11 Posterior Decompression for Cervical Spondylotic Myelopathy: Laminectomy, Laminectomy and Fusion or Laminoplasty

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Introduction

Degenerative cervical myelopathy (DCM) represents a spectrum of chronic atraumatic spinal cord injury that occurs secondary to compression from disc spondylosis, hypertrophy of the ligamentum flavum, or ossification of the posterior longitudinal ligament (OPLL), etc. [1]. While surgical management has been shown to arrest the progressive deterioration and provide neurological and functional improvement, the selection of surgical procedures pertaining to specific cases is subject to much controversy [2–4]. While the subject of anterior versus posterior spinal decompression has been repeatedly debated amongst the experts, this chapter

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R. H. M. A. Bartels et al. (eds.), *Evidence for Neurosurgery*,
https://doi.org/10.1007/978-3-030-16323-5_11

will focus on posterior surgical options and anterior alternatives will not be further elaborated.

The posterior cervical decompression techniques have a long track record of success in halting the progression of DCM. Prior to the introduction of cervical instrumentation strategies, posterior cervical laminectomies (LA) were a common procedure utilized to treat multilevel compressions [5–7]. Although initially found to be clinically effective, the development of late neurological deterioration secondary to post-operative instability and kyphosis [8–11] has led to the drive for alternative procedures. Since its introduction, laminectomy and instrumented fusion (LF) has been gaining popularity among the options in cervical decompression procedures [12–15]. In the modern era, the use of lateral mass screws and titanium rods allowed us to move away from wiring and plating of the cervical spine and to increase the safety of these procedures [16–20]. However, despite the advantages, the added stability with instrumentation comes at a cost of significant loss of mobility and range of motion (ROM) in the cervical spine [21–23].

The cervical laminoplasty (LA) procedure was designed to increase the overall spinal canal diameter by partial opening and elevating the laminae while keeping the posterior elements intact [24]. While a number of techniques have been described in the literature, they are largely the variations of two common procedures known as the “open-door” and the “French door” [25–28]. Although the posterior elements are preserved in these surgeries, post-laminoplasty kyphosis has been described in the literature [29–33]. Therefore, it is generally not the surgical procedure of choice when severe preoperative kyphotic deformity is present. Additionally, since the procedure itself avoids fusion, the benefit of relative preservation of motion comes at a cost of postoperative neck pain [34, 35].

Furthermore, the drive to preserve motion and prevent instability while achieving adequate decompression in the cervical spine has let to the development of a minimally-invasive, mucle-preserving posterior approach utilized in skip laminectomy (sLA), where only selective laminectomies are performed. Since this technique was introduced by Shiraishi et al. in 1998, it has shown promising results as a non-instrumented alternative for posterior decompression [36–38].

Nowadays, it is generally accepted that a fusion procedure should accompany any cervical decompression in the presence of kyphotic deformity [5, 39]. However, controversy exists as to the optimal procedure for DCM in a lordotic cervical spine. The goal of this chapter is to systematically review and summarize the evidence in the literature on the comparative efficacy and safety of the common posterior cervical spine procedures.

Material and Methods

Generation of Key Questions

Key questions were formulated to address important clinical inquiries: (Q1) What is the efficacy of LA or sLA compared to LF based on clinically important changes in neurological and functional status? (Q2) What is the efficacy of LP compared to LA or sLA based on clinically important changes in neurological and functional status? (Q3) What is the efficacy of LF compared with LP based on clinically important changes in neurological and functional status? (Q4) What is the safety profile of LA or sLA compared to LF? (Q5) What is the safety profile of LP compared to LA or sLA? (Q6) What is the safety profile of LF compared to LP?

Electronic Literature Search

The literature search was performed by an experienced librarian using Ovid MEDLINE, Embase, and Cochrane library databases. To ensure high sensitivities in our systematic review, appropriate search concepts were developed with relevant subject headings complimented by text word searches of titles and abstracts using relevant MeSH terms and synonyms. Appropriate truncations, adjacent operators, parentheses and Boolean operators were employed to ensure the inclusiveness as well as the precision of the search.

For the purpose of this chapter, only English language articles published after January 2000 were included. For inclusion into the review, articles must include adult human patients (age >18), diagnosed with DCM, surgically treated with either LP, LA, sLA, or LF. Studies must have a clear reporting of neurological and/or functional outcomes both preoperatively and postoperatively or describe the spectrum and incidence of complications. In order to present the highest quality of evidence in the literature, the selection was further limited to only randomized control trials (RCT) and comparative studies with ≥10 patients in each treatment group.

Two authors independently screened titles and abstracts for relevant articles pertaining to the scope of this chapter. Full manuscripts of the selected articles subsequently underwent extensive review by the same authors. When conflicting opinion on the inclusion and exclusion of articles arose, the issues were either resolved by discussion, or when necessary, the advice from a third author was sought. For each article selected, the references list was carefully reviewed for additional relevant articles to include.

Data Extraction

An exhaustive assessment of outcome scores was attempted to address Q1–3 in this review, but the overall paucity of generalized reporting algorithms hindered this effort. Therefore, owing to their relatively consistent appearance across studies, the Japanese Orthopaedic Association (JOA) and the modified JOA (mJOA) Score for the Assessment of Cervical Myelopathy along with the Neck Disability Index (NDI) were selected as the primary measures of neurological and functional outcomes. The Visual Analogue Scale (VAS), Ishihara's cervical curvature index [40], and neck range of motion (ROM) were included as secondary outcomes. For Q4–5, the spectrum and incidence of key intraoperative and postoperative complications of each procedure were evaluated.

Evaluation of Level of Evidence and Strength of Literature

Gradings of the level of evidence were independently performed by two authors for each published article based on the criteria suggested by the *Journal of Bone & Joint Surgery* and Agency for Healthcare Research and Quality (AHRQ) [41, 42]. The overall strength of evidence for each outcome of interest was determined based on the recommendations by Grading of Recommendation Assessment, Development and Evaluation Working Group [43–46] and the AHRQ [42].

Data Analysis

For Q1–3, in order to compare the clinical effectiveness of the procedures, the difference in means, standardized mean difference (SMD), and 95% confidence interval (CI) between the treatment groups were calculated based on the preoperative and postoperative data reported in the manuscript. Missing data were input using methods proposed by the Cochrane Handbook for Systematic Reviews of Intervention [47]. To address the effectiveness of an intervention, the suggested measure by Cohen [48] was used whereby an effect size of 0.2 is considered as "small", 0.5 as "medium" and ≥0.8 as "large". For Q4–5, the spectrum and incidence of complications were extracted from the studies. For each complication, relative risk or risk ratio (RR) and 95% CI were calculated. Statistical calculations were performed using the Comprehensive Meta Analysis Version 3.3.070 (Biostat, Inc. Englewood, NJ, USA) [49].

Results

The literature search resulted in 6344 articles after removal of duplications. Through exclusion based on title, abstract, and year of publication, 178 articles remained for full manuscript review. Electronic manuscripts were obtained, and careful review of the articles was performed. By applying our inclusion and exclusion criteria, 16 articles were finally selected for the systematic review plus three additional articles that were found through screening of the reference lists (Fig. 11.1). A total of two articles were found that addressed Q1 [50, 51], six articles addressing Q2 [36, 37, 50–53], 12 articles for Q3 [21–23, 50, 51, 54–60], two articles for Q4 [51, 61], four articles for Q5 [36, 37, 51, 62] and 11 articles for Q6 [21–23, 51, 54–56, 58–60, 63]. The list of all included articles as well as their level of evidence are presented in Table 11.1.

For Q1 and 2, due to the limited number of studies identified through the literature that specifically addressed these questions, a qualitative review is presented in this chapter. The summary of reported outcome scores, imputed values, calculated SMD and 95% CI for each comparison are presented in Table 11.2. For Q3, although an adequate number of articles were identified, due to high heterogeneity of the studies, the pooling of the data for meta-analysis

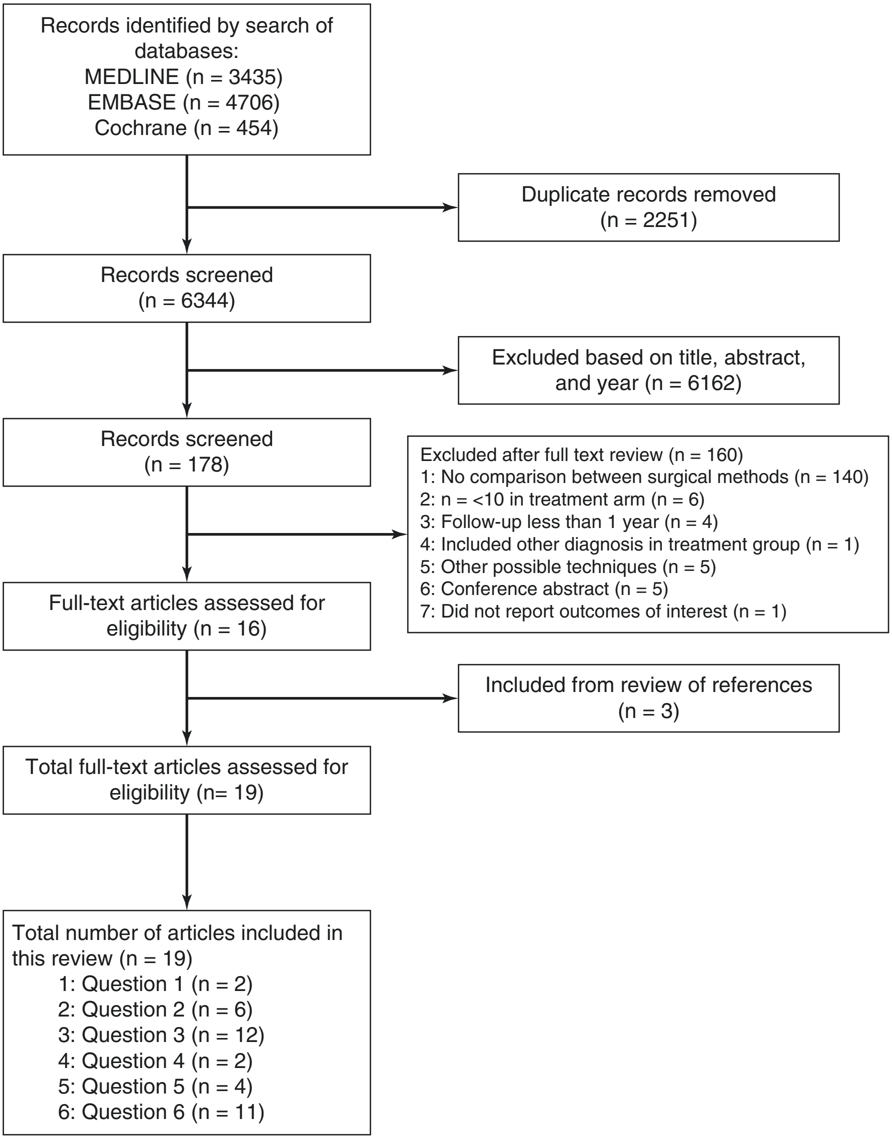


Fig. 11.1 Flowchart of literature search

was not performed. The calculated SMD and 95% CI for each outcome are presented in the form of forest plots (Fig. 11.2). For Q4 and 5, qualitative review of the literature is presented due to the limited number of studies. Results of calculated RR and 95% CI are summarized in Table 11.3. Finally, for Q6, due to the larger number of studies, a forest plot was used to present the summarized results (Fig. 11.3).

Table 11.1 Summary of the level of evidence for included studies

Author	Design	Randomization sequence generation[a]	Concealment of allocation[a]	Intention to treat analysis[a]	Blinding independent assessment	Co-intervention applied equally	Follow up (>80%)	Adequate Sample size	Controlling of confounders	Class of evidence	Risk of bias
Blizzard et al. [21]	Retrospective cohort							•	•	III	Moderately high
Chang et al. [52]	Prospective cohort							•	•	III	Moderately high
Della Pepa et al. [62]	Retrospective cohort							•		III	Moderately high
Du et al. [50]	Retrospective cohort							•	•	III	Moderately high
Fehlings et al. [54]	Prospective cohort					•		•	•	II	Moderately low
Heller et al. [22]	Retrospective cohort							•	•	III	Moderately high
Highsmith et al. [55]	Retrospective cohort							•	•	III	Moderately high
Lau et al. [56]	Retrospective cohort							•	•	III	Moderately high
Lee et al. [63]	Retrospective cohort							•	•	III	Moderately high
Lee et al. [51]	Retrospective cohort							•	•	III	Moderately high
Miyamoto et al. [57]	Retrospective cohort							•	•	III	Moderately high
Nurboja et al. [52]	Retrospective cohort							•		III	Moderately high

Shirashi et al. [36]	Prospective cohort						•	•	•	III	Moderately high
Stephens et al. [58]	Retrospective cohort							•	•	III	Moderately high
Woods et al [59]	Retrospective cohort					•	•	•	•	II	Moderately low
Yang et al. [23]	Retrospective cohort						•	•		III	Moderately high
Yehya et al. [61]	Randomized controlled trial	•						•	•	II	Moderately Low
Yuan et al. [60]	Prospective cohort							•	•	III	Moderately high
Yukawa et al. [37]	Randomized controlled trial						•	•	•	II	Moderately low

[a]Criteria applies only to randomized control trials

Table 11.2 Summary outcomes of laminectomy vs. laminectomy and fusion, laminoplasty vs. laminectomy, laminoplasty vs. selective/skip laminectomy

	Preoperative (mean ± SD)	Postoperative (mean ± SD)	Difference in score	Preoperative (mean ± SD)	Postoperative (mean ± SD)	Difference in score	Difference in mean	Standard mean difference	95% confidence interval: Lower limit	95% confidence interval: Upper limit
	Laminectomy			Laminectomy and fusion						
JOA/mJOA scores										
Du et al. [50]	n = 30, mean follow up 9.4 years (range 7.6–11.7)			n = 32, mean follow up 8.9 years (range 7.2–11.5)			−1.18	−0.92	−1.44	−0.40
	8.10 ± 1.18	13.07 ± 1.23	4.97	8.16 ± 1.11	14.31 ± 1.33	6.15				
NDI score										
Lee et al. [51][a]	n = 15, follow up >24 months			n = 21, follow up >24 months			−2.60	−0.30	−0.96	0.37
	18.30 ± 14.70	16.80 ± 3.10	1.50	17.90 ± 12.90	13.80 ± 11.20	4.10				
Ishihara index										
Du et al. [50]	n = 30, mean follow up 9.4 years (range 7.6–11.7)			n = 32, mean follow up 8.9 years (range 7.2–11.5)			−2.00	−0.35	−0.85	0.15
	16.10 ± 5.10	12.90 ± 6.10	−3.20	15.30 ± 4.70	14.10 ± 5.30	−1.20				
Lee et al. [51][a]	n = 15, follow up >24 months			n = 21, follow up >24 months			−0.90	−0.087	−0.75	0.58
	11.70 ± 8.80	7.70 ± 12.00	−4.00	8.40 ± 8.30	5.30 ± 8.90	−3.10				
VAS-neck										
Lee et al. [51][a]	n = 15, follow up >24 months			n = 21, follow up >24 months			0.20	0.091	−0.57	0.75
	2.80 ± 2.80	1.70 ± 1.70	1.10	2.90 ± 3.30	2.00 ± 2.50	0.90				
	Laminoplasty			*Laminectomy*						
JOA/mJOA scores										
Du et al. [50]	n = 36, mean follow up 9.2 years (range 7.3–11.4)			n = 30, mean follow up 9.4 years (range 7.6–11.7)			0.92	0.73	0.23	1.23
	8.08 ± 1.13	13.97 ± 1.28	5.89	8.10 ± 1.18	13.07 ± 1.23	4.97				

NDI score										
Lee et al. [51][a]	n = 21, follow up >24 months			n = 15, follow up >24 months			2.00	0.30	−0.37	0.96
	12.30 ± 5.60	8.80 ± 8.40	3.5	18.30 ± 14.70	16.80 ± 3.10	1.50				
Ishihara index										
Du et al. [50]	n = 36, mean follow up 9.2 years (range 7.3–11.4)			n = 30, mean follow up 9.4 years (7.6–11.7)			0.60	0.11	−0.37	0.60
	15.80 ± 4.30	13.20 ± 4.60	−2.60	16.10 ± 5.10	12.90 ± 6.10	−3.2				
Lee et al. [51][a]	n = 21, follow up >24 months			n = 15, follow up >24 months			−1.20	−0.13	−0.80	0.53
	10.90 ± 6.50	5.70 ± 6.40	−5.20	11.70 ± 8.80	7.70 ± 12.00	−4.00				
Nurboja et al. [52]	n = 75, mean follow up 96 months ±44			n = 34, mean follow up 58 months ±51			−0.3	−0.04	−0.45	0.36
	6.70 ± 12.20	0.70 ± 5.50[b]	−6.00	7.60 ± 16.80	1.90 ± 9.05[b]	−5.70				
VAS-neck										
Lee et al. [51][a]	n = 21, follow up >24 months			n = 15, follow up >24 months			−0.40	−0.17	−0.83	0.50
	3.40 ± 3.50	2.70 ± 2.80	0.70	2.80 ± 2.80	1.70 ± 1.70	1.10				
Nurboja et al. [52]	n = 48, mean follow up 96 months ±44			n = 33, mean follow up 58 months ±51			0.00	0.00	−0.44	0.44
	1.00 ± 5.00	1.00 ± 2.80[b]	0.00	2.00 ± 6.50	2.00 ± 1.70[b]	0.00				
	Laminoplasty			*Selective/skip laminectomy*						
JOA/mJOA scores										
Yukawa et al. [37]	n = 21, mean follow up 28 months ±10.1			n = 20, mean follow up 28 months ±10.1			−0.2	NA	NA	NA
	11.1 ± NR	14.4 ± NR	3.3	10.1 ± NR	13.6 ± NR	3.5				
NDI score										
Chang et al. [52]	n = 35, mean follow up 18.4 months ±6.9			n = 32, mean follow up 18.4 months ±6.9			0.60	0.10	−0.38	0.58
	17.90 ± 10.70	13.80 ± 4.10	4.10	18.30 ± 6.60	14.80 ± 7.40	3.50				

(continued)

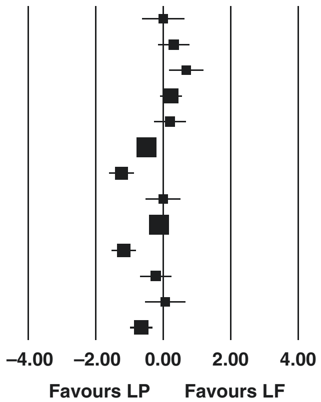
Table 11.2 (continued)

	Preoperative (mean ± SD)	Postoperative (mean ± SD)	Difference in score	Preoperative (mean ± SD)	Postoperative (mean ± SD)	Difference in score	Difference in mean	Standard mean difference	95% confidence interval	
									Lower limit	Upper limit
	Laminectomy			Laminectomy and fusion						
Ishihara index										
Shiraishi et al. [36]	n = 51, mean follow up 43 months (range 24–66)			n = 43, mean follow up 30 months (range 24–41)			−5.9	NA	NA	NA
	16.0 ± NR	11.8 ± NR	−4.2	11.4 ± NR	13.1 ± NR	1.7				
VAS neck										
Chang et al. [52]	n = 35, mean follow up 18.4 months ±6.9			n = 32, mean follow up 18.4 months ±6.9			−0.40	−0.21	−0.69	0.28
	3.40 ± 2.30	2.70 ± 1.90	0.70	2.80 ± 2.50	1.70 ± 2.00	1.10				
ROM outcome										
Chang et al. [52]	n = 35, mean follow up 18.4 months ±6.9			n = 32, mean follow up 18.4 months ±6.9			8.10	0.89	0.39	1.39
	17.04 ± 9.19	15.05 ± 9.60	−1.99	20.00 ± 10.76	9.91 ± 8.54	−10.09				
Yukawa et al. [37]	n = 21, mean follow up 28.1 months ±10.1			n = 20, mean follow up 28.1 months ±10.1			−7.00	−0.71	−1.34	−0.08
	49.00 ± 10.70	35.80 ± 10.20	−13.20	43.40 ± 10.40	37.20 ± 9.50	−6.20				

SD Standard deviation, *NR* Not reported, *NA* Not applicable
[a]Lee et al. [51]
[b]Missing standard deviation imputed based on methods recommended by Cochrane Handbook for Systematic Review

a

Study name	Outcome	Std diff in means	Lower limit	Upper limit
Yuan et al 2015	JOA	0.000	–0.637	0.637
Blizzard et al 2017	JOA	0.310	–0.159	0.779
Myiamoto et al 2014	JOA	0.683	0.162	1.203
Yang et al 2013	JOA	0.237	–0.095	0.569
Du et al 2013	JOA	0.199	–0.278	0.677
Fehlings et al 2017	mJOA	–0.492	–0.744	–0.240
Stephens et al 2017	mJOA	–1.231	–1.605	–0.856
Highsmith et al 2017	mJOA	0.000	–0.525	0.525
Fehlings et al 2017	NDI	–0.119	–0.367	0.129
Stephens et al 2017	NDI	–1.165	–1.536	–0.793
Blizzard et al 2017	NDI	–0.216	–0.684	0.251
Lee et al 2016	NDI	0.061	–0.544	0.666
Yang et al 2013	NDI	–0.655	–0.995	–0.316



b

Study name	Outcome	Std diff in means	Lower limit	Upper limit
Lee et al 2016	Ishihara Index	0.271	–0.337	0.879
Yang et al 2013	Ishihara Index	–0.083	–0.414	0.248
Du et al 2013	Ishihara Index	0.283	–0.195	0.762
Heller et al 2001	ROM	–1.559	–2.436	–0.681
Blizzard et al 2017	ROM	–2.193	–2.781	–1.605
Yang et al 2013	ROM	–2.521	–2.964	–2.079
Lau et al 2017	VAS Neck	0.435	0.077	0.792
Highsmith et al 2017	VAS Neck	1.217	0.645	1.788
Stephens et al 2017	VAS Neck	0.732	0.377	1.088
Blizzard et al 2017	VAS Neck	0.270	–0.199	0.738
Lee et al 2016	VAS Neck	0.075	–0.530	0.680
Yang et al 2013	VAS Neck	–1.050	–1.403	–0.698

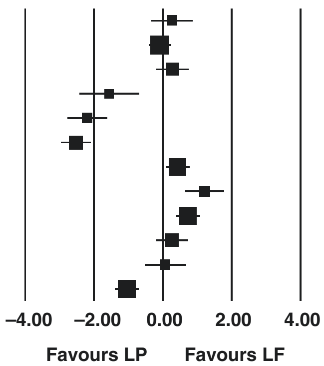


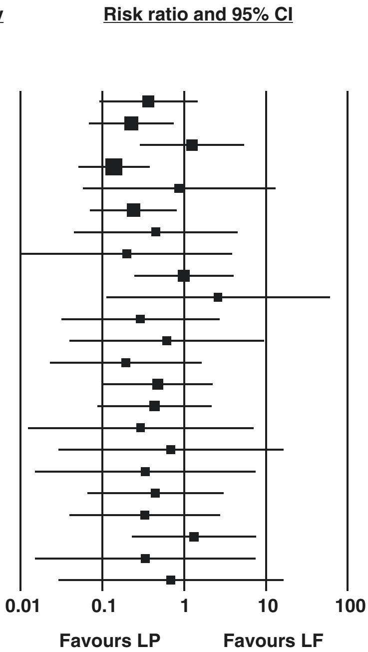
Fig. 11.2 (**a**) Summary of standardized mean difference comparing the improvements of neurological and functional outcomes as measured by JOA/mJOA and NDI achieved through laminoplasty and laminectomy and fusion as reported by individual studies. (**b**) Compiled summary of standardized mean differences of secondary outcomes achieved by laminoplasty and laminectomy and fusion as reported by individual studies

Table 11.3 Summary of studies reporting complications of laminectomy vs. laminectomy and fusion, laminoplasty vs. laminectomy, laminoplasty vs. selective/skip laminectomy, and laminoplasty vs. laminectomy and fusion

	Dural tear/CSF leak	C5 palsy	Infection	Kyphosis	Dural tear/CSF leak	C5 palsy	Infection	Kyphosis
	Laminectomy				Laminectomy and fusion			
Lee et al. [51][a]	NR	0/15 (0%)	NR	NR	NR	2/21 (9.52%)	NR	NR
Yehya [61]	1/30 (3.33%)	NR	2/30 (6.67%)	NR	2/32 (6.25%)	NR	3/32 (9.38%)	NR
	Laminoplasty				*Laminectomy*			
Della Pepa et al. [62]	0/33 (0.0%)	NR	0/33 (0%)	0/33 (0%)	0/24 (0%)	NR	0/24 (0%)	3/24 (12.5%)
Lee et al. [51][a]	NR	0/21 (0%)	NR	NR	NR	0/15 (0%)	NR	NR
	Laminoplasty				*Selective laminectomy*			
Shiraishi et al. [36]	0/51 (0.0%)	3/51 (5.88%)	NR	NR	2/43 (4.7%)	0/43 (0%)	NR	NR
Yukawa et al. [37]	NR	0/21 (0%)	0/21 (0%)	NR	NR	0/20 (0%)	0/20 (0%)	NR
	Laminoplasty				*Laminectomy and fusion*			
Blizzard et al. [21]	NR	3/41 (7.31%)	1/41 (2.43%)	NR	NR	10/31 (32.25%)	4/31 (12.9%)	NR
Fehlings et al. [67]	3/100 (3.0%)	3/100 (3%)	2/100 (2%)	1/100 (1%)	5/166 (3.0%)	4/166 (2.41%)	7/166 (4.21%)	5/166 (3%)
Heller et al. [22]	NR	NR	0/13 (0%)	0/13 (0%)	NR	NR	1/13 (7.69%)	1/13 (7.69%)
Highsmith et al. [55]	1/30 (1.3%)	1/30 (3.33%)	2/30 (6.67%)	NR	0/26 (0.0%)	1/26 (3.85%)	4/26 (15.38%)	NR
Lau et al. [56]	NR	NR	2/101 (1.98%)	NR	NR	NR	2/45 (4.44%)	NR
Lee et al. [51][a]	NR	0/21 (0%)	NR	NR	NR	2/21 (9.52%)	NR	NR
Lee et al. [63][b]	NR	4/100 (4%)	NR	NR	NR	26/90 (28.89%)	NR	NR
Stephens et al. [58]	NR	3/85 (3.53%)	1/85 (1.18%)	NR	NR	5/52 (9.62%)	1/52 (1.92%)	NR
Woods et al. [59]	NR	NR	0/39 (0%)	0/39 (0%)	NR	NR	1/82 (1.22%)	1/82 (1.22%)
Yang et al. [23]	1/75 (1.33%)	3/75 (4%)	0/75 (0%)	3/75 (4%)	3/66 (4.55%)	11/66 (16.67%)	1/66 (1.52%)	2/66 (3.03%)
Yuan et al. [60]	NR	1/20 (5%)	NR	NR	NR	2/18 (11.11%)	NR	NR

[a]Lee et al. [51]
[b]Lee et al. [63]

Study name	Outcome	Statistics for each study		
		Risk ratio	Lower limit	Upper limit
Stephens et al 2017	C5 Palsy	0.367	0.092	1.472
Blizzard et al 2017	C5 Palsy	0.227	0.068	0.755
Fehlings et al 2017	C5 Palsy	1.245	0.284	5.449
Lee et al 2016*	C5 Palsy	0.138	0.050	0.381
Highsmith et al 2011	C5 Palsy	0.867	0.057	13.177
Yang et al 2013	C5 Palsy	0.240	0.070	0.824
Yuan et al 2015	C5 Palsy	0.450	0.044	4.554
Lee et al 2016**	C5 Palsy	0.200	0.010	3.931
Fehlings et al 2017	CSF leak	0.996	0.243	4.078
Highsmith et al 2011	CSF leak	2.613	0.111	61.511
Yang et al 2013	CSF leak	0.293	0.031	2.752
Stephens et al 2017	Infection	0.612	0.039	9.572
Blizzard et al 2017	Infection	0.195	0.023	1.662
Fehlings et al 2017	Infection	0.474	0.100	2.239
Highsmith et al 2011	Infection	0.433	0.086	2.177
Yang et al 2013	Infection	0.294	0.012	7.093
Woods et al 2011	Infection	0.692	0.029	16.604
Heller et al 2001	Infection	0.333	0.015	7.501
Lau et al 2017	Infection	0.446	0.065	3.064
Fehlings et al 2017	Kyphosis	0.332	0.039	2.801
Yang et al 2013	Kyphosis	1.320	0.227	7.660
Heller et al 2001	Kyphosis	0.333	0.015	7.501
Woods et al 2016	Kyphosis	0.692	0.029	16.604



*Lee CH, Jahng TA, Hyun SJ, Kim KJ, Kim HJ. Expansive laminoplasty versus laminectomy alone versus laminectomy and fusion for cervical ossification of the posterior longitudinal ligament. Journal of Spinal Disorders and Techniques. 2016;29(1):E9-E15
**Lee SH, Suk KS, Kang KC, Cho SW, Juh HS, Lee JH, et al. Outcomes and Related Factors of C5 Palsy Following Cervical Laminectomy With Instrumented Fusion Compared With Laminoplasty. Spine. 2016;41(10):E574-9.

Fig. 11.3 Summary of risk ratios comparing rates of complications between laminoplasty and laminectomy and fusion

What Is the Efficacy of LA or sLA Compared to LF Based on Clinically Important Changes in Neurological and Functional Status?

Comparison of LA versus LF was found in two retrospective comparative studies and no studies were found comparing sLA to LF (Table 11.2). Only one identified study compared the neurological recovery between the two procedures. Du et al. [50] reported significant JOA improvement in both the LA (n = 30) and LF (n = 32) treatment groups, with a statistically significant difference in recovery in favor of LF. In terms of functional recovery, one of the studies compared NDI recovery in patients with cervical myelopathy secondary to OPLL treated with either LA (n = 15) or LF (n = 21) [51]. In this study, Lee et al. [51] noted that patients in both treatment groups demonstrated substantial improvement in the NDI score, and the degree of recovery was not significantly different between the groups.

In terms of the secondary outcomes, a single study by Lee et al. [51] found no significant difference in the postoperative improvement in the VAS-neck score between LA and LF. The cervical curvature was assessed by both studies using the Ishihara Index [50, 51]. Their conclusions, however, were inconsistent with Du et al. [50] reporting significantly more loss of cervical lordosis after LA, while Lee et al. [51] reported an equivocal decrease over time with both procedures. Interestingly in the latter study, a lower mean preoperative Ishihara Index was noted in the LF group, demonstrating the authors' predilection for fusion in patients with less cervical lordosis [51].

None of the studies reported on postoperative ROM changes.

What Is the Efficacy of LP Compared to LA or sLA Based on Clinically Important Changes in Neurological and Functional Status?

LP Versus LA

Three retrospective studies compared clinical outcomes between patients treated with LP and LA (Table 11.2). Du et al. [50] reported significant improvements in postoperative JOA score with both LP (n = 36) and LA (n = 30), but revealed significantly higher recovery rates in patients treated with LP. In terms of NDI improvement, one article by Lee et al. [51] did not find a statistically significant difference between LP (n = 21) and LA (n = 15).

For the secondary outcomes, two studies evaluated the change in VAS-neck score. The study by Lee et al. [51] showed equivocal postoperative improvements in both procedures. A relatively larger study by Nurboja et al. [53] (n = 48 for LP, n = 33 for LA) reported no difference in VAS-Neck scores with either surgical technique. Interestingly, authors of the latter study found that the pain relief in the LA group only became significant when surgery was performed on ≥4 vertebral levels.

The changes in Ishihara Index were also compared between the two procedures and reported by all three studies. In the retrospective study by Du et al. [50], a loss of cervical lordosis was described in both groups with more pronounced changes noted after LA, but their results were not reproduced by the other studies. Lee et al. [51], on the other hand, found the loss of lordosis to be of similar magnitude amongst techniques, and Nurboja et al. [53] in their evaluation of LP (n = 75) and LA (n = 34) reported minimal change in sagittal alignment over time in either group.

None of the studies in this review compared the postoperative changes in ROM.

LP Versus sLA

A total of three articles were identified in the literature search addressing the outcomes of LP compared to sLA (Table 11.2). In a single prospective randomized control trial, Yukawa et al. [37] concluded that the long-term JOA score improvements or other functional outcomes were not significantly different between DCM patients treated with LP (n = 21) and sLA (n = 20). Chang et al. [52], in a retrospective review of patients treated with LP (n = 35) and sLA (n = 32), showed improvement in both NDI and VAS-Neck with no difference between the two treatment groups.

Shiraishi et al. [36] reported the postoperative changes in Ishihara index on their cohorts undergoing sLA (n = 43) in comparison to LP (n = 51), and noted that while the curvature index was maintained after sLA, a significant decrease was seen in the LP group.

Finally, the pre- and postoperative ROM was assessed by two of the studies with inconsistent findings. While Yukawa et al. [37] reported slightly more preserved ROM after sLA, the article by Chang et al. [52] reported significantly less postoperative ROM.

What Is the Efficacy of LF Compared with LP Based on Clinically Important Changes in Neurological and Functional Status?

For eight studies that reported the preoperative and postoperative JOA/mJOA scores, the calculated SMD and the 95% CI are demonstrated in Fig. 11.2a. The majority (five studies) reported no or "small" effect without statistical significance. Only in one study was a significantly "large" effect detected in favor of LP (SMD 1.231). In this retrospective analysis by Stephens et al. [58], the comparison was made between LP (n = 85) and LF (n = 52). Although significant results were noted, the authors reported baseline differences between groups and possible selection bias in treatment. Two studies reported "medium" effect with conflicting findings. One single retrospective study by Miyamoto et al. [57] favored LF (n = 30) over LP (n = 30) in JOA improvement, while a large multicentered, prospective, observational study by Fehlings et al. [54] (n = 100 for LP, n = 166 for LF) showed more improvement in the LP group [54]. The assessment of functional improvement using preoperative and postoperative NDI was reported by five studies. Most of the support for LP derives from two studies with one "large" (SMD 1.165) and one "medium" (SMD 0.655) effect by Stephens et al. [58] and Yang et al. [23], respectively. The study by Stephens et al. [58] suffers from the possibility of bias as mentioned above, but the retrospective study by Yang et al. [23] showed significant NDI improvement in LP (n = 75) compared to the LF (n = 66) group. Two other studies were in favor of LP with "small" and non-significant effect [21, 54], while one study showed no difference between procedures [51].

The results of the assessment of secondary outcomes were summarized in Fig. 11.2b. A total of six studies reported postoperative improvement of VAS-neck pain. Of the studies that were found to favor LF, the retrospective study by Highsmith et al. [55] (n = 30 for LP, n = 26 for LF) showed the largest effect (SMD 1.217), with the LP group experiencing an increase in VAS-neck pain while the LF group reported a significant improvement. To a lesser extent, the retrospective study by Stephens et al. [58] also supported LF with statistical significance (SMD 0.732). Three other studies showed "small" effects in favor of LF. On the other hand, the study by Yang et al. [23] was found to have a "large" (SMD −1.050) effect favoring LP.

In terms of the Ishihara Index, two of the three studies favored LF in maintaining the curvature index with a "small" effect, while one study showed a SMD of 0.083 in favor of LP. None of the studies showed a strong effect. Finally, all three studies comparing ROM revealed a “large” effect favoring LP in preserving more neck motion.

What Is the Safety Profile of LA or sLA Compared to LF?

The comparison of complication rates between LA and LF were found in two studies (Table 11.3). The rate of C5 palsy was reported by a single retrospective review by Lee et al. [51]. The authors found no incidence of the event (0/75) in the LA group and 9.52% (2/21) in the LF group [51]. In a prospective randomized comparative study, postoperative infection was documented in 6.67% (2/30) and 9.38% (3/32) after LA and LF, respectively [61]. In the same study, the authors reported the observed incidence of dural tear/CSF leak after LP at 3.33% (1/30) while it was 6.25% (2/32) for LF. None of the studies reported or compared the rates of postoperative kyphosis, and no studies comparing sLA to LF were found.

What Is the Safety Profile of LP Compared to LA or sLA?

Two studies compared complication rates between LP and LA (Table 11.3). Della Pepa et al. [62], in their retrospective review, found no infection (0/33 for LP, 0/24 for LA) or dural tear/CSF leak (0/33, 0/24) in both groups. However, the LA group demonstrated a 12.5% (3/24) rate of postoperative kyphosis in comparison to none (0/33) reported in the LP group [62]. Regarding the rate of C5 palsy, Lee et al. [51], reported 0% in both LP (0/21) and LA (0/15) groups in their retrospective study.

In terms of LP and sLA, the data on complications were acquired from two studies. In the RCT by Yukawa et al. [37], the rate of infection was found to be 0% in both groups (0/21 for LP, 0/20 for sLA). In the retrospective study by Shiraishi et al. [36], no incidence of CSF leak was reported in the LP (0/51) group compared to 4.65% (2/43) in the sLA group. Both studies reported on postoperative C5 palsy, with rates of 5.88% (3/51) versus 0% (0/43) [36], and 0% (0/21) versus 0% (0/20) [37], respectively, compared between LP and sLA.

What Is the Safety Profile of LF Compared to LP?

A total of 11 articles presented a comparison of complication rates between LP and LF (Table 11.3). The calculated RR and 95% CI are presented in Fig. 11.3. Of the studies that reported on rates of C5 palsy, the majority (seven of the eight articles) showed reduced risk of this complication with LP. However, only three studies [21, 23, 63] reached statistical significance with RR of 0.227, 0.240, and 0.138. Only one article showed a slight favoring of LF (RR 1.245), which failed to reach statistical significance [54].

Three studies reported rates of dural tear/CSF leak, with one study showing no difference in the rate between the two procedures [54], while the other two studies were inconsistent with one favoring LF (RR 2.613) [55] and the other favoring LP (RR 0.293) [23]. However, none of the studies reached statistical significance.

There were eight articles reporting on postoperative rates of infection. Analysis of RR revealed that all studies trended toward reduced risk of infection with LP, however, none of the studies reached statistical significance.

The rate of postoperative kyphosis was also described in four studies. Although none showed statistically significant differences, two studies reported a lower risk of postoperative kyphosis in LP (RR 0.332 and 0.692) [22, 54], while one study was in favor of LF (RR 1.320) [23].

Level of Evidence

The strengths of evidence are presented in Table 11.4.

Discussion

With the rapid advancement in the field of DCM, evidence-based clinical management guidelines have been developed to assist clinicians and surgeons in formulating treatment decisions [64–69]. While the clinical importance and efficacy of surgical decompression is not called into question, controversy still exists concerning the best surgical approach in the treatment of DCM. This chapter focuses on the common types of posterior cervical procedures and provides a synopsis of current evidence.

The clinical efficacy of posterior cervical decompressive procedures has a long track record of proven success in the treatment of DCM by providing clinically important improvements in neurological and functional outcomes [21, 23, 36, 37, 50–52, 54, 55, 57, 58, 60, 70]. Due to the unique characteristics of each technique, the selection of one over the other is still based mostly on surgeon preference and remains a heated debate in the spine community. However, it is generally accepted that due to the risk of instability and delayed deformity development, pre-existing cervical kyphosis is a contraindication for LA and LP [5, 8–11, 29–33, 39].

To best present the evidence, a systematic review of the literature was conducted focusing on the contemporary literature (after year 2000) and on studies with comparative data between the procedures. Due to the heterogeneity intrinsic to the available literature, the inconsistent methods of reporting outcomes and complications, as well as the lack of well-designed high-quality studies, it was not possible to recommend one of the surgical techniques as being superior. However, from the review of the current evidence, several important conclusions can be drawn to assist the surgeons and patients in making evidence-based decisions concerning surgical approach.

Table 11.4 Strength of evidence summary

	Strength of evidence	Comments and conclusions	Baseline	Upgrade	Downgrade
Question 1: What is the efficacy of laminectomy or selective/skip laminectomy compared to laminectomy and fusion regarding clinically important change in neurological and functional status?					
Laminectomy vs. laminectomy and fusion					
JOA/mJOA score	Low	There is low evidence to support laminectomy and fusion procedures regarding JOA improvement. Based on a single study, there is reportedly more statistically significant improvement in JOA score in the laminectomy and fusion group. However, due to the limited study and small sample size, estimates are at risk of imprecision	Low	Large effect (1)	Imprecise (1)
NDI score	Insufficient	There is insufficient evidence to favor either approach regarding improving functional (NDI) recovery. A single retrospective study reported improvement of NDI with both procedures with no significant difference. Given the small number of participants and limited study, estimates are at risk of imprecision	Low	None	Imprecise (1)
VAS neck	Insufficient	There is insufficient evidence to suggest either approach as superior in terms of reducing postoperative VAS neck score. A single retrospective study reported no significant difference in improvement between the treatments. However, estimates are imprecise due to limited study with small number of participants	Low	None	Imprecise (1)
Ishihara index	Insufficient	There is insufficient evidence to suggest either procedure would lead to more loss of cervical lordosis. One study reported equivocal loss of cervical lordosis with both procedures. Whereas the other reported more loss of cervical curvature with laminectomy, the calculated effect is "small"	Low	None	Inconsistent (1) Imprecise (1)
ROM	Insufficient	No studies reported on ROM	NA	NA	NA
Skip laminectomy vs. laminectomy and fusion:					
NA	NA	No study was found comparing skip laminectomy to laminectomy and fusion	NA	NA	NA
Question 2: What is the efficacy of laminoplasty compared to standard laminectomy or skip laminectomy regarding clinically important change in neurological and functional status?					
Laminoplasty vs. standard laminectomy					

JOA/mJOA score	Insufficient	There is insufficient evidence in favoring either procedure regarding overall JOA improvement. A single retrospective study reported showing significant difference in JOA improvement in favor of laminoplasty. However, the calculated effect was found to be "medium". Evidence is downgraded due to limited study and small sample size	Low	None	Imprecise (1)
NDI score	Insufficient	There is insufficient evidence to suggest one procedure as more efficacious over the other in regard to NDI improvement. A single retrospective study reported no difference in the overall NDI improvement between the two procedures. Evidence downgraded secondary to limited study and small number of participants	Low	None	Imprecise (1)
VAS neck	Insufficient	There is insufficient evidence in supporting either procedure with in regard to postoperative VAS neck improvement. Of the two retrospective studies identified, one reported that VAS neck did not change postoperatively with either procedure. The other study however, reported improvement in VAS neck but failed to detect any significant difference between the magnitude of improvement	Low	None	Inconsistent (1)
Ishihara index	Insufficient	There is insufficient evident to suggest one procedure in being more protective toward reducing loss of cervical lordosis than the other. Of the three retrospective studies, two slightly favored laminectomy and one favored laminoplasty in reduced loss of cervical lordosis. All three studies did not reach statistical significance	Low	None	Inconsistent (1)
ROM	Insufficient	No studies reported on ROM	NA	NA	NA
Laminoplasty vs. skip laminectomy					
JOA/mJOA score	Insufficient	There is insufficient evidence in supporting either procedure in terms of postoperative JOA improvement. A single randomized control trial showed no difference between the two treatment groups. However due to the poor technique of randomization and blinding of evaluators, the overall quality of evidence downgraded. Additionally, the lack of reporting of standard deviation limited our analysis	Low	None	Risk of bias (1) Impression (1)

(continued)

Table 11.4 (continued)

	Strength of evidence	Comments and conclusions	Baseline	Upgrade	Downgrade
NDI score	Insufficient	The overall strength of evidence is insufficient in favoring either procedure regarding NDI improvement. Given one prospective cohort study, no significant difference in NDI improvement between the two procedures. Evidence downgraded for imprecision of estimate due to limited study and small sample size	Low	None	Imprecise (1)
VAS neck	Insufficient	There is insufficient evidence favoring either procedure in providing more improvement in postoperative VAS score. One prospective cohort study detected no significant difference between the treatment groups. Due to limited study and small number of participants, estimate is at risk of imprecision	Low	None	Imprecise (1)
Ishihara index	Insufficient	There is insufficient evidence to suggest that one procedure is more protective of postoperative loss of cervical lordosis. One study reported more reduction in Ishihara index with laminoplasty, but limited study and the lack of reporting of standard deviation limited our analysis	Low	None	Imprecise (1)
ROM	Insufficient	There is insufficient evidence to conclude whether one procedure would be more protective of preserving postoperative ROM. One prospective cohort study reported significantly more loss of ROM with skip laminectomy, while another randomized control trial concluded more preserved ROM with the procedure. Overall evidence downgraded due to inconsistency, and limitation in the methodology of the randomized control trial	Low	None	Risk of bias (1) Inconsistency (1)
Question 3: What is the efficacy of laminectomy plus fusion procedure compared with laminoplasty regarding clinically important change in neurological and functional status?					
JOA/mJOA score	Insufficient	There is overall insufficient to favor either procedure regarding JOA/mJOA improvement in treating DCM. Amongst the eight studies, three favored laminectomy and fusion. One study was found to have "moderate" effect, whereas the other two studies had "small" effects that are not statistically significant. Two studies supported laminoplasty with "large" and "moderate" effect. Three studies showed minimal to no effect between the two procedures. The overall evidence downgraded for inconsistency in the results and risk of bias as reported by the authors with the study showing the largest effect	Low	None	Risk of bias (1) Inconsistency (1)

NDI score	Insufficient	There is overall low evidence in favor of laminoplasty in terms of postoperative NDI improvement. Of the five studies, three studies showed evidence supporting more improvement of NDI in patients treated with laminoplasty procedure with one "large", one "moderate" and one "small" effect. The remaining two studies, one was a prospective cohort study showing trend favoring laminoplasty without reaching statistical significance, and the other was a small retrospective study (n = 21 in each group) showing no significant difference between the techniques. The evidence was down grade due to inconsistency and risk of bias as reported by the author of the study with the largest effect	Low	Large effect (1)	Risk of bias (1) Inconsistency (1)
VAS neck	Insufficient	There is overall insufficient evidence to favor either procedure in terms of improvement of postoperative VAS neck score. Of the six studies, four of which are in favor of laminectomy and fusion with one "large", two "moderate" and one "small" effect. Although one study showed "large" effect in favor of laminoplasty. The presence of major inconsistency and downgraded the overall strength of evidence	Low	None	Inconsistency (1)
Ishihara Index	Insufficient	There is overall insufficient evidence to suggest either procedure as more protective of postoperative loss of cervical lordosis. Of the three retrospective studies, two showed "small" effect favoring laminectomy and fusion in reducing the loss of cervical lordosis and one study showing minimal effect favoring laminoplasty	Low	None	Inconsistency (1)
ROM	Moderate	The is overall moderate evidence favoring laminoplasty as the more ROM preserving procedure. All three retrospective studies showed "large" effects favoring more ROM in laminoplasty patients postoperatively	Low	Large effect (1)	None
Question 4: What is the safety profile of laminectomy alone compared to laminectomy and fusion?					
Dural tear/ CSF leak	Insufficient	There is insufficient evidence to conclude the safety profile in favor of either procedure regarding dural tear/CSF leak. One randomized control trial reported 3.3% in laminectomy and 6.3% in laminectomy and fusion. The evidence is downgraded due to is imprecise estimate secondary to low number of events	Low	None	Imprecision (1)

(continued)

Table 11.4 (continued)

	Strength of evidence	Comments and conclusions	Baseline	Upgrade	Downgrade
C5 palsy	Insufficient	There is insufficient evidence to conclude the safety profile in favor of either procedure in terms of rate of C5 palsy. One retrospective study reported 0% with laminectomy and 9.5% with laminectomy and fusion. The estimate however is imprecise due to small number of events	Low	None	Imprecision (1)
Infection	Insufficient	There is insufficient evidence in favoring either procedure regarding rate of postoperative infection. One single study reported 6.67% in laminectomy group and 9.38% in laminectomy and fusion group. Due to small number of events, estimate is limited by imprecision	Low	None	Imprecision (1)
Kyphosis	Insufficient	No studies reported on rate of postoperative kyphosis	NA	NA	NA
Question 5: What is the safety profile of laminoplasty compared to standard laminectomy or skip laminectomy?					
Laminoplasty vs. standard laminectomy					
Dural tear/ CSF leak	Insufficient	There is insufficient evidence to favor either procedure in terms of dural tear/CSF leak. The single study found in this review showed no dural tear/CSF leak in either treatment group. However, based on the methodology reported by authors, confounding cannot be ruled out	Low	None	Risk of bias (1) Imprecision (1)
C5 palsy	Insufficient	The overall strength of evidence is insufficient to draw conclusions on the rate of C5 palsy in either procedures. Since the single study reported 0% rate of event in both treatment group	Low	None	Imprecision (1)
Infection	Insufficient	There is insufficient evidence to conclude on the rate of infection comparing both procedures. Since the single study reported 0% in either group. Based on the methodology reported by authors, confounding cannot be ruled out	Low	None	Risk of bias (1) Imprecision (1)
Kyphosis	Insufficient	There is insufficient evidence to draw conclusion on the comparative rate of postoperative kyphosis between the two procedures. The single study reported 0% vs 12.5% kyphosis in the laminoplasty and laminectomy group respectively. However, the study methodology used by authors and limited number events hindered the drawing of firm conclusion	Low	None	Risk of bias (1) Imprecision (1)

Laminoplasty vs. skip laminectomy					
Dural tear/ CSF leak	Insufficient	There is insufficient evidence to favor either procedure in the rate of dural tear/ CSF leak. The one prospective cohort study reported 0% in the laminoplasty group and 4.7% in the skip laminectomy group. The evidence is downgrade due to imprecision secondary to limited number of events	Low	None	Imprecision (1)
C5 palsy	Insufficient	There is insufficient evidence to favor either procedure in terms of the rate for postoperative C5 palsy. Two studies reported rate of C5 palsy. One study reported 5.88% with the laminoplasty procedure and 0% with skip laminectomy. The other reported no event in either treatment group. Given the limited study and small number of events, estimates are at risk of imprecision	Low	None	Imprecision (1) Inconsistency (1)
Infection	Insufficient	There is insufficient evidence to favor either procedure in terms of rate of postoperative infection. Since the single randomized control trial reported no infection in either group	Low	None	Imprecision (1)
Kyphosis	Insufficient	No studies reported on rate of postoperative kyphosis	NA	NA	NA
Question 6: What is the safety profile of laminectomy plus fusion compared to laminoplasty?					
Dural tear/ CSF leak	Insufficient	The overall strength of evidence is insufficient to suggest either procedure as the safer procedure for reduced rate of dural tear CSF leak. Of the three studies, one study showed no difference in risk, one study favored laminectomy and fusion where as the other favored laminoplasty. Evidence downgraded for inconsistency and imprecision due to small number of events	Low	None	Imprecision (1) Inconsistency (1)

(continued)

Table 11.4 (continued)

	Strength of evidence	Comments and conclusions	Baseline	Upgrade	Downgrade
C5 palsy	Low	The overall strength of evidence is low in favor of laminoplasty in regard to lower rate of postoperative C5 palsy. Of the eight studies, three studies showed significant lower rate of C5 palsy with one study reaching "very large" effect (RR 0.138). Three other studies showed trends towards favoring the laminoplasty procedure without reaching statistical significance. Inconsistency exist where one study showed largely equivocal risk and another favoring laminectomy and fusion. Although both did not reach statistical significance. Evidence also downgraded due to small number of events and large confidence interval	Low	Very large effect (2)	Imprecision (1) Inconsistency (1)
Infection	Insufficient	The overall strength of evidence is insufficient to favor either procedure for rate of infection. Although all of the eight studies trended toward lower risk in the laminoplasty group, none of the studies reached statistical significance. Due to large confidence intervals, evidence downgraded for imprecision	Low	None	Imprecision (1)
Kyphosis	Insufficient	The overall strength of evidence is insufficient to favor either procedure for rate of postoperative kyphosis. Of the four studies, three reportedly favored laminoplasty while one study favored laminectomy and fusion. Given the inconsistency and low number of events the overall evidence was downgraded	Low	None	Imprecision (1) Inconsistency (1)

Regarding clinical outcomes, the systematic literature search resulted in only two retrospective studies addressing the efficacy of LA versus LF, and three retrospective studies evaluating LA versus LP. Similarly, the number of articles identified regarding the safety profile of the procedures was low (two studies comparing LA and LF and two studies for LP and LA). The paucity of literature on these comparisons likely reflects the dramatic decline in the utilization of LA in the contemporary era due to the increased awareness of the high-risk for postoperative kyphosis, instability, as well as the added possibility of neurological deterioration with their development [8–11, 50]. The extracted data from the limited number of studies provides "insufficient" evidence to recommend LA as a primary procedure for DCM (Table 11.4). In fact, there is "low" evidence in favor of LF regarding postoperative neurological improvement, and a trend toward potentially added improvement in functional outcomes with LF and LP [50].

From the included studies, it is recognizable that a trend exists suggesting loss of cervical lordosis post LA [50, 62]. Interestingly, it was noted that many of the authors, being aware of the issue of postoperative kyphosis, either limited their study by excluding patients with severe preoperative cervical deformity or tailored the treatment to offer fusion in the less-lordotic cases [50, 51]. Therefore, although the evidence presented was graded as "insufficient" in confirming an increased risk of kyphosis in LA, these studies indirectly provided insight that increased awareness surrounding this issue has led to changes in the practices of the spine community.

Given its relatively recent introduction, the evidence on the comparative effectiveness and safety of sLA compared to other posterior cervical procedures was limited to three studies found by literature search. Due to the overall lack of evidence and imprecision with reporting, no conclusive recommendation can be generated on the utility of sLA for DCM (Table 11.4), but studies appear to suggest that the clinical outcome and safety profile of sLA is comparable to that of LP [36, 37, 52]. The sLA procedure was designed to address issues with post decompression instability and kyphosis while preserving ROM [36, 38], and the limited reports on the potential of this procedure to maintain cervical curvature are promising [36–38], but this analysis fails to confirm these due to the limited and inconsistent evidence.

With the advancement of knowledge and the evolution of instrumentation technology, the field of spine surgery has seen rapid development over recent years. As LA has been gradually phased out in favor of LP and LF, a shift in the research focus nowadays is geared towards quality control and improvement. As a reflection of this change, 12 studies addressing the clinical outcomes and 11 studies comparing the complications of LP and LF were found by literature search. However, given the resources, there is still "insufficient" overall evidence to favor either procedure regarding neurological improvement, functional outcome or safety profile (Table 11.4). Given the inconsistencies seen in the literature and the difficulty in proving the superiority of one procedure over the other, it appears that LP and LF have overall clinical equipoise in treating DCM. While it is generally agreed upon that LP is associated with more postoperative neck pain [34, 35], insufficient evidence was found in this review in terms of VAS-neck pain score changes. However, it appears that the overall trend tends to favor more improvement with LF (Fig. 11.2). Unsurprisingly, a large difference was found with "moderate" evidence confirming greater loss of ROM with LF [21–23]. Of interest, it appears that "low" evidence exists supporting a lower rate of C5 palsy in LP, which is an observation that has been previously reported [71, 72]. However, given the state of the literature, it is difficult to provide absolute evidence favoring either procedure, and further research is necessary.

Conclusion

In conclusion, this chapter summarizes the current evidence concerning the common posterior spinal surgical approaches for the treatment of DCM. The evidence presented here is not a strict guideline but should serve as a suggestion to assist clinicians, surgeons, and patients when deciding a treatment plan. Ultimately, the approach of choice should be based on clinical judgement and tailored toward each individual patient depending on their clinical presentation, imaging findings, and the surgeon's own experience. Overall this systematic review strengthens the evidence that LP and LF have overall clinical equipoise in terms of clinical outcome, while finding insufficient evidence to recommend LA or sLA as primary treatment options for DCM.

Patient Preference

See Table 11.5.

Table 11.5 Patient preference chart

	Advantage	Disadvantage
Laminectomy	Insufficient evidence to suggest any advantage of the procedure	Risk of postoperative kyphosis and instability
Skip laminectomy	Insufficient evidence to suggest any advantage of the procedure	Insufficient evidence to recommend this procedure over its counterparts
Laminoplasty	Clinical equipoise in providing neurological and function improvement compared to laminectomy and fusion	Evidence showing a trend toward increased postoperative neck pain
	Safety profile overall similar to laminectomy and fusion in rate of dural tear/CSF leak, infection, and postoperative kyphosis	
	Low level of evidence in support of reduced rate of C5 palsy compared to laminectomy and fusion	
Laminectomy and fusion	Low evidence in providing increased neurological improvement compared to laminectomy	Decreased postoperative neck ROM
	Clinical equipoise in providing neurological and functional improvement compared to laminoplasty	
	Safety profile ovSerall similar to laminoplasty in rate of dural tear/CSF leak, infection and postoperative kyphosis	
	Trend toward reducing loss of cervical lordosis with laminectomy and fusion	

Box

1. What is known:
   (a) Cervical laminectomy has a risk of postoperative instability and kyphosis.
   (b) Cervical laminoplasty is associated with postoperative neck pain.
   (c) Cervical laminectomy and fusion are associated with decreased postoperative ROM.
2. What is new:
   (a) There is a trend showing reduced cervical lordosis with laminectomy and fusion procedures, although not reaching statistical significance.
   (b) Cervical laminoplasty and laminectomy and fusion have shown similar effects regarding overall clinical outcomes and safety profile, with the exception of low level-evidence suggesting decreased rates of C5 palsy in the laminoplasty group.
3. Consequences for clinical practice:
   (a) We do not recommend cervical laminectomy as the primary treatment for degenerative cervical myelopathy.
   (b) We cannot make recommendations for cervical skip laminectomy due to insufficient evidence showing its superiority over other common posterior cervical procedures.
   (c) We do not recommend the use of cervical laminoplasty when there is present or suspected instability.
   (d) We do not recommend the use of cervical laminoplasty in the presence of cervical kyphosis.
   (e) We recommend both cervical laminoplasty and laminectomy and fusion in degenerative cervical myelopathy but recommend laminectomy and fusion when instability and/or cervical deformity are present.

References

1. Nouri A, Tetreault L, Singh A, et al. Degenerative cervical myelopathy: epidemiology, genetics, and pathogenesis. Spine (Phila Pa 1976). 2015;40:E675–93.
2. Badhiwala JH, Wilson JR. The natural history of degenerative cervical myelopathy. Neurosurg Clin N Am. 2018;29:21–32.
3. Fehlings MG, Wilson JR, Kopjar B, et al. Efficacy and safety of surgical decompression in patients with cervical spondylotic myelopathy: results of the AOSpine North America prospective multi-center study. J Bone Joint Surg Am. 2013;95:1651–8.
4. Lawrence BD, Jacobs WB, Norvell DC, et al. Anterior versus posterior approach for treatment of cervical spondylotic myelopathy: a systematic review. Spine (Phila Pa 1976). 2013;38:S173–82.
5. Geck MJ, Eismont FJ. Surgical options for the treatment of cervical spondylotic myelopathy. Orthop Clin North Am. 2002;33:329–48.
6. Carol MP, Ducker TB. Cervical spondylitic myelopathies: surgical treatment. J Spinal Disord. 1988;1:59–65.

7. Epstein JA. The surgical management of cervical spinal stenosis, spondylosis, and myeloradiculopathy by means of the posterior approach. Spine (Phila Pa 1976). 1988;13:864–9.
8. Kaptain GJ, Simmons NE, Replogle RE, et al. Incidence and outcome of kyphotic deformity following laminectomy for cervical spondylotic myelopathy. J Neurosurg. 2000;93:199–204.
9. Hansen-Schwartz J, Kruse-Larsen C, Nielsen CJ. Follow-up after cervical laminectomy, with special reference to instability and deformity. Br J Neurosurg. 2003;17:301–5.
10. Kato Y, Iwasaki M, Fuji T, et al. Long-term follow-up results of laminectomy for cervical myelopathy caused by ossification of the posterior longitudinal ligament. J Neurosurg. 1998;89:217–23.
11. Yonenobu K, Okada K, Fuji T, et al. Causes of neurologic deterioration following surgical treatment of cervical myelopathy. Spine (Phila Pa 1976). 1986;11:818–23.
12. An HS, Coppes MA. Posterior cervical fixation for fracture and degenerative disc disease. Clin Orthop Relat Res. 1997;335:101–11.
13. Nazarian SM, Louis RP. Posterior internal fixation with screw plates in traumatic lesions of the cervical spine. Spine (Phila Pa 1976). 1991;16:S64–71.
14. Jeanneret B, Magerl F, Ward EH, et al. Posterior stabilization of the cervical spine with hook plates. Spine (Phila Pa 1976). 1991;16:S56–63.
15. Anderson PA, Henley MB, Grady MS, et al. Posterior cervical arthrodesis with AO reconstruction plates and bone graft. Spine (Phila Pa 1976). 1991;16:S72–9.
16. Ebraheim NA, Rupp RE, Savolaine ER, et al. Posterior plating of the cervical spine. J Spinal Disord. 1995;8:111–5.
17. Benzel EC, Kesterson L. Posterior cervical interspinous compression wiring and fusion for mid to low cervical spinal injuries. J Neurosurg. 1989;70:893–9.
18. al Baz MO, Mathur N. Modified technique of tension band wiring in flexion injuries of the middle and lower cervical spine. Spine (Phila Pa 1976). 1995;20:1241–4.
19. Deen HG, Nottmeier EW, Reimer R. Early complications of posterior rod-screw fixation of the cervical and upper thoracic spine. Neurosurgery. 2006;59:1062–7; discussion 7-8.
20. Deen HG, Birch BD, Wharen RE, et al. Lateral mass screw-rod fixation of the cervical spine: a prospective clinical series with 1-year follow-up. Spine J. 2003;3:489–95.
21. Blizzard DJ, Caputo AM, Sheets CZ, et al. Laminoplasty versus laminectomy with fusion for the treatment of spondylotic cervical myelopathy: short-term follow-up. Eur Spine J. 2017;26:85–93.
22. Heller JG, Edwards ICC, Murakami H, et al. Laminoplasty versus laminectomy and fusion for multilevel cervical myelopathy: an independent matched cohort analysis. Spine. 2001;26:1330–6.
23. Yang L, Gu Y, Shi J, et al. Modified plate-only open-door laminoplasty versus laminectomy and fusion for the treatment of cervical stenotic myelopathy. Orthopedics. 2013;36:e79–87.
24. Kawai S, Sunago K, Doi K, et al. Cervical laminoplasty (Hattori's method). Procedure and follow-up results. Spine (Phila Pa 1976). 1988;13:1245–50.
25. Hirabayashi K, Satomi K. Operative procedure and results of expansive open-door laminoplasty. Spine (Phila Pa 1976). 1988;13:870–6.
26. Hirabayashi K, Watanabe K, Wakano K, et al. Expansive open-door laminoplasty for cervical spinal stenotic myelopathy. Spine (Phila Pa 1976). 1983;8:693–9.
27. Tomita K, Kawahara N, Toribatake Y, et al. Expansive midline T-saw laminoplasty (modified spinous process-splitting) for the management of cervical myelopathy. Spine (Phila Pa 1976). 1998;23:32–7.
28. Hukuda S, Mochizuki T, Ogata M, et al. Operations for cervical spondylotic myelopathy. A comparison of the results of anterior and posterior procedures. J Bone Joint Surg Br. 1985;67:609–15.
29. Rhee JM, Basra S. Posterior surgery for cervical myelopathy: laminectomy, laminectomy with fusion, and laminoplasty. Asian Spine J. 2008;2:114–26.
30. Lee JS, Son DW, Lee SH, et al. The predictable factors of the postoperative kyphotic change of sagittal alignment of the cervical spine after the laminoplasty. J Korean Neurosurg Soc. 2017;60:577–83.
31. Suk KS, Kim KT, Lee JH, et al. Sagittal alignment of the cervical spine after the laminoplasty. Spine (Phila Pa 1976). 2007;32:E656–60.

32. Dugoni DE, Mancarella C, Landi A, et al. Post laminoplasty cervical kyphosis-case report. Int J Surg Case Rep. 2014;5:853–7.
33. Ellwitz J, Roberto R, Gupta M, et al. Patient and surgeon factors associated with postoperative kyphosis after laminoplasty. Evid Based Spine Care J. 2011;2:53–4.
34. Hosono N, Yonenobu K, Ono K. Neck and shoulder pain after laminoplasty. A noticeable complication. Spine (Phila Pa 1976). 1996;21:1969–73.
35. Kawaguchi Y, Matsui H, Ishihara H, et al. Axial symptoms after en bloc cervical laminoplasty. J Spinal Disord. 1999;12:392–5.
36. Shiraishi T, Fukuda K, Yato Y, et al. Results of skip laminectomy-minimum 2-year follow-up study compared with open-door laminoplasty. Spine (Phila Pa 1976). 2003;28: 2667–72.
37. Yukawa Y, Kato F, Ito K, et al. Laminoplasty and skip laminectomy for cervical compressive myelopathy: range of motion, postoperative neck pain, and surgical outcomes in a randomized prospective study. Spine. 2007;32:1980–5.
38. Shiraishi T. Skip laminectomy--a new treatment for cervical spondylotic myelopathy, preserving bilateral muscular attachments to the spinous processes: a preliminary report. Spine J. 2002;2:108–15.
39. Matsunaga S, Sakou T, Nakanisi K. Analysis of the cervical spine alignment following laminoplasty and laminectomy. Spinal Cord. 1999;37:20–4.
40. Ishihara A. Roentgenographic studies on the normal pattern of the cervical curvature. Nihon Seikeigeka Gakkai Zasshi. 1968;42:1033–44.
41. Wright JG, Swiontkowski MF, Heckman JD. Introducing levels of evidence to the journal. J Bone Joint Surg Am. 2003;85-A:1–3.
42. West S, King V, Carey TS, et al. Systems to rate the strength of Scientific Evidence. Evidence Report/Technology Assessment No. 47 (Prepared by the Research Triangle Institute–University of North Carolina Evidence-based Practice Center under Contract No. 290-97-0011). AHRQ Publication No. 02-E016. Rockville: Agency for Healthcare Research and Quality; 2002.
43. Atkins D, Best D, Briss PA, et al. Grading quality of evidence and strength of recommendations. BMJ. 2004;328:1490.
44. Balshem H, Helfand M, Schunemann HJ, et al. GRADE guidelines: 3. Rating the quality of evidence. J Clin Epidemiol. 2011;64:401–6.
45. Andrews J, Guyatt G, Oxman AD, et al. GRADE guidelines: 14. Going from evidence to recommendations: the significance and presentation of recommendations. J Clin Epidemiol. 2013;66:719–25.
46. Zhang Y, Coello PA, Guyatt GH, et al. GRADE guidelines: 20. Assessing the certainty of evidence in the importance of outcomes or values and preferences-inconsistency, imprecision, and other domains. J Clin Epidemiol. 2018. https://doi.org/10.1016/j.jclinepi.2018.05.011.
47. Higgins JPT, Cochrane GS. Handbook for systematic reviews of interventions version 5.1.0 [updated March 2011]. The Cochrane Collaboration 2011. http://handbook.cochrane.org.
48. Cohen J. Statistical power analysis for the behavioral sciences. 2nd ed. Hillsdale: Lawrence Erlbaum Associates; 1988.
49. Borenstein M, Hedges L, Higgins J, Rothstein H. Comprehensive meta-analysis version 3. Englewood: Biostat; 2013.
50. Du W, Wang L, Shen Y, et al. Long-term impacts of different posterior operations on curvature, neurological recovery and axial symptoms for multilevel cervical degenerative myelopathy. Eur Spine J. 2013;22:1594–602.
51. Lee CH, Jahng TA, Hyun SJ, et al. Expansive laminoplasty versus laminectomy alone versus laminectomy and fusion for cervical ossification of the posterior longitudinal ligament. J Spinal Disord Tech. 2016;29:E9–E15.
52. Chang H, Kim C, Choi BW. Selective laminectomy for cervical spondylotic myelopathy: a comparative analysis with laminoplasty technique. Arch Orthop Trauma Surg. 2017;137:611–6.
53. Nurboja B, Kachramanoglou C, Choi D. Cervical laminectomy vs laminoplasty: is there a difference in outcome and postoperative pain. Neurosurgery. 2012;70:965–70; discussion 70

54. Fehlings MG, Santaguida C, Tetreault L, et al. Laminectomy and fusion versus laminoplasty for the treatment of degenerative cervical myelopathy: results from the AOSpine North America and international prospective multicenter studies. Spine J. 2017;17:102–8.
55. Highsmith JM, Dhall SS, Haid RW Jr, et al. Treatment of cervical stenotic myelopathy: a cost and outcome comparison of laminoplasty versus laminectomy and lateral mass fusion - clinical article. J Neurosurg Spine. 2011;14:619–25.
56. Lau D, Winkler EA, Than KD, et al. Laminoplasty versus laminectomy with posterior spinal fusion for multilevel cervical spondylotic myelopathy: influence of cervical alignment on outcomes. J Neurosurg Spine. 2017;27:508–17.
57. Miyamoto H, Maeno K, Uno K, et al. Outcomes of surgical intervention for cervical spondylotic myelopathy accompanying local kyphosis (comparison between laminoplasty alone and posterior reconstruction surgery using the screw-rod system). Eur Spine J. 2014;23:341–6.
58. Stephens BF, Rhee JM, Neustein TM, et al. Laminoplasty does not lead to worsening axial neck pain in the properly selected patient with cervical myelopathy. Spine. 2017;42:1844–50.
59. Woods BI, Hohl J, Lee J, et al. Laminoplasty versus laminectomy and fusion for multilevel cervical spondylotic myelopathy. Clin Orthop Relat Res. 2011;469:688–95.
60. Yuan W, Zhu Y, Liu X, et al. Postoperative three-dimensional cervical range of motion and neurological outcomes in patients with cervical ossification of the posterior longitudinal ligament: cervical laminoplasty versus laminectomy with fusion. Clin Neurol Neurosurg. 2015;134:17–23.
61. Yehya A. The clinical outcome of lateral mass fixation after decompressive laminectomy in cervical spondylotic myelopathy. Alex J Med. 2015;51:153–9.
62. Della Pepa GM, Roselli R, La Rocca G, et al. Laminoplasty is better of laminectomy in cervical stenotic myelopathy: myth or truth? Eur Rev Med Pharmacol Sci. 2014;18:50–4.
63. Lee SH, Suk KS, Kang KC, et al. Outcomes and related factors of C5 palsy following cervical laminectomy with instrumented fusion compared with laminoplasty. Spine. 2016;41:E574–9.
64. Fehlings MG, Tetreault LA, Riew KD, et al. A clinical practice guideline for the management of degenerative cervical myelopathy: introduction, rationale, and scope. Global Spine J. 2017;7:21S–7S.
65. Tetreault LA, Karadimas S, Wilson JR, et al. The natural history of degenerative cervical myelopathy and the rate of hospitalization following spinal cord injury: an updated systematic review. Global Spine J. 2017;7:28S–34S.
66. Rhee J, Tetreault LA, Chapman JR, et al. Nonoperative versus operative management for the treatment degenerative cervical myelopathy: an updated systematic review. Global Spine J. 2017;7:35S–41S.
67. Fehlings MG, Tetreault LA, Kurpad S, et al. Change in functional impairment, disability, and quality of life following operative treatment for degenerative cervical myelopathy: a systematic review and meta-analysis. Global Spine J. 2017;7:53S–69S.
68. Tetreault LA, Rhee J, Prather H, et al. Change in function, pain, and quality of life following structured nonoperative treatment in patients with degenerative cervical myelopathy: a systematic review. Global Spine J. 2017;7:42S–52S.
69. Fehlings MG, Tetreault LA, Riew KD, et al. A clinical practice guideline for the management of patients with degenerative cervical myelopathy: recommendations for patients with mild, moderate, and severe disease and nonmyelopathic patients with evidence of cord compression. Global Spine J. 2017;7:70S–83S.
70. Huang RC, Girardi FP, Poynton AR, et al. Treatment of multilevel cervical spondylotic myeloradiculopathy with posterior decompression and fusion with lateral mass plate fixation and local bone graft. J Spinal Disord Tech. 2003;16:123–9.
71. Yamanaka K, Tachibana T, Moriyama T, et al. C-5 palsy after cervical laminoplasty with instrumented posterior fusion: clinical article. J Neurosurg Spine. 2014;20:1–4.
72. Takemitsu M, Cheung KM, Wong YW, et al. C5 nerve root palsy after cervical laminoplasty and posterior fusion with instrumentation. J Spinal Disord Tech. 2008;21:267–72.