

Comparison of laminoplasty versus laminectomy and fusion in the treatment of multilevel cervical ossification of the posterior longitudinal ligament

A systematic review and meta-analysis

Lei Ma, MD^a, Feng-Yu Liu, MD^b, Li-Shuang Huo, MD^c, Zheng-Qi Zhao, MD^b, Xian-Ze Sun, MD^b, Feng Li, MD^b, Wen-Yuan Ding, MD^{a,d,*}

Abstract

Background: Laminoplasty (LP) and laminectomy with fusion (LF) were recognized as two reliable and effective way in treating multilevel cervical ossification of the posterior longitudinal ligament (OPLL). However, there was no clear conclusion on which method is better. A meta-analysis was conducted to evaluate the clinical results between LP and LF in the treatment of multilevel cervical OPLL.

Methods: An extensive search of literature was performed in PubMed, Embase, the Cochrane library, CNKI (Chinese database), and WANFANG (Chinese database). The following outcomes were extracted: the Japanese Orthopedic Association (JOA) scores, visual analog scale (VAS), cervical lordosis, cervical range of motion (ROM), complications, blood loss, and operation time. Data analysis was conducted with RevMan 5.3.

Results: A total of 11 studies were included in the final analysis. The results indicated that no significant differences between LP and LF group in terms of preoperative JOA scores ($P = .58$), postoperative JOA scores ($P = .60$), JOA scores improvement rate ($P = 0.64$), preoperative VAS ($P = .34$), postoperative VAS ($P = .20$), preoperative range of motion (ROM) ($P = .10$), postoperative ROM ($P = .18$), preoperative cervical lordosis ($P = .56$), C5 palsy ($P = .16$), and axial pain ($P = .21$). LF group showed larger postoperative cervical lordosis than LP group [standardized mean difference (SMD) = 1.13 (2.03, 0.24), $P = .01$]. However, LP group showed lower operation time [mean difference (MD) = 19.42 (26.87, 11.97), $P < .001$] and blood loss [MD = 94.78 (179.05, 10.51), $P = .03$] than LF group.

Conclusion: Both LP and LF can achieve clinical improvement in the treatment of multilevel cervical OPLL. LF was superior to LP in maintaining cervical lordosis. However, LP showed lower surgical trauma than LF. Kyphosis line (K-line) may be a good criterion in the selection of posterior surgery. LP was performed for the patients with K-line (+) and LF for K-line (−).

Abbreviations: CI = confidence interval, JOA = Japanese Orthopedic Association, K-line = kyphosis line, LF = laminectomy with fusion, LP = laminoplasty, MD = mean difference, OPLL = ossification of the posterior longitudinal ligament, OR = odd ratio, ROM = range of motion, SMD = standardized mean difference, VAS = visual analog score.

Keywords: cervical, laminectomy, laminoplasty, meta-analysis, ossification of the posterior longitudinal ligament

1. Introduction

Ossification of the posterior longitudinal ligament (OPLL) is an important cause of cervical myelopathy.^[1] Surgical treatment is

needed because it usually lead to progressive and stepwise deterioration of neurologic function.^[2] Surgical treatment with either anterior or posterior approaches can result in satisfactory clinical results.^[3] When ≥ 3 segments are involved, the complication rates associated with anterior surgery accelerate. It makes posterior option more attractive.^[4] The posterior procedures, including laminoplasty (LP) and laminectomy with fusion (LF), are recognized as reliable and effective way in treating multilevel cervical OPLL.^[5,6] However, there is no clear conclusion on which method, LP or LF, is better.^[7] Therefore, we performed a meta-analysis to assess the effectiveness and safety of the 2 surgical procedures for multilevel cervical OPLL.

2. Materials and methods

2.1. Ethics statement

As all analyses were based on previously published studies, ethical approval was not necessary in this review.

2.2. Search strategy and study selection

An extensive search of literature was performed in PubMed, Embase, the Cochrane library, CNKI (Chinese database), and WANFANG (Chinese database) up to November 1, 2017. The languages were restricted to Chinese or English and only the

Editor: Nicandro Figueiredo.

LM, F-YL, and L-SH contributed equally to this work.

The manuscript submitted does not contain information about medical device(s)/drug(s).

The authors have no conflicts of interest to disclose.

^a Department of Spine Surgery, The Third Hospital of Hebei Medical University,

^b Department of Spine Surgery, The Third Hospital of Shijiazhang, ^c Department of Endocrinology, The First Hospital of Shijiazhang, ^d Hebei Provincial Key Laboratory of Orthopedic Biomechanics, Shijiazhuang, China.

* Correspondence: Wen-Yuan Ding, Department of Spine Surgery, The Third Hospital of Hebei Medical University, Hebei Provincial Key Laboratory of Orthopedic Biomechanics, No. 139 Ziqiang Road, Shijiazhuang 050051, China (e-mail: doctortliufy@126.com).

Copyright © 2018 the Author(s). Published by Wolters Kluwer Health, Inc.

This is an open access article distributed under the terms of the Creative Commons Attribution-Non Commercial-No Derivatives License 4.0 (CCBY-NC-ND), where it is permissible to download and share the work provided it is properly cited. The work cannot be changed in any way or used commercially without permission from the journal.

Medicine (2018) 97:29(e11542)

Received: 5 December 2017 / Accepted: 25 June 2018

<http://dx.doi.org/10.1097/MD.00000000000011542>

published articles were included. The following terms were used in our search: cervical AND laminoplasty AND laminectomy AND (ossification of the posterior longitudinal ligament OR ossified posterior longitudinal ligament OR calcification of the posterior longitudinal ligament). The reference lists of included studies were also hand-searched for additional qualified studies.

2.3. Inclusion and exclusion criteria

Studies were included if they met the following criteria: Participants: patients with cervical myelopathy due to OPLL. Interventions: the intervention in the experimental group was cervical LP. Comparisons: the intervention in the control group was cervical LF. Outcomes: JOA scores, VAS, ROM, cervical lordosis, axial symptoms, C5 palsy, operation time, and blood loss were collected as the outcomes. Study design: prospective or retrospective comparative study. The exclusion criteria were as follows: case reports, reviews, or letters; the same data had been published repeatedly; outcomes of interest did not be reported. Two reviewers (Lei Ma and Feng-Yu Liu) independently selected the potentially qualified studies according to the inclusion and exclusion criteria. Any disagreement was resolved by discussion and the conformity was reached.

2.4. Data extraction and management

Two reviewers (Xian-Ze Sun and Li-Shuang Huo) extracted data independently. The data extracted included the following categories: study design, patients demographic data (sample size, age, and sex), duration of follow-up, clinical evaluation (JOA and VAS), radiography evaluation (ROM and cervical lordosis), complications (axial symptoms and C5 palsy), blood loss and operation time.

2.5. Quality assessment

As all studies included were nonrandomized controlled studies, the Newcastle-Ottawa Scale was used to assess the quality of each study. This scale for nonrandomized case controlled studies and cohort studies was used to allocate a maximum of 9 points for the quality of selection, comparability, exposure, and outcomes for study participants.^[8]

2.6. Statistical analysis

We calculated odd ratio (OR) with 95% confidence interval (CI) for dichotomous outcomes and mean difference (MD) with 95% CI for continuous outcomes. *P* values less than .05 denoted significant differences. I^2 statistic was used to quantify heterogeneity, which I^2 greater than 50% implied significant heterogeneity. The random-effects model was used if there was significant heterogeneity. Otherwise, the fix-effects model was used. Sensitivity analysis was conducted to examine the influence of excluding each study. Funnel plot was used to test the publication bias. Review Manager 5.3 (The Nordic Cochrane Center, The Cochrane Collaboration, Copenhagen, Denmark) was used for the statistical analyses.

3. Results

3.1. Search results

A total of 334 records were identified by the initial database search. By reviewing the titles and abstracts, 229 studies were

excluded due to duplicates, irrelevant studies, case reports, not comparative studies and review. The remaining 105 reports underwent a detailed and comprehensive evaluation. Finally, 11 studies were included in this meta-analysis. The literature search procedure is shown in Fig. 1.

3.2. Baseline characteristics and quality assessment

There were 11 studies included in this meta-analysis. These studies were published between 2009 and 2016. The number of study patients in LP group and LF group ranged from 11 to 41 (total=292) and 7 to 35 (total=272), respectively. Five studies were published in English, and the other 6 studies were in Chinese. Characteristics of included studies are presented in Table 1.

As all studies included were nonrandomized controlled studies (3 in prospective and 7 in retrospective), the Newcastle-Ottawa Scale was used to assess the quality of each study. Of these, 9 studies scored 8 points and 2 studies scored 7 points. Therefore, the quality of each study was high (Table 2).

3.3. Clinical evaluation

Preoperative and postoperative JOA scores (final follow-up) were analyzed in 9 studies (238 patients in LP group and 217 patients in LF group). There was no significant difference between the 2 groups in preoperative JOA scores [$P=.58$, MD=.18 (−0.46, 0.82); heterogeneity: $P<.001$, $I^2=86\%$, random-effect model] and in postoperative JOA scores [$P=.60$, MD=−0.35 (−1.67, 0.97); heterogeneity: $P<.001$, $I^2=96\%$, random-effect model] (Fig. 2).

JOA scores improvement rate was analyzed in 6 studies (163 patients in LP group and 157 patients in LF group). There was no significant difference between the 2 groups in JOA scores improvement rate [$P=.64$, MD=−3.15 (−16.20, 9.90); heterogeneity: $P<.001$, $I^2=96\%$, random-effect model] (Fig. 2).

Preoperative and postoperative VAS (final follow-up) were analyzed in 5 studies (128 patients in LP group and 126 patients in LF group). There was no significant difference between the 2 groups in preoperative VAS [$P=.34$, MD=−0.21 (−0.64, 0.22); heterogeneity: $P=.95$, $I^2=0\%$, fixed-effect model] and in postoperative VAS [$P=.20$, MD=0.47 (−0.24, 1.19); heterogeneity: $P<.001$, $I^2=85\%$, random-effect model] (Fig. 3).

3.4. Radiography evaluation

Preoperative and postoperative cervical lordosis were analyzed in 7 studies (192 patients in LP group and 188 patients in LF group). There was no significant difference between the 2 groups in preoperative cervical lordosis [$P=.56$, SMD=−0.10 (−0.44, 0.24); heterogeneity: $P=.01$, $I^2=63\%$, random-effect model]. However, there were significant differences between the 2 groups in postoperative cervical lordosis [$P=.01$, SMD=−1.13 (−2.03, −0.24); heterogeneity: $P<.001$, $I^2=94\%$, random-effect model] (Fig. 4).

Preoperative and postoperative cervical ROM were analyzed in 2 studies (53 patients in LP group and 56 patients in LF group). There was no significant difference between the 2 groups in preoperative cervical ROM [$P=.10$, MD=−4.04 (−8.84, 0.76); heterogeneity: $P=.17$, $I^2=46\%$, fixed-effect model] and postoperative cervical ROM [$P=.18$, MD=3.23 (−1.49, 7.95); heterogeneity: $P=.21$, $I^2=37\%$, fixed-effect model] (Fig. 5).

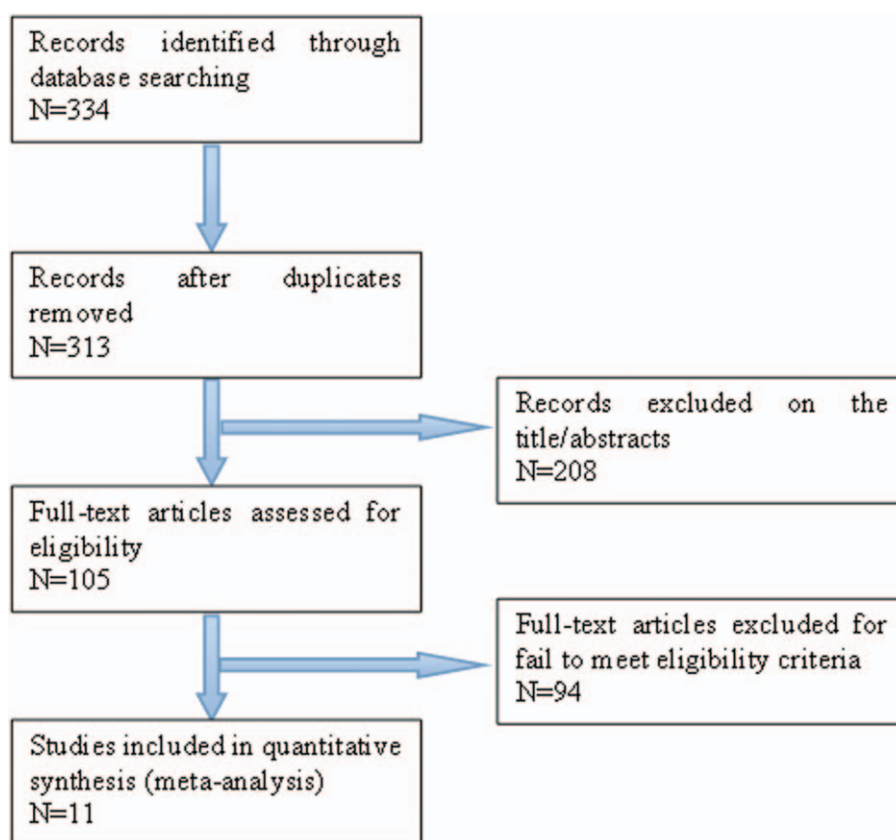


Figure 1. Flow diagram of study selection.

3.5. Complications

Axial symptoms were analyzed in 7 studies (196 patients in LP group and 177 patients in LF group). There was no significant difference between the 2 groups in axial symptoms [$P = .21$, MD = 1.38 (0.83, 2.30); heterogeneity: $P = .26$, $I^2 = 22\%$, fixed-effect model] (Fig. 6).

C5 palsy was analyzed in 8 studies (196 patients in LP group and 177 patients in LF group). There was no significant difference between the 2 groups in C5 palsy [$P = .16$, MD = 0.60 (0.29, 1.23); heterogeneity: $P = .21$, $I^2 = 28\%$, fixed-effect model] (Fig. 6).

3.6. Operation time and blood loss

Operation time was analyzed in 3 studies (78 patients in LP group and 64 patients in LF group). LP group showed lower operation time [$P < .001$, MD = -19.42 (-26.87, -11.97); heterogeneity: $P = .53$, $I^2 = 0\%$, fixed-effect model] than LF group (Fig. 7).

Blood loss was analyzed in 3 studies (78 patients in LP group and 64 patients in LF group). LP group showed lower blood loss [$P = .03$, MD = -94.78 (-179.05, -10.51); heterogeneity: $P = .10$, $I^2 = 57\%$, random-effect model] than LF group (Fig. 7).

Table 1

Characteristics of included studies.

Study	Design	No. of patients		Mean age, y		No. of males/females		Mean follow-up, mo
		Laminoplasty	Laminectomy + fusion	Laminoplasty	Laminectomy + fusion	Laminoplasty	Laminectomy + fusion	
Wang et al ^[9]	Retrospective	33	24	54.8	51.7	15/18	9/15	21
Chen et al ^[10]	Retrospective	25	28	54.2	55.3	16/9	19/9	—
Chen et al ^[11]	Retrospective	41	32	46.3	52.6	33/8	19/13	48
Wang et al ^[12]	Retrospective	14	12	53.1	63.7	—	—	27.6
Lee et al ^[13]	Prospective	21	21	54.2	63.7	15/6	19/3	24
Liu et al ^[14]	Retrospective	32	35	59	60	26/6	25/10	38
Chen et al ^[15]	Prospective	34	33	63.8	61.2	19/15	13/10	12
Shen and Shen ^[16]	Retrospective	20	22	52.97	52.97	25/17	23.2	—
Zhong and Xu ^[17]	Retrospective	11	7	55.91	60.14	7/4	6/1	26.5
Bai and Zhang ^[18]	Prospective	32	32	51.04	50.18	24/8	21/11	12
Miao et al ^[19]	Retrospective	29	26	61.9	56.3	—	—	—

Table 2

The quality assessment according to the Newcastle Ottawa Scale of each study.

Study	Selection	Comparability	Exposure	Total score
Wang et al ^[9]	3	2	3	8
Chen et al ^[10]	3	2	2	7
Chen et al ^[11]	3	2	3	8
Wang et al ^[12]	3	2	3	8
Lee et al ^[13]	3	2	3	8
Liu et al ^[14]	3	2	3	8
Chen et al ^[15]	3	2	3	8
Shen and Shen ^[16]	3	2	3	8
Zhong and Xu ^[17]	3	2	3	8
Bai and Zhang ^[18]	3	2	3	8
Miao et al ^[19]	3	2	2	7

3.7. Sensitivity analysis

To confirm the stability of the meta-analysis, sensitivity analysis was performed by sequentially omitting individual eligible studies.^[8] The pooled results were not materially changed after

any single study was excluded which indicated the stability of the results.

3.8. Publication bias

Assessment of publication bias for included studies was performed by funnel plots on visual inspection (Fig. 8). Funnel plots showed nearly symmetric for C5 palsy, indicating no significant publication bias among the included studies.

4. Discussion

Cervical OPLL results from pathologic replacement of cervical posterior longitudinal ligament with lamellar bone.^[20] OPLL cause spinal cord compression and neurologic deterioration including changes in gait or balance, loss of fine motor control, and upper extremity weakness, numbness, or paresthesias.^[9] Patients with cervical OPLL are at an increased risk of acute spinal cord injury with trauma and rapid neurologic deterioration in association with even a minor trauma.^[10]

Cervical OPLL is classified radiographically into 4 types: localized, segmental, continuous, and mixed.^[11] The incidence of

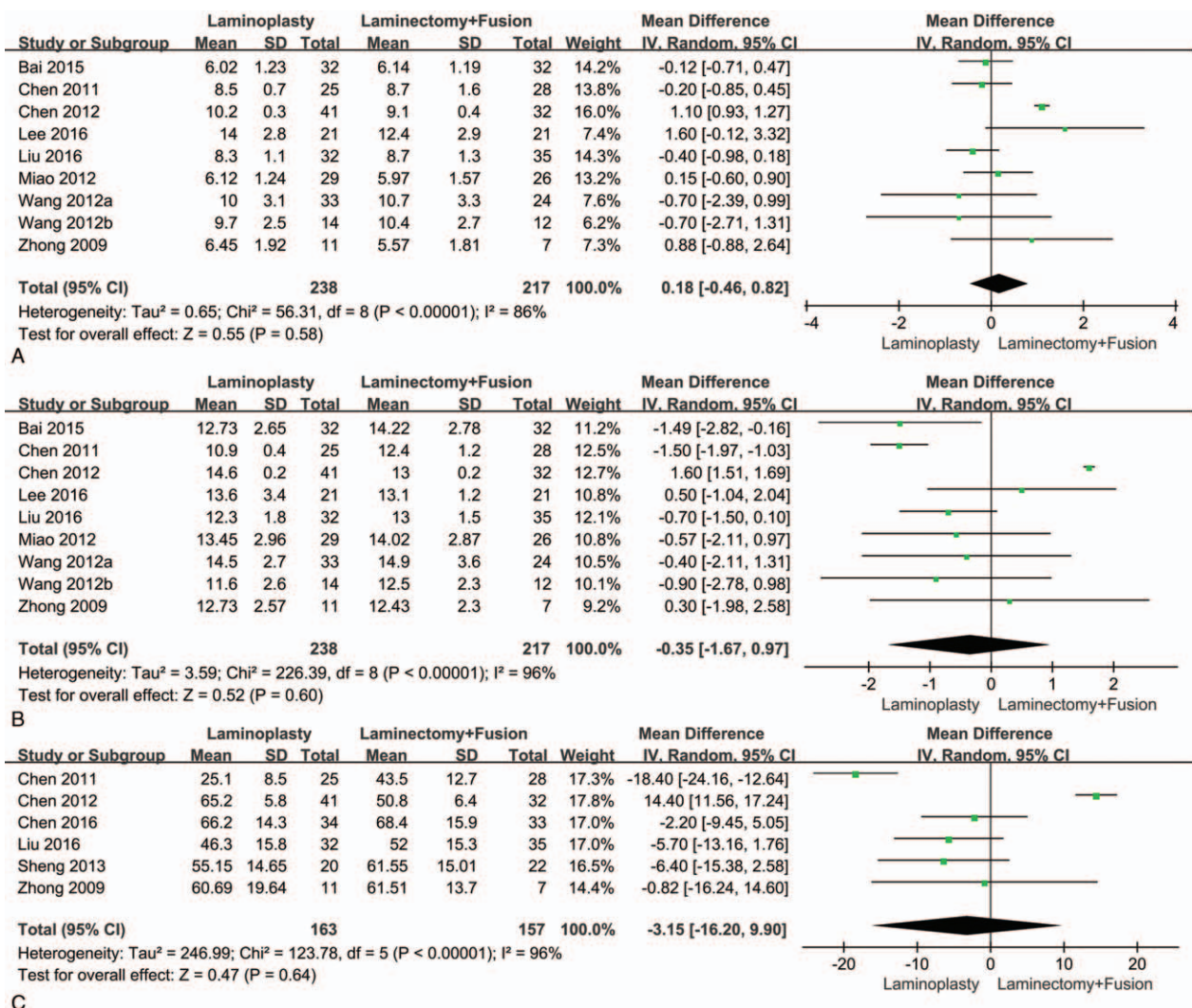


Figure 2. Forest plots of preoperative JOA (A), postoperative JOA (B), and JOA scores improvement rate (C) in laminoplasty group and laminectomy + fusion group.

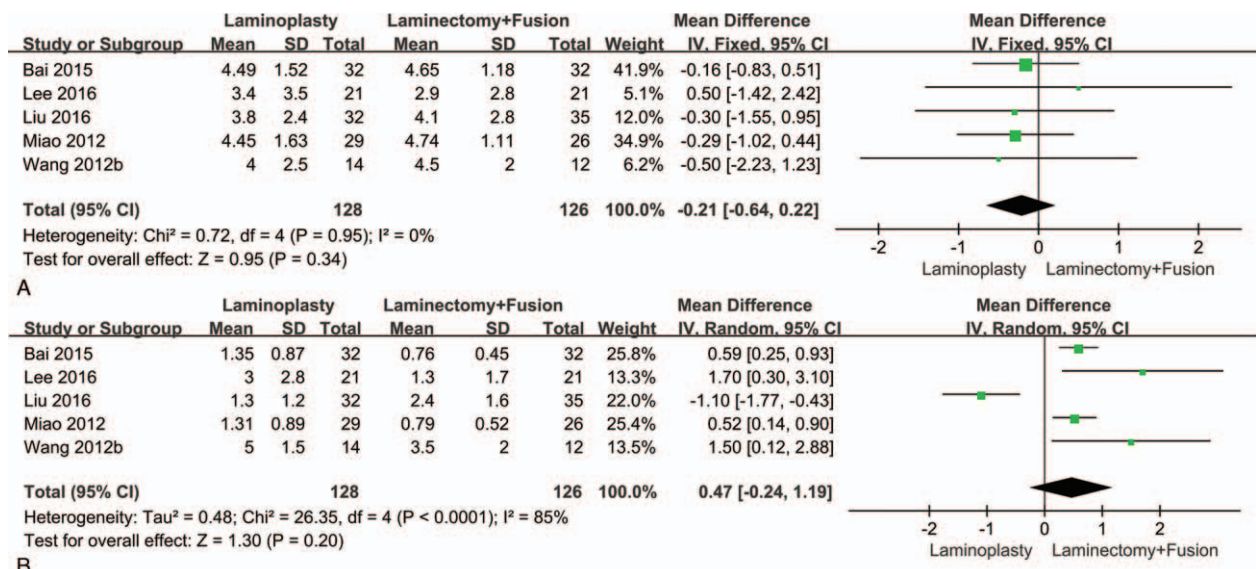


Figure 3. Forest plots of preoperative VAS (A) and postoperative VAS (B) in laminoplasty group and laminectomy + fusion group.

OPLL ranges from 1.9% to 4.3% in East Asian countries and from 0.01% to 1.7% in Caucasian populations.^[12]

OPLL is an important cause of cervical myelopathy. As OPLL is a multifactorial disease and no conservative treatment has been confirmed to be effective, surgical treatment is usually required. Surgical treatment includes anterior approach, posterior approach, and combined anterior and posterior approach.^[13]

Anterior decompression and direct removal of OPLL seems to be radical, because the major pathomechanism of OPLL is anterior compression of the spinal cord.^[14] But risk of complications such as spinal cord injury, dural tears, and hemorrhage cannot be ignored. Anterior approach becomes

more technically demanding and risky with the increasing narrowing rate and extent of ossification.^[15]

Posterior decompression is the preferred choice of surgical treatment for multilevel cervical OPLL in many institutes. For its a relatively safer procedure and can provide extensive decompression of segments more easily.^[16] LP and LF are recognized as reliable and effective posterior approach in treating multilevel cervical OPLL.^[17]

The advantages of LP are as follows: it is easy to master the technique; it can preserve the motion capability; it is safer. It also has disadvantages which are: poor operative outcomes due to the indirect decompression; Its premise is the cervical lordosis curve; postoperative instability may lead to neurological worsen; the

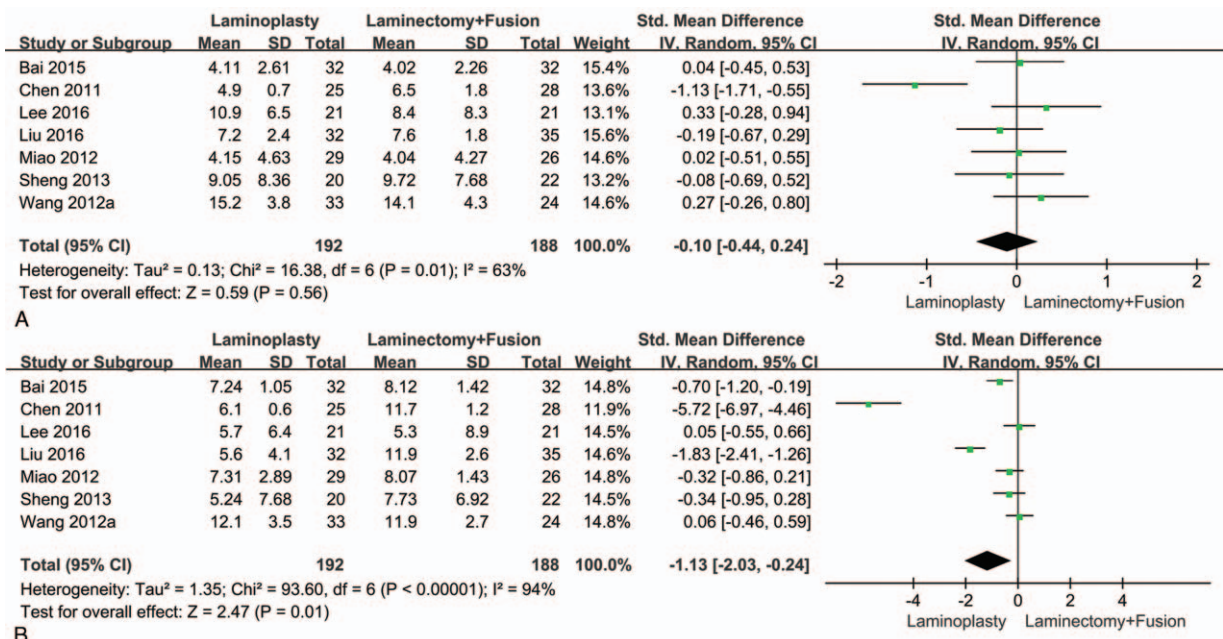


Figure 4. Forest plots of preoperative cervical lordosis (A) and postoperative cervical lordosis (B) in laminoplasty group and laminectomy + fusion group.

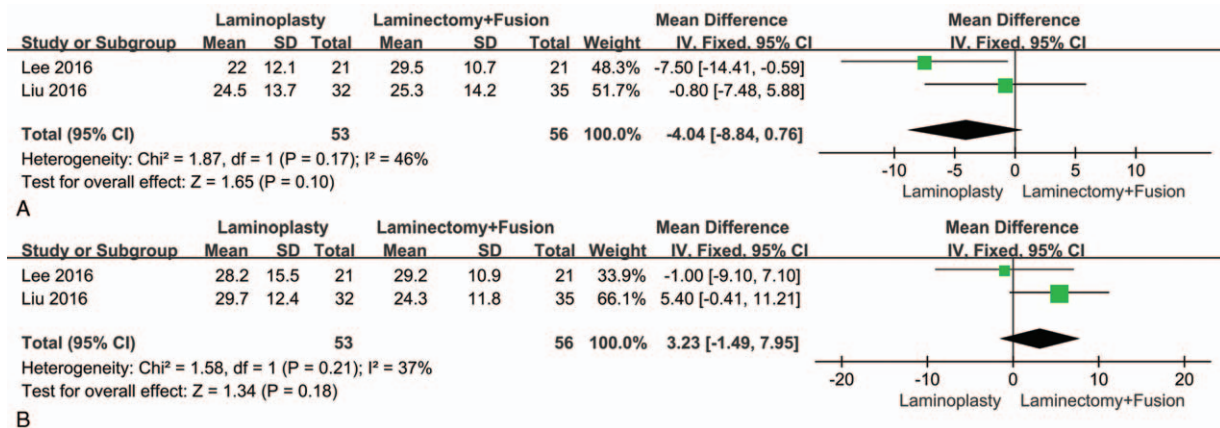


Figure 5. Forest plots of preoperative cervical ROM (A) and postoperative cervical ROM (B) in laminoplasty group and laminectomy + fusion group.

incidence of cervical 5 nerve paralysis; postoperative neck pain.^[18]

The relative advantages of LF are as follow: allow decompression of entire cervical spine, low complication rate, and low risk of kyphotic progression. However, the disadvantages are as follow: indirect decompression may lead to poor outcomes, especially for highly occupied OPLL; high risk of C5 palsy; and loss of cervical ROM.^[19]

Surgical strategy for multilevel cervical OPLL still remains controversial. Therefore, we performed a meta-analysis to assess the effectiveness and safety of the 2 surgical procedures for multilevel cervical OPLL.

JOA score and VAS were often used to evaluate the improvement of nerve function.^[21] The pooled data showed

that there was no significant difference between the 2 groups in preoperative and postoperative JOA score, JOA score improvement rate, preoperative and postoperative VAS. So both techniques can have sufficient decompression and nerve improvement. Both techniques were effective.

C5 palsy and axial pain were 2 common complications after cervical posterior surgery.^[22] The pooled data showed that there was no significant difference between the 2 groups in C5 palsy and axial pain.

Cervical ROM and cervical lordosis were selected for analysis. The pooled data showed that there was no significant difference between the 2 groups in preoperative cervical ROM, preoperative cervical lordosis, and postoperative cervical ROM. However, LF group showed greater postoperative cervical lordosis than LP

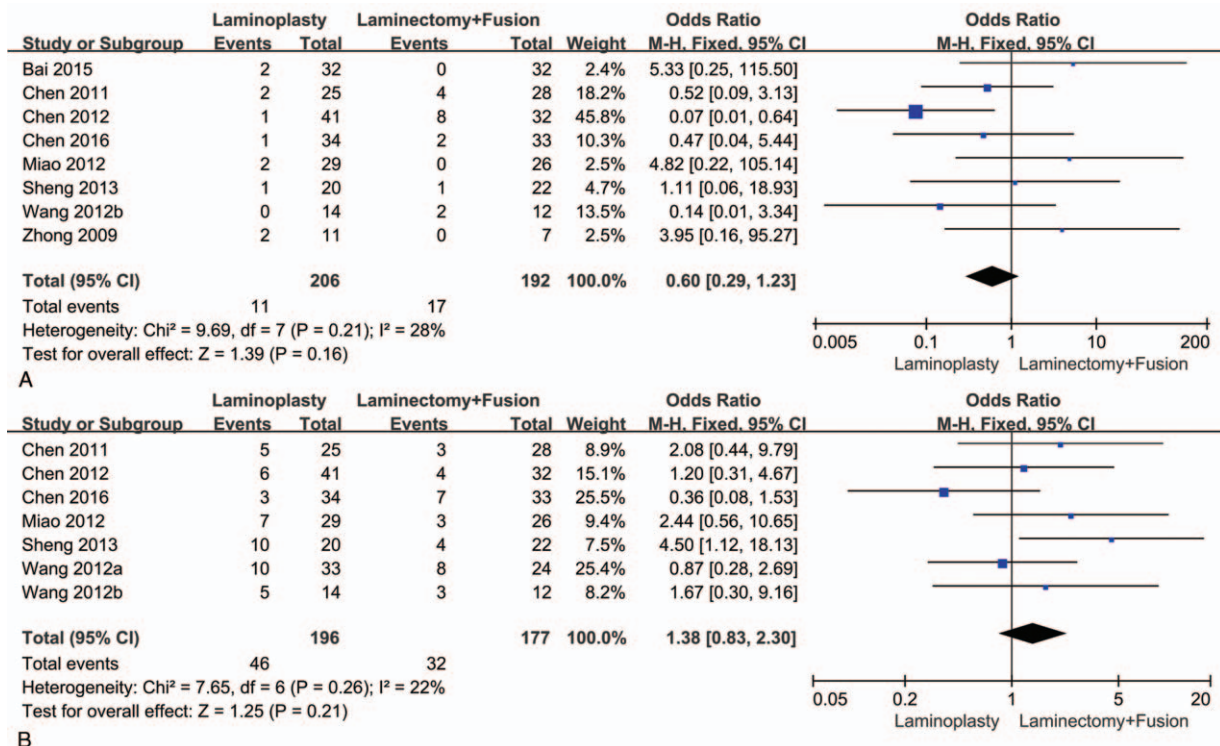


Figure 6. Forest plots of C5 palsy (A) and axial symptoms (B) in laminoplasty group and laminectomy + fusion group.

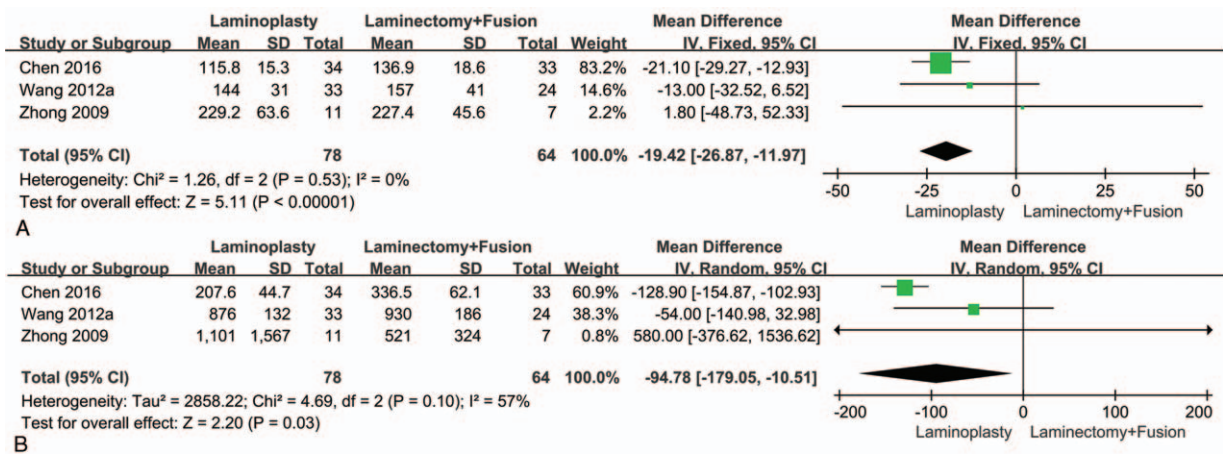


Figure 7. Forest plots of operation time (A) and blood loss (B) in laminoplasty group and laminectomy + fusion group.

group. So LF was superior to LP in maintaining cervical lordosis. Chen et al^[23] reported that the LF could improve cervical lordosis whilst provide a better decompression effect and good prognosis for patients with OPLL in the long-term follow-up. Saruhashi et al^[24] reported that 30% of patients developed kyphosis during a mean 5-year follow-up after LP. Researches of Iwasaki et al^[25] and Lee et al^[26] showed that the patients with straight lordosis may develop kyphosis deformity after the LP. It is caused by the destructions of posterior structure including cervical muscles ligament complex and bony elements during the procedure of the posterior surgery and may lead to cervical spine instability and cervical kyphosis.^[27] Furthermore, the incidence of progression of OPLL after LP has been reported at 70% to 73%, and this risk is greater with increasing length of follow-up. So progressive kyphosis and progression of OPLL after LP were responsible for delayed neurologic deterioration.^[28]

Operation time and blood loss were important factors for assessing surgical trauma.^[29] In this study, LF group had greater blood loss and longer operation time than LP group. So LP showed lower surgical trauma than LF in the treatment of multilevel cervical OPLL.

The kyphosis line (K-line) was first described by Fujiyoshi et al in 2008.^[30] K-line was drawn from the center of the canal at C2 to the center of the canal at C7. It was widely used in making decisions regarding the surgical approach for patients with

cervical OPLL. K-line (-) and K-line (+) were respectively defined when the OPLL exceeded or did not exceed the K-line. K-line could evaluate cervical alignment and the size of OPLL at the same time, which was convenient and applied.^[31] So the choice of surgical option should base on pathological extent of OPLL and K-line. Pathological extent of OPLL was the compressive extent of the spinal cord on MRI. Short-segment pathology was treated via the anterior approach. Posterior approach should be used in long-segment pathology which compressive lesion more than 3 cervical levels.^[32] When the posterior approach was selected, LP was performed for the patients with K-line (+) and LF for K-line (-).

At present, no standards or guidelines exist for the treatment of OPLL. Furthermore, none of the surgical options were perfect.^[1] We should select the approach which is safe and effective. For patients with multilevel cervical OPLL, posterior approach could be performed. If symptom recovery was not ideal, anterior approach could be performed secondarily. It would be safer than only anterior approach in the treatment of multilevel cervical OPLL. In a word, following factors should be fully considered: operative skill of surgeon, physical condition of patients, type of OPLL, pathological extent of OPLL, and K-line.^[33,34]

4.1. Study limitations

There were several limitations in this study. First, the progression of OPLL was an important complication after cervical posterior surgery. However, few studies analyzed it and related data could be extracted. Second, LP including different techniques, such as open door and French door, and these differences were not considered. Third, follow-up time varied between the studies which may influence our results. Fourth, though we did strict literature retrieval, most included articles were from China. The conclusions may be more suitable for Chinese patients. Finally, none of the studies included in the meta-analysis was randomized controlled trial.

5. Conclusions

Both LP and LF could achieve clinical improvement in the treatment of multilevel cervical OPLL.

LF was superior to LP in maintaining cervical lordosis. However, LP showed lower surgical trauma than LF. K-line may be a good criterion in the selection of posterior surgery. LP was performed for the patients with K-line (+) and LF for K-line (-).

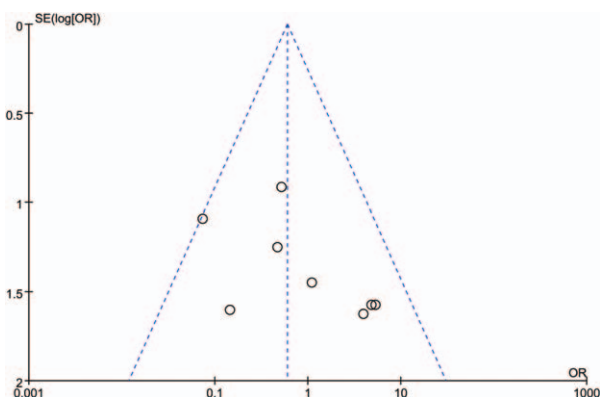


Figure 8. Funnel plots for included studies in C5 palsy.

Author contributions

Conceptualization: Wen-Yuan Ding.

Data curation: Lei Ma.

Formal analysis: Feng-Yu Liu.

Investigation: Li-Shuang Huo.

Methodology: Zheng-Qi Zhao.

Project administration: Zheng-Qi Zhao.

Resources: Xian-Ze Sun.

Software: Xian-Ze Sun.

Supervision: Feng Li.

Validation: Feng Li.

Writing – original draft: Feng-Yu Liu.

Writing – review & editing: Li-Shuang Huo.

References

- An HS, Al-Shihabi L, Kurd M. Surgical treatment for ossification of the posterior longitudinal ligament in the cervical spine. *J Am Acad Orthop Surg* 2014;22:420–9.
- Singhatanadgige W, Limthongkul W, Valone F, et al. Outcomes following laminoplasty or laminectomy and fusion in patients with myelopathy caused by ossification of the posterior longitudinal ligament: a systematic review. *Global Spine J* 2016;6:702–9.
- Feng F, Ruan W, Liu Z, et al. Anterior versus posterior approach for the treatment of cervical compressive myelopathy due to ossification of the posterior longitudinal ligament: a systematic review and meta-analysis. *Int J Surg* 2016;27:26–33.
- Liu W, Hu L, Chou PH, et al. Comparison of anterior decompression and fusion versus laminoplasty in the treatment of multilevel cervical ossification of the posterior longitudinal ligament: a systematic review and meta-analysis. *Ther Clin Risk Manag* 2016;12:675–85.
- Chen Z, Liu B, Dong J, et al. Comparison of anterior corpectomy and fusion versus laminoplasty for the treatment of cervical ossification of posterior longitudinal ligament: a meta-analysis. *Neurosurg Focus* 2016;40:E8.
- Mehdi SK, Alentado VJ, Lee BS, et al. Comparison of clinical outcomes in decompression and fusion versus decompression only in patients with ossification of the posterior longitudinal ligament: a meta-analysis. *Neurosurg Focus* 2016;40:E9.
- Lee CH, Sohn MJ, Lee CH, et al. Are there differences in the progression of ossification of the posterior longitudinal ligament following laminoplasty versus fusion?: a meta-analysis. *Spine (Phila Pa 1976)* 2017;42:887–94.
- Liu FY, Yang SD, Huo LS, et al. Laminoplasty versus laminectomy and fusion for multilevel cervical compressive myelopathy: a meta-analysis. *Medicine (Baltimore)* 2016;95:e3588.
- Wang H, Ding WY, Shen Y, et al. Analysis of axial symptoms after indirect decompression for ossification of the posterior longitudinal ligament of the cervical spine. *Zhonghua Wai Ke Za Zhi* 2012;50:601–6.
- Chen Y, Guo Y, Lu X, et al. Surgical strategy for multilevel severe ossification of posterior longitudinal ligament in the cervical spine. *J Spinal Disord Tech* 2011;24:24–30.
- Chen Y, Liu X, Chen D, et al. Surgical strategy for ossification of the posterior longitudinal ligament in the cervical spine. *Orthopedics* 2012;35:e1231–7.
- Wang XW, Yuan W, Chen DY, et al. Surgical options and clinical outcomes of cervical ossification of the posterior longitudinal ligament. *Zhonghua Wai Ke Za Zhi* 2012;50:596–600.
- 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: is there a difference in the clinical outcome and sagittal alignment? *Clin Spine Surg* 2016;29: E9–15.
- Liu X, Chen Y, Yang H, et al. Expansive open-door laminoplasty versus laminectomy and instrumented fusion for cases with cervical ossification of the posterior longitudinal ligament and straight lordosis. *Eur Spine J* 2017;26:1173–80.
- Chen G, Dai T, Shi KQ. A comparison of unilateral open-door cervical expansive laminoplasty and laminectomy for treatment of ossification of the posterior longitudinal ligament. *Orthop J China* 2016;24:589–602.
- Shen CH, Shen Y. Analysis of Related Factors Affecting Prognosis After Indirect Decompression for Long Segmental Ossification of Cervical Posterior Longitudinal Ligament[D]. Hebei Province: Hebei Medical University, 2013;Y2337605:1–35.
- Zhong CJ, Xu WH. Laminectomy Followed by Fusion in Treating Severe Ossification of the Posterior Longitudinal Ligament. Fujian Province: Fujian Medical University, 2009;20090301:1–49.
- Bai ZF, Zhang XH. Effects of laminectomy and fusion on 32 cases of cervical ossification of the posterior longitudinal ligament. *J Shanxi Med* 2015;44:1232–5.
- Miao J, Shen Y, Wang LF, et al. Long-term influence of three cervical posterior operative methods for multilevel cervical spondylotic myelopathy: a retrospective study of cervical curvature and clinical outcomes. *Orthop J China* 2012;20:978–81.
- Wang S, Xiang Y, Wang X, et al. Anterior corpectomy comparing to posterior decompression surgery for the treatment of multi-level ossification of posterior longitudinal ligament: a meta-analysis. *Int J Surg* 2017;40:91–6.
- Epstein N. Diagnosis and surgical management of cervical ossification of the posterior longitudinal ligament. *Spine J* 2002;2:436–49.
- Mizuno J, Nakagawa H. Ossified posterior longitudinal ligament: management strategies and outcomes. *Spine J* 2006;6(6 suppl):282S–85S.
- Chen Y, Guo Y, Chen D, et al. Long-term outcome of laminectomy and instrumented fusion for cervical ossification of the posterior longitudinal ligament. *Int Orthop* 2009;33:1075–80.
- Saruhashi Y, Hukuda S, Katsuura A, et al. A long-term follow-up study of cervical spondylotic myelopathy treated by “French window” laminoplasty. *J Spinal Disord* 1999;12:99–101.
- Iwasaki M, Kawaguchi Y, Kimura T, et al. Long-term results of expansive laminoplasty for ossification of the posterior longitudinal ligament of the cervical spine: more than 10 years follow up. *J Neurosurg* 2002;96(2 suppl):180–9.
- Lee CK, Shin DA, Yi S, et al. Correlation between cervical spine sagittal alignment and clinical outcome after cervical laminoplasty for ossification of the posterior longitudinal ligament. *J Neurosurg* 2016;24:100–7.
- Epstein N. Ossification of the cervical posterior longitudinal ligament: a review. *Neurosurg Focus* 2002;13:EC1.
- Sugrue PA, McClendon JJr, Halpin RJ, et al. Surgical management of cervical ossification of the posterior longitudinal ligament: natural history and the role of surgical decompression and stabilization. *Neurosurg Focus* 2011;30:E3.
- Matsumoto M, Chiba K, Toyama Y. Surgical treatment of ossification of the posterior longitudinal ligament and its outcomes: posterior surgery by laminoplasty. *Spine (Phila Pa 1976)* 2012;37:E303–8.
- Fujiyoshi T, Yamazaki M, Kawabe J, et al. A new concept for making decisions regarding the surgical approach for cervical ossification of the posterior longitudinal ligament: the K-line. *Spine (Phila Pa 1976)* 2008;33:E990–3.
- Li J, Zhang Y, Zhang N, et al. Clinical outcome of laminoplasty for cervical ossification of the posterior longitudinal ligament with K-line (–) in the neck neutral position but K-line (+) in the neck extension position: a retrospective observational study. *Medicine (Baltimore)* 2017;96: e6964.
- Yoon ST, Hashimoto RE, Raich A, et al. Outcomes after laminoplasty compared with laminectomy and fusion in patients with cervical myelopathy: a systematic review. *Spine (Phila Pa 1976)* 2013;38(22 suppl 1):S183–94.
- Kommu R, Sahu BP, Purohit AK. Surgical outcome in patients with cervical ossified posterior longitudinal ligament: a single institutional experience. *Asian J Neurosurg* 2014;9:196–202.
- 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.