

# Neck Pain Following Cervical Laminoplasty: Does Preservation of the C2 Muscle Attachments and/or C7 Matter?

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## Abstract

**Study Design** Systematic review.

**Objective** In patients aged 18 years or older, with cervical spondylotic myelopathy or ossification of the posterior longitudinal ligament (OPLL), does sparing the C2 muscle attachments and/or C7-preserving cervical laminoplasty lead to reduced postoperative axial pain compared with conventional C3 to C7 laminoplasty? Do these results vary based on early active postoperative cervical motion?

**Methods** A systematic review of the English-language literature was undertaken for articles published between 1970 and August 17, 2012. Electronic databases and reference lists of key articles were searched to identify studies evaluating C2/C3- or C7-preserving cervical laminoplasty for the treatment of cervical spondylotic myelopathy (CSM) or OPLL in adults. Studies involving traumatic onset, cervical fracture, infection, deformity, or neoplasms were excluded, as were noncomparative studies. Two independent reviewers assessed the level of evidence quality using the grading of recommendations assessment, development and evaluation (GRADE) system, and disagreements were resolved by consensus.

**Results** We identified 11 articles meeting our inclusion criteria. Only the randomized controlled trial (RCT) showed no significant difference in late axial pain (at 12 months) when C7 spinous muscle preservation was compared with no preservation. However, seven other retrospective cohort studies showed significant pain relief in the preserved group compared with the nonpreserved group. The preservation group included those with preservation of the C7 spinous process and/or attached muscles, the deep extensor muscles, or C2 muscle attachment and/or C3 laminectomy (as opposed to laminoplasty). One study that included preservation of either the C2 or C7 posterior paraspinal muscles found that only preservation of the muscles attached to C2 resulted in reduced postoperative pain. Another study that included preservation of either the C7 spinous process or the deep extensor muscles found that only preservation of C7 resulted in reduced postoperative pain.

## Keywords

- ▶ laminoplasty
- ▶ axial neck pain
- ▶ C7 preservation
- ▶ semispinalis cervicis
- ▶ C3 laminectomy

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**Conclusion** Although there is conflicting data regarding the importance of preserving or the semispinalis cervicis muscle attachments to C2, there is enough evidence to suggest that surgeons should make every attempt to preserve these structures whenever possible since there appears to be little downside to doing so, unless it compromises the neurologic decompression.

## Study Rationale and Context

The most important extensor muscle of the cervical spine is the *semispinalis cervicis* muscle, which originates from the transverse processes of the upper thoracic vertebrae and inserts into the spinous processes of C2 through C5, with the most important insertion being at C2. Disruption of this insertion can result in kyphosis, and possibly axial neck pain. Another important structure for neck extension is the spinous process of C7, the *vertebra prominens*. The height of this spinous process increases the moment arm of the extensor muscle complex. Theoretically, at least, loss of the C7 spinous process height or muscular insertion into C2 might result in cervical kyphosis and axial neck pain. The purpose of this article is to perform a systematic review of the available relevant literature to determine the effect on axial neck pain of preserving the C7 spinous process and the semispinalis cervicis insertion into C2.

## Objective or Clinical Question

In patients 18 years or older, with cervical spondylotic myelopathy (CSM) or ossification of the posterior longitudinal ligament (OPLL), does a C2 muscle attachment and/or C7-preserving cervical laminoplasty lead to reduced postoperative axial pain compared with conventional C3 through C7 laminoplasty? Are these results altered by early active postoperative cervical motion?

## Methods

**Study Design:** Systematic review.

**Search:** PubMed, Cochrane, and National Guideline Clearinghouse Databases; bibliographies of key articles.

**Dates Searched:** Up through August 17, 2012.

**Inclusion Criteria:** Studies directly comparing C2/C3 or C7 preserving with conventional nonpreserving cervical laminoplasty in patients 18 years or older with CSM or OPLL.

**Exclusion Criteria:** Studies in patients younger than 18 years, those with a cervical fracture, neoplasm, infection, or deformity; noncomparative studies, comparative studies with fewer than 10 patients per treatment group; nonhuman *in vivo*, *in vitro*, and biomechanical studies.

**Outcomes:** Pain (visual analog scale [VAS], Hosono criteria).

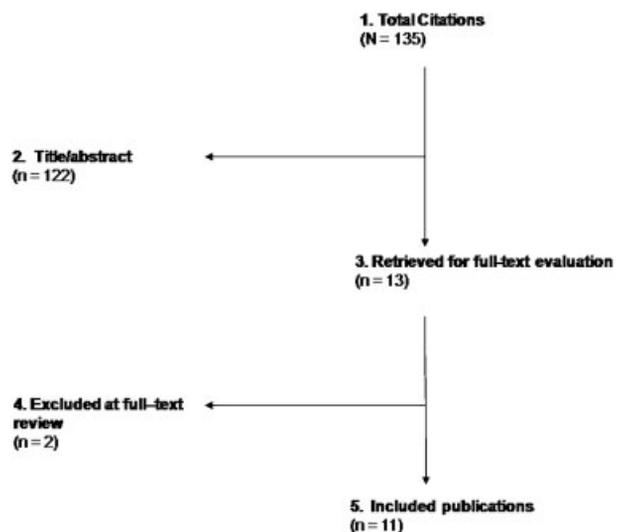
**Analysis:** Descriptive statistics, means, standard deviation, and ranges were abstracted from the original reports as available. Mean percentage improvement in VAS scores was calculated by dividing the change score from baseline to

follow-up by the baseline score. Pooling of data was not done due to concerns regarding study quality and heterogeneity of treatments and study populations. We attempted to answer the question of the effect of early motion on pain by stratifying the results based on the length of collar use.

**Overall Strength of Evidence:** Risk of bias for individual studies was based on using criteria set by *The Journal of Bone and Joint Surgery*<sup>1</sup> modified to delineate criteria associated with methodological quality and risk of bias based on recommendation from the Agency for Healthcare Research and Quality.<sup>2,3</sup> The overall strength of evidence across studies was based on precepts outlined by the Grading of Recommendations Assessment, Development and Evaluation (GRADE) Working Group<sup>4</sup> and recommendations made by the Agency for Healthcare Research and Quality (AHRQ).<sup>2,3</sup> (See online supplementary material.)

## Results

From a total of 135 citations retrieved, 13 were evaluated for full-text review, and 11 met the inclusion criteria for this report (→ Fig. 1). Five studies evaluated cervical laminoplasty using the open-door technique and six studies used the French-door technique. The included studies examined preservation compared with nonpreservation of C2/C3 (two studies) or C7 (six studies) spinous process and attached muscles or ligaments, the deep extensor muscles at C2 and/or C7 (four studies), or the nuchal ligament at C6 to C7 (one study); two studies compared



**Fig. 1** Flow chart showing results of literature search.

three treatment groups (►Table 1). The study populations comprised CSM patients only or a mixture of mostly CSM and OPLL patients. Populations in included studies were predominantly male and middle aged. With the exception of one randomized controlled trial (RCT) (CoE II), all studies are retrospective cohort studies (CoE III).

### Preservation of C2 Muscle Attachment with a C3 Laminectomy versus Nonpreservation

#### Pain Measured as Decreased, Complete Relief, or Any

Two retrospective cohort studies reported less axial pain with preservation of the C2 muscle attachment compared with no preservation at 24 months<sup>5</sup> or 17 to 30 months.<sup>6</sup> This was done by performing a laminectomy of C3, instead of a laminoplasty, since a laminoplasty requires more muscle detachment at C2 and also adds bulk to the area where the muscle attaches.

- Kato et al reported a significantly decreased proportion of patients in the preserved group experiencing postoperative pain in a multivariate analysis (odds ratio = 0.13, 95% confidence interval: 0.02 to 0.98).<sup>5</sup>
- Takeuchi et al reported that significantly more patients in the preserved group (52.5% with no pain, 47.5% with any pain) experienced complete relief of symptoms compared with the nonpreserved group (19% with no pain, 81% with any pain,  $p = 0.035$ ). The proportion of patients whose pain was made worse by the surgery was significantly smaller in the preserved group (17.5% worsened) compared with the nonpreserved group (50% worsened,  $p = 0.02$ ).<sup>6</sup>

### Preservation of C7 versus Nonpreservation

#### Pain Measured as Severity or Any

Two studies reported no difference in axial pain with C7 preservation compared with nonpreservation at 24 months<sup>5</sup> or 12 months.<sup>7</sup>

- An RCT showed no significant difference in severity or incidence of any late axial pain when C7 spinous muscle preservation was compared with no preservation.<sup>7</sup>
- Kato et al reported that preservation of the muscles attached to C7 resulted in a similar proportion of patients experiencing postoperative axial pain compared with nonpreservation in multivariate analysis (odds ratio = 0.7, 95% confidence interval: 0.16 to 0.13).<sup>5</sup>

### Pain Measured per Hosono Criteria (►Table 2)

- Three studies reported early axial pain ranging from 15 to 56% in the C7-preserved group compared with 49 to 86% in the nonpreserved group.<sup>8-10</sup> The preserved group experienced significantly less pain than the nonpreserved group in two of the studies.<sup>9,10</sup>
- Four studies reported late axial pain ranging from 5.4 to 38% in the preserved group compared with 30 to 73% in the nonpreserved group.<sup>7-10</sup> The preserved group experienced significantly less pain than the nonpreserved group in two of the studies.<sup>9,10</sup>

### Pain Measured by VAS (►Table 3; ►Fig. 2)

Two studies were inconsistent in their results of axial pain.

- In Takeuchi et al, the C7-preserved group had significantly improved VAS scores at 12 and 24 months compared with the nonpreserved group, while Kowatari et al reported that no significant difference was seen between the C7-preserved group and the nonpreserved group in VAS pain score at 12 months.<sup>7,11</sup>

### Aggravation of Symptoms (see online supplementary material)

- One study found that aggravation of symptoms at a late postoperative period was significantly less common in the C7-preserved group (12%) compared with the nonpreserved group (66%,  $p = 0.002$ ).<sup>8</sup>

### Other Types of Preservation

#### Pain Measured per Hosono Criteria (►Table 2)

- Three studies using different preservation techniques reported early axial pain ranging from 15 to 21% in the deep extensor muscle or nuchal ligament preserved group compared with 17 to 49% in the nonpreserved group.<sup>10,12,13</sup> The C7 deep extensor muscle-preserving group experienced significantly less pain than the nonpreserved group in one of the studies.<sup>10</sup>
- These three studies also reported late axial pain ranging from 5 to 11% in the preserved group compared with 6 to 30% in the nonpreserved group.<sup>10,12,13</sup> The group preserving the deep extensor muscles at C7 experienced significantly less pain than the nonpreserved group in one of the studies.<sup>10</sup>

### Pain Measured by VAS (►Table 3; ►Fig. 2)

- Two studies using deep extensor muscle preservation reported on VAS pain at 6 or 38 months.<sup>14,15</sup> In one study, the muscle-preserved group experienced significantly less pain at 38 months ( $2.3 \pm 2.3$ ) compared with the nonpreserved group ( $4.9 \pm 2.6$ ,  $p = 0.05$ ).<sup>14</sup>
- In the other study, the muscle-preserved group experienced significantly greater mean percentage improvement in VAS pain score at 6 months compared with the nonpreserved group.<sup>15</sup>

### Effect of Early Motion (►Figs. 3 and 4)

None of the included studies conducted a formal analysis of the effect of early cervical motion on postoperative axial pain.

- Seven studies reported the use of a collar ranging from 1 to 8 weeks,<sup>5-9,12,13</sup> two studies reported that no collar was used,<sup>14,15</sup> and two studies did not report on collar use.<sup>10,11</sup>
- The effect of early motion on early and late axial pain is shown in ►Figs. 3 and 4. There appears to be a trend of increasing postoperative axial pain with increasing length of collar use; however, these studies comprise different types of laminoplasty procedures, preservation techniques, follow-up time, and collar type and length of use. No data were available to compare collar use to no collar use.

**Table 1** Characteristics of included studies

Author (year)/study design <sup>a</sup>	Demographics <sup>b</sup>	Diagnosis	Interventions: levels decompressed, preservation	Follow-up (% followed-up)	Post-op care: collar, exercise, early cervical motion
<b>C2/C3 preservation</b>					
Kato (2008) <sup>c</sup> Retrospective cohort See also C7 preservation below	C7-preserving: N = 33 Mean age (± SD): 62.1 ± 12.4 y, male: 70% C2-preserving: N = 32 Mean age (± SD): 57.6 ± 10.5 y, male: 70% Conventional: N = 88 Mean age (± SD): NR, male: 70%	CSM, OPLL	French door: various levels from C3–C6, preserved C7 posterior paraspinal muscles French door: various levels from C4–C7, preserved C2 posterior paraspinal muscles French door (conventional): C3–C7, posterior muscle insertions detached	24 mo (89.5%)	Hard neck collar (3 wk) Active neck exercise (after initial 3 wk) No early motion
Takeuchi (2005) Retrospective cohort	SSG-preserving: N = 71 Mean age: 63 (26–90) y, male: 68% Conventional: N = 20 Mean age: 59 (46–76) y, male: 69%	CSM, OPLL	French door: C4–C7 + C3 laminectomy, preserved SSC French door (conventional): C3–C7, SSC reattached	Mean 17–30 mo (12–42 mo) (61.5%)	Collar (for 1–2 wk) Exercise started 1–2 wk post-op Patients permitted movement within 1 wk post-op
<b>C7 preservation</b>					
Cho (2010) Retrospective cohort	C7-preserving: N = 16 Mean age (± SD): 61.0 ± 12.1 y, male: 81% Conventional: N = 15 Mean age (± SD): 60.9 ± 9.1, male: 81%	CSM, OPLL, calcification of ligamentum flavum	Open door using titanium plate: C2–C6 (3–5 levels, mean 3.78 ± 0.71), preserved C7 spinous process Open door using titanium plate: C2–C7 (4–6 levels, mean 4.86 ± 0.51), no preservation of C7 spinous process	Mean 28.9 ± 24 mo (6–84 mo) (% NR)	Philadelphia collar (2 mo) Exercise: NR Patients permitted to get out of bed within 1 wk after surgery with collar
Kowatari (2009) RCT	C7-preserving: N = 35 Mean age: 60.0 (41–84) y, male: 76% Conventional: N = 36 Mean age: 58.7 (41–75) y, male: 68%	CSM, OPLL, cervical spondylotic amyotrophy	French door: C4–C6 + C3, preserved C7 spinous process and muscles French door (conventional): C4–C7 + C3, no preservation of C7 process or muscles	Preserved: mean 21.7 (12–29 mo) Nonpreserved: mean 26 mo (12–38 mo) (58%)	Soft cervical collar (for 2–3 wk) Exercise: NR Early mobilization: NR
Kato (2008) <sup>c</sup> Retrospective cohort See also C2/C3 preservation above	C7-preserving: N = 33 Mean age (± SD): 62.1 ± 12.4 y, male: 70% C2-preserving: N = 32 Mean age (± SD): 57.6 ± 10.5 y, male: 70% Conventional: N = 88 Mean age (± SD): NR, male: 70%	CSM, OPLL	French door: various levels from C3–C6, preserved C7 posterior paraspinal muscles French door: various levels from C4–C7, preserved C2 posterior paraspinal muscles French door (conventional): C3–C7, posterior muscle insertions detached	24 mo (89.5%)	Hard neck collar (3 wk) Active neck exercise (after initial 3 wk) No early motion

(Continued)

**Table 1** (Continued)

Author (year)/study design <sup>a</sup>	Demographics <sup>b</sup>	Diagnosis	Interventions: levels decompressed, preservation	Follow-up (% followed-up)	Post-op care: collar, exercise, early cervical motion
Hosono (2007) Retrospective cohort See also other types of preservation below	C7-preserving (left): N = 31 Mean age (± SD): 60.7 ± 15.1 y, male: 61% C7-preserving (right): N = 23 Mean age (± SD): 64.3 ± 10.5 y, male: 78% Conventional: N = 37 Mean age (± SD): 63.0 ± 10.2 y, male: 81%	CSM, OPLL, herniated nucleus pulposus	Open door (left): C3–C6 (open on left side of laminae), preserved C7 spinous process and deep extensor muscles on hinged (right) side Open door (right): C3–C6 (open on right side of laminae), preserved C7 spinous process and deep extensor muscles on hinged (left) side Open door (left): C3–C7 (open on left side of laminae), no preservation of C7 spinous process; preserved deep extensor muscles on hinged (right) side	> 24 mo (% NR)	Collar: NR Exercise: NR Early motion: NR
Takeuchi (2007) Retrospective cohort	C7-preserving: N = 19 Mean age: 69.7 (35–85) y, male: 79% Conventional: N = 22 Mean age: 63.9 (34–80) y, male: 59%	CSM, OPLL, ossification of ligamentum flavum, trauma	French door: C3–C6, preserved C7 spinous process and nuchal ligament French door (conventional): C3–C7, no preservation of C7	> 26 mo (% NR)	Collar: NR Isometric neck/shoulder exercises (within a few days post-op) Patients allowed ambulation 1 day post-op
Hosono (2006) Retrospective cohort	C7-preserving: N = 37 Mean age: 61.7 (31–87) y, male: 70% Conventional: N = 28 Mean age: 61.2 (44–79) y, male: 79%	CSM	Open door (unilateral): C3–C6, preserved C7 spinous process, muscles, and ligaments Open door (unilateral): C3–C7, no preservation of C7 spinous process	> 12 mo (% NR)	Soft collar (2 weeks) Exercise: NR Early motion: NR
<b>Other types of preservation</b>					
Kotani (2012) <sup>c</sup> Retrospective cohort	Muscle-preserving: N = 63 Mean age (± SD): 63 ± 11 y, male: 76% Conventional: N = 27 Mean age (± SD): 64 ± 12 y, male: 67%	CSM	French door: typical decompression pattern: C4–C6 (mean 3.3 ± 0.8 levels; C7 or T1 included in n = 7), preserved deep extensor muscles and ligaments to C2 and C7 French door (conventional): typical decompression pattern: C3–C6 or C3–C7 (mean 3.9 ± 1.2 levels; C7 or T1 included in n = 6), no preservation of deep extensor muscles	7.7 y (range, 36–128 mo) (% NR)	No collar use Isometric cervical muscle exercise (started on day 3 after surgery) Patients allowed to mobilize neck freely immediately after surgery
Sakaura (2010) Retrospective cohort	Muscle-preserving: N = 18 Mean age (± SD): 66.0 ± 11.0 y, male: 78% Conventional: N = 18 Mean age (± SD): 62.5 ± 16.0 y, male: 72%	CSM	Open door: C3–C6, preservation of deep extensor muscles to subaxial spinous processes on hinged side; preserved bilateral muscles to C2 and C7 Open door (conventional): C3–C6, no preservation of bilateral subaxial	> 24 mo (% NR)	Soft collar (for 2 weeks) Exercise: NR Early motion: NR

**Table 1** (Continued)

Author (year)/study design <sup>a</sup>	Demographics <sup>b</sup>	Diagnosis	Interventions: levels decompressed, preservation	Follow-up (% followed-up)	Post-op care: collar, exercise, early cervical motion
Kotani (2009) <sup>c</sup> Retrospective cohort	Muscle-preserving: N = 42 Mean age: 62 (34–87) y, male: 76% Conventional: N = 42 Mean age: 62 (34–87) y, male: 76%	CSM, OPLL	deep extensor muscles; preservation of bilateral muscles to C2 and C7  French door: typical decompression pattern: C4–C6 (mean 3.7 ± 1 levels; C7 included in n = 10), preservation of deep extensor muscles French door (conventional): typical decompression pattern: C3–C6 or C3–C7 (mean 5.4 ± 0.8 levels; C7 included in n = 28), no preservation of muscles	38 mo (% NR)	No collar Isometric cervical muscle exercise (started on day 3 after surgery) Patients allowed to mobilize neck freely immediately after surgery
Sakaura (2008) Retrospective cohort	C6 and C7-preserving: N = 19 Mean age ( ± SD): 60.2 ± 13.1 y, male: 84% C6-preserving: N = 18 Mean age ( ± SD): 66.0 ± 11.0 y, male: 72%	CSM	Open door: C3–C6, preserved muscles and funicular section of nuchal ligament to C6 and C7 spinous processes Open door: C3–C6, preserved muscles and funicular section of nuchal ligament to C7 spinous process	24 mo (% NR)	Soft collar (2 wk) Exercise: NR Early motion: NR
Hosono (2007) Retrospective cohort See also C7 preservation above	C7-preserving (left): N = 31 Mean age ( ± SD): 60.7 ± 15.1 y, male: 61% C7-preserving (right): N = 23 Mean age ( ± SD): 64.3 ± 10.5 y, male: 78% Conventional: N = 37 Mean age ( ± SD): 63.0 ± 10.2 y, male: 81%	CSM, OPLL, herniated nucleus pulposus	Open door (left): C3–C6 (open on left side of laminae), preserved C7 spinous process and deep extensor muscles on hinged (right) side Open door (right): C3–C6 (open on right side of laminae), preserved C7 spinous process and deep extensor muscles on hinged (left) side Open door (left): C3–C7 (open on left side of laminae), no preservation of C7 spinous process; preserved deep extensor muscles on hinged (right) side	> 24 mo (% NR)	Collar: NR Exercise: NR Early motion: NR

Abbreviations: CoE, class of evidence; CSM, cervical spondylotic myelopathy; NR, not reported; OPLL, ossification of posterior longitudinal ligament; RCT, randomized controlled trial; SD, standard deviation; SSC, semispinalis cervicis.

<sup>a</sup>It is likely that the following studies have overlapping patient populations, although the extent of the overlap cannot be determined (Hosono 2006 and Hosono 2007, Hosono 2007 and Sakaura 2010, Kotani 2009 and Kotani 2012, Takeuchi 2005 and Kowatari 2009).

<sup>b</sup>Percent male reported for both treatment groups combined.<sup>10</sup> Percent male reported for all three treatment groups combined; sample sizes indicate number of patients analyzed; original cohort included 162 patients, distribution among treatment groups unknown; eight patients (C4–C6 and C5–C6) are included in both C7-preserving and C3-preserving analyses.<sup>7</sup> Mean age and percent male reported for both treatment groups combined.<sup>16</sup> Author stated that 74 patients received laminoplasty, but reported details on 71 patients.<sup>9</sup>

<sup>c</sup>Three studies report using open door laminoplasty; however, the authors of this report have determined that a French door technique was used based on a description of the surgical procedure.<sup>7,16,17</sup>

**Table 2** Early and late axial pain according to Hosono criteria<sup>a</sup>

Study (year) Type of laminoplasty	Category(ies) of preservation	Preserved group (% of patients)	Nonpreserved group (% of patients)	p-Value
<b>Pre-op axial pain</b>				
Cho (2010) Open door	C7 (spinous process)	19	20	NR
<b>Early axial pain<sup>b</sup></b>				
Cho (2010) Open door	C7 (spinous process)	56	86	NR
Hosono (2006) Open door	C7 (spinous process)	16	50	0.006
Hosono (2007) <sup>c</sup> Open door	C7 (spinous process) and other preservation (deep extensor muscles at C7)	15	49	0.0008
Sakaura (2010) Open door	Other preservation (deep exten- sor muscles at C2 and C7 on hinged side)	16.7	22.2	NS
Sakaura (2008) Open door	Other preservation (funicular section of nuchal ligament to C6 and C7)	21	17	NS
<b>Late axial pain<sup>b</sup></b>				
Cho (2010) Open door	C7 (spinous process)	12	73	NR
Hosono (2006) Open door	C7 (spinous process)	5.4	29	0.015
Hosono (2007) <sup>b</sup> Open door	C7 (spinous process) and other preservation (deep extensor muscles at C7)	6	30	0.0036
Kowatari (2009) <sup>d</sup> French door	C7 (spinous process and attached muscles)	38	37	NR
Sakaura (2010) Open door	Other preservation (deep exten- sor muscles at C2 and C7 on hinged side)	11.1	11.1	NS
Sakaura (2008) Open door	Other preservation (funicular section of nuchal ligament to C6 and C7)	5	6	NS

Abbreviations: NR, not reported; NS, not significant.

Note: Axial pain/symptoms is defined as neck pain with neck stiffness, shoulder stiffness, or both<sup>8</sup>; neck and/or shoulder girdle pain that worsened after a long period of sitting or standing<sup>1</sup>; or not defined.<sup>9,10,16,17</sup>

<sup>a</sup>Hosono pain grading: severe (analgesics or injection of anesthetics to the painful muscles regularly needed), moderate (physical therapy including massage or thermotherapy for the painful muscles regularly needed), mild (no treatment needed).<sup>9</sup>

<sup>b</sup>Early axial pain is defined as severe or moderate axial pain persisting for more than 1 wk during the first month after surgery. Late axial pain is defined as severe or moderate axial pain persisting for more than 1 mo after surgery.<sup>9</sup> Summation of moderate and severe percentages from original data for pre-op, early, and late axial pain.<sup>8</sup>

<sup>c</sup>Results for preserved group combine the open left and open right treatment groups.<sup>10</sup>

<sup>d</sup>Late axial pain is defined as severe or moderate pain measured at 1 year F/U, duration of pain NR.<sup>1</sup>

## Clinical Guidelines

Guidelines were found addressing cervical laminoplasty for the treatment of CSM; however, these guidelines did not recommend any particular laminoplasty approach.<sup>16,17</sup>

## Evidence Summary (→ Table 4)

The overall strength of evidence evaluating C2/C3 or C7-preserving laminoplasty compared with nonpreserving lam-

inoplasty with respect to patient-reported pain outcomes is low, meaning we have low confidence that the evidence reflects the true effect and that further research is likely to change the confidence in the estimate of effect and likely to change the estimate.

## Illustrative Case

The patient is a 52-year-old male with cervical myelopathy due to OPLL. He had mild axial neck pain preoperatively, but

**Table 3** Mean visual analog scale (VAS) pain scores from preoperative to follow-up

Study (year) Type of laminoplasty	Category(ies) of preservation	VAS mean $\pm$ SD or (range) (% improvement from pre-op) <sup>a</sup>		
		Preserved group	Nonpreserved group	p-Value (preserved vs. nonpreserved mean score)
<b>Pre-op</b>				
Kotani (2012) French door	Other preservation (deep extensor muscles at C2 and C7)	4.1 $\pm$ 3.3	5.5 $\pm$ 4.0	NS
Kotani (2009) French door	Other preservation (deep extensor muscles at C2 and/or C7)	3.5 $\pm$ 3.2 <sup>b</sup>	3.5 $\pm$ 3.2 <sup>b</sup>	NA
Takeuchi (2007) French door	C7 (spinous process and nuchal ligament)	5.4 $\pm$ 1.7	5.6 $\pm$ 1.4	0.506
<b>6 mo</b>				
Kotani (2012) French door	Other preservation (deep extensor muscles at C2 and C7)	2.8 $\pm$ 2.5 (31.7%)	4.5 $\pm$ 2.4 (18.2%)	< 0.01
<b>12 mo</b>				
Kowatari (2009) French door	C7 (spinous process and attached muscles)	2.9	3.5	NS
Takeuchi (2007) French door	C7 (spinous process and nuchal ligament)	2.4 $\pm$ 1.9 (55.6%)	6.4 $\pm$ 1.7 (-14.3%)	< 0.05
<b>24 mo</b>				
Takeuchi (2007) French door	C7 (spinous process and nuchal ligament)	2.3 $\pm$ 1.8 (57.4%)	6.2 $\pm$ 1.9 (-10.7%)	< 0.05
<b>38 mo</b>				
Kotani (2009) French door	Other preservation (deep extensor muscles at C2 and/or C7)	2.3 $\pm$ 2.3	4.9 $\pm$ 2.6	0.05
<b>7.7 y</b>				
Kotani (2012) French door	Other preservation (deep extensor muscles at C2 and C7)	2.2 $\pm$ 2.2 (46.3%)	4.3 $\pm$ 2.4 (21.8%)	< 0.01

Abbreviations: NA, not applicable; NS, not significant; SD, standard deviation; VAS, visual analog scale.

<sup>a</sup>VAS reported on 0–10 mm scale<sup>11,12,15</sup>; reported on a 0–100 mm scale and normalized to a 0–10 mm scale for comparison purposes.<sup>1</sup>

<sup>b</sup>Mean VAS reported for combined treatment groups at pre-op, no significant difference in VAS score between the groups.<sup>11</sup>

said that he could live with the pain as long as the myelopathy is resolved. When given a choice between fusion with laminectomy, which would limit his motion, and a laminoplasty, he chose the latter. A C3 laminectomy and C4 to C6 laminoplasty were performed. He had no worsening of his axial neck pain and felt that it was often better than it was preoperatively. **►Fig. 5** shows the preoperative lateral radiograph. **►Fig. 6a, b** shows the sagittal CT views. **►Fig. 7** is the postoperative lateral radiograph, showing the C3 laminectomy and laminoplasty of C4 to C6 with plates.

## Discussion

- This systematic review is limited by the following:
  - Axial pain/symptoms were variously defined or not defined at all.
  - There was no indication in the literature of the reliability, validity, or responsiveness of the Hosono pain grading criteria in this or any other patient population.
  - Loss to follow-up was not reported in the majority of studies.
  - All but one of the studies was CoE III.

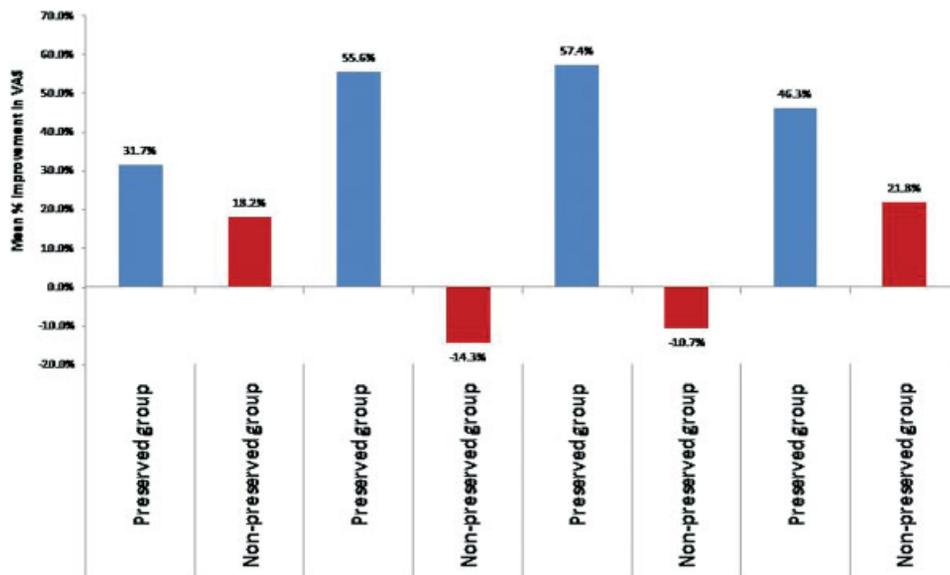


Fig. 2 Overall mean percent improvement in visual analog scale (VAS) pain score at last follow-up for two studies.

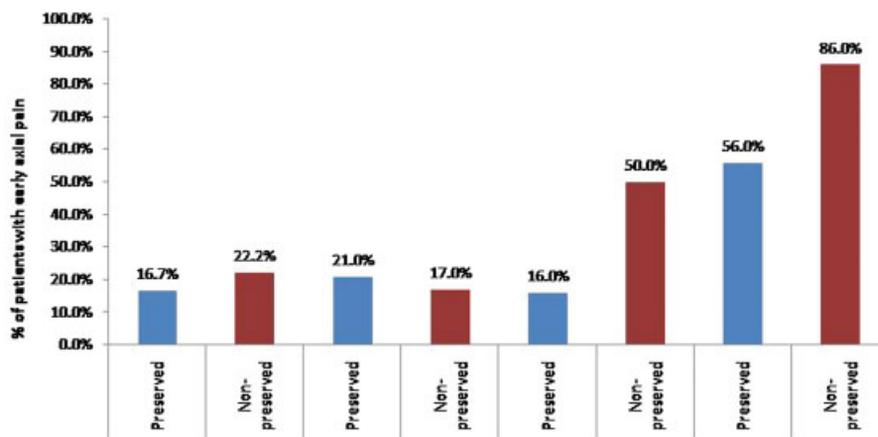


Fig. 3 Collar use and early axial pain for studies grading pain using the Hosono criteria.

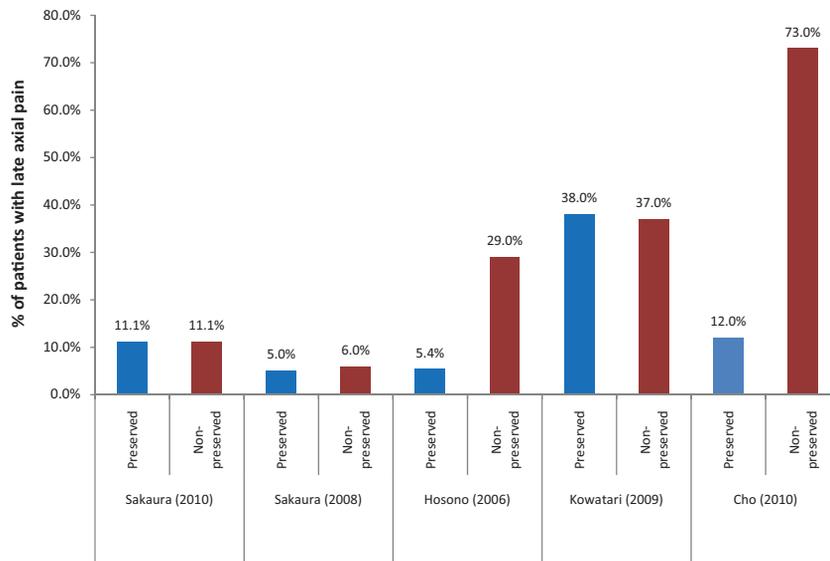


Fig. 4 Collar use and late axial pain for studies grading pain using the Hosono criteria.

**Table 4** Summary of strength of evidence

	Strength of evidence	Conclusions/comments	Baseline	Upgrade (levels)	Downgrade (levels)
Patient-reported outcomes					
Improvement in pain (VAS or Hosono criteria)	Low	<ul style="list-style-type: none"> <li>The only RCT included in this report found no significant difference in axial pain between C7-preserved and nonpreserved groups.</li> <li>Both C2-preservation studies and two-thirds of the C7-preservation studies showed improved pain relief in the C2 or C7 preservation group. One of these cohort studies comparing C2 and C7 preservation to nonpreservation found that C2 preservation resulted in reduced pain compared with nonpreservation, but C7 preservation and nonpreservation had similar pain outcomes.</li> <li>None of the included studies conducted a formal analysis of the effect of early cervical motion on postoperative pain.</li> </ul>	Low		

Abbreviations: RCT, randomized controlled trial; VAS, visual analog scale.

Baseline quality: High = majority of articles Level I/II. Low = majority of articles Level III/IV.

Upgrade: Large magnitude of effect (1 or 2 levels); dose response gradient (1 level).

Downgrade: Inconsistency of results (1 or 2 levels); indirectness of evidence (1 or 2 levels); imprecision of effect estimates (1 or 2 levels).

**Fig. 5** Preoperative lateral.

- Five of the studies had a relatively small sample size (< 70 patients).
- Several studies' treatment groups comprised different time periods, resulting in potential differences between the groups regarding surgical technique or postoperative care.
- Despite the low strength of evidence, we conclude that:
  - There is no downside to using techniques to preserve C7 or the semispinalis cervicis attachment to C2, as long as the neurologic decompression is not compromised.
  - Whenever possible, surgeons should attempt to preserve the attachments of the *semispinalis cervicis* to C2. C3 laminectomy, instead of laminoplasty, helps to achieve this.
  - If an adequate decompression can be achieved without including C7 in the laminoplasty, it should be preserved with its muscle attachments.

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#### Conflict of Interest

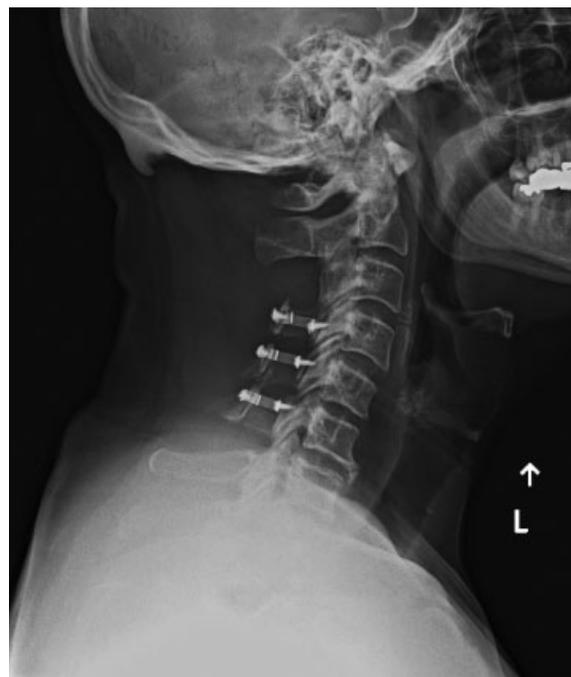
John G. Heller received royalties from Medtronic for a device related to this topic, and also owns stock shares and has consulted for Medtronic.



**Fig. 6** (a) Parasagittal preoperative CT image demonstrating severe ossification of the posterior longitudinal ligament (OPLL). (b) Midsagittal preoperative CT image demonstrating severe OPLL.

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**Fig. 7** Postoperative lateral.

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## Editorial Perspective

The authors received unanimous applause from our *EBSJ* reviewers for the idea of the study, the methodology, and its useful conclusions. Protracted postoperative neck pain has been one of the major concerns regarding laminoplasty surgery and this systematic review thoroughly looked at preservation of muscle attachments to the two most prominent posterior cervical spinous processes—C2 and C7. It appears that there are few downsides to this technique adaptation, aside from performing a more anatomic dissection and adjusting for a potentially more limited exposure of the transition segments by changing the decompression techniques for C3 and C7 levels. The role of postoperative immobilization is another intriguing aspect of trying to

optimize patients' long-term pain outcomes following laminoplasty. Here, the current data are insufficient for a clear message. The general trend of this comparison, however, seems to point to a clear preference for limiting the duration of immobilization and maximizing opportunities for early functional recovery. This early observation seems to be an outright open invitation for a prospective trial.

In general, this systematic review endorses the general concept of laminoplasty as a successful treatment strategy for certain patients afflicted with symptomatic cervical stenosis. There seems to be room for improvement in outcomes by refining the surgical and perioperative care strategies employed.