Systematic Review and Meta-Analysis

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Comparison of the surgeries for the ossification of the posterior longitudinal ligament-related cervical spondylosis

A PRISMA-compliant network meta-analysis and literature review

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Abstract

Objective: We designed and performed a network meta-analysis to compare the clinical outcomes among the 5 surgeries—anterior cervical corpectomy and fusion (ACCF), anterior controllable antedisplacement fusion (ACAF), laminoplasty (LP), laminectomy (LC), and posterior decompression with instrumented fusion (PDF)—for patients with cervical spondylosis related to the ossification of the posterior longitudinal ligament (OPLL).

Methods: Databases, including PubMed, EMBASE, Cochrane Library, Google Scholar, and Web of Science (firstly available-2019) were selected for literature search. We performed a network meta-analysis with the included studies. A Newcastle-Ottawa scale was employed to assess the study quality of the included studies.

Results: Total 23 studies with 1516 patients were included in our analysis. We found that ACCF achieved the most improvement in the Japanese Orthopaedic Association Scores and excellent and good recovery rate, ACAF achieved the best improvement of the improvement rate and lordosis. LP got the best operative time and blood loss.

Conclusions: Our results suggested that both anterior (ACCF and ACAF) and posterior (LP, LC, and PDF) procedures have their strengths and weaknesses. Clinicians need to select the most appropriate surgery with a comprehensive consideration of the clinical condition of each patient with OPLL-related cervical spondylosis.

Abbreviations: ACAF = anterior controllable antedisplacement and fusion, ACCF = anterior cervical corpectomy and fusion, CI = confidence intervals, IR = improvement rate, JOA = Japanese orthopaedic association, LC = laminectomy, LP = laminoplasty, MCMC = Markov Chains Monte Carlo, NOS = Newcastle-Ottawa scale, OPLL = ossification of the posterior longitudinal ligament, OR = odds ratio, PDF = posterior decompression and fusion, PRISMA = Preferred Reporting Items for Systematic Reviews and Meta-Analyses, RCTs = randomized controlled trails, SMD = standardized mean difference, SUCRA = surface under the cumulative ranking.

Keywords: anterior cervical corpectomy and fusion, anterior controllable antedisplacement fusion, cervical spondylosis, laminoplasty, ossification of posterior longitudinal ligament

Editor: Jin-Sung Kim.

SL and JP contributed equally to this work.

This study was supported by grants from Fujian Natural Science Foundation (2016J01560), grants from the Youth Program of the Health Commission of Fujian Province (2016-ZQN-73), grants from the Japan Society for the Promotion of Science (Grant-in-Aid for Young Scientists, Type B, No. 20791025 and Grant-in-Aid for Scientific Research C, General, No. 24592157,15k10358 and 18K08991).

The authors report no conflicts of interest.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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How to cite this article: Li S, Peng J, Xu R, Zheng R, Huang M, Xu Y, He Y, Chai Y, Song H, Asakawa T. Comparison of the surgeries for the ossification of the posterior longitudinal ligament-related cervical spondylosis: A PRISMA-compliant network meta-analysis and literature review. Medicine 2021;100:9(e24900).

Received: 5 June 2020 / Received in final form: 29 September 2020 / Accepted: 1 February 2021

http://dx.doi.org/10.1097/MD.0000000000024900

1. Introduction

Ossification of the posterior longitudinal ligament (OPLL) is an important inducement of cervical myelopathy. The OPLL-related cervical spondylosis that is associated with severe neurological disorders is common in East Asia.[1–4] However, the optimal treatment approach remains controversial. Although conservative treatments may transiently alleviate symptoms, it cannot fundamentally relieve spinal cord oppression.[4] The Long-term efficacy of such conservative treatments is unsatisfactory, and neurological symptoms commonly developed with the progression of cervical spondylosis.[1] Thus, surgical decompression processes are usually used for OPLL-related cervical spondylosis. Cervical spine decompression surgeries can be classified as follows: anterior approaches, posterior approaches, and mixed approaches (including anterior and posterior). Anterior approaches include anterior cervical corpectomy and fusion (ACCF) and anterior controllable antedisplacement fusion (ACAF). Posterior approaches include laminoplasty (LP), laminectomy (LC), and posterior decompression with instrumented fusion (PDF). At present, these 5 procedures are being widely used and reported, particularly ACCF and LP. Each procedure has its strength and weakness. It is worthwhile to compare the efficacy and safety of these procedures. However, the available studies on this topic have the following limitations: some studies have compared only two procedures[5–7]; other studies[8,9] have simply clarified and compared the surgeries as "anterior and posterior approaches," However, the subtypes of each approach vary too widely to be analyzed as "one approach". For example, in the posterior approaches, PDF is remarkably different from those in LP and LC. Lack of consideration of these differences thereby considering the treatments of PDF, LP, and LC as one "posterior approach" can thus cause substantial bias. To our knowledge, no previous study has compared all the anterior and posterior procedures; thus, we designed this study to conduct this comparison that would provide interesting and insightful results. A network meta-analysis can be employed to compare several treatments in one study. Here, we designed a network meta-analysis to evaluate the efficacy and safety of these 5 surgical procedures seriously as per the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).[10] We attempted to explore the relative strengths and weaknesses of these 5 procedures that might enable clinicians to select an appropriate surgical procedure to treat OPLL-related cervical spondylosis.

2. Materials and methods

2.1. Literature searching strategy

We searched multiple electronic databases, including PubMed, EMBASE, Cochrane Library, Google Scholar, and Web of Science (from firstly available to Dec 2019). We used the keywords "Ossification of posterior longitudinal ligament" AND "cervical spondylosis" AND "anterior cervical corpectomy and fusion" OR "anterior controllable antedisplacement fusion" OR "laminoplasty" OR "laminectomy" OR "posterior decompression with instrumented fusion". Only articles in English were included.

The inclusion criteria were as follows: randomized controlled trails (RCTs) or cohort studies; patient diagnosis "cervical spondylosis" associated with OPLL; interventions including ACCF, ACAF, LP, LC, or PDF; report of at least one of the following outcome assessments: Japanese orthopaedic association (JOA) scores, improvement rate (IR = [Postoperative JOA Scores − Preoperative JOA Scores] / [17 − Preoperative JOA Scores] × 100%), excellent and good recovery rate (Surgical outcome was defined by the IR as follows: excellent [IR $\geq$ 75%], good [75% $>$ IR $\geq$ 50%], fair [50% $>$ IR $\geq$ 25%], and poor [IR $<$ 25%]), lordosis, operative time, blood loss and complications; publications with complete data. The exclusion criteria were as follows: review paper, meta-analysis, case report and serials case report, letters, and non-English studies.

2.2. Ethics

This study is a network meta-analysis designed as per the PRISMA guideline. All data included in this study were extracted from published reports. No patient recruitment and animal experiments were involved in the present study. In addition, we did not collect any personal information and biological materials. Hence ethical approval is not required for this study.

2.3. Data extraction

Two independent researchers (SL, JP) were engaged in the literature search who screened the literature as per the inclusion/exclusion criteria by reading the title and abstract, removing the excluded study types, and reading the full text to exclude studies that did not meet the inclusion criteria. This process was cross-checked and then checked by 2 senior researchers to confirm the quality and reliability of the included literature (TA, HS). After the identification of suitable studies, the data, including patient information, treatment, experimental design (sample size, randomization, information of control group, and flaws), and outcome assessment, were independently extracted by 3 other researchers (RX, RZ, MH). We analyzed the assessments used in the original text. A weeklong discussion was performed to resolve any disagreements. All the data were finally checked by three third-party authors (YX, YC, YH). Before the data were submitted for analysis, consensus was reached among all authors.

Data, including general information, surgery, and clinical outcome, were extracted and saved to an excel spreadsheet. The observed indices included the following: JOA, IR, excellent and good recovery rate, lordosis, operative time, blood loss, and complications. If data of the included articles could not be extracted, emails were sent to the corresponding author to obtain the original data.

2.4. Assessment of the study quality

The study quality of the involved studies was assessed by the two authors (SL, JP) using a Newcastle-Ottawa scale (NOS).[11] Three specific domains, including selection, comparability, and outcome, were evaluated. In case of a disagreement, the third investigator made the decision. Consistency of the results was evaluated using a node-splitting analysis. $P > .05$ means consistency of the results, whereas $P < .05$ means inconsistency of the results.[12]

2.5. Statistical analyses

First, pairwise meta-analysis was conducted for a direct comparison of the different treatments using a RevMan 5.3 software (The Nordic Cochrane Center, The Cochrane Collaboration, Copenhagen, Denmark). A DerSimonian-Laird random effects model was employed to evaluate the standardized mean difference (SMD), odds ratio (OR) and its 95% confidence intervals (CI). χ^2 test and I^2 squared test were used to assess the heterogeneity. Subsequently, a Bayesian random effects model network meta-analysis was performed using a GeMTC 0.14.3 software (http://www.drugis.org/software/addis1/gemtc). We used the Markov Chains Monte Carlo (MCMC) method to calculate the results. For each outcome, the consistency model was applied that was based on 100,000 simulation iterations for each of the four chains. The tuning iterations were set as 50,000, and the thinning interval was 10. The Bayesian approach and the surface under the cumulative ranking (SUCRA) were used to calculate the probabilities of treatment ranking. Conversely, node-splitting analysis was used to estimate the inconsistency in the network meta-analysis. The plots of network and SUCRA were generated by using a STATA 15 (StataCorp, College Station, TX) software.

3. Results

3.1. Searching Results

We included 1037 studies. First, 255 studies were excluded due to repetition. Second, 722 studies were excluded for the following reasons: 431 literatures were inconsistent with the aim of the present study; 117 were review articles and 174 lacked a control group and thus were excluded. Then, we read the full-text of the remaining 60 studies. Total 37 studies were excluded because they were not in agreement with the inclusion criteria. Finally, 23 studies[1–9,11,13–37] were included and submitted for analysis (Fig. 1). The characteristics of the included studies are listed in Table 1. Only 2 studies[29,37] were prospective in nature, whereas the other 21[14–16,18–26,28,30–37] were retrospective studies. The network meta-analysis involved 1516 patients, of which 591 underwent ACCF, 575 patients underwent LP, 249 patients underwent PDF, 50 patients underwent LC, and 51 patients underwent ACAF. The follow-up duration of the involved studies was ranged from 12 to 122.4 months (Table 1).

3.2. Assessment of the study quality

The study quality of the included studies, evaluated using the New Castle-Ottawa Quality Assessment Scale, is listed in Table 2. In the selection column, 2 studies achieved full score (4 points),[24,31] 2 studies scored 2 points,[20,35] and the other studies scored 3 points. In the comparability column, 7 studies[20,23–26,28,35] scored 2 points, and the other studies scored 1 point. In the outcome section, 15 studies[17,19–21,24–31,33,37] scored 3 points, and the other studies scored 2 points. The study quality involved in this study was satisfactory (Table 2). The results of node-splitting analysis showed that only 1 item, namely ACCF versus LC in the complication, exhibited inconsistency ($P=.04$), whereas the other results were consistent ($P>.05$) (Table 3). Hence the results in this study are consistent.

3.3. Clinical outcomes

3.3.1. JOA scores.

As shown in Figure 2A, total 18 articles[14–16,18,20,22–25,27,28,30,31,33–37] with 1126 patients reported JOA to assess the postoperative clinical outcome. Compared to the LP group, the ACCF group had significantly higher postoperative JOA scores. However, no significant differences were found among the other groups (Table 4). According to the ranking chart, patients undergoing ACCF were most likely to receive the highest score (the best efficacy), followed by those undergoing ACAF, PDF, LP, and LC (the lowest score indicated the weakest efficacy) (Fig. 3A).

3.3.2. IR.

Fifteen studies[14–16,18,20,22–25,27,30,31,33–36] with 952 patients reported the IR (Fig. 2B). We found that the IR of the

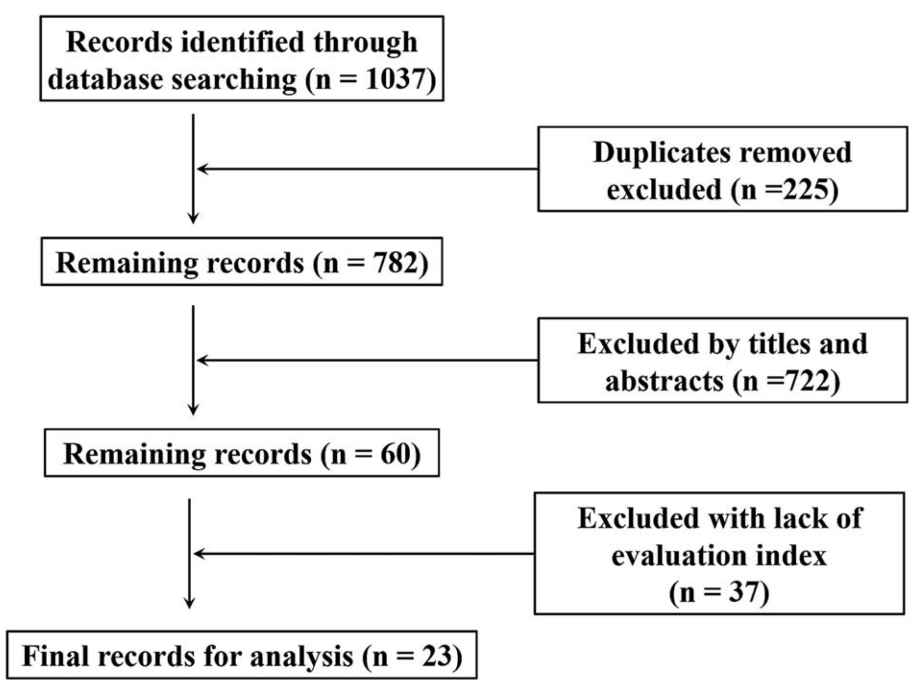

Figure 1. Flow chart of the strategy used for identifying and selecting suitable literature reports.

Table 1

Characteristics of the included studies.

Authors	Design	Interventions	Sample size	Average age (MD, SD)	Sex (M/F)	Follow-up, mo
Chen et al, 2011[22]	R	1 vs 2 vs 2	22 vs 25 vs 28	57.2 vs 54.2 vs 55.3	14/8 vs 16/9 vs 19/9	>48
Chen et al 2012[23]	R	1 vs 2 vs 2	91 vs 41 vs 32	48.7 vs 46.3 vs 52.6	63/28 vs 33/8 vs 19/13	>48
Fujimori et al, 2014[27]	R	1 vs 2	12 vs 15	55.6 vs 58.7	7/5 vs 12/3	>24
Hou et al, 2018[37]	R	2 vs 5	22 vs 17	46.1 vs 44.5	14/8 vs 11/6	15.27 vs 16.01
Iwasaki et al, 2007[14,15]	R	1 vs 2	27 vs 66	58 vs 57	15/12 vs 51/15	72 vs 122.4
Katsumi et al 2016[30]	R	2 vs 2	22 vs 19	59 vs 61	14/8 vs 14/5	52±19 vs 51±21
Kim et al, 2015[28]	R	1 vs 2	71 vs 64	57.3 vs 56.4	51/20 vs 49/15	48 vs 41
Koda et al, 2016[31]	R	1 vs 2 vs 2	15 vs 16 vs 17	57.7 vs 60.3 vs 65.0	10/5 vs 12/4 vs 14/3	58.6 vs 46.0 vs 42.0
Lee et al, 2008[21]	R	1 vs 2	20 vs 27	56.8 vs 54.7	15/5 vs 26/1	21.8 vs 29.1
Lee et al, 2016[32]	R	2 vs 2 vs 4	21 vs 21 vs 15	54.2 vs 63.7 vs 61.3	15/6 vs 19/2 vs 13/2	>24
Lin et al, 2012[24]	R	1 vs 2	26 vs 30	54.7 vs 56.2	15/11 vs 17/13	36.3±6.4 vs 37.6±6.7
Liu et al, 2013[26]	R	1 vs 2	68 vs 59	54.4 vs 57.9	36/32 vs 25/34	81.6
Liu et al, 2017[35]	R	2 vs 2	32 vs 35	59 vs 60	26/6 vs 25/10	38±13 vs 42±9
Masaki et al, 2007[20]	R	1 vs 2	19 vs 40	51.8 vs 62.6	14/5 vs 30/10	≥ 12
Mizuno and Nakagawa, 2006[19]	R	1 vs 2	111 vs 10	N/A	N/A	≥ 24
Ota et al, 2016[33]	R	2 vs 2	23 vs 27	59.8 vs 63.7	20/3 vs 23/4	47.2±29.3 vs 45.4±32.6
Sakai et al, 2012[25]	P	1 vs 2	20 vs 22	59.5 vs 58.4	3.67	50
Tani et al, 2002[18]	R	1 vs 2	14 vs 12	62 vs 66	11/3 vs 9/3	49±34 vs 50±43
Yang et al, 2018[17]	R	1 vs 5	36 vs 34	58.4 vs 58.6	19/17 vs 21/13	12.4±4.7 vs 10.1±2.8
Yoo et al, 2017[36]	R	2 vs 4	38 vs 35	60.93 vs 64.57	30/8 vs 25/10	35.17±15.91 vs 40.93±22.94
Yoshii et al, 2016[34]	R	1 vs 2	39 vs 22	61.1 vs 60.6	31/8 vs 18/4	44.5±18.8 vs 37.2±16.3
Yuan et al, 2015[29]	P	2 vs 2	20 vs 18	59 vs 62	14/6 vs 11/7	12

ACAF = anterior controllable antedisplacement and fusion, ACCF = anteriorcervical corpectomy and fusion, LC = laminectomy, LP = laminoplasty, P = Prospective, PDF = posterior decompression, R = Retrospective.

ACCF group was significantly higher than that of the LP group, whereas that of the other groups did not differ significantly (Table 4). According to the ranking chart, ACAF showed the highest IR followed by ACCF, PDF, LP, and LC (the lowest probability of improvement) (Fig. 3B).

3.3.3. Excellent and good recovery rate. Eight studies[14,15,18–20,22,24,27,28] with 592 patients reported excellent and good recovery rate (Fig. 2C). This rate was significantly higher in the ACCF group than the LP group. We did not find any difference in this rate among the other treatments (Table 4). According to the ranking chart, ACCF tended to achieve the best excellent and good recovery rate followed by ACCF, PDF, and LP (Fig. 3C).

Table 2

Assessment of the study quality.

Authors	Selection	Comparability	Outcome	Total
Chen et al, 2011[22]	3	1	2	6
Chen et al, 2012[23]	3	2	2	7
Fujimori et al 2014[27]	2	1	3	6
Hou et al, 2018[37]	3	1	3	7
Iwasaki et al, 2007[14,15]	3	1	2	6
Katsumi et al, 2016[30]	2	1	3	6
Kim et al, 2015[28]	3	2	3	8
Koda et al, 2016[31]	3	1	3	7
Lee et al, 2008[21]	3	1	3	7
Lee et al, 2016[32]	3	1	2	6
Lin et al, 2012[24]	3	2	3	8
Liu et al, 2013[26]	3	2	3	8
Liu et al, 2017[35]	3	2	2	8
Masaki et al, 2007[20]	3	2	3	8
Mizuno and Nakagawa, 2006[19]	4	1	3	8
Ota et al, 2016[33]	3	1	3	7
Sakai et al, 2012[25]	4	2	3	9
Tani et al, 2002[18]	3	1	2	7
Yang et al, 2018[17]	3	1	3	7
Yoo et al, 2017[36]	3	1	3	7
Yoshii et al, 2016[34]	3	1	2	6
Yuan et al, 2015[29]	3	1	3	7

3.3.4. Lordosis. Eleven studies[21,22,25,27,30–32,34–37] with 577 patients employed curvature as the postoperative measurement for lordosis (Fig. 2D). The data in Table 4 show no significant difference among treatments. The postoperative cervical curvature ranking was as follows: ACAF, ACCF, PDF, LP, and LC (the worst) (Fig. 3D).

3.3.5. Operative time. Twelve studies[14–16,24–27,30,31,33–35,37] with 721 patients reported the operative time (Fig. 2E). In comparison to the LP group, the ACCF and PDF groups reported significantly longer operative times. No significant difference was found among the other treatments (Table 4). According to the ranking chart, the sequence of the time-consuming from long to short was as follows: ACCF, PDF, ACAF, and LP (Fig. 3E).

3.3.6. Blood loss. The same 12 studies that reported the operative time also reported blood loss. Blood loss in the LP group was significantly lower than that in the PDF group; there was no significant difference between the PDF and ACAF groups (Table 4). The lowest boos loss was in the LP group followed by that in the ACAF, ACCF, and PDF groups (Fig. 3F).

3.3.7. Complications. Twenty studies[14–16,18,19,21–27,29–37] with 1322 patients reported postoperative complications (Fig. 2). We employed the inconsistency model to analyze the complications; no significant differences were found among the groups (Table 4). The node-splitting analysis showed that with respect to the complications, there was a significant difference in the direct effect and indirect effect between the ACCF group and LC group (Table 3). Thus, a ranking chart could not be created.

Table 3

Results of the node-splitting analysis.

Endpoints	Comparison	Direct effect	Indirect effect	Overall	*P*
JOA	1 vs 2	−1.55 (−2.77 to −0.42)	−1.05 (−4.00 to 1.95)	−1.40 (−2.49 to −0.37)	.74
	1 vs 3	−1.62 (−3.37 to −0.03)	−0.68 (−4.24 to 2.81)	−1.31 (−2.78 to 0.09)	.59
	1 vs 5	0.88 (−2.32 to 4.12)	−1.90 (−5.41 to 1.62)	−0.32 (−2.73 to 2.11)	.23
	2 vs 3	0.27 (−1.52 to 2.09)	0.94 (−2.79 to 4.74)	0.09 (−1.34 to 1.53)	.72
	2 vs 5	−0.36 (−3.76 to 3.05)	2.45 (−0.91 to 5.92)	1.09 (−1.31 to 3.48)	.22
IR	1 vs 2	−23.38 (−39.63 to −7.81)	−22.20 (−70.20 to 25.76)	N/A	.96
	1 vs 3	−16.05 (−37.63 to 5.26)	−17.29 (−63.91 to 27.72)	N/A	.96
	2 vs 3	9.39 (−14.14 to 33.88)	19.88 (−30.56 to 70.07)	N/A	.69
Excellent and good recovery rate	2 vs 3	1.03 (−1.78 to 4.16)	0.92 (−2.25 to 4.19)	0.65 (−1.25 to 2.59)	.94
Lordosis	1 vs 2	−3.26 (−8.69 to 2.27)	−2.13 (−11.16 to 7.47)	−2.99 (−7.61 to 2.00)	.82
	1 vs 3	−1.00 (−7.69 to 5.61)	−2.08 (−10.92 to 6.51)	−0.99 (−6.31 to 4.09)	.83
	2 vs 3	1.87 (−4.01 to 7.07)	4.05 (−9.54 to 16.97)	2.02 (−2.96 to 6.39)	.74
	3 vs	−3.38 (−16.73 to 9.84)	−0.27 (−13.08 to 13.17)	−1.72 (−10.31 to 7.12)	.71
Time	1 vs 2	−119.46 (−199.03 to −42.34)	−77.78 (−198.92 to 45.53)	−111.01 (−177.65 to −43.66)	.52
	1 vs 3	−16.38 (−121.76 to 88.16)	−5.31 (−134.00 to 122.00)	−7.71 (−88.76 to 71.94)	.88
	1 vs 5	39.42 (−121.90 to 196.45)	−118.99 (−288.39 to 52.12)	−33.38 (−158.24 to 93.49)	.16
	2 vs 3	122.78 (33.34 to 211.37)	55.04 (−92.42 to 201.66)	103.32 (27.93 to 177.74)	.39
	2 vs 5	4.72 (−156.52 to 163.71)	163.12 (−11.54 to 336.09)	77.44 (−46.71 to 204.01)	.15
Blood loss	1 vs 2	−96.93 (−352.38 to 163.71)	−168.38 (−570.55 to 245.19)	137.69 (−343.15 to 70.77)	.74
	1 vs 3	57.94 (−250.14 to 421.04)	233.49 (−164.35 to 623.77)	121.41 (−120.49 to 386.13)	.47
	1 vs 5	12.59 (−520.19 to 558.80)	−188.00 (−773.52 to 399.13)	−81.14 (−455.44 to 294.47)	.56
	2 vs 3	351.28 (132.52 to 580.72)	−58.64 (−400.83 to 322.89)	259.15 (33.66 to 510.13)	.06
	2 vs 5	−33.76 (−584.86 to 523.64)	165.01 (−425.09 to 762.74)	55.03 (−316.25 to 431.70)	.58
Complication	1 vs 2	−0.80 (−1.90 to 0.21)	−0.83 (−2.52 to 0.84)	−0.79 (−1.68 to 0.05)	.98
	1 vs 3	−0.78 (−2.19 to 0.48)	0.21 (−1.51 to 1.89)	−0.39 (−1.44 to 0.60)	.33
	1 vs 4	2.68 (−0.07 to 5.49)	−0.89 (−3.09 to 1.18)	0.42 (−1.45 to 2.21)	**.04***
	1 vs 5	−1.70 (−4.96 to 1.38)	−1.33 (−4.43 to 1.70)	−1.51 (−3.69 to 0.54)	.87
	2 vs 3	0.53 (−0.46 to 1.50)	−0.39 (−2.44 to 1.76)	0.39 (−0.58 to 1.35)	.42
	2 vs 4	0.04 (−2.12 to 2.06)	3.62 (0.76 to 6.60)	1.20 (−0.56 to 2.96)	.05
	2 vs 5	−0.52 (−3.48 to 2.46)	−0.91 (−4.30 to 2.35)	−0.72 (−2.88 to 1.35)	.86
	3 vs 4	−0.76 (−4.91 to 2.75)	1.55 (−0.68 to 3.86)	0.81 (−1.06 to 2.72)	.26

ACAF = anterior controllable antedisplacement and fusion, ACCF = anterior cervical corpectomy and fusion, IR = improvement rate, JOA = Japanese orthopaedic association, LC = laminectomy, LP = laminoplasty, PDF = posterior decompression and fusion.

* $P < 0.05$.

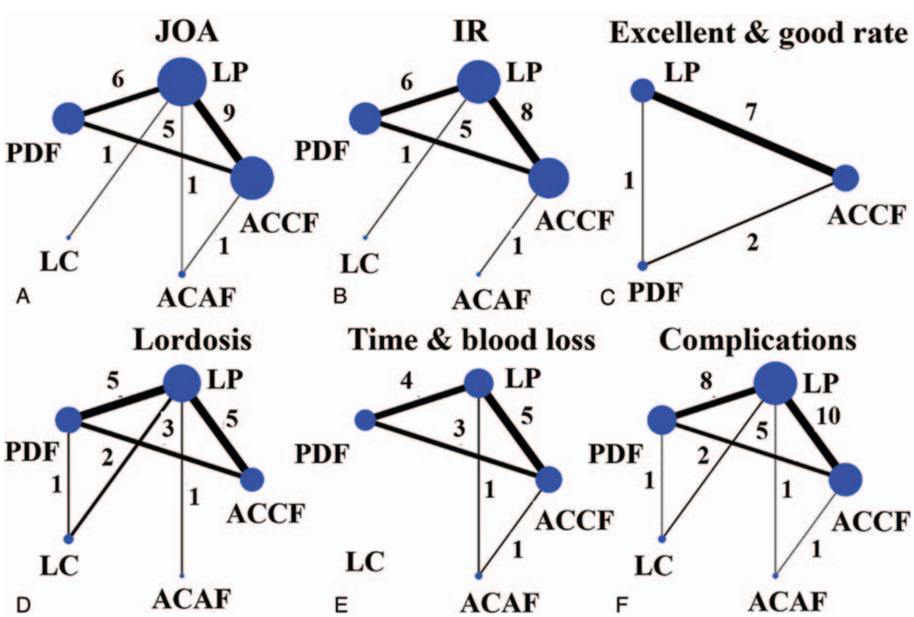

Figure 2. Network plots of comparative interventions. The width of the black line presents the number of trials compared in each treatment pair. The size of the blue circle represents the sample size of the corresponding intervention.

Table 4

Estimated effects of the network meta-analysis.

Items	ACCF	LP	PDF	LC	ACAF
JOA					
ACCF	1				
LP	1.42 (0.38 to 2.53)	1			
PDF	1.31 (−0.09 to 2.76)	−0.10 (−1.56 to 1.33)	1		
LC	1.95 (−1.39 to 5.37)	0.54 (−2.66 to 3.72)	0.65 (−2.82 to 4.18)	1	
ACAF	0.31 (−2.05 to 2.80)	−1.10 (−3.53 to 1.37)	−0.99 (−3.66 to 1.77)	−1.65 (−5.66 to 2.46)	1
IR					
ACCF	1				
LP	22.64 (8.24 to 37.22)	1			
PDF	14.27 (−3.67 to 32.86)	−8.28 (−26.48 to 10.04)	1		
LC	30.09 (−13.30 to 74.17)	7.62 (−33.71 to 49.06)	16.13 (−29.26 to 60.79)	1	
ACAF	−10.78 (−52.16 to 30.07)	−33.37 (−77.22 to 10.34)	−25.05 (−70.73 to 19.85)	−40.94 (−102.27 to 18.53)	1
Excellent and good recovery rate					
ACCF	1				
LP	3.11 (1.14 to 9.89)	1			
PDF	1.65 (0.29 to 10.52)	0.53 (0.07 to 3.54)	1		
Lordosis					
ACCF	1				
LP	2.92 (−2.02 to 7.54)	1			
PDF	0.97 (−4.15 to 6.35)	−1.95 (−6.34 to 3.03)	1		
LC	2.62 (−6.65 to 11.91)	−0.30 (−8.30 to 7.90)	1.64 (−7.28 to 10.36)	1	
ACAF	−6.75 (−19.86 to 6.46)	−9.63 (−21.81 to 2.75)	−7.70 (−21.03 to 5.33)	−9.42 (−24.32 to 5.23)	1
Operative time					
ACCF	1				
LP	110.20 (44.30 to 178.15)	1			
PDF	6.90 (−73.05 to 86.98)	−103.31 (−178.56 to −29.73)	1		
ACAF	32.88 (−92.28 to 158.43)	−77.20 (−202.23 to 46.35)	25.74 (−113.63 to 165.50)	NA	1
Blood loss					
ACCF	1				
LP	135.57 (−67.34 to 344.65)	1			
PDF	−125.44 (−389.19 to 121.68)	−260.82 (−509.87 to −36.80)	1		
ACAF	80.42 (−293.97 to 463.60)	−55.58 (−433.69 to 312.13)	204.46 (−208.80 to 646.39)	NA	1
Complications					
ACCF	1				
LP	2.37 (0.92 to 6.46)	1			
PDF	1.54 (0.50 to 4.89)	0.65 (0.22 to 1.80)	1		
LC	0.96 (0.14 to 8.53)	0.41 (0.06 to 3.34)	0.62 (0.08 to 5.84)	1	
ACAF	4.67 (0.46 to 49.92)	1.98 (0.18 to 20.22)	3.01 (0.26 to 36.58)	4.85 (0.22 to 88.51)	1

ACAF = anterior controllable antedisplacement and fusion, ACCF = anterior cervical corpectomy and fusion, IR = improvement rate, JOA = Japanese orthopaedic association, LC = laminectomy, LP = laminoplasty, PDF = posterior decompression and fusion.

4. Discussion

In the present study, we performed a network meta-analysis to compare the effect and safety of 5 commonly used surgical procedures for treating the OPLL-related cervical spondylosis. To our knowledge, this is the first report to simultaneously compare these 5 procedures. We found that each procedure has its strength and weakness in the different evaluating indices. We believe that the present findings would help clinicians to select an appropriate therapeutic protocol in clinical practice.

Several commonly used clinical indices were evaluated in the present study. The results of the JOA scores showed that ACCF was superior to LP and no significant difference was found among LP and the other procedures. The ranking superiority for JOA was ACCF > ACAF > PDF > LP > LC (Fig. 3A). The data on the IR suggested that ACCF was superior to LP; the ranking for IR was as follows: ACAF > ACCF > PDF > LP > LC (Fig. 3B). The data of excellent and good recovery rate suggested that ACCF was better than LP, and that the ranking superiority was as follows: ACAF > PDF > LP (Fig. 3C). The data of lordosis did not suggest any significant difference among the procedures; however, the ranking superiority was as follows: ACAF > ACCF > PDF > LP > LC (Fig. 3D). With respect to the operative time, LP was the shortest, and the time consumption from lowest to highest was as follows: LP < ACAF < PDF < ACCF (Fig. 3E). The results of blood loss indicated that LP involved lowest blood loss; the blood loss ranking was as follows: LP < ACAF < ACCF < PDF (Fig. 3F). All the procedures were associated different complications. Our results indicated that the anterior procedures (ACCF and ACAF) tended to achieve better efficacy, whereas the posterior procedure LP tended to have better safety (less operative time and blood loss).

The comparison of anterior vsersus posterior has been discussed in many studies.[38–40] Anterior procedures, such as ACCF and ACAF, have better efficacy (vs posterior procedures) in the postoperative function. ACCF solves the problem by directly removing the vertebral body and the ossified mass, whereas ACAF moves the vertebral body and the ossified mass forward. Therefore, anterior procedures provide immediate

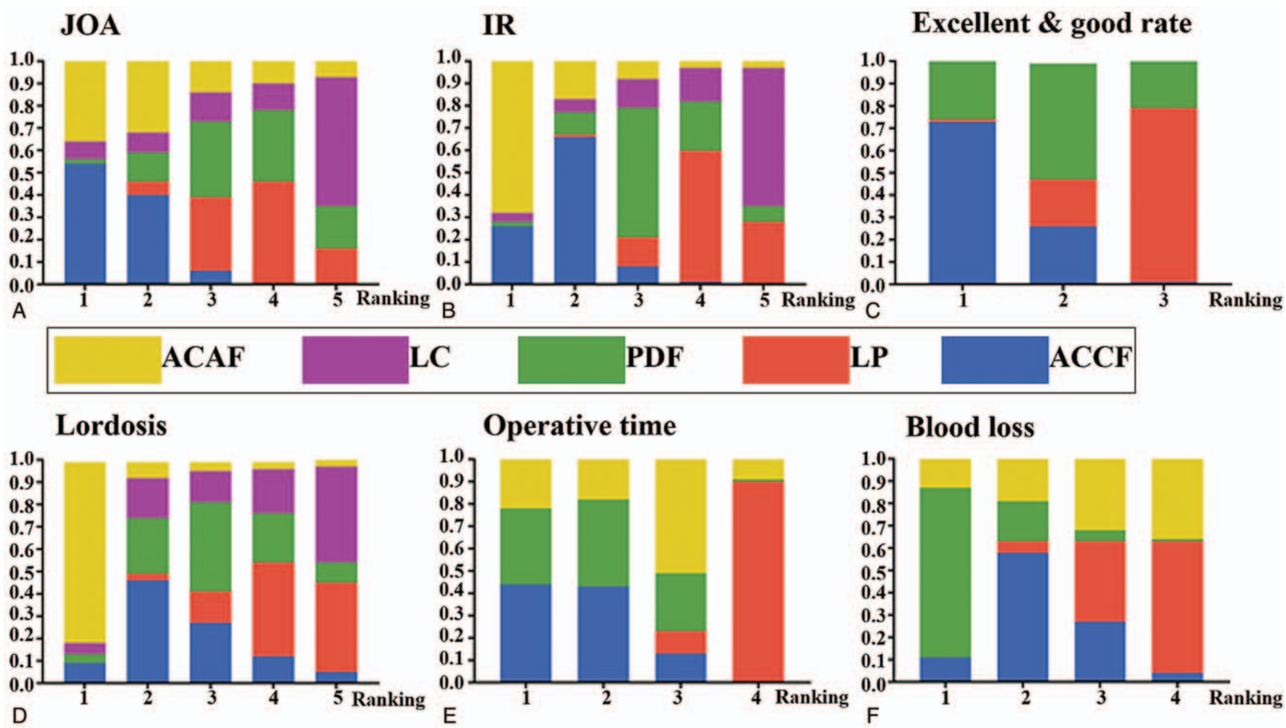

Figure 3. Rank probability of the interventions.

decompression for constrictive cervical canal secondary to OPLL.[16,23,41] Posterior procedures (LP, LC, and PDF) conduct indirect decompression by opening the space behind the spinal canal. Therefore, the posterior approaches require dissection of the posterior cervical muscles, as reported to be associated with the incidence of axial neck pain.[42] Moreover, the posterior procedures with indirect decompression might involve the risk of unsatisfactory decompression because the spinal cord likely bowstrings against anterior OPLL.[22] Another important issue is the structural stability of the cervical spine that should not be neglected. Although our results did not find any difference in lordosis, our ranking data show that the anterior procedures are superior to the posterior procedures. Posterior approaches might cause destruction of soft tissue and bone structure in the neck posterior column structure that may affect the stability of the cervical spine and cause complications, such as kyphotic cervical alignment. Thus, PDF was developed as a posterior fixation surgery of the cervical spine based on LC that sacrifices the range of movement (ROM) of neck for stability.[31] Some long-term follow-up studies have also suggested that anterior procedures have better efficacy vs. posterior procedures.[26,31] Therefore, many surgeons prefer to select the anterior rather than the posterior procedure.[41] The posterior procedures were alternative because they have certain merits. Anterior approaches, such as ACCF and ACAF, use materials for reconstruction of the anterior column and fixation with plate after decompression[16,37] that may affect the ROM of the neck. LP can retain the ROM of the necks.[43–45] Our results show that LP has a shorter operative time and less blood loss. It will reduce the operative complications.

With regard to complications, different approach exhibits different complications. Due to the surgical technology, the incision of the posterior procedures is commonly larger than that of the anterior procedures. Hence the posterior procedures, no matter LP, LC and PDF, always have a relative larger incision, as well as a severer surgical injury, which are associated with higher risk to complicate with postoperative complications in comparison with the anterior surgeries. Regardless of the anterior or posterior procedures, the extent of ossified ligament occupancy in the spinal canal appears to have a certain impact on the postoperative complications. Decompression and resection of the lesion will increase the risk of complications if OPLL occupies a high space in the spinal canal or involves dural ossification. The highest incidence of complications after ACCF was that of cerebrospinal fluid leakage (14.7%), followed by neurological deterioration (13.3%).[46] C5 palsy (C5P) is a common postoperative complication involved in both anterior and posterior procedures. Anatomically, the nerve rootlets and root of C5 are shorter than other segments, and the C5 segment is commonly the apex of the decompression area in LP. Moreover, C5 level has the strongest extent of posterior shifting of cord.[47] Hence the C5 never root is believed to have high risk for palsy. We found that the incidences of C5P were 5.88% (8/136) in the anterior procedures, whereas 22.70% (37/163) in the posterior procedures in the present study. The posterior procedures complicated more C5 palsy than the anterior procedures ($P < .05$). It has been reported the rate in the anterior procedures was 4.3% (range 1.6%–12.1%), whereas 4.6% (range 0%–30%) in the posterior procedures.[47] Our results are in agreement with these ranges. In this study, no infection event was reported in anterior procedures, whereas the infection rate in posterior procedures was 1.84% (3/163). Our data, along with the previous reports which reported the infection rate was 0.34% (range 0.07–1.6%)[48] in the anterior and 2.94% (range 6.0%–

18.2%)[49] in the posterior, are in agreement with our clinical experience, that infection mainly occurred in the posterior surgery.

In this study, a total of 23 studies with 1516 patients were included in this study. The follow-up duration was long. The results of New Castle-Ottawa Quality Assessment Scale suggested a satisfactory study quality of the involved studies (Table 2). Moreover, our results of node-splitting analysis indicated that most of the results (excluding ACCF vs LC in the complication) were consistent ($P > .05$, Table 3). Because heterogeneity and inconsistency are closely relevant in a network meta-analysis,[12] hence we believe that the evidence obtained in this study is reliable. This is the strength of the evidence. However, there are several limitations in this study. First, for the aim of the study, we had to use a network meta-analysis, which can perform only a cursory comparison among the five procedures. Forest plot was not available to visually depict the results. Second, the included patients undergoing LC and ACAF were less than those of other surgeries. The unbalanced distribution of the samples might lead a biased result. Third, although the study quality of the involved studies was satisfactory, no randomized controlled trial was included, which might reduce the reliability of the evidence obtained from the present study.

5. Conclusions

Overall, our study suggested that both the anterior and posterior procedures have their strengths and weaknesses. ACCF demonstrated the best performance in the indices of JOA score and excellent and good recovery rate. ACAF was the best in terms of IR and lordosis. LP offered the best operative time and blood loss. Both anterior and posterior procedures were comparable in terms of the onset of complications. These findings may contribute toward appropriate treatment selection by clinicians in the treatment of OPLL-related cervical spondylosis.

Acknowledgments

The authors thank Enago (www.enago.jp) for the English language review

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