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ORIGINAL ARTICLE

Anterior cervical corpectomy and fusion versus posterior laminoplasty for the treatment of oppressive myelopathy owing to cervical ossification of posterior longitudinal ligament: a meta-analysis

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Abstract

Purpose The purpose of this research is to compare the clinical efficacy, postoperative complication and surgical trauma between anterior cervical corpectomy and fusion versus posterior laminoplasty for the treatment of oppressive myelopathy owing to cervical ossification of the posterior longitudinal ligament (OPLL).

Study design Systematic review and meta-analysis.

Methods An comprehensive search of literature was implemented in three electronic databases (Embase, Pubmed, and the Cochrane library). Randomized or non-randomized controlled studies published since January 1990 to July 2017 that compared anterior cervical corpectomy and fusion (ACCF) versus posterior laminoplasty (LAMP) for the treatment of cervical oppressive myelopathy owing to OPLL were acquired. Exclusion criteria were non-human studies, non-controlled studies, combined anterior and posterior operative approach, the other anterior or posterior approaches involving cervical discectomy and fusion and laminectomy with (or without) instrumented fusion, revision surgeries, and cervical myelopathy caused by cervical spondylotic myelopathy. The quality of the included articles was evaluated according to GRADE. The main outcome measures included: preoperative and postoperative Japanese Orthopedic Association (JOA) score; neuro-functional recovery rate; complication rate; reoperation rate; preoperative and postoperative C2–C7 Cobb angle; operation time and intraoperative blood loss; and subgroup analysis was performed according to the mean preoperative canal occupying ratio (Subgroup A:the mean preoperative canal occupying ratio < 60%, and Subgroup B:the mean preoperative canal occupying ratio ≥ 60%).

Results A total of 10 studies containing 735 patients were included in this meta-analysis. And all of the selected studies were non-randomized controlled trials with relatively low quality as assessed by GRADE. The results revealed that there was no obvious statistical difference in preoperative JOA score between the ACCF and LAMP groups in both subgroups. Also, in subgroup A (the mean preoperative canal occupying ratio < 60%), no obvious statistical difference was observed in the postoperative JOA score and neurofunctional recovery rate between the ACCF and LAMP groups. But, in subgroup B (the mean preoperative canal occupying ratio ≥ 60%), the ACCF group illustrated obviously higher postoperative JOA score and neurofunctional recovery rate than the LAMP group ($P < 0.01$, WMD 1.89 [1.50, 2.28] and $P < 0.01$, WMD 24.40 [20.10, 28.70], respectively). Moreover, the incidence of both complication and reoperation was markedly higher in the ACCF group compared with LAMP group ($P < 0.05$, OR 1.76 [1.05, 2.97] and $P < 0.05$, OR 4.63 [1.86, 11.52], respectively). In addition, the preoperative cervical C2–C7 Cobb angle was obviously larger in the LAMP group compared with ACCF group ($P < 0.05$, WMD − 5.77 [− 9.70, − 1.84]). But no statistically obvious difference was detected in the postoperative cervical C2–C7 Cobb angle between the two groups. Furthermore, the ACCF group showed significantly more operation time as well as blood loss compared with LAMP group ($P < 0.01$, WMD 111.43 [40.32,182.54], and $P < 0.01$, WMD 111.32 [61.22, 161.42], respectively).

Conclusion In summary, when the preoperative canal occupying ratio < 60%, no palpable difference was tested in postoperative JOA score and neurofunctional recovery rate. But, when the preoperative canal occupying ratio ≥ 60% ACCF was associated with better postoperative JOA score and the recovery rate of neurological function compared with LAMP.

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Synchronously, ACCF in the cure for cervical myelopathy owing to OPLL led to more surgical trauma and more incidence of complication and reoperation. On the other hand, LAMP had gone a diminished postoperative C2–C7 Cobb angle, that might be a cause of relatively higher incidence of postoperative late neurofunctional deterioration. In brief, when the preoperative canal occupying ratio < 60%, LAMP seems to be effective and safe. However, when the preoperative canal occupying ratio ≥ 60%, we prefer to choose ACCF while complications could be controlled by careful manipulation and advanced surgical techniques. No matter which option you choose, benefits and risks ought to be balanced.

Keywords Cervical myelopathy · Ossification of the posterior longitudinal ligament · Anterior cervical corpectomy and fusion · Laminoplasty · Meta-analysis

Introduction

Cervical oppressive myelopathy is mainly caused by ossification of the posterior longitudinal ligament (OPLL) and Cervical spondylotic myelopathy (CSM). In East Asian region, the prevalence of OPLL ranges from 1.9 to 4.3%, while the prevalence ranges from 0.1 to 1.7% among Caucasians [1, 2]. For cervical myelopathy due to OPLL, surgical treatment is the preferred option, as conservative treatment is usually invalid. The surgical approaches include anterior, posterior as well as combined anterior and posterior. The anterior approach usually involves anterior cervical discectomy with fusion (ACDF) and anterior cervical corpectomy with fusion (ACCF), while laminoplasty and laminectomy with (or without) internal fixation fusion represent posterior approach. ACCF and LAMP are the frequently used approaches in general. However, which approach has better clinical results remains controversial.

With regard to ACCF, it seems perfect that direct decompression is achieved by removing the ossified mass. It has several advantages as follows: (1) complete decompression via resection of the ossified mass seems perfect; (2) the stability of the cervical spine is reconstructed by bone grafts fusion. Meanwhile, the disadvantages about ACCF are obvious, it requires higher techniques, more bone grafts for fusion, and it has higher incidence of complications and reoperation, and longer postoperative cervical immobilization [3, 4].

As for LAMP, which first described by Tsuji [5], indirect decompression is feasible owing to the enlarged spinal canal and the dorsal movement of spinal cord. Advantages are as follows: (1) the technique is relatively easier and safer than ACCF; (2) LAMP brings about a shorter postoperative cervical immobilization by cervical collar. But the following disadvantages of LAMP are clear: (1) it requires adequate cervical lordosis [6]; (2) if the backward movement of spinal cord is not adequate, and the ventral compression may persist, resulting in an unsatisfactory neurofunctional recovery; (3) the postoperative instability, progression of OPLL and kyphosis change of the cervical spine may induce the late neurofunctional deterioration [4, 7, 8]; (4) the postoperative complications of cervical axial pain and C5 palsy remain to be addressed [9, 10].

Up to now, neither standards nor guidelines have been formulated for the treatment of oppressive myelopathy caused by cervical OPLL; this systematic review and meta-analysis were conducted to evaluate the clinical outcomes of ACCF compared with LAMP for the treatment of cervical oppressive myelopathy owing to OPLL.

Materials and methods

Search strategy

A comprehensive search of studies published from January 1990 to July 2017 that compared clinical outcomes of ACCF with LAMP for the treatment of oppressive myelopathy caused by cervical OPLL was performed in three databases including Pubmed, Embase, and Cochrane library. We set no language restrictions, and the terms were used as follows: (1) anterior OR ventral OR anterior approach OR ventral approach OR ACCF OR anterior cervical corpectomy and fusion OR corpectomy OR ventral decompression OR anterior decompression OR anterior decompression and fusion; (2) posterior OR dorsal OR posterior approach OR dorsal approach OR LAMP OR laminoplasty OR posterior decompression OR dorsal decompression; (3) cervical myelopathy OR cervical OR myelopathy OR cervical stenosis OR cervical spinal stenosis OR cervical canal stenosis OR stenosis; (4) ossification of the posterior longitudinal ligament OR OPLL OR ossified posterior longitudinal ligament OR calcification of the posterior longitudinal ligament OR calcific posterior longitudinal ligament; (1), (2), (3) and (4). Reference lists of all retrieved studies were skimmed to chase down extra-potentially relevant researches. Two reviewers independently skimmed the titles and abstracts of all retrieved studies, and obtained full-text duplicates of all relevant studies.

Inclusion criteria

The inclusion criteria were as follows: (1) study design: randomized and/or non-randomized controlled trials; (2) study population: the surgery patients with oppressive myelopathy due to cervical OPLL; (3) intervention purpose: to compare clinical outcomes of ACCF with LAMP; (4) outcome measurements: neurological recovery rate, complication, late neurological deterioration, reoperation rate, C2–C7 Cobb angle and surgical trauma involving operation time and intraoperative blood loss.

Exclusion criteria

The exclusion criteria were listed as below: (1) duration of follow-up was shorter than one year; (2) patients with cervical myelopathy caused by tumors, trauma, disc herniation; (3) patients had experienced previous cervical surgery; (4) the surgery was performed by combined anteroposterior surgical approach; (4) studies were case reports, animal studies, non-comparative studies and review articles.

Data extraction

The data were extracted from each included studies as listed below: (1) study ID; (2) type of study design; (3) study site; (4) patient demographics; (5) follow-up time; (6) surgical approach; (7) number of surgical segments; (8) preoperative canal occupying ratio; (9) preoperative and postoperative JOA score; (10) the recovery rate of neurological function; (11) complication and reoperation; (12) preoperative and postoperative C2–C7 Cobb angle; (13) surgical trauma involving the operation time and intraoperative blood loss.

Subgroup analysis

Subgroup analysis was performed according to the mean preoperative canal occupying ratio. Subgroup A included researches in which the mean preoperative canal occupying ratio < 60%, while subgroup B included researches in which the mean preoperative canal occupying ratio ≥ 60%.

Data analysis

We implemented all statistical analyses using the Review Manager (RevMan Version 5.1; The Cochrane Collaboration). Not directly supplied data of the standard deviation were estimated using the range and sample size [11]. Heterogeneity among the included studies was examined by Chi-square test and quantified via calculating I^2 statistic. $P < 0.05$ and $I^2 \geq 50\%$ were considered to have a statistical significance. To the pooled effects, standard mean difference (SMD) or weighted mean difference (WMD) was calculated for the continuous variables in accordance with the consistency of measurement units, whereas odds ratio (OR) was used for calculating the dichotomous variables. Continuous variables were presented in the form of WMD and 95% confidence intervals (95% CI), while dichotomous variables were presented as OR and 95% CI. When $P < 0.05$ and $I^2 \geq 50\%$, the random-effects model was used; and when $P \geq 0.05$ or $I^2 < 50\%$, we chose the fixed-effects model.

Results

Search results

The flow chart of the process for identifying relative studies is present in Fig. 1. A total of 1385 articles were obtained from PubMed, Embase, Cochrane library and other sources. Ten studies [4, 8, 12–19] were finally included into this meta-analysis according to both inclusion and exclusion criteria which were set previously.

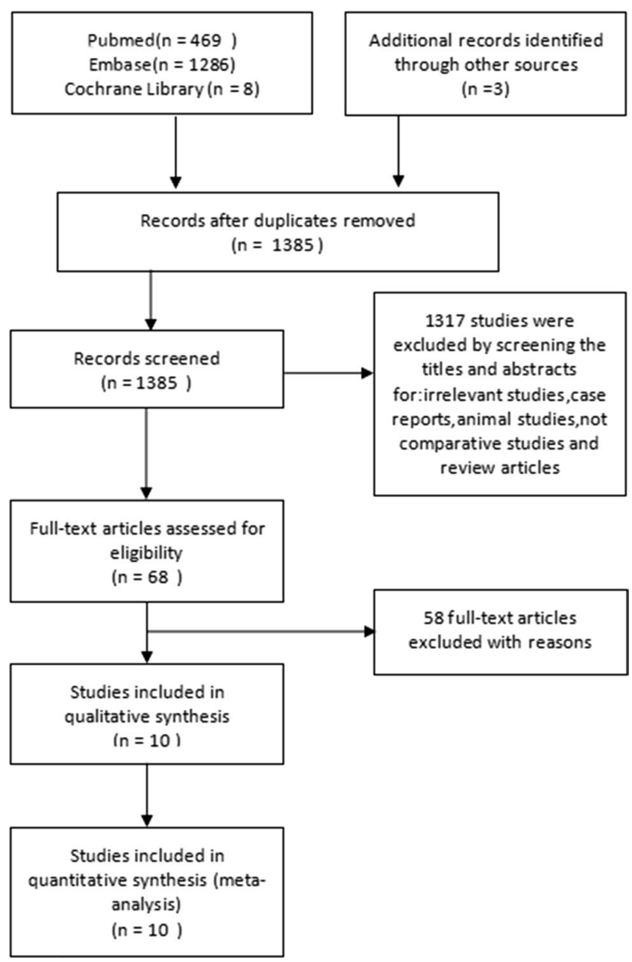


Fig. 1 The flow chart shows the process for identifying relative studies

Quality assessment and baseline characteristics

All ten articles included in our meta-analysis were non-randomized controlled studies: nine were retrospective cohort studies and one was prospective cohort study. The quality of included studies was all relatively low according to the GRADE scale [20] (Table 1). Ten studies [4, 8, 12–19] contained 735 patients in total, among which 364 patients underwent ACCF and 371 patients underwent LAMP. The baseline characteristics of ten studies included were presented in Table 2.

Clinical outcome

Preoperative JOA score

Eight studies (n = 558 patients; 270 in the ACCF group and 288 in the LAMP group) provided preoperative JOA score with mean ± standard deviation. No statistically significant difference was observed in preoperative JOA score between the ACCF group and LAMP group in both subgroup A and B (A:$P > 0.05$, WMD 0.05 [− 0.50, 0.61], heterogeneity: $\chi^2 = 0.92$, $df = 4$, $P = 0.92$, $I^2 = 0\%$; B: $P > 0.05$, WMD 0.16 [− 0.35,0.66], heterogeneity: $\chi^2 = 0.99$, $df = 4$, $P > 0.05$, $I^2 = 0\%$; Fig. 2), which indicated that the preoperative nerve function was similar between the two groups regardless of preoperative canal occupying ratio.

Postoperative JOA score

Eight studies (n = 558 patients; 270 in the ACCF group and 288 in the LAMP group) provided postoperative JOA score. There was no statistically significant difference in the postoperative JOA score between the ACCF group and LAMP group in subgroup A (P = 0.17 > 0.05, WMD 0.69 [− 0.30, 1.68], heterogeneity: $\tau^2 = 0.90$, $\chi^2 = 13.58$, $df = 4$, $P < 0.01$, $I^2 = 71\%$). In contrary, the ACCF group showed significantly higher postoperative JOA score compared with the LAMP group in subgroup B ($P < 0.01$, WMD 1.89 [1.50, 2.28], heterogeneity: $\tau^2 = 0.00$, $\chi^2 = 3.44$, $df = 4$, $P = 0.49$, $I^2 = 0\%$; Fig. 3).

Recovery rate

Eight studies (n = 558 patients; 270 in the ACCF group and 288 in the LAMP group) containing neurofunctional recovery rate were analyzed. No statistically significant difference exists in the neurofunctional recovery rate between the two groups in subgroup A ($P > 0.05$, WMD 10.75 [− 0.67, 22.18], heterogeneity: $\tau^2 = 119.59$, $\chi^2 = 17.11$, $df = 4$, $P < 0.01$, $I^2 = 77\%$). In contrary, the recovery rate of neurological function was visibly higher in the ACCF group compared with LAMP group in subgroup B ($P < 0.001$, WMD 24.40 [20.10, 28.70], heterogeneity: $\tau^2 = 5.13$, $\chi^2 = 5.99$, $df = 5$, $P > 0.05$, $I^2 = 17\%$; Fig. 4). The information above revealed that the recovery rate of neurological function was similar in the two groups

Table 1 Quality evaluation according to GRADE

Author	Published year	Risk of bias	Indirectness	Imprecision	Publication bias	Large effect	Plausible residual confounding	Total	Quality of evidence
Byeongwoo Kim [12]	2015	− 1	0	N/A	− 1	0	0	− 2	Very low
Haichun Liu [13]	2013	− 1	0	N/A	− 1	0	0	− 2	Very low
Kenichiro Sakai[a] [8]	2012	− 1	0	N/A	− 1	0	0	− 1	Very low
Motoki Iwasaki [4]	2007	− 1	0	N/A	− 1	0	0	− 2	Very low
Sang-ho Lee [14]	2008	− 1	0	N/A	− 1	0	0	− 2	Very low
TakahitoFujimori [15]	2013	− 1	0	N/A	− 1	0	0	− 2	Very low
Toshikazu Tani [16]	2002	− 1	0	N/A	− 1	0	0	− 2	Very low
Yu Chen [17]	2011	− 1	0	N/A	− 1	0	0	− 2	Very low
Yu Chen [18]	2012	− 1	0	N/A	− 1	0	0	− 2	Very low
Yutaka Masaki [19]	2007	− 1	0	N/A	− 1	0	0	− 2	Very low

[a]Prospective cohort study + 1. The rest are retrospective studies

Table 2 Baseline characteristics of included studies A:the ACCF group, L:the LAMP group

Study ID	Study design	Study location	Surgical approach	Sample size			Mean age (years, range)	Gender M/F)	Surgical segments	Follow-up time (months, range)
				Total	Subgroup A	Subgroup B				
Byeongwoo Kim [12]	Retrospective	South Korea	A:ACCF	A:71	44	27	A:57.3 (35–76)	A:51/20	A:NA	A:48 (12–68)
			L:LAMP	L:64	35	29	L:56.4 (35-76)	L:49/15	L:NA	L:41 (24-64)
Haichun Liu [13]	Retrospective	China	A:ACCF	A:68	58	10	A:54.4 ± 12.8	A:36/32	A:NA	A:≥ 60
			L:LAMP	L:59	37	22	L:57.9 ± 9.5	L:25/34	L:NA	L:≥ 60
Kenichiro Sakai [8]	Prospective	Japan	A:ACCF	A:20	NA	NA	A:59.5 ± 9.3	A:NA	A:3.1 (1-5)	A:≥ 60
			L:LAMP	L:22	NA	NA	L:58.4 ± 9.6	L:NA	L:4.5 (4–5)	L:≥ 60
Motoki Iwasaki [4]	Retrospective	Japan	A:ACCF	A:27	17	10	A:58 (41-74)	A:15/12	A:3 (2-5)	A:72 (24-120)
			L:LAMP	L:66	60	6	L:57 (41–75)	L:51/15	L:≥ 2	L:122.4 (60-240)
SANG-HO LEE [14]	Retrospective	South Korea	A:ACCF	A:20	NA	NA	A:56.8 (42-72)	A:15/5	A:≥ 3	A:21.8 (6-61)
			L:LAMP	L:27	NA	NA	L:54.7 (30–70)	L:26/1	L: ≥ 3	L:29.1 (11-64)
Takahito Fujimori [15]	Retrospective	Japan	A:ACCF	A:12	NA	NA	A:55.6 ± 7.8	A:7/5	A:3.3 ± 0.9	A:118.8 ± 49.2
			L:LAMP	L:15	NA	NA	L:58.7 ± 9.1	L:13/2	L:5.4 ± 1.2	L:122.4 ± 68.4
Toshikazu Tani [16]	Retrospective	Japan	A:ACCF	A:14	6	8	A:62 ± 11	A:11/3	A:3.5 ± 1	A:49 ± 34
			L:LAMP	L:12	3	9	L:66 ± 6	L:9/3	L:4 ± 1.2	L:50 ± 43
Yu Chen 2011 [17]	Retrospective	China	A:ACCF	A:22	NA	NA	A:57.2 (43-71)	A:14/8	A:3.23	A: ≥ 48
			L:LAMP	L:25	NA	NA	L:54.2 (32–66)	L:16/9	L:≥ 3	L: ≥ 48
Yu Chen 2012 [18]	Retrospective	China	A:ACCF	A:91	52	39	A:48.7 ± 1.4	A:63/28	A:2.7 ± 0.2	A:≥ 48
			L:LAMP	L:41	31	10	L:46.3 ± 2.5	L:33/8	L:4.1 ± 0.2	L:≥ 48
Yutaka Masaki 2007 [19]	Retrospective	Japan	A:ACCF	A:19	NA	NA	A:51.8 ± 6.6	A:14/5	A:2.9 ± 0.9	A:≥ 12
			L:LAMP	L:40	NA	NA	L:62.6 ± 10.3	L:30/10	L:4.6 ± 0.5	L:≥ 12

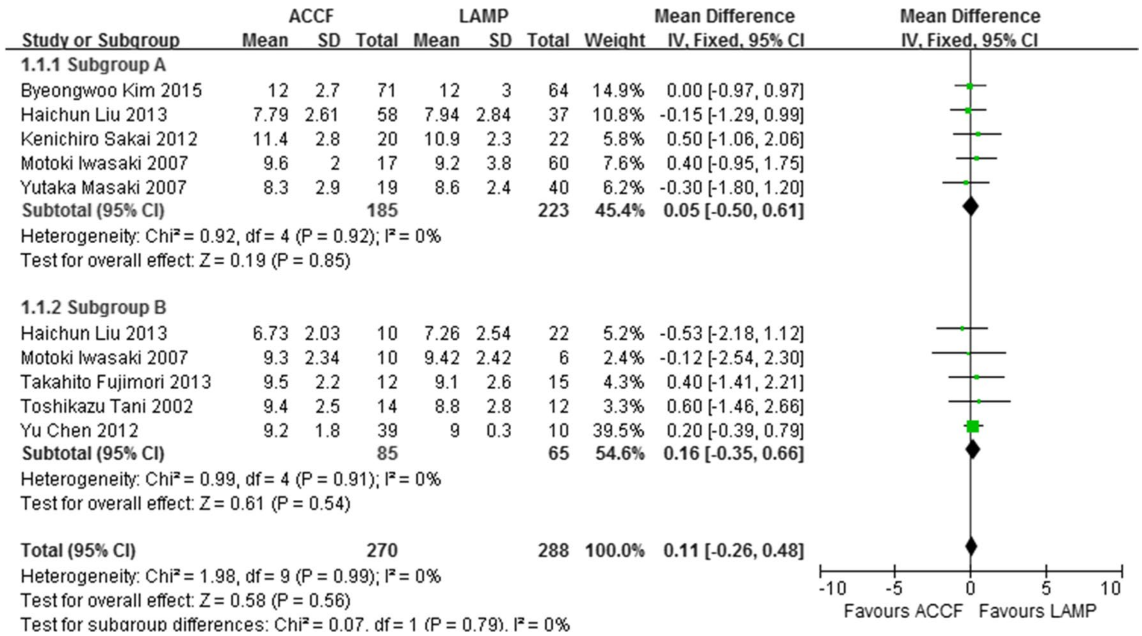


Fig. 2 Weighted mean difference of preoperative JOA score between the ACCF group and the LAMP group. *SD* standard deviation, *CI* confidence interval, *IV* inverse variance

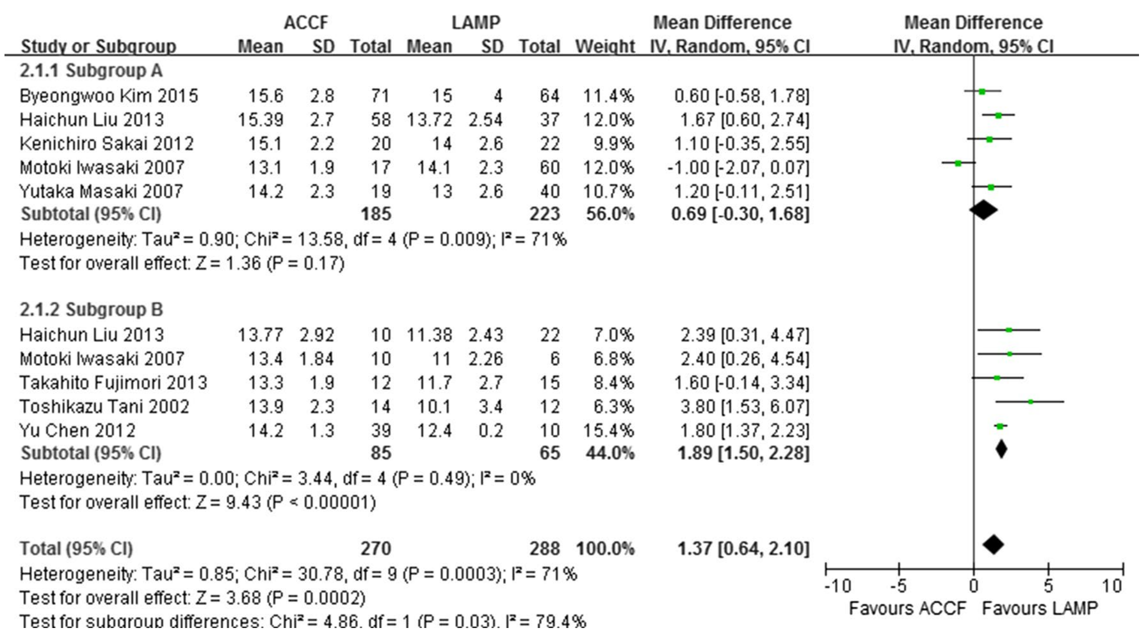


Fig. 3 Weighted mean difference of postoperative JOA score between the ACCF group and the LAMP group. *SD* standard deviation, *CI* confidence interval, *IV* inverse variance

when the mean preoperative canal occupying ratio < 60%. But the neurofunctional recovery rate in the ACCF group was much better than that in the LAMP group when the mean preoperative canal occupying ratio ≥ 60%.

Complications

Seven studies with a total of 407 patients (247 in the ACCF group and 160 in the LAMP group) were analyzed. The incidence of surgical complication was obviously higher in the

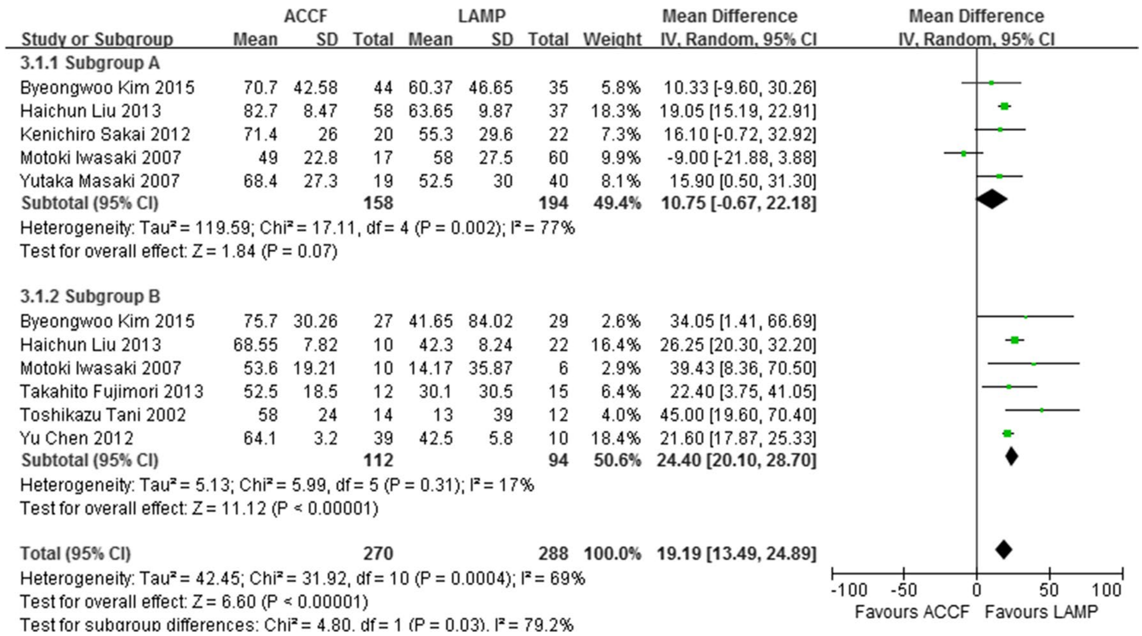


Fig. 4 Weighted mean difference of the neurofunctional recovery rate between the ACCF group and the LAMP group. *SD* standard deviation, *CI* confidence interval, *IV* inverse variance, *CI* confidence interval, *M–H* Mantel–Haenszel

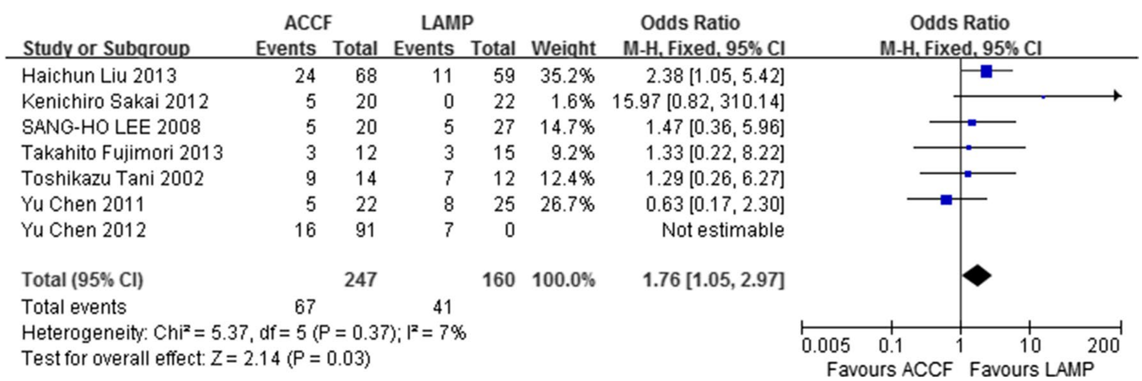


Fig. 5 Odds ratio of postoperative complication rates between the ACCF group and the LAMP group

ACCF group compared with LAMP group ($P < 0.05$, WMD 1.76 [1.05, 2.97], heterogeneity: $\chi^2 = 5.37$, $df = 5$, $P > 0.05$, $I^2 = 7\%$; Fig. 5). Moreover, the primary complications in the ACCF group were the CSF leakage (8.10%) and dysphagia/dysphonia (5.67%), while the LAMP group was associated with higher rates of C5 palsy (5.63%) and axial neck pain (12.5%) (Table 3).

Table 3 Number and percentage of complication and late neurofunctional deterioration between the two groups

Complication	ACCF ($N = 247$)	LAMP ($N = 160$)
CSF leakage	20 (8.10%)	4 (2.50%)
Dysphagia/dysphonia	14 (5.67%)	–
Implant dislocation	4 (1.62%)	–
Hematoma	2 (0.81%)	2 (1.25%)
Pseudarthrosis	1 (0.40%)	–
C5 palsy	2 (0.81%)	9 (5.63%)
Axial neck pain	–	20 (12.5%)
Central neurological dysfunction	6 (2.43%)	–
	ACCF ($N = 102$)	LAMP ($N = 99$)
Late neurological deterioration	2 (1.96%)	11 (11.11%)

Reoperation

Six studies ($n = 282$ patients; 115 in the ACCF group and 167 in the LAMP group) contained reoperation rate were analyzed. The ACCF group showed visibly higher reoperation rate compared with LAMP group ($P < 0.05$, WMD 4.63

[1.86, 11.52], heterogeneity: $\chi^2 = 6.22$, $df = 5$, $P > 0.05$, $I^2 = 20\%$; Fig. 6).

Preoperative and postoperative C2–C7 Cobb angle

Three studies (n = 116 patients; 52 in the ACCF group and 64 in the LAMP group) provided the preoperative and postoperative cervical C2–C7 Cobb angle. The pre-operative cervical C2–C7 Cobb angle was significantly lower in the ACCF group compared with LAMP group ($P < 0.05$, WMD − 5.77 [− 9.70, − 1.84], heterogeneity: $\chi^2 = 2.29$, $df = 2$, $P > 0.05$, $I^2 = 13\%$; Fig. 7). But no statistically significant difference was detected in the postoperative cervical C2–C7 Cobb angle between the ACCF and LAMP groups ($P > 0.05$, WMD 2.06 [− 6.20, 10.33], heterogeneity: $\tau^2 = 42.69$, $\chi^2 = 10.25$, $df = 2$, $P < 0.01$, $I^2 = 80\%$; Fig. 8). In addition, we performed further analysis to seek the change of cervical C2–C7 Cobb angle between postoperation and preoperation in the ACCF group and LAMP group, respectively. In the ACCF group, no statistically significant difference was observed in the preoperative cervical C2–C7 Cobb angle compared with the postoperative cervical C2–C7 Cobb angle ($P > 0.05$, WMD 3.10 [− 0.65,6.85], heterogeneity: $\chi^2 = 0.53$, $df = 2$, $P > 0.05$, $I^2 = 0\%$; Fig. 9). But in the LAMP group, the postoperative cervical C2–C7 Cobb angle was significantly lower than the preoperative cervical C2–C7 Cobb angle ($P < 0.05$, WMD − 4.07 [− 7.81, − 0.33], heterogeneity: $\chi^2 = 1.53$, $df = 2$, $P > 0.05$, $I^2 = 0\%$; Fig. 10).

Operation time and intraoperative blood loss

Operation time and intraoperative blood loss were used for evaluating the surgical trauma. Four studies (n = 289 patients; 127 in the ACCF group and 162 in the LAMP

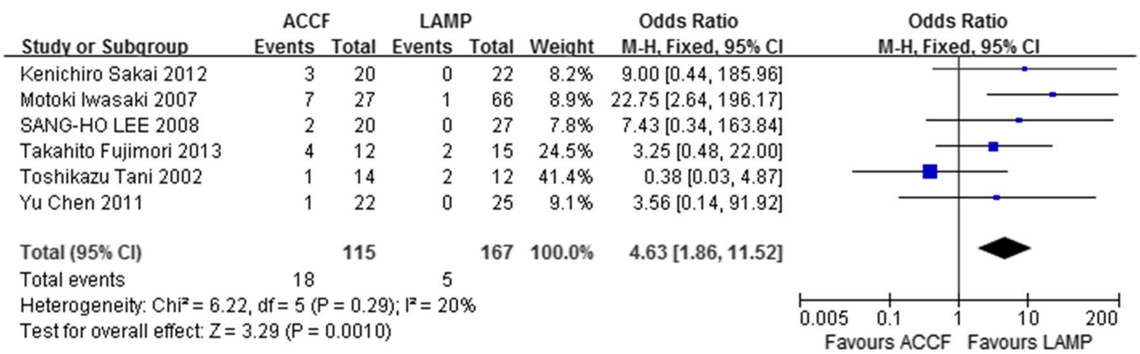


Fig. 6 Odds ratio of reoperation rates between the ACCF group and the LAMP group. *CI* confidence interval, *M–H* Mantel–Haenszel

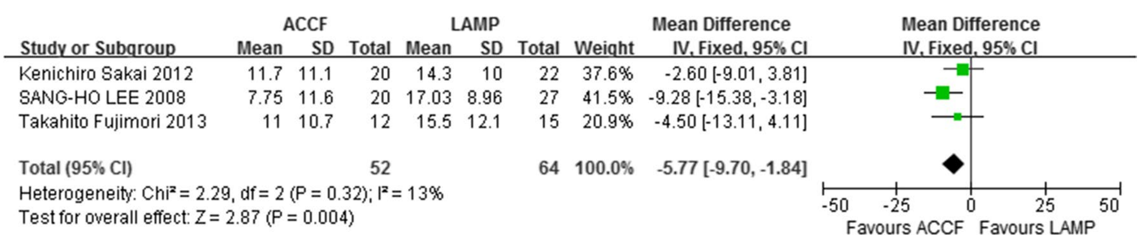


Fig. 7 Weighted mean difference of preoperative cervical C2–C7 Cobb angle between the ACCF group and the LAMP group. *SD* standard deviation, *CI* confidence interval, *IV* inverse variance

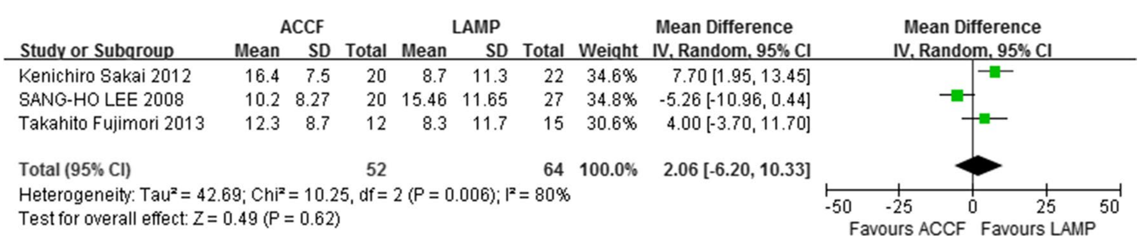
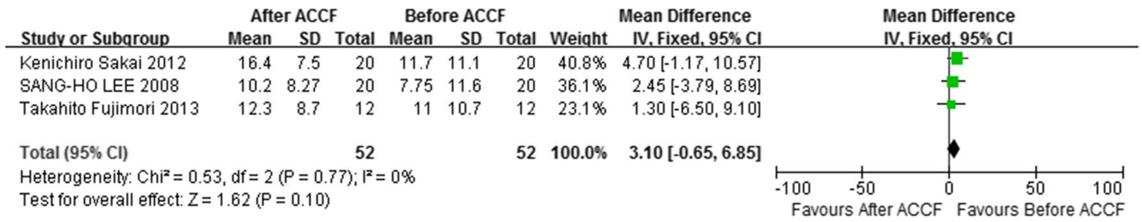


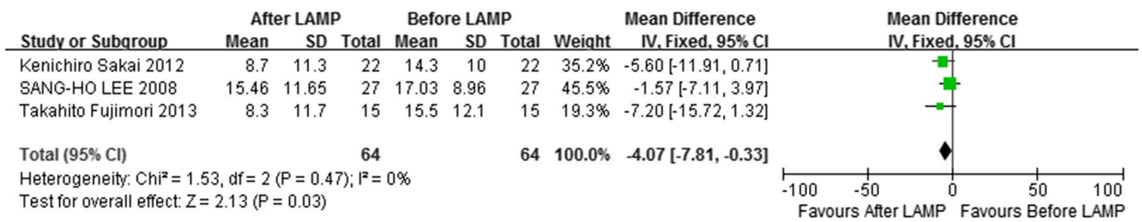
Fig. 8 Weighted mean difference of postoperative cervical C2–C7 Cobb angle between the ACCF group and the LAMP group. *SD* standard deviation, *CI* confidence interval, *IV* inverse variance



Study or Subgroup	After ACCF Mean	SD	Total	Before ACCF Mean	SD	Total	Weight	Mean Difference IV, Fixed, 95% CI
Kenichiro Sakai 2012	16.4	7.5	20	11.7	11.1	20	40.8%	4.70 [-1.17, 10.57]
SANG-HO LEE 2008	10.2	8.27	20	7.75	11.6	20	36.1%	2.45 [-3.79, 8.69]
Takahito Fujimori 2013	12.3	8.7	12	11	10.7	12	23.1%	1.30 [-6.50, 9.10]
Total (95% CI)			**52**			**52**	**100.0%**	**3.10 [-0.65, 6.85]**

Heterogeneity: Chi² = 0.53, df = 2 (P = 0.77); I² = 0%
Test for overall effect: Z = 1.62 (P = 0.10)

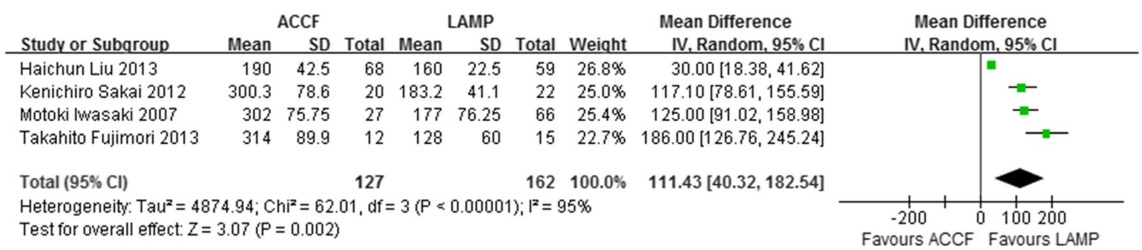
Fig. 9 Weighted mean difference of cerviacl C2–C7 Cobb angle between postoperation and preoperation in the ACCF group. *SD* standard deviation, *CI* confidence interval, *IV* inverse variance



Study or Subgroup	After LAMP Mean	SD	Total	Before LAMP Mean	SD	Total	Weight	Mean Difference IV, Fixed, 95% CI
Kenichiro Sakai 2012	8.7	11.3	22	14.3	10	22	35.2%	-5.60 [-11.91, 0.71]
SANG-HO LEE 2008	15.46	11.65	27	17.03	8.96	27	45.5%	-1.57 [-7.11, 3.97]
Takahito Fujimori 2013	8.3	11.7	15	15.5	12.1	15	19.3%	-7.20 [-15.72, 1.32]
Total (95% CI)			**64**			**64**	**100.0%**	**-4.07 [-7.81, -0.33]**

Heterogeneity: Chi² = 1.53, df = 2 (P = 0.47); I² = 0%
Test for overall effect: Z = 2.13 (P = 0.03)

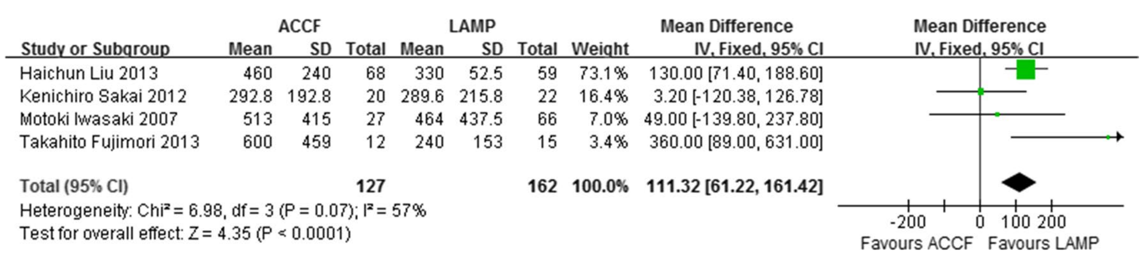
Fig. 10 Weighted mean difference of cervical C2–C7 Cobb angle between postoperation and preoperation in the LAMP group. *SD* standard deviation, *CI* confidence interval, *IV* inverse variance



Study or Subgroup	ACCF Mean	SD	Total	LAMP Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Haichun Liu 2013	190	42.5	68	160	22.5	59	26.8%	30.00 [18.38, 41.62]
Kenichiro Sakai 2012	300.3	78.6	20	183.2	41.1	22	25.0%	117.10 [78.61, 155.59]
Motoki Iwasaki 2007	302	75.75	27	177	76.25	66	25.4%	125.00 [91.02, 158.98]
Takahito Fujimori 2013	314	89.9	12	128	60	15	22.7%	186.00 [126.76, 245.24]
Total (95% CI)			**127**			**162**	**100.0%**	**111.43 [40.32, 182.54]**

Heterogeneity: Tau² = 4874.94; Chi² = 62.01, df = 3 (P < 0.00001); I² = 95%
Test for overall effect: Z = 3.07 (P = 0.002)

Fig. 11 Weighted mean difference of operation time between the ACCF group and the LAMP group. *SD* standard deviation, *CI* confidence interval, *IV* inverse variance



Study or Subgroup	ACCF Mean	SD	Total	LAMP Mean	SD	Total	Weight	Mean Difference IV, Fixed, 95% CI
Haichun Liu 2013	460	240	68	330	52.5	59	73.1%	130.00 [71.40, 188.60]
Kenichiro Sakai 2012	292.8	192.8	20	289.6	215.8	22	16.4%	3.20 [-120.38, 126.78]
Motoki Iwasaki 2007	513	415	27	464	437.5	66	7.0%	49.00 [-139.80, 237.80]
Takahito Fujimori 2013	600	459	12	240	153	15	3.4%	360.00 [89.00, 631.00]
Total (95% CI)			**127**			**162**	**100.0%**	**111.32 [61.22, 161.42]**

Heterogeneity: Chi² = 6.98, df = 3 (P = 0.07); I² = 57%
Test for overall effect: Z = 4.35 (P < 0.0001)

Fig. 12 Weighted mean difference of intraoperative blood loss between the ACCF group and the LAMP group. *SD* standard deviation, *CI* confidence interval, *IV* inverse variance

group) provided date about operation time and blood loss. Significantly, the ACCF group showed much more operation time compared with the LAMP group ($P < 0.01$, WMD 111.43 [40.32,182.54], heterogeneity: $\tau^2 = 4874.94$, $\chi^2 = 62.01$, $df = 3$, $P < 0.01$, $I^2 = 95\%$; Fig. 11). Similarly, intraoperative blood loss was much more in the ACCF group compared with LAMP group ($P < 0.01$, WMD 111.32

[61.22, 161.42], heterogeneity: $\chi^2 = 6.98$, $df = 3$, $P > 0.05$, $I^2 = 57\%$; Fig. 12).

Discussion

ACCF and LAMP are both classical surgical procedures, which are frequently used for treating patients with cervical myelopathy due to OPLL. But up till today, which approach has better clinical results remains controversial. A few of meta-analysis papers [21, 22] had been completed to compare the clinical outcomes between anterior and posterior approach for the treatment of cervical OPLL. Unfortunately, these papers mentioned had one or more of the following defects: the results of them were not convincible; the studies included were incomplete; comparison was not between ACCF and LAMP; no subgroup analysis was performed.

Therefore, we performed this meta-analysis to systematically compare clinical effectiveness between ACCF and LAMP for patients with oppressive myelopathy due to cervical OPLL. Our meta-analysis included ten cohort studies with sufficient methodological quality from January 1990 to July 2017. Subgroup analysis was performed according to the mean preoperative canal occupying ratio, with the purpose of reducing plausible confounding effects. Results showed that the preoperative JOA score was similar between the ACCF group and LAMP group. Also, no obvious difference was observed in the postoperative JOA score and recovery rate of neurological function between the two groups when the mean preoperative canal occupying ratio < 60%. However, when the preoperative canal occupying ratio ≥ 60%, ACCF was associated with much better postoperative JOA score and the recovery rate of neurological function compared with LAMP. But ACCF leads to more surgical trauma (such as operation time and blood loss) and more incidence of complication and reoperation. Besides, LAMP had gone a diminished postoperative cervical C2–C7 Cobb angle.

Hirabayashi et al. [23] reported the method of evaluating postoperative neurological recovery rate in the first instance. Several reports noted that the recovery rate of neurological function after ACCF was superior to that after LAMP [4, 17, 19]. Further more, some authors advocated that ADF achieved better neurofunctional recovery rate than LAMP for the treatment of cervical OPLL with preoperative canal occupying ratio > 50 or 60% [8, 12, 15, 18]. And that was identified in subgroup analysis of the recovery rate of neurological function between the two groups in our study with an extremely low heterogeneity in subgroup B ($\chi^2 = 5.99$, $df = 5$, $P = 0.31$, $I^2 = 17\%$). Although, it seems perfect that ACCF achieved good recovery rate by removing the ossified mass, you have to consider technical difficulties, insufficient decompression, surgical trauma and higher incidence of surgery-related complications and reoperation. Dural tear, CSF leakage, dysphagia/dysphonia, iatrogenic neurological deterioration, implant dislocation, and pseudoarthrosis were more frequently mentioned in ACCF group. M Mazur et al. [24] reported that the incidence of CSF leakage after anterior decompression for cervical OPLL ranged from 4.3 to 32%. Table 3 in our study showed that the primary complication in the ACCF group was the CSF leakage (8.10%). Sometimes, floating method was used to prevent dural tear and iatrogenic spinal cord injury when OPLL was attached to dural sac [25, 26]. And ‘‘Double-layer’’ signal on preoperative CT axial films provided a specific indicator which was firstly described by Hida [27].

Since 1970s, LAMP has been widely used as a surgical procedure in the treatment of multilevel cervical OPLL [28]. For patients with cervical OPLL which affected more than two or three levels, posterior approach was preferred because of efficacy as well as the technical ease and lower complication rate [29]. And a meta-analysis paper reported that when the number of surgical segments was equal to or more than 3, no significant difference was observed in the postoperative neural function or neurological recovery rate between anterior decompression and fusion (ADF) and laminoplasty in the treatment of cervical compressive myelopathy [30]. Although it seems safer and less trauma, if backward drift of the spinal cord is not enough, ventral compression may persist, resulting in an unsatisfactory neurofunctional recovery. Also, LAMP relies on adequate cervical lordosis. Yamazaki et al. [6] reported that preoperative cervical lordosis which is less than 10° and thickness of OPLL which is more than 7 mm were double risk factors for spinal cord clinging to ossified mass. Fujiyoshi et al. [31] found an interesting indicator, the K-line, which could achieve comprehensive evaluation of cervical alignment and preoperative canal occupying ratio of OPLL.

Axial pain and C5 palsy were common complications after LAMP, and the pathogenic mechanism of them was unknown. Kawaguchi Y et al. [32] reported that the incidence of cervical axial pain after LAMP can decrease by shortening the duration of external fixation and premature functional exercise. Table 3 in our study indicated the higher rates of C5 palsy (5.63%) and axial neck pain (12.5%) in the LAMP group. Only four studies which contained a total of 201 patients (102 in the ACCF group and 99 in the LAMP group) mentioned late neurofunctional deterioration, which was also significantly higher in the LAMP group (11.11%).

Cervical kyphotic change after LAMP in the patients with cervical OPLL has also been observed. Sakai et al. [8] reported that it existed in 50% of the patients who undergone LAMP at 5-year follow-up. Our meta-analysis showed that in the LAMP group, the postoperative cervical C2–C7 Cobb angle was significantly smaller than the preoperative C2–C7 Cobb angle ($P < 0.05$, WMD − 4.07

[− 7.81, − 0.33], heterogeneity: $\chi^2 = 1.53$, $df = 2$, $P > 0.05$, $I^2 = 0\%$). Besides, Ogawa et al. [7] reported that enlarged postoperative C2–C7 ROM after LAMP was associated with late neurofunctional deterioration in patients with segmental pattern of OPLL. Masaki et al. [19] suggested that segmental motion at the peak of OPLL was also a risk factor of poor surgical outcome after laminoplasty. Moreover, biomechanical analysis of cervical OPLL suggested that stress distribution raised along with postoperative progression of kyphosis, which might cause the late neurofunctional deterioration [33]. When selecting LAMP for cervical OPLL, not only do we consider the canal occupying ratio, but also synthetically evaluate the preoperative cervical alignment and segmental motion at the cord compression level. Thus, laminoplasty should be avoided as a preferred method of treatment for patients with preoperative kyphosis or instability [30]. Some authors reported that posterior instrumented fusion had advantages in restoring cervical alignment and preventing kyphotic deformity; also patients with cervical OPLL in posterior instrumented fusion group had significantly better recovery rate of neurological function than the LAMP group [34]. Liu et al. [35] reported that posterior instrumented fusion was superior in neurological recovery rate compared with LAMP especially in K (−) groups.

In addition, progression of cervical OPLL has also been found in both ACCF and LAMP. For example, Sakai et al. [8] reported that progression of cervical OPLL after surgery at five-year follow-up was found in 5.0% of the ACCF group and 50.0% of the LAMP group, respectively. Sakaura et al. [36] advocated that progression of cervical OPLL after LAMP was detected in 63.6% of the patients with OPLL over 5-year follow-up. Tanno et al. [37] provided evidence that mechanical stress played an important role in the progression of OPLL. Keiichi Katsumi et al. [38] suggested that additional posterior instrumented fusion following laminoplasty suppresses the progression of OPLL, which supported the hypotheses that dynamic factors stimulate the progression of OPLL [39].

Consequently, the postoperative instability, progress of OPLL and kyphosis change of the cervical spine were three principal reasons for late neurological deterioration after LAMP.

Given the advantages and disadvantages of both approaches, we have to weigh comprehensively between the clinical benefits and risks when making surgical strategies.

Our meta-analysis has certain limitations. First, all studies included were non-randomized controlled studies, and the quality of them was relatively low according to the GRADE scale. Second, the ten studies included were all published in English, which might exist as a potential publication bias. Third, as too few studies were included, some outcome measures could not be performed by subgroup analysis. Fourth, clinical heterogeneity existed due to the different surgical indications as well as the varied surgical technologies used by surgeons in various treatment centers. Moreover, duration of follow-up varied among the studies included in our meta-analysis, and that might exert an effect on our results. Finally, all the studies included paid attention to the assessment of neurofunctional improvement, but ignored the evaluation of the patient's overall quality of life.

Conclusion

Based on this meta-analysis, when the preoperative canal occupying ratio ≥ 60%, ACCF was associated with better postoperative JOA score and neurofunctional recovery rate compared with LAMP. Thus, we recommend ACCF for the treatment of oppressive myelopathy due to cervical OPLL when the preoperative canal occupying ratio ≥ 60%, although it led to more surgical trauma and more incidence of complication and reoperation. In contrast, when the preoperative canal occupying ratio < 60%, no significantly statistical difference was observed in the postoperative JOA score and neurofunctional recovery rate between ACCF and LAMP. Therefore, considering both the effectiveness and security, we choose LAMP as a preferred method for the treatment of cervical OPLL when the preoperative canal occupying ratio < 60%. Finally, considering the limitations of our meta-analysis, a well-designed, prospective, randomized controlled study with large sample ought to be needed to acquire a more convincing conclusion.

Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest.

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