Cervical laminoplasty developments and trends, 2003–2013: a systematic review

Stephan Duetzmann, MD, Tyler Cole, BS, and John K. Ratliff, MD

Department of Neurosurgery, Stanford University School of Medicine, Stanford, California

OBJECT Despite extensive clinical experience with laminoplasty, the efficacy of the procedure and its advantages over laminectomy remain unclear. Specific clinical elements, such as incidence or progression of kyphosis, incidence of axial neck pain, postoperative cervical range of motion, and incidence of postoperative C-5 palsies, are of concern. The authors sought to comprehensively review the laminoplasty literature over the past 10 years while focusing on these clinical elements.

METHODS The authors conducted a literature search of articles in the Medline database published between 2003 and 2013, in which the terms “laminoplasty,” “laminectomy,” and “posterior cervical spine procedures” were used as key words. Included was every single case series in which patient outcomes after a laminoplasty procedure were reported. Excluded were studies that did not report on at least one of the above-mentioned items.

RESULTS A total of 103 studies, the results of which contained at least 1 of the prespecified outcome variables, were identified. These studies reported 130 patient groups comprising 8949 patients. There were 3 prospective randomized studies, 1 prospective nonrandomized alternating study, 15 prospective nonrandomized data collections, and 84 retrospective reviews. The review revealed a trend for the use of miniplates or hydroxyapatite spacers on the open side in Hirabayashi-type laminoplasty or on the open side in a Kurokawa-type laminoplasty. Japanese Orthopaedic Association (JOA) scoring was reported most commonly; in the 4949 patients for whom a JOA score was reported, there was improvement from a mean (± SD) score of 9.91 (± 1.65) to a score of 13.68 (± 1.05) after a mean follow-up of 44.18 months (± 35.1 months). The mean preoperative and postoperative C2–7 angles (available for 2470 patients) remained stable from 14.17° (± 0.19°) to 13.98° (± 0.19°) of lordosis (average follow-up 39 months). The authors found significantly decreased kyphosis when muscle/posterior element–sparing techniques were used (p = 0.02). The use of hardware in the form of hydroxyapatite spacers or miniplates did not influence the progression of deformity (p = 0.889). An overall mean (calculated from 2390 patients) of 47.3% loss of range of motion was reported. For the studies that used a visual analog scale score (totaling 986 patients), the mean (cohort size–adjusted) postoperative pain level at a mean follow-up of 29 months was 2.78. For the studies that used percentages of patients who complained of postoperative axial neck pain (totaling 1249 patients), the mean patient number–adjusted percentage was 30% at a mean follow-up of 51 months. The authors found that 16% of the studies that were published in the last 10 years reported a C-5 palsy rate of more than 10% (534 patients), 41% of the studies reported a rate of 5%–10% (n = 1006), 23% of the studies reported a rate of 1%–5% (n = 857), and 12.5% reported a rate of 0% (n = 168).

CONCLUSIONS Laminoplasty remains a valid option for decompression of the spinal cord. An understanding of the importance of the muscle-ligament complex, plus the introduction of hardware, has led to progress in this type of surgery. Reporting of outcome metrics remains variable, which makes comparisons among the techniques difficult.

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KEY WORDS laminoplasty; cervical spine; cervical laminectomy

The optimal surgical treatment of multilevel cervical spinal cord compression caused by OPLL (ossification of the posterior longitudinal ligament) or cervical spondylosis remains controversial. Despite an extensive clinical experience with laminoplasty, the efficacy of the procedure, as well as its advantages over laminectomy, remain unclear.71 This statement introduced a review of cervical laminoplasty 10 years ago. It could still stand at the beginning of any recent review on laminoplasty. This review’s main conclusion, that there is no benefit to laminoplasty over laminectomy in adult patients in terms of spinal align-
ment, incidence of kyphotic deformity, and neurological outcome, was cited and addressed in the literature in the following years, often at the center of the discussion. Some surgical innovations generated by further laminoplasty research might be driven by these obstacles.

Ten years after publication of this article, we have reviewed the complete English-language laminoplasty literature and focused on the incidence or progression of kyphosis, incidence of axial neck pain, postoperative cervical range of motion (ROM), and incidence of postoperative C-5 palsies. We sought to provide an overview of the results of laminoplasty procedures and different modifications today to help in surgical decision making and counseling. Also, we wanted to determine whether there had been any major developments in surgical techniques over those being used 10 years ago that led to significant changes in the aforementioned outcome items or if we could determine, via meta-analysis, outcome differences between the surgical techniques.

**Methods**

We conducted a literature search of the Medline database, in which the terms “laminoplasty,” “laminectomy,” and “posterior cervical spine procedures” were used as key words spanning from January 1, 2003, to December 31, 2013. Our goal was to review a representative database of the English-language laminoplasty literature to assess the effects of laminoplasty techniques on neurological outcome, axial neck pain, spinal deformity, cervical ROM, and incidence of C-5 palsies. We used a PubMed internet-based search. Every study was searched for a patient group that had a laminoplasty procedure done. Then, we determined whether any of the outcome items were reported. We excluded publications that did not report on at least 1 of the above-mentioned items. All the articles could be retrieved electronically from the Internet.

We did not aim to compare any of these techniques with laminectomy and fusion. Trends and new developments were highlighted. Because nearly all new technical modifications are based on either a Kurokawa-type or a Hirabayashi-type laminoplasty, we dichotomized these 2 techniques and further subcategorized the type of modification according to the following: 1) if and what type of material was used to keep the opened space open, and 2) if a muscle-sparing technique was used (a technique was considered muscle sparing if it was explicitly mentioned in the methods section of the article that muscles attached to C-2 or C-7 were preserved).

We also recorded the country in which the patients were treated, which was inferred from either the methods section or the senior author’s affiliation.

Mean preoperative and final follow-up numbers were recorded, including the following values: modified Japanese Orthopaedic Association (mJOA) score, neck pain visual analog scale (VAS) score, C2–7 angle, percentage ROM loss, and rate of C-5 palsies. These numbers were adjusted for the patient numbers when reporting overall means by multiplying the mean score of the treatment group with the patient number of that treatment group. Mean overall values were then calculated by summing up the adjusted means and dividing by patient number.

**Statistical Analysis**

Statistical analyses were performed using commercially available software (R, http://www.r-project.org/). Normalized data were compared by using the paired Student t-test, binomial dichotomized data were compared using the Fisher exact test, and categorical data were compared using the chi-square test. A p value of < 0.05 was considered statistically significant. Missing data are pointed out clearly in the text and the figure. As stated already, mean values were adjusted for patient numbers. Mean values are presented ± the SD.

**Results**

We screened 126 studies with groups of patients who underwent a laminoplasty procedure. We excluded 21 studies because they did not include any of the outcome items in question. Two articles were excluded because they were available only in the Chinese or Japanese language. We identified 103 studies reporting results that contained at least one of the prespecified outcome variables, and these studies led to 130 patient groups comprising 8949 patients. Multiple articles that reported the same patient series may have artificially inflated the number of cases, and among them a multicenter study that focused on C-5 palsies and included nearly 2000 patients. The majority of the studies were from Japan (57.1%), followed by China (13.4%), Korea (12.5%), and the United States (8.9%).

**Quality of Evidence**

Among the studies were 3 prospective randomized studies, 1 prospective nonrandomized alternating study, 15 prospective nonrandomized data collections, and 84 retrospective reviews (Table 1). Because restriction to only higher-quality prospective reviews would have generated an unrepresentative review of the present literature, we chose to take an inclusive approach and included retrospective series.

**Trends**

Compared with the results of Ratliff and Cooper’s first article, a trend to use miniplates or hydroxyapatite spacers on the open side in Hirabayashi-type and Kurokawa-type laminoplasties has emerged. Whereas only 6% of the articles reviewed in the Ratliff and Cooper article 10 years ago reported results of hardware augmentation, we found that 53.1% of articles reported results of using miniplates, screws, or hydroxyapatite spacers. A future trend may be to use muscle-sparing techniques. We found that 25% of the articles that reported results of laminoplasty also reported results of patients who were operated on using muscle-sparing techniques (depicted in Fig. 1).
Neurological Outcome

The majority of the studies (68%) reported outcomes in the form of mJOA scores. Overall, the 4949 patients whose mean mJOA scores were reported improved from a mean of 9.91 (± 1.65) to 13.68 (± 1.05) after a mean follow-up period of 44.18 months (± 35.1) (Table 2). The amount of improvement did not increase or decrease over the 10-year publication period. On average, Hirabayashi-type and

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**TABLE 1. Overview of included studies**

<table>
<thead>
<tr>
<th>Type of Study</th>
<th>No. Included</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prospective, randomized</td>
<td>3</td>
</tr>
<tr>
<td>Prospective, nonrandomized, alternating</td>
<td>1</td>
</tr>
<tr>
<td>Prospective, nonrandomized data collection</td>
<td>15</td>
</tr>
<tr>
<td>Retrospective review</td>
<td>84</td>
</tr>
</tbody>
</table>

**FIG. 1.**

A: Hirabayashi-type laminoplasty. The spinous processes are removed, and bilateral troughs are created at the facet-lamina junctions. A thin rim of bone is left on one side. The laminae are elevated and secured to the facet using sutures. 

B: Kurokawa-type laminoplasty. The spinous processes are split by using a high-speed drill or T-saw. Troughs are drilled into the lateral aspects of the laminae and medial facets. The spinous processes are split in the midline, and bone graft is used as a spacer.

C: Hardware-augmented Hirabayashi-type laminoplasty. The procedure is similar to that depicted in panel A, but at the final step, titanium miniplates are placed to secure the elevated laminae.

D: Hardware-augmented Kurokawa-type laminoplasty. The procedure is similar to that depicted in panel B, but instead of autologous bone, hydroxyapatite spacers keep the spinous processes apart.

E: Amalgam of the muscle-sparing type of Hirabayashi-type laminoplasty. The interspinous ligaments are kept intact, and the C-7 spinous process is spared. The trough is drilled on the contralateral side either with a muscle-splitting technique or with the spinous process temporarily cut and retracted, which preserves the attachment of the semispinalis and rotatores muscles. Muscles attached to the C-2 spinous process are also spared.

F: The muscle-sparing type of Kurokawa-type laminoplasty, which spares the muscle attachments of the rhomboid and trapezius muscles to C-7. Also, the muscles attached to the C-2 spinous process are preserved without detachment from the C-2 spinous process. Surgical exposure is limited to as little as possible. Copyright Hannah Ahn. Published with permission.
Postoperative Spinal Alignment and Deformity

The literature on postlaminoplasty kyphosis is wanting, and standardized reporting has often been insufficient; 32.5% of the studies did not report on preoperative or postoperative kyphosis assessments.

With regard to change in cervical alignment, the literature reported a wide range of values, from a 7° loss of lordosis after 29 months of follow-up to a 16.7° gain of lordosis in a separate study after 9 months of follow-up.9,19

Most reports that noted kyphosis and changes in cervical alignment offered intergroup comparisons but failed to provide statistics for preoperative and postoperative comparisons.5,6,9,21,25,45,52,89

Usually, the C2–7 angle was measured to report postoperative kyphosis, but occasionally, the cervical curvature index was used13,104 or the measurement method was not detailed in the methods section.32,87,92,105 Other reports just provided the incidence or percentage of postoperative kyphotic deformity.5,28,67,107

Only 21 (20%) studies reported statistical comparisons between the preoperative and postoperative C2–7 angles. The mean preoperative and postoperative C2–7 angles (available for 2470 patients) remained stable from 14.17° (± 0.19°) to 13.98° (± 0.19°) of lordosis (average follow-up time 39 months) (Table 2). The use of hardware in the form of hydroxyapatite spacers or miniplates did not influence the progression of deformity (p = 0.889). The variability among the studies was considerable.

Concentrating on reviews that offered mean preoperative and postoperative C2–7 angles or curvature index numbers, 28.8% of the studies reported stable alignment, 45.0% of the studies reported worse kyphosis (i.e., a mean decreased C2–7 angle or curvature index), and 26.3% reported increased lordotic curve.

It was surprising that the studies that reported statistically proven increased kyphosis had less follow-up.

Considering mean preoperative and postoperative C2–7 angles or curvature index values, the previous review73 pointed out that a higher percentage of studies reported the technique by Hirabayashi to be associated with worsening kyphosis. We found a slight predominance of studies reporting the results of Kurokawa-type laminoplasty with worsening of cervical alignment (not statistically significant, p = 0.669, chi-square).

Other authors suggested posterior element–sparing techniques62,82 or restriction of the laminoplasty from C-3 to C-6 instead of C-7 to reduce kyphosis.79 Reduced surgical exposure and no detachment of the semispinalis cervicis muscle from the C-2 spinous process or avoiding the C-2 lamina in total have also been claimed to be as-
versus 50.0% rate in all studies in which muscle-preservation techniques were not used.

Postoperative ROM

Diminution of ROM has been noted in virtually all series in which postoperative cervical movement was reported (46% of all studies), except for the series of Cansa et al. and Fujibayashi et al. An overall mean (calculated from 2390 patients) of 47.3% loss of ROM was reported. Of all the studies, 49% (representing 1264 patients) reported an ROM decrease of < 25%, whereas 51% of the studies reported an ROM decrease of > 25% (1126 patients). The mean follow-up period in the studies that reported a smaller degree of loss of ROM was shorter (mean follow-up time 32 months) than that in the studies with a > 25% loss of ROM (mean follow-up time 54 months).

Associated Complications

Neck Pain

Approximately 50% of the studies that reported neck pain used measures other than the standard VAS score. Reported only the number of patients whose neck pain was aggravated, failed to provide preoperative values, or just used theirVAS data for correlation analysis. Thus, only 26% of the studies provided preoperative and postoperative VAS scores. For the studies that used the VAS score (totaling 986 patients), the mean (cohort size–adjusted) postoperative pain level at a mean follow-up period of 29 months was 2.78. For the studies that used percentages of patients complaining of postoperative axial neck pain (totaling 1249 patients), the mean patient number–adjusted percentage was 30% at a mean follow-up period of 51 months.

The authors of recent literature reports attempted to reduce the incidence of axial neck pain by using muscle-preserving techniques. Emphasis was placed on the semispinalis cervicis, which they tried to preserve or repair. Furthermore, they also tried to preserve muscles that attach to the spinous processes of C-2 and postoperative axial symptoms. Other authors introduced the C-7–sparing technique, which restricts the laminoplasty from C-3 to C-6 instead of C-7, and reported that only 3% of their patients complained about axial neck pain after 5 years of follow-up, which is in contrast to 70% of patients claiming axial symptoms in earlier studies. In some comparative studies, the C-7–preserving technique was far superior to the C-7–utilizing technique. We did not find that studies explicitly reporting muscle preservation reported less reduction in their VAS scores than those that did not mention muscle preservation.

The use of miniplates was shown to be more effective for postoperative pain reduction in 2 studies. A separate report noted the use of hydroxyapatite spacers in combination with a muscle-sparing technique, which led to only 10% of patients complaining of neck pain. We could not corroborate that the use of miniplates or hydroxyapatite spacers leads to a reduction in postoperative neck pain.

Long-term studies showed that axial symptoms do not decrease with long-term follow-up. In one study, 30% of the patients still suffered from axial neck pain even after > 10 years of follow-up. We did not find any correlation between length of follow-up and severity of neck pain.

Neck pain has been shown to be worse after the Hirabayashi-type laminoplasty, a finding that we could not corroborate.

Finally, some authors did not find any “burdensome axial pain” in their population at all.

Dysfunction of the C-5 Nerve Root

As stated before, dysfunction of the C-5 nerve root may occur after anterior or posterior cervical surgery at the C4–5 level and is not peculiar to cervical laminoplasty. In contrast to results in our previous report, 55% of the studies we reviewed here reported their rates of C-5 palsies. The most accurate numbers may be in the range of 2.3%–4%, determined in 2 multi-institutional studies that used nationwide samples of > 1800 and 500 patients, respectively. Excluding those reviews, we found that 16% of the studies that were published in the last 10 years reported a C-5 palsy rate of > 10% (totaling 534 patients), 41% reported a rate of 5%–10% (totaling 1006 patients), 23% reported a rate of 1%–5% (totaling 857 patients), and 12.5% reported a rate of 0% (totaling 168 patients).

To address dysfunction of the C-5 root, Lee et al. left bony gutters, which led to a low rate of C-5 palsies. Other authors suggested that the main etiology of C-5 palsy is impairment of the C-5 nerve root induced by preexisting C-4/5 foraminal stenosis. Thus, prophylactic foraminotomies are advocated, although they have shown limited success.

Discussion

In this article, we review a broad sampling of the laminoplasty literature and present a comprehensive analysis of the laminoplasty literature of the last 10 years. Although most of the studies were retrospective in nature and publication bias is inherent in this analysis, our review is an attempt to summarize the operative results of nearly 9000 patients who underwent laminoplasty.

The majority of studies were from Japan (57.1%), followed by China (13.4%), Korea (12.5%), and the United States (8.9%). One might infer that there are geographical preferences that favor laminoplasty over other posterior approaches for the same type of pathology in daily practice. This inference is supported by data from Fehlings et al., who conducted an international survey that showed that, for example, posterior approaches are applied more frequently in Asia than in Europe. These regional differences have multivariate reasons, and explanations for them are speculative. Different schools of thought and teaching tend to perpetuate beliefs if differences between output are small enough to merit the negligence of other approaches. Surgery is taught by surgeons in a personal relationship, and if the teacher is traditionally more com-
fortable with one technique, the student will get more exposure to this technique and might apply it because he or she has had good experience with it.

In our review of numerous series of patients, we have shown that considerable progress has been made in the last 10 years. With regard to numerous elements that are proposed to justify the use of laminoplasty, though, some problems remain unsolved.

Neurological Outcome

We found unanimously that the laminoplasty procedure achieves its primary goal: to make neurological recovery possible by decompressing the spinal cord. It is not surprising that patients who undergo laminoplasty experience neurological improvement; the procedure expands the spinal canal and allows the cord to move posteriorly in a fashion analogous to that after laminectomy.21 Hirabayashi-type and Kurokawa-type laminoplasty reports have noted, on average, equal improvement in preoperative and postoperative JOA scores. A critical comparison among series remains difficult, because of heterogeneous patient populations and outcome measures and various follow-up lengths.

Neck Pain

Ten years ago, the incidence of postlaminoplasty axial neck pain was unclear. In many studies there was no mention of the incidence of postlaminoplasty neck or shoulder pain.71 Because proponents of laminoplasty claim the procedure’s superior effectiveness on postoperative pain, which has been shown in 1 randomized study involving 13 patients,44 we expected it to be reported more frequently. We found neck pain reported in only 986 (11% of the total population) patients in studies that used the standard VAS score plus 1249 (14%) patients in studies that used percentages of patients suffering neck pain. Only 26% of all the studies provided preoperative and postoperative VAS scores.

According to our review, the reduction of neck pain seems to be the most difficult aspect for improvement. A wide disparity exists between single studies, ranging from 0% to 100%.9,15 as it did 10 years ago when Ratliff and Cooper71 found disparities between 6% and 60%.

The debate on whether extensive muscle dissection is responsible to a major extent for postoperative pain is generally fought by the fact that early and late pain are not differentiated. Comparable to minimally invasive techniques, the preservation of muscle did not lead to reduced long-term pain in randomized controlled trials,3,46 although most of the retrospective cohort studies found significant pain relief in patients in the muscle-preserved group compared with those in the non–muscle-preserved group. This phenomenon is well known in evidence-based medicine.50

Neck pain is not associated with loss of ROM.9,15

Kyphosis

An important rationale for the use of laminoplasty is the prevention of kyphotic deformity, a known complication of laminectomy. In an earlier review,71 there was a high incidence of change from preoperative lordotic alignment to postoperative straightened or kyphotic alignment.

We expected that cervical alignment would be routinely reported from laminoplasty studies. It is unfortunate that statistical comparisons between preoperative and postoperative lordotic angles were done in only 20% of the studies we found. One cannot exclude bias in the fact that a huge number of studies did not report preoperative and postoperative statistics.

Most reports noting kyphosis and changes in cervical alignment offered intergroup comparisons but failed to provide statistics for preoperative and postoperative comparisons.5,6,9,21,25,42,44,47,60,70,73,74,98,108,109 Usually, the C2–7 angle was measured to report postoperative kyphosis, but occasionally, the cervical curvature index was used108,109 or the measurement method was not detailed in the methods section.32,87,92,109 Other reports just provided the incidence or percentage of postoperative kyphotic deformity.4,23,67,107

Only 21 studies (20%) reported statistical comparisons between preoperative and postoperative C2–7 angles.

The literature reported a wide range of values, from a 7° loss of lordosis after 29 months of follow-up to a 16.7° gain of lordosis in a separate study with 9 months of follow-up.9,99

A recent trend is to combine a fusion procedure with a laminoplasty procedure, which has provided excellent results regarding postoperative kyphosis.70,103 Because laminoplasty leads to a worse outcome, especially in patients who already have local kyphosis.105 Noteworthy is that in patients with multi-level cervical myelopathy and C4–C4 anterior release, there has been a disturbingly high incidence of C5–C6 fusions noted.106 and some reports even showed worsening of kyphosis after fusion surgery rather than laminoplasty surgery.106

Regarding hardware in general, we did not find an increased incidence of stable deformity when hardware of any kind (miniplates, etc.) was used.

Ten years ago, Ratliff and Cooper71 found worsening alignment in 23%–50% of the cases reported, depending on the technique used. Because we found that, globally, the mean C2–7 angle did not change over the large reviewed population, progress might have been achieved here.

Still, in one-quarter of the studies that reported statistics, it was found that postoperative cervical alignment was worse than preoperative alignment. It is surprising that 19% of the studies reported improved cervical alignment. Muscle preservation techniques might play a role in preventing kyphotic deformity. Thus, the known association between increased preoperative kyphosis and worse neurological outcome84 might also be a result of fixed preexisting preoperative neurological damage that leads to the development of kyphotic deformity. The quality of the literature and the variety of reporting techniques make critical assessment of changes in cervical alignment and loss of cervical lordosis difficult.

Range of Motion

“Because patients who have undergone laminoplasty experience progressive restriction of cervical ROM that parallels that in fusion-treated patients, one proposed benefit of this technique is questionable.” This statement was written 10 years ago and can stand at the beginning of this review today as well. Our mean loss of nearly 50% ROM in the 2390 patients for whom results were reported is in-
dicative of the fact that laminoplasty might not be supe-
rior to laminectomy and fusion. This percentage remained
virtually unchanged from that reported in the Ratliff and
Cooper\textsuperscript{31} review reported 10 years ago. Because ROM
measurements entail standard cervical radiographs, it is
not surprising that only one-fourth of the patient popula-
tion was examined for ROM; in retrospective analyses,
standard radiographs may not be available for every pa-
tient. The clinical impact of this loss of ROM is not clear;
patient quality-of-life metrics may not be affected by a
decrease in ROM, but one goal of the laminoplasty pro-
cedure is still not achieved.

Muscle-Sparing Techniques
Numerous variations on muscle-sparing techniques for
laminoplasty have been presented in the literature. Moto-
suneya et al.\textsuperscript{62} proposed a mere ligament-sparing tech-
nique; the paravertebral muscles are retracted laterally and
the supraspinous ligament and medial portion of the rhom-
boid and trapezius muscles are preserved in a continuous
band. In a modification by Kihara et al.\textsuperscript{39} dissection of
the paravertebral muscles is carried upward to the upper
edge of the lamina of C-3, which prevents injury to deep
paravertebral muscles such as the semispinalis cervicis
muscles, which run inferolaterally from the spinous pro-
cess. The semispinalis cervicis muscle is not cut off from
the spinous process of C-2. In the event of C-2 or C-6/7
involvement, a dome-like resection of the inferior part of
the C-2 lamina or resection of the superior one-third of
the C-7 lamina is performed by undercutting cortical bone
without detaching the muscle–ligament complex.\textsuperscript{39,50,74}
Other authors have proposed selective laminoplasty at just
the stenotic levels\textsuperscript{63} or that spares only C-7.\textsuperscript{9}

In parallel to the other technique modifications noted
above, the Kurokawa procedure is performed by sparing
the muscle attachments of the rhomboid and trapezius
muscles to C-7.\textsuperscript{39,66} Other authors focused most of their at-
tention on the preservation of muscle attachment to C-2.\textsuperscript{30}
Kato et al.\textsuperscript{33} reported a series in which the detached inser-
tion of the posterior paraspinal muscles was resutured with
the original spinous process after the elevation. Kotani et
al.\textsuperscript{43} rather, focused on preservation of the deep extensor
muscles.

Limitations
The study methodologies used in many of the foun-
dational articles discussed in this report may have been
suboptimal. Our inclusive approach was subject to pub-
cation bias of the literature, because not every laminoplas-
ty procedure was reported. Furthermore, reports of new
techniques were subject to performance bias and selection
bias. The pain scores reported were subject to recall and
interviewer bias, and in general, confounders were not
routinely identified. Nevertheless, we still believe there is
value in offering a broad assessment of the laminoplasty
literature. Restricting our analysis to prospective trials
would not have produced a representative sampling of the
literature. We believe the present laminoplasty literature
deserves comprehensive review.

Conclusions
Laminoplasty remains a valid option for dorsal de-
compression of the spinal cord. A previous review of the
laminoplasty literature 10 years ago reported a consistent
decrease in ROM, a significant incidence of postoperative
kyphosis and worsening cervical alignment, and incidenc-
es of C-5 palsies and of axial neck pain that ranged widely
between reports.

This updated review, which assessed the laminoplasty
literature from 2003 to 2013, reveals some similar findings
and some evidence of improved clinical outcomes. With
long-term follow-up, the decrease in ROM of approxi-
ately 50% continues to call into question the advantage of
laminoplasty over other posterior cervical procedures
as a motion-preserving operation. The chance in cervical
alignment is unclear. There seems to be a continued sig-
ificant incidence of postoperative cervical kyphosis, with
some specific techniques resulting in a decrease in the in-
cidence of postoperative worsening alignment. The occur-
dence of neck pain continues to range widely between dif-
ferent studies, varying from 0% to 100%. The incidence of
C-5 palsies can now be better estimated at approximately
2%–4%.

Newer reports have focused on the importance of the
posterior muscle–ligament complex, perhaps with im-
provement in maintenance of postoperative cervical lor-
dosis and a decrease in the incidence of cervical kyphosis.
The introduction of instrumented techniques has not cor-
related with improved clinical outcomes.

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**Author Contributions**

Conception and design: Ratliff. Acquisition of data: Duetzmann. Analysis and interpretation of data: all authors. Drafting the article: Duetzmann. Critically revising the article: Ratliff. Statistical analysis: Cole. Administrative/technical/material support: Ratliff.

**Correspondence**

John Kevin Ratliff, Department of Neurosurgery, Stanford University, 300 Pasteur Dr., Stanford, CA 94043. email: jratliff@stanford.edu.