---|---|---|---|---|
| Maeda et al., 2002 | 44 patients w/ OPLL underwent FWL. Avg age was 59 yrs w/ 3.2 yrs FU. | FUs only available in 30 of 44 patients. Curvature index of Ishiara decreased from 14.5% to 2%. Decrease in ROM was 41.3° to 24°. This correlated w/ decreased function on JOA. | III | Negative correlation between loss of lordosis & JOA. |
| Hosono et al., 1996 | 98 patients w/ CSM (avg age 58 yrs, min 2-yr FU) underwent ODL (n = 72) or ACF (n = 26). Laminoplasty (1984–1990) & ACF (1982–1984). | Presence of absence of pain assessed. No quantization of pain completed. Pain assessed as nuchal pain, shoulder pain, or shoulder spasm. 5/26 (19%) & 43/72 (60%) patients had postop pain w/ significantly higher levels in laminoplasty patients ($p < 0.05$). | III | Class III due to historical controls. However, laminoplasty appears to be associated w/ increased pain over ACF. |
| Takeuchi et al., 2005 | Group A was 40/71 patients w/ CSM (35)/OPLL (5) followed >1 yr who underwent C-3 laminectomy & C4–7 laminoplasty; Group B was 16/20 patients w/ CSM (9)/OPLL (7) who underwent C4–7 laminoplasty w/ 1 yr FU. | Outcome was subjective grading of pain (no, mild, severe) & cross-sectional area of muscle. Group A had more patients w/ no or mild pain ($p < 0.02$) & atrophy percentage was 2% vs 10% in B ($p < 0.001$). | III | Historical controls used since technique changed after 2001; also, pain outcome measure subjective. However, preserving C-2 muscle reduces atrophy. |
| Shiraishi et al., 2003 | 43 patients w/ CSM (32)/OPLL (11) who underwent skip laminectomy (after 1998); age 69 yrs w/ 2-yr FU; Comparison to ODL in 51 patients (CSM36/OPLL15); 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 → 13.4 w/ skip vs 16.0 → 11.8 in laminoplasty ($p < 0.05$); atrophy was 13% in skip vs 60% in laminoplasty on T2-weighted MRI. | III | Historical controls (Class III): however skip laminectomy reduces atrophy & reduces risk of kyphosis. |
| Yonenobu et al., 1992 | 100 patients w/ CSM of whom 83 had 2-yr FU; 41 patients underwent ACF (1976–1983) while 42 underwent FWL. | 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. |
| Hatta et al., 2005 | 26 consecutive patients w/ 2–3 level CSM underwent selective laminoplasty (age 60 yrs, FU 19 mos) vs historical controls: 25 of 56 (2–3 level CSM; age 62 yrs, FU 38 mos) who underwent ODL. | Recovery was 66% in both using JOA. Selective group had 1.1-mm cord shift while ODL had 2.7-mm cord shift ($p < 0.05$); C-5 palsy in latter was 8% but 0% in former. | III | Class III due to historic controls. However, selective technique produces same result despite less cord shift. Less cord shift seems to be associated w/ lower C-5 palsy. |
| Komagata et al., 2004 | 305 patients w/ CSM or OPLL underwent ODL. Evaluation w/ preop EMG & curvature index. 230/305 patients had foraminotomy. | 3/118 patients w/ abnormal EMG developed C-5 palsy. Whereas 6/140 (8.4%) w/ normal EMG developed C-5 palsy. Curvature index did not affect C-5 palsy rate (4.3%). C-5 palsy occurred in 1/162 gutters w/ foraminotomy & w/ 12/298 gutters w/o ($p < 0.05$). | III | Foraminotomy may prevent C-5 palsy but selection criteria too obtuse, so Class III. Abnormal EMG does not predict C-5 palsy. |
| Sasai et al., 2003 | 111 patients w/ CSM underwent laminoplasty. Group A (n = 74) who underwent EMG. 11/74 had abnormal EMG & underwent foraminotomy. Group B (n = 37) were evaluated by different surgeons & did not have EMG. | In Group A, 11/74 had abnormal EMGs. 0/74 had C-5 palsy. In Group B, 3/37 had C-5 palsy ($p < 0.05$). | III | Class III due to selection bias. All C-5 palsies occurred in group selected by different surgeons. EMG evaluation appeared to help indicate which patients might benefit from foraminotomy. |

*(continued)*

**TABLE 1: Evidentiary summary of studies regarding treatment outcome and laminoplasty for cervical degenerative myelopathy* *(continued)***

| Authors & Year | Description | Results | Class | Conclusions |
|---|---|---|---|---|
| Uematsu et al., 1998 | 365 patients had undergone laminoplasty; 20 patients (5.5%) developed postop radiculopathy (mostly at C-5) w/ timing hours to days after surgery. | Degree of stenosis, clinical symptomatic severity, flatness of spinal cord, cervical curvature, anterior articular process protrusion did not affect outcome. Angle of lamina >60° of hinge side & lateral gutters had negative prognosis ($p < 0.05$). | III | Multiple techniques utilized & case series make this Class III. Too great an angle is associated w/ cervical radiculopathy. |
| Chiba et al., 2002 | Retrospective review of 208 patients who underwent laminoplasty. 15 patients developed segmental paralysis. Paralysis developed an avg of 4.6 days postop. | 11/15 patients recovered. Patients who developed segmental paralysis had (14/15) severe preop dysesthetic pain that did not recover. T2 signal changes seen on postop MRI in all 15 patients (100%) compared to 58% in patients w/o deficit ($p < 0.01$). | III | Retrospective review (Class III) correlates postop segmental paralysis w/ T2 signal changes. |
| Wada et al., 1999 | 85 patients w/ CSM described. 10 were excluded initially & 25 did not receive imaging. MRIs analyzed in 50 patients after surgery. Age, JOA score, transverse area of spinal cord, duration of symptoms evaluated. | A transverse area >40 $mm^2$ at maximal compression, duration of symptoms, & AP canal diameter were the best predictors of outcome. Age, preop JOA scores, & isolated T2 signal were not ideal predictors of outcome. Multisegmental T2 hyperintensity was correlated w/ poor results ($p < 0.01$). | III | Multisegmental T2 hyperintensity is associated w/ poor outcome. This study was graded Class III due to nonrandomized selection & limited numbers of patients (50/85) who received postop imaging. |
| 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. Avg age 55 yrs w/ 25 mos FU. | Nurick improved 2.3 to 1.1 w/ laminoplasty vs 2.2 to 1.5 w/ fusion ($p > 0.05$); laminoplasty had a better Ishihara (0.09 to 0.9) index. Both preserved the index w/ surgery.<br>Reduction of ROM:<br>arthrodesis: 36→11°<br>laminoplasty: 40→26° ($p < 0.002$). Complication higher w/ fusion. | III | Laminectomy + arthrodesis has similar clinical outcome but a greater loss of ROM & increased complication rate; unclear why the loss of numbers. |
| Edwards et al., 2002 | 38 patients CSM studied retrospective w/ matched cohorts Group A (13 corpectomy, before 1996) & Group B (25 laminoplasties of which 13 chosen, after 1996). ODL in 3 patients & T-saw in 10 patients. FU >40 mos. | Nurick improved 1.9 to 1.0 in Group A & 2.3 to 0.8 in Group B (NS). Pain improved to 0.5 in Group A & 1.0 in Group B (NS).<br>ROM reduced from 37°→16° in Group A & 39°→24° in Group B (NS) w/ pseudarthrosis, Group A had higher complication rate (9/1). | III | Unclear matching technique & different periods. Both corpectomy & laminoplasty reliable. Laminoplasty appears to have fewer complications. |
| Sakaura et al., 2003 | 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 yrs, 1987–94). Avg FU was 15 yrs in Group A & 10 yrs in 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 reop 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. ACF 1–2 levels, & laminoplasty ≥3 levels. | Mean recovery in JOA was 71% in disc patients; same result w/ ACF or laminoplasty. In CSM, 49% recovery w/ ACF & 58% w/ laminoplasty (NS). 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. |

*(continued)*

**TABLE 1: Evidentiary summary of studies regarding treatment outcome and laminoplasty for cervical degenerative myelopathy* *(continued)***

| Authors & Year | Description | Results | Class | Conclusions |
|---|---|---|---|---|
| Hasegawa et al., 2002 | 90 patients w/ CSM. Age >70 yrs (n = 40, 27-mo 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 vs younger patients: 15% vs 8%. | III | Multiple subgroups in series. However, age does not appear to be a risk factor except for complications. Also, technique does not appear to change control of myelopathy. |
| Tomita et al., 1988 | 23 patients w/ OPLL & JOA <12. Avg age was 60 yrs & avg 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% vs 80% of nonoperated 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. |
| Kimura et al., 2000 | 39 patients w/ cervical myelopathy (CSM 25, OPLL 8, CDH 6) who underwent split-laminae laminoplasty. One group (n = 8, B) developed differing grades of the boomerang deformity while the other (n = 31, C) did not develop this deformity. | No differences in pre- & postop JOA were noted. However, those w/ the boomerang deformity had a higher flattening (sagittal/transverse) ratio & a smaller transverse diameter between the split laminae. | III | Although this was a cohort study, only 1 person completed the measurements & it was uncertain if that person was blinded. However, the boomerang deformity is more likely to develop in a patient w/ a small flattening ratio & a small transverse diameter between split laminae. |

* 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*. Abbreviations: AP = anteroposterior; avg = average; b/c = because; CDH = cervical disc herniation; DM = diabetes mellitus; FDL = French-door laminoplasty; FU = follow-up; FWL = French-window laminoplasty; HgbA1c = hemoglobin A1c; ISI = increased signal intensity; NS = not significant; ODL = open-door laminoplasty; SC/VB = spinal canal/vertebral body.

improved significantly from a preoperative average of 8.8 to a postoperative average of 11.9 ($p < 0.001$). Simultaneously, alignment deteriorated in some (loss of 12.5°) and stabilized in others (gain of 1.1°). In comparing these 2 groups, the authors observed no significant difference in mean JOA scale scores. This study was graded as Class III due to a small series and poorly described methodology.

Kawaguchi and colleagues[16] described a modified laminoplasty technique used in 28 patients with a mean age of 62.7 years. The surgeons placed bone spacers at every other level, with no bone placed on the hinge side. They evaluated ROM in this cohort and compared the results to those achieved in 28 historical control patients who underwent standard open-door laminoplasty (mean age 60.4 years). The follow-up period was 2.5 years. Range of motion was preserved 48% in the open-door group and 71% preservation was achieved in the modified laminoplasty group ($p < 0.02$). In addition, an average of only 0.8 levels were fused in the modified group compared to 2.1 in the control group ($p < 0.0001$). This study was graded Class III because of the use of historical controls. Shiraishi et al.[37] compared skip laminectomy (in 43 patients, mean age 69 years, 32 with CSM, and 11 with OPLL) to open-door laminoplasty (in 51 patients, mean age 67 years, 36 with CSM, and 15 with OPLL) for the treatment of cervical myelopathy. Minimum follow-up was 2 years, and the JOA scale recovery was similar in the 2 groups. However, ROM was 98% preserved in the skip laminectomy group compared to 44% in the laminoplasty group ($p < 0.05$). This study was graded Class III due to the use of historical controls.

In a Class III study, Edwards et al.[4] specifically evaluated pain in 18 patients who underwent laminoplasty by splitting of the spinous process (mean age 54 years, 2-year follow-up). The authors assessed pain with the Robinson pain scale. Pain levels significantly decreased (2.0 to 0.9; $p < 0.002$). In this same group, ROM diminished significantly (37 to 23°; $p < 0.05$). Compared to a historical control group of patients who underwent laminectomy (22 patients, mean age 54 years), Kaminsky et al.[14] found that the pain level was significantly reduced (57 vs 8%, $p < 0.004$) with laminoplasty in 20 consecutive patients (mean age 53 years). However, this study was graded Class III because the laminoplasty group started with a significantly higher pain score than the historical control group. In a similar study, Takeuchi et al.[39] modified a C3–7 laminoplasty to preserve the C2–3 muscular attachments, and compared their results in 40 patients to 16 historical control patients. The modified laminoplasty group had significantly fewer patients with severe pain ($p < 0.02$). They compared this technique to C4–7 laminoplasty with undercutting of the C-3 lamina. In this Class III study, the authors demonstrated no difference in clinical outcomes, but did show reduced pain and muscle atrophy with this modified technique. Hosono and colleagues[11] compared the presence of nuchal and shoulder pain in 72 patients who underwent laminoplasty versus a 26-patient historical cohort who underwent ACF. The average age for both groups was 58 years, with a minimum 2-year follow-up period. Nuchal or shoulder pain was present in 5 (19%) of 26 patients who underwent ACF and 43 (60%) of 72 patients who underwent laminoplasty ($p < 0.05$).

## Complications

The most commonly described complication after laminoplasty is arm weakness due to C-5 palsy.[13,30,35,43,47] Ratliff and Cooper[31] reported a cumulative incidence of 8%. Satomi et al.[35] reported on open-door laminoplasty in 206 patients (106 with OPLL and 98 with CSM) of whom 80 were followed up for 5 years. In this Class III series, a complication rate of 7.8% was reported for arm weakness. Other authors have reported an incidence of 5–8%.[8,13,30,47]

Hatta and colleagues[8] compared selective laminoplasty (in 26 patients with an average age of 60 years, and a 19-month follow-up period) to a historical control group of 25 patients who underwent the standard open-door technique (mean age 62 years, 38-month follow-up period). All patients had CSM over 2–3 levels. Recovery assessed with JOA scale scores was 66% in both groups. The authors compared the posterior cord shift between the 2 groups. In the selective laminoplasty group, posterior shift was 1.1 mm, with 0% C-5 palsy. In the standard historical control group, cord shift was 2.7 mm with 8% C-5 palsy. Accordingly, posterior cord shift was associated with C-5 palsy.[8] Through selective laminoplasty, Hatta et al.[8] reduced the incidence of C-5 palsy while maintaining a similar level of improvement in JOA scores. This study was graded Class III because of the use of historical controls.

Sasai et al.[34] reported on 111 patients who underwent laminoplasty. One group of surgeons treated 74 patients all of whom underwent preoperative EMG studies. A second group of surgeons treated 37 patients who did not undergo preoperative EMG. Eleven of 74 patients with abnormal EMG results at C-5 underwent prophylactic foraminotomy. In the first group, none of the patients had postoperative radiculopathy, while postoperative radiculopathy developed in 3 patients in latter group. The authors concluded that preoperative EMG was helpful. This study was graded Class III due to the significant selection bias between the groups. Komogata and colleagues[24] did not show a correlation between EMG abnormalities and C-5 palsy. They reported on 305 patients, of whom 230 underwent foraminotomy in addition to laminoplasty. The study assessed patients with EMG preoperatively. Three of 118 patients with abnormal EMG results developed C-5 palsy (3.5%) in contrast to 6 of 140 patients with normal EMG results (8.4%). These authors reported a reduced incidence of C-5 palsy in gutters that had a foraminotomy. This study was graded Class III because of obtuse entry criteria; however, the authors did demonstrate that preoperative EMG findings did not necessarily correlate with outcome.[25]

Both Uematsu et al.[42] and Chiba et al.[2] examined the relationship of C-5 postoperative palsy to clinical factors. In a series of 365 patients, Uematsu and colleagues[42] reported an incidence of 5.5% for C-5 palsy. These authors found the development of C-5 palsy did not correlate with degree of stenosis, clinical severity of myelopathy, or the

spinal curvature index. They reported that elevation of the laminae to an angle > 60° was associated with greater likelihood of C-5 palsy. This study was graded Class III because of the multiple techniques used for laminoplasty. Chiba and colleagues[2] described a retrospective series of 208 patients who underwent laminoplasty. Segmental motor paralysis developed in 15 patients, in most cases at C-5. Weakness developed an average of 4.6 days after surgery. Fourteen of 15 patients had severe dysesthetic pain in the hands prior to surgery, a symptom that did not improve. Magnetic resonance imaging evaluation after surgery showed focal hyperintensity on T2-weighted images in all 15 patients with segmental motor paralysis, in contrast to an incidence of 58% in the patients without deficit. This study was graded Class III because of its retrospective nature.

Ratliff and Cooper[31] reported a cumulative incidence of postlaminoplasty kyphosis of 10%. In their study of 92 patients with OPLL, Iwasaki et al.[13] conducted follow-up in 56 patients over a 10-year period, and described a long-term kyphosis rate of 8%. Both Saruhashi et al.[33] and Suda et al.[38] examined postoperative kyphosis and outcome. In the Saruhashi et al.[33] study described above, 30 patients with CSM underwent laminoplasty with a 5-year follow-up period. Patients who developed kyphosis (–12.5°) had similar clinical outcomes as those who had lordosis preserved (+1.1°). This study was graded Class III because it is a small series with poorly described methodology. Suda et al.[38] conducted follow-up in 114 patients with CSF for 5 years. The C2–7 angle was used to assess for preservation of lordosis. In this study, development of kyphosis and the presence of local kyphosis predicted poor outcome ($p < 0.05$).[38] This study was graded Class III because of the heterogeneous definition of kyphosis the authors used—some patients began the study with loss of cervical lordosis and could not "develop" kyphosis. In a different Class III study, Maeda et al.[26] reported follow-up in 30 of 44 patients who underwent laminoplasty for OPLL. The average patient age was 59 years, and the follow-up period averaged 3.2 years. The authors found that the curvature index reduced from 14.5 to 2% after laminoplasty, with ROM deteriorating from 41 to 24°. They reported a correlation between diminished ROM, diminished curvature index, and reduced JOA scale scores. Because of the significant loss of study patients, this study was graded Class III.

Kimura and colleagues[22] examined the "boomerang" deformity that occasionally developed in the spinal cord with posterior shift after split laminae laminoplasty. They reviewed 39 consecutive cases of laminoplasty (in patients with CSM, OPLL, and cervical disc herniation) for cervical myelopathy. The boomerang deformity developed in 8 patients with migration of the spinal cord between the split laminae. These patients were compared with 31 patients in whom this deformity did not develop. There were no significant differences in age, pre- and postoperative JOA scale scores, or recovery rates between patients with and without this deformity. Patients who developed the "boomerang" spinal cord deformities were significantly more likely to have had a lower flattening ratio (sagittal/transverse diameter; $p < 0.027$) and/or a lower transverse diameter between the split laminae ($p < 0.0003$). This study was graded Class III because only 1 author completed the patient measurements, and it was uncertain whether that author was blinded to the patient group.

### Comparison With Other Techniques

Laminoplasty was compared to ACDF in 3 studies in patients with single-level disc displacement and myelopathy.[12,32,48] In the Class III studies by Iwasaki et al.[12] and Sakaura et al.,[32] patients underwent ACF in the beginning of the study period, and laminoplasty if diagnosed more recently. In Iwasaki and colleagues'[12] study, which included 17 ACDFs and 16 laminoplasties, the JOA recovery rates were 93 and 81%, respectively. The Sakaura et al.[32] study, which included 15 ACDFs and 18 laminoplasties, showed JOA score recovery rates of 71 and 70%, respectively. In a Class III study, Yoshida et al.[48] compared 32 patients who had undergone laminoplasty with 44 patients who underwent ACDF. Unlike the laminoplasty group, however, 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 due to graft site complications.[12,48]

Laminoplasty was compared to ACF in 6 studies of treatment for CSM.[3,7,20,41,43,47] In their Class III study, Wada et al.[43] compared subtotal corpectomy (23 patients, mean 2.5 operated levels, average age 53 years, and a 15-year follow-up) to open-door laminoplasty (24 patients with an average age of 56 years, 12-year follow-up). The JOA scale scores improved in both groups: from 7.9 to 13.4 in the corpectomy group, and from 7.4 to 12.2 in the laminoplasty group. The incidence of moderate or severe pain was greater with laminoplasty (40 vs 15%; $p < 0.05$), and ROM was better preserved with corpectomy (49 vs 29%). In another Class III study, Yonenobu et al.[47] reported on 83 patients with CSM of whom 42 underwent French-window laminoplasty, and 41 underwent ACF. All had 2 years of follow-up, and the JOA scale scores improved in both groups (44% with laminoplasty and 55% with ACF). Outcomes were also similar in patients with canal stenosis (< 12 mm). The complications were higher with ACF due to graft complications (29 vs 7%). However, of the 6 studies above, not all showed a higher complication rate for the anterior approach nor did all show better preservation of ROM with an anterior approach.

Laminoplasty was compared with a variety of posterior techniques in several studies. In a Class III study, Kaminsky et al.[14] 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. 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 compared to 3.09 to 2.50 for laminectomy. The difference in recovery rates (49 vs 18%) was statistically significant ($p < 0.0001$). However, the preoperative Nurick scores were also significantly worse for the laminectomy group ($p < 0.0001$). In the Class III study described above, Shiraishi et al.[37] compared the results of skip laminectomy for the treatment of cervical myelopathy in 43 pa-

tients to results achieved in 51 patients who underwent open-door laminoplasty. The JOA scale score recovery was 59% with laminectomy versus 60% with laminoplasty; however, the skip technique preserved ROM and increased the Ishiara index (from 11.4 to 13.4) compared with laminoplasty (from 16.0 to 11.8; $p < 0.05$).

Heller and colleagues[9] compared laminoplasty (midline and open-door) to laminectomy with arthrodesis in 13 patients each with CSM (mean patient age 55 years, 2-year 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 this trend was not statistically significant. Not surprisingly, laminoplasty was associated with greater preservation of ROM ($p < 0.002$).[9] This study was graded Class III due to significant selection bias.

## Summary

Although there have been no Class I or II studies to suggest that laminoplasty is superior to nonoperative therapy for treatment of myelopathy caused by CSM or OPLL, numerous large series with long-term follow-up that demonstrate substantially improved neurological function when laminoplasty is used are evident. An ~ 55–60% recovery rate (JOA scale) is anticipated. Class II evidence does suggest that duration of symptoms, severity of stenosis, severity of myelopathy, and poorly controlled diabetes are negative risk factors. There is conflicting Class II evidence regarding patient age, with 1 study citing age as a risk factor and another not demonstrating this result.

Class II evidence reveals that better JOA scale scores (both pre- and postoperatively) are associated with returning to work. Laminoplasty has been linked to reduced preservation of ROM and development of C-5 palsy. There is conflicting Class II evidence regarding the development of kyphosis and functional outcome, with 2 studies concluding a negative correlation between them.

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, ACF, and laminectomy with arthrodesis. Class III evidence is unclear regarding differences in complication rates among these techniques.

## Key Issues

Prospective comparison of results with laminoplasty to results in a nonoperative group of patients with CSM would be an appropriate evaluation both of this surgical treatment and of surgery versus nonoperative treatment for this dynamic disease.

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*Address correspondence to:* Paul G. Matz, M.D., Neurosurgery and Neurology, LLC, 232 South Woods Mill Road, Chesterfield, Missouri 63017. email: matzpg@yahoo.com.