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Systematic Review

Efficacy and Safety of Surgical Interventions for Treating Multilevel Cervical Spondylotic Myelopathy via Anterior Approach: A Network Meta-Analysis

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Background: Anterior cervical discectomy, with or without interbody fusion, is a common technique to treat cervical spondylotic myelopathy (CSM). To date, controversy still exists among spine surgeons regarding the anterior surgical approach to be used for the treatment of multilevel CSM.

Objectives: To evaluate the effectiveness and safety of anterior cervical discectomy and fusion (ACDF), anterior cervical corpectomy and fusion (ACCF), cervical total disc replacement (CTDR), and hybrid surgery (HS) in the treatment of multilevel CSM.

Study Design: Network meta-analysis (NMA) of randomized or nonrandomized controlled studies for the treatment of multilevel CSM.

Methods: The databases such as PubMed, CENTRAL, and EMBASE were used to search and identify the clinical trials involving the evaluations for the treatment of multilevel CSM. The Newcastle-Ottawa Scale was used for the assessment of methodological qualities, whereas the Cochrane Collaboration tool was used for assessing the risk of bias. Outcome assessments included duration of surgery, Neck Disability Index (NDI) scores, and complications. Odds ratio was used to express dichotomous outcomes, whereas mean difference with a 95% confidence interval was used to express continuous outcomes.

Results: Sixteen relevant studies were identified, and 1,639 patients were included in this analysis. CTDR demonstrated a prominently decreased NDI score and total incidence of complications compared with ACDF, ACCF, and HS. In addition, ACDF resulted in shorter operation times compared with ACCF, CTDR, and HS. The ranked order of NDI score improvement in decreasing order was: CTDR, HS, ACDF, followed by ACCF. The rank order for reduction in operation time increased progressively from ACDF, HS, ACCF to CTDR. The total incidence of complications also showed a decreasing trend in the decreasing order—CTDR, ACDF, HS, ACCF, and finally CTDR with the lowest complication rate.

Limitations: The limitations of this NMA include inconformity of the follow-up times and surgical skill, and implants of different treatment centers vary.

Conclusions: The analysis of this study has shown that the best method for improvement of functional outcome and reduction in total incidence of complications for multilevel CSM is CTDR.

Key words: Multilevel cervical spondylotic myelopathy, anterior cervical discectomy and fusion, anterior cervical corpectomy and fusion, cervical total disc replacement, hybrid surgery, effectiveness, safety, network meta-analysis

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Cervical spondylotic myelopathy (CSM) is one of the most common degenerative diseases that lead to significant neurologic disability (1). A study done in Taiwan stated that the incidences of CSM-related hospitalization was approximately 4.04 per 100,000 people per year, with older people, especially men, more likely to be affected (2). The incidences of CSM are increasing every year leading to high risk of disability. To rescue neural function and prevent further disability, the traditional approach for CSM includes surgical decompression in cases when the conservative therapy is ineffective, or in the case of deteriorating radiculopathy or myelopathy (3,4). However, it has been observed that compared with posterior surgery approaches, anterior approaches demonstrate similar improvements with regard to neurologic, functional, and quality of life outcomes, and also have lower rates of perioperative complications (5). The anterior surgical approaches involve anterior cervical discectomy and fusion (ACDF), anterior cervical corpectomy and fusion (ACCF), cervical total disc replacement (CTDR), and hybrid surgery (HS), wherein any 2 of the former 3 techniques can be incorporated. Every reconstruction technique has its unique advantages and disadvantages, which are briefly discussed. ACDF has historically been the gold-standard technique for cervical spondylosis with successful fusion rates and excellent clinical results, but its various limitations following the surgery are a persistent clinical concern. These limitations include risk of incomplete decompression, injury to the spinal cord, limited visual exposure, and the adjacent segment degeneration (ASD) (6). ACCF, however, is associated with relatively good fusion rates, but multilevel corpectomy weakens the initial stability of the fusion segment and brings about higher incidences of reconstruction failure (7). CTDR, as one of the anterior approaches, restores and sustains mobility and functions of the operated level and reduces the incidence of ASD, but indications required for CTDR are much more stringent (8). The purpose of HS is to combine the advantages of the 2 techniques in regard to vertebral stability and spine motion preservation. However, the procedure used for HS may be longer thereby leading to the possibility of increased blood loss and wound complications. Controversies still exist among spine surgeons with regard to the anterior approach to be used. Pairwise meta-analysis conducted to date could not acquire hierarchies of these techniques because the techniques have not been compared one on one. Compared with traditional pairwise meta-analysis, network meta-analysis (NMA) is a novel evidence-based technique that could make comparisons among multiple interventions. When there are no sufficient data to perform the direct comparison between 2 groups, an indirect comparison could be conducted by a Bayesian NMA. NMA could also combine indirect and direct evidences to compare multiple treatments and then recommend an optimal clinical option in terms of safety, effectiveness, et cetera (9).

Here, in this study, we have compared the effectiveness and safety of these 4 surgical approaches (ACDF, ACCF, CTDR, and HS) for treating multilevel CSM by NMA. The study is targeted to present hierarchies of the operation time, Neck Disability Index (NDI) score, and total incidence of complications to drive clinical recommendations.

Methods

Search Strategy and Eligibility Criteria

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement was used as a reference for this study (10). We have also registered this systematic review and meta-analysis in PROSPERO (CRD42018094841). The public databases including Cochrane Register of Controlled Trials (CENTRAL, November 2017), PubMed (January 1980 to November 2017), and EMBASE (1980 to November 2017) were used to identify all the studies used for the treatment of multilevel CSM by ACDF, ACCF, CTDR, and HS. "Intervertebral disc degeneration," "cervical spondylotic myelopathy," "anterior cervical discectomy and fusion," "anterior cervical corpectomy and fusion," "cervical total disc replacement," "cervical disc arthroplasty," and "hybrid surgery" were the keywords and MeSH terms that have been used in the search strategy.

The inclusion criteria used to select studies for analysis were target population, intervention, and methodological criteria. All the studies involving patients with age > 18 years along with 2-levels or more cervical disc degeneration were included in the analysis. All the randomized or nonrandomized controlled studies with interventions comprising ACDF, ACCF, CTDR, and HS were included in the study. The exclusion criteria were patients < 18 years of age or those who had ossification of the posterior longitudinal ligament. All the case reports, cohort studies, literature reviews or meta-analyses, or any other study that had repeated data or did not report outcomes of interest were excluded from the analysis. The studies were independently selected by 2 authors based on a standardized approach. Any inconsistencies, if observed, were resolved by discussion until a consensus was reached.

Outcome Assessment

The primary outcome measure was NDI score. The secondary outcome measures included operation time and total incidence of complications (e.g., dysphagia, hoarseness, infection, C5 palsy, cerebrospinal fluid leakage, epidural hematoma).

Data Collection and Quality Assessments

Two investigators extracted the data independently. Data for study information, which included type of study, country where the study was conducted, sample size of the study, length of follow-up period, and interventions were collected using standard data extraction methods. The data were also collected on random sequence generation, allocation concealment, blinding, selective reporting, and incomplete outcome data from randomized controlled trials (RCTs). For controlled clinical trials, the data were gathered on representativeness of cases, definition of controls, selection of controls, ascertainment of exposure, comparability of cases and controls, equivalent methods of diagnosis, and determination of response rate for cases and controls. The evaluation indicators from each study included NDI score, operation time, and total number of complications.

The quality of RCTs was assessed by the assessment of risk of bias that was performed using the Cochrane Collaboration tool (11). The selection and comparability of the study groups and outcome determination was performed to assess the quality of case–control trials by using the Newcastle-Ottawa Scale (12). The following criteria of the Cochrane Collaboration tool were used to evaluate RCTs: assessment of selection bias by randomization sequence generation, allocation concealment while the assessment for performance and detection bias was done by blinding level. Also, the assessment for attrition bias was done by incomplete outcome data, whereas the reporting bias assessment was done by selective reporting. The case–control studies were done by calculating the total Newcastle-Ottawa Scale score with a maximum of 9 points (12).

Statistical Analysis

Two investigators extracted data independently as per the specified selection criteria. Discussion was used to resolve the disagreements until a consensus was reached. In each of the studies, the relative risk (RR) was calculated for dichotomous outcomes (e.g., total complications), and treatment effects for continuous outcomes (e.g., NDI score and operation time) including mean differences (MDs) for studies with comparable outcome measures used a 95% confidence interval (CI).

STATA Version 12.0 (Stata Corp, College Station, TX), an open and free statistics software, was downloaded. We choose the random effects model to perform pairwise meta-analysis for all the available outcomes in this study. Standardized MD for continuous outcomes and RRs for dichotomous outcomes were used as summary statistics, with corresponding 95% CI. The Bayesian NMA was performed on the Markov chain Monte Carlo method in WinBUGS statistical software Version 1.4.3. To rank the 4 interventions for multilevel CSM, we implemented the surface under the cumulative ranking curve (SUCRA). The percentage is the most common form of expression for the SUCRA that ranged from 0% (or 0) to 100% (or 1). It is clearly understood that highest (namely, 100% or 1) or lowest SUCRA (namely, 0% or 0) represents the best and the worst treatment, respectively (13).

Inconsistencies of this NMA were assessed by the node-splitting analysis. Significance levels < 0.05 were considered an evidence of inconsistency. Results of different random effects and fixed effects models were compared for the sensitivity analysis.

Results

Description of Included Studies

The PRISMA diagram for study selection process is shown in Fig. 1. The searches performed in PubMed, EMBASE, and CENTRAL identified 693 studies initially in which PubMed identified 351 studies, EMBASE identified 287 studies, and 55 studies were identified from CENTRAL. This was followed by screening of titles of the studies, and as a result 615 studies were excluded because they were either irrelevant or duplicates. The remaining 78 studies were further screened by analysis of the title and summary. This led to further exclusion of 60 studies because these did not meet the inclusion criteria. Also, it was observed that 3 studies were reported on the same population at various follow-up periods and were therefore included as only one article for NMA. These analyses led to a final selection of 16 studies that met the inclusion criteria for NMA (7,14-28). Of these 16 studies, 8 were prospective trials and the others are retrospective (Table 1).

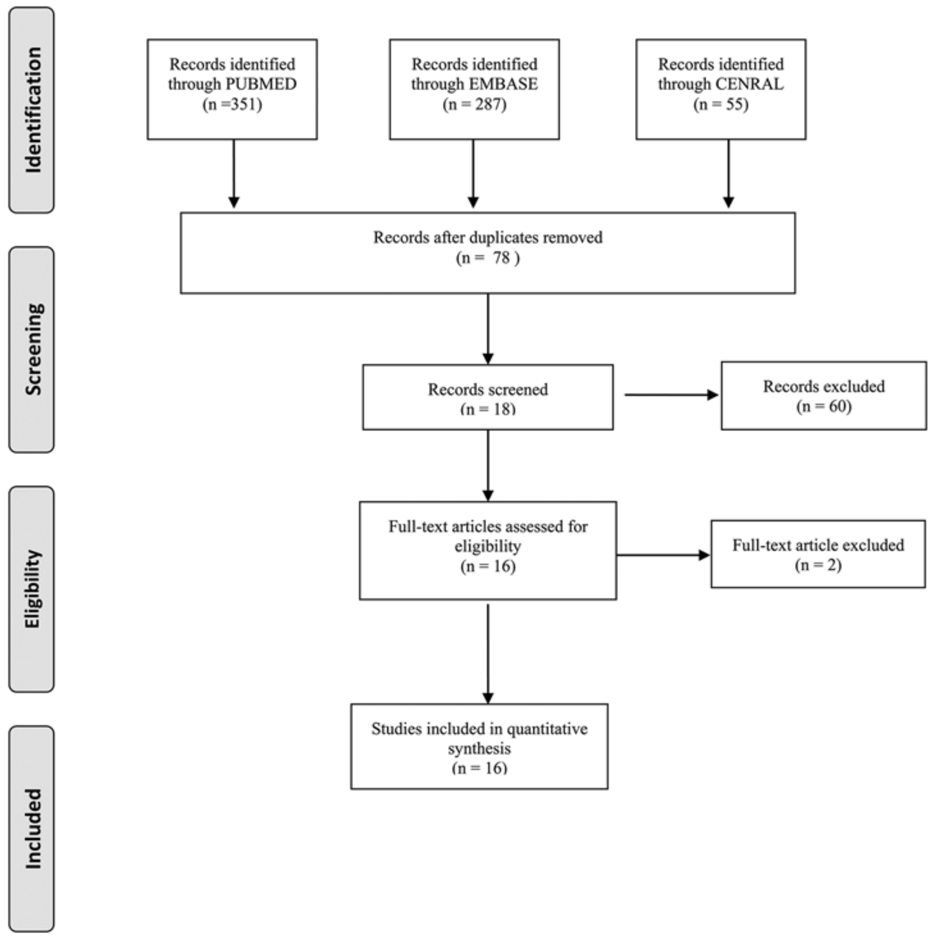

Fig. 1. *Flow chart of the selection process for relative studies in meta-analysis.*

Study Characteristics and Risk of Bias

A total of 1,639 patients were included for NMA. For the 4 interventions, 630 patients were assigned to ACDF intervention, 333 to ACCF intervention, 329 to CTDR intervention, and 347 to CTDR intervention. The sample size of the study ranged from 7 to 225. In all the 16 studies, a direct comparison was made of one surgical intervention with the other. All the studies used in this analysis were published between 2009 and 2017. Of the 16 studies, 10 used NDI score as an evaluation indicator, 12 used operation time, and 14 used total complications.

Of the 4 RCTs (18,20,21,26), the Cochrane Collaboration tool indicated that 3 trials (18,20,26) used adequate randomization and 2 trials (18,20) used adequate allocation concealment. For detection, 3 studies (18,20,26) reported outcome assessment blinding. Four studies (18,20,21,26) were free of selective reporting and stated the incomplete outcome data (Fig. 2). According to the Newcastle-Ottawa Scale, 3 case–control studies (22,23,25) scored 9 points, 3 studies (15,24,27) scored 8 points, and 6 studies (7,14,16,17,19,28) scored 7 points (Table 2).

NDI Score

Ten of the included studies used NDI score as an evaluation indicator. The following surgical procedures for treating multilevel CSM were tested in the trials: ACDF versus ACCF (4 trials with 488 patients) (8,14,16,17); ACDF versus CTDR (5 trials with 534 patients) (18,20-23); ACDF versus HS (4 trials with 394 patients) (7,16,23,25);

Table 1. *Characteristics of included studies comparing different anterior surgical approach fortreating multilevel CSM.*

Study	Study Design	Country	Disease Status	Interventions	Sample Size (mean age: yrs)	Follow-Up (month)	For Analysis
Sun et al (18) 2016	RCT	China	2-level noncontiguous cervical spondylosis	ACDF vs. CTDR	16 (48.13)/14 (46.79)	34.2	NDI score; operation time; total complications
Davis et al (20) 2013	RCT	United States	2-level symptomatic degenerative disc disease	ACDF vs. CTDR	105 (46.2)/225 (45.3)	24	NDI score; operation time; total complications
Cheng et al (21) 2009	RCT	China	2-level cervical disc disease	ACDF vs. CTDR	34 (47)/31 (45)	24	total complications
Kang et al (26) 2013	RCT	China	3-level cervical disc disease	ACDF vs. HS	12 (55.3)/12 (53.6)	33.2/32.8	operation time; total complications
Hou et al (22) 2014	PC	China	cervical disc disease	ACDF vs. CTDR	88 (51.2)/32 (46.3)	23.3/24.2	NDI score; total complications
Grasso (25) 2015	PC	Italy	multilevel cervical degenerative disc disease	ACDF vs. CTDR vs. HS	20 (47.3)/20 (40.5)/20 (44.2)	24	NDI score; operation time
Shin et al (27) 2009	PC	South Korea	2-level cervical disc disease	ACDF vs. HS	20 (48.0)/20 (45.7)	24	operation time; total complications
Lian et al (24) 2010	PC	China	CSM	HS vs. ACCF	55 (59.7)/50 (60.8)	31.5	operation time; total complications
Li et al (14) 2017	NRC	China	4-level CSM	ACDF vs. ACCF	31 (54.9)/39 (56.8)	36.9	NDI score; operation time; total complications
Liu et al (7) 2012	NRC	China	multilevel CSM	ACDF vs. ACCF vs. HS	103 (53.48)/87 (53.68)/96 (54.36)	43.2	NDI score; total complications
Liu et al (16) 2012	NRC	China	3-level CSM	ACDF vs. ACCF vs. HS	69 (46.1)/39 (47.8)/72 (46.9)	26.1	NDI score; operation time; total complications
Guo et al (15) 2011	NRC	China	3-level CSM	ACDF vs. ACCF vs. HS	43 (52.7)/24 (55.2)/53 (53.4)	37.3	operation time; total complications
Lin et al (17) 2012	NRC	China	3- or 4-level CSM	ACDF vs. ACCF	57 (58.74)/63 (57.90)	24	NDI score; operation time; total complications
Song et al (19) 2012	NRC	South Korea	3- or 4-level CSM	ACDF vs. ACCF	25 (50.3)/15 (54.1)	87.3/94.3	operation time; total complications
Hey et al (23) 2013	NRC	Singapore	CSM	ACDF vs. CTDR vs. HS	7 (48)/7 (46)/7 (51)	24	NDI score; operation time; total complications
Liu et al (28) 2009	NRC	China	CSM	HS vs. ACCF	12 (NA)/16 (NA)	17.3	NDI score; total complications

Abbreviations: NA, not applicable; NRC, nonrandomized retrospective comparative; PC, prospective comparative

ACCF versus HS (3 trials with 322 patients) (7,16,28); and CTDR versus HS (2 trials with 54 patients) (23,25).

Figure 3A shows the network of comparisons of NDI score. The effect size hierarchies on the NDI score is shown in Table 3. The distribution of cumulative probability and probability of NDI score for each intervention are shown by ranking graphs as depicted in Fig. 3B and 3C. Based on the direct and indirect comparisons, CTDR lowered the NDI score significantly compared with the other 3 groups, and ACCF accounted for a greater NDI score as compared with the other 3 groups. Based on the results obtained from SUCRA, CTDR ranked first (0.9154), followed by HS (0.5763), ACDF (0.3903), and ACCF being the last (0.118).

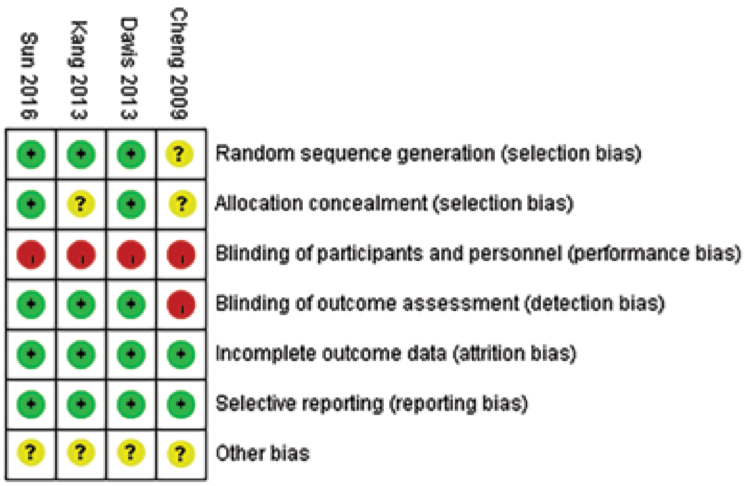

Fig. 2. *Risk of bias summary: review authors' judgements about each risk of bias item for each included study.*

Operation Time

Twelve trials that reported operation time as an indicator of evaluation were incorporated in the NMA. Figure 4A shows the network of comparisons of operation time. Hierarchies of effect size on the incidence is reported in Table 4. The distribution of cumulative probability and probability of operation time for each intervention were represented by ranking graphs and have been shown in Fig. 4B and 4C. Based on the direct and indirect comparisons, ACDF results in shorter operation time than ACCF, CTDR, and HS. However, based on SUCRA, ACDF ranked first (0.9864), followed by HS (0.5894), ACCF (0.4242), and CTDR (0.0).

Table 2. *Quality assessment of case–control studies comparing different anterior surgical approach for treating multilevel CSM using Newcastle-Ottawa Scale*

Author Group	Selection				Comparability	Exposure		
	Adequate Case Definition	Representativeness of the Case	Selection of Controls	Definition of Controls	Comparability of Cases and Controls	Ascertainment of Exposure	Same Method of Ascertainment	Nonresponse Rate
Li et al (14) 2017	1	1	1	1	1	1	1	-
Liu et al (7) 2012	1	1	1	1	1	1	1	-
Liu et al (16) 2012	1	1	1	1	1	1	1	-
Guo et al (15) 2011	1	1	1	1	2	1	1	-
Lin et al (17) 2012	1	1	1	1	1	1	1	-
Song et al (19) 2012	1	1	1	1	1	1	1	-
Hou et al (22) 2014	1	1	1	1	2	1	1	1
Hey et al (23) 2013	1	1	1	1	2	1	1	1
Grasso (25) 2015	1	1	1	1	2	1	1	1
Shin et al (27) 2009	1	1	1	1	1	1	1	1
Liu et al (28) 2009	1	1	1	1	1	1	1	-
Lian et al (24) 2010	1	1	1	1	1	1	1	1

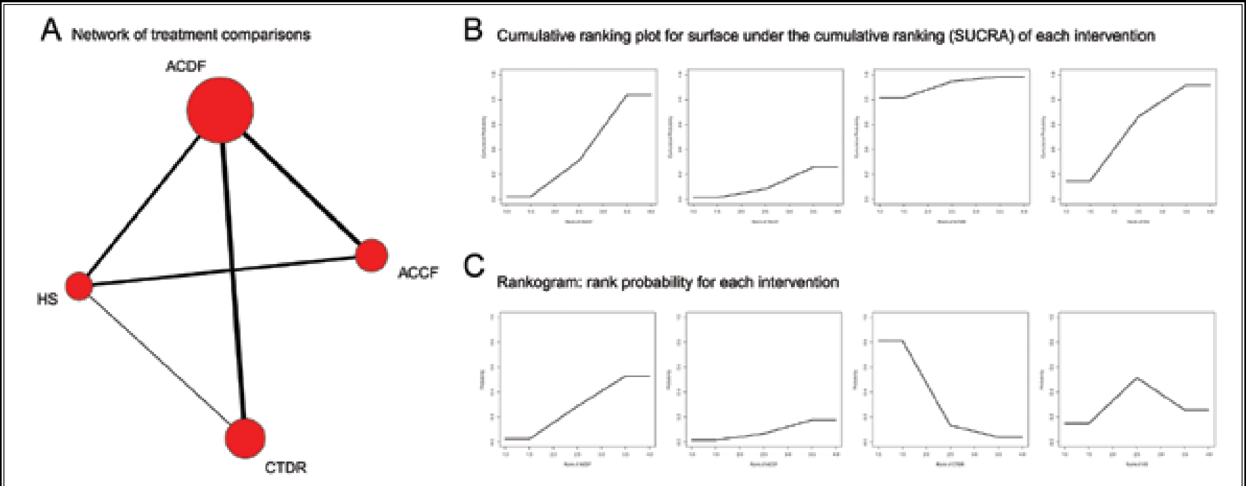

Fig. 3. *(A) Network of treatment comparisons for NDI score. The size of the node corresponds to the total sample size of treatments. Directly comparable treatments are linked with a line, the thickness of which represents the number of trials that were compared. (B) Cumulative ranking plot for SUCRA for each intervention of NDI score. (C) Rankogram: rank probability for each intervention of NDI score.*

Table 3. *Results for NDI score from NMA (lower diagonal part) and pairwise meta-analysis (upper diagonal part).*

ACDF	−0.405 (−0.588 to −0.222)	0.315 (0.131 to 0.500)	0.019 (−0.179 to 0.217)
−0.8643 (−3.258 to 1.542)	**ACCF**	NA	0.389 (0.163 to 0.615)
2.041 (−0.4234 to 5.293)	2.906 (−0.234 to 6.918)	**CTDR**	−0.239 (−0.785 to 0.308)
0.505 (−1.868 to 2.914)	1.369 (−1.237 to 4.02)	−1.536 (−5.267 to 1.393)	**HS**

NA, not applicable.

Table 4. *Results for operation time from NMA (lower diagonal part) and pairwise meta-analysis (upper diagonal part).*

ACDF	0.091(−0.116 to 0.298)	−0.433(−0.653 to −0.213)	0.187(−0.041 to 0.416)
−7.281 (−13.88 to −0.6533)	**ACCF**	NA	0.347(0.102 to 0.593)
−34.12(−41.25 to −26.96)	−26.83(−36.15 to −17.52)	**CTDR**	1.673(0.710 to 2.635)
−5.032(−10.03 to −0.03869)	2.249(−4.567 to 9.051)	29.08(21.36 to 36.75)	**HS**

NA, not applicable.

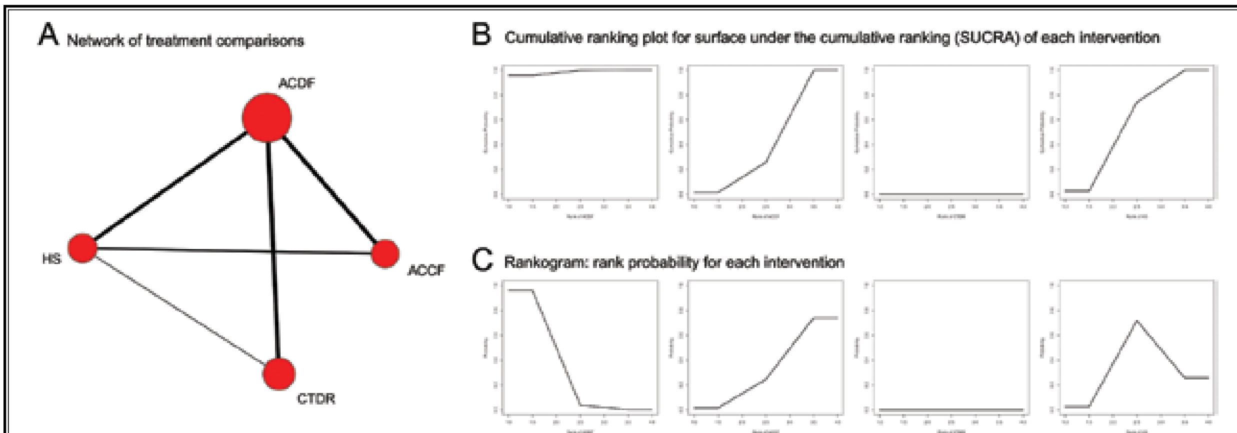

Fig. 4. *(A) Network of treatment comparisons for operation time. The size of the node corresponds to the total sample size of treatments. Directly comparable treatments are linked with a line, the thickness of which represents the number of trials that were compared. (B) Cumulative ranking plot for SUCRA for each intervention of operation time. (C) Rankogram: rank probability for each intervention of operation time.*

Total Incidence of Complications

Fifteen trials that reported the total incidence of complications were incorporated in the NMA. The networks of comparisons on total incidence of complications are shown in Fig. 5A. The hierarchies of effect size on total incidence of complications are shown in Table 5, and the ranking graphs of the cumulative probability and probability distribution on total incidence of complications for each intervention is shown in Fig. 5B and 5C. Based on the direct and indirect comparisons, CTDR resulted in a lower incidence of complications than ACCF, CTDR, and HS. Based on SUCRA, CTDR ranks first (0.9923), followed by ACDF (0.6361), HS (0.3567), and ACCF being the last (0.01495).

Inconsistency and Sensitivity Analysis

In general, the results obtained from the pairwise meta-analysis were in correlation with that of NMA, and when the result was analyzed by the use of node-splitting analysis, no inconsistencies were identified (Table 6). The sensitivity analysis was performed by the comparison of the results of different random and fixed effects models. The results of the random effects model, in which effective number of parameters (pD) = 20.19 and deviance information criterion (DIC) = 50.57 were observed, were similar to the fixed effects model (pD = 17.59 and DIC = 48.97).

Discussion

The NMA provided hierarchies for the NDI score, operation time, and total incidence of complications in patients with multilevel CSM treated with different surgical interventions via anterior approach, which had predominance contrast with traditional pairwise meta-analyses (29-36). The results showed that: 1) CTDR significantly decreased NDI score compared with other groups, and ACCF resulted in significantly higher NDI score compared with other groups; 2) ACDF results in

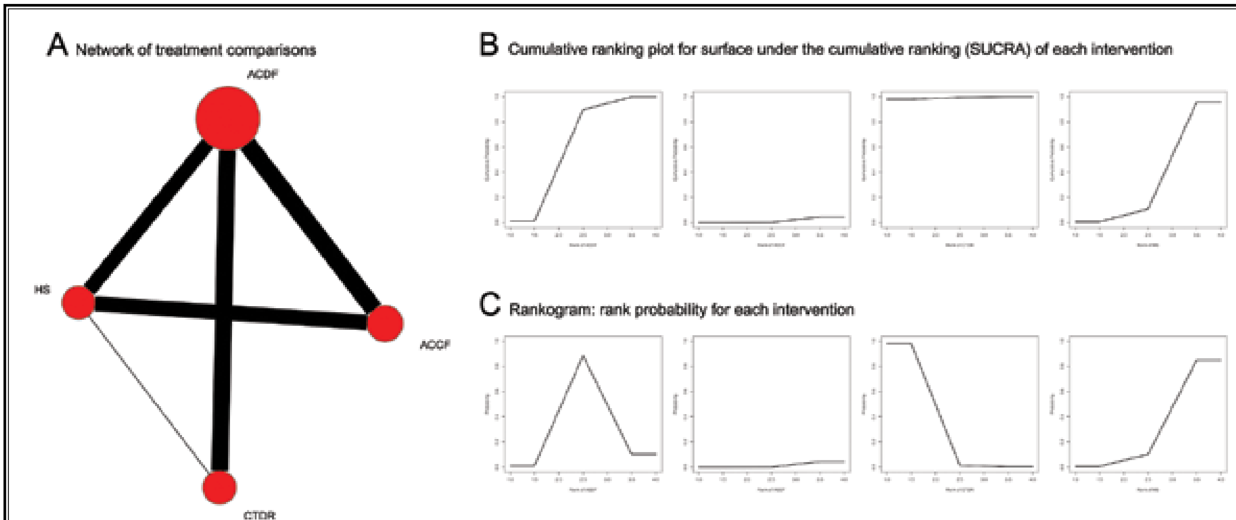

Fig 5. *(A) Network of treatment comparisons for incidence of total complications. The size of the node corresponds to the total sample size of treatments. Directly comparable treatments are linked with a line, the thickness of which represents the number of trials that were compared. (B) Cumulative ranking plot for SUCRA for each intervention of incidence of total complications. (C) Rankogram: rank probability for each intervention of incidence of total complications*

Table 5. *Results for total complications from NMA (lower diagonal part) and pairwise meta-analysis (upper diagonal part).*

ACDF	0.575 (0.433 to 0.764)	1.736 (1.251 to 2.409)	0.717 (0.483 to 1.064)
0.4525 (0.2866 to 0.7353)	**ACCF**	NA	1.438 (1.042 to 1.984)
1.9829 (1.1125 to 3.7523)	4.1494 (2.0661 to 9.4518)	**CTDR**	0.500 (0.058 to 4.335)
0.7008 (0.4244 to 1.2313)	1.5076 (0.939 to 2.6427)	0.32239 (0.1594 to 0.7776)	**HS**

NA, not applicable.

Table 6. *Node-splitting analysis for inconsistency of NMA*.

Comparison	Direct Effect	Indirect Effect	Network	*P* Value
1 vs. 2	0.80 (0.27, 1.4)	0.37 (–2.0, 2.6)	0.76 (0.32, 1.2)	0.698550
1 vs. 4	0.45 (–0.24, 1.3)	0.089 (–1.7, 1.6)	0.32 (–0.21, 0.85)	0.652850
2 vs. 4	–0.52 (–1.1, 0.048)	–0.51 (–2.5, 1.4)	–0.45 (–0.97, 0.053)	0.995100
3 vs. 4	1.1 (–2., 4.8)	1.1 (0.19, 1.9)	1.1 (0.23, 1.8)	0.990625

1: ACDF; 2: ACCF; 3: CTDR; 4: HS.

shorter operation time than ACCF, CTDR, and HS; 3) CTDR results in a lower incidence of complications than ACCF, ACDF, and HS; 4) the rank of treatments in the aspect of NDI score was: CTDR, HS, ACDF, and ACCF; 5) for reduction of operation time, the rank of treatments was: ACDF, HS, ACCF, and CTDR; and 6) the rank of treatments in the aspect of reducing complications was: CTDR, ACDF, HS, and ACCF.

The advantages of this study have been highlighted in the following points: 1) common methods were used for the conduction of the study that was designed in a way to allow reproducible research selection and inclusion; 2) an extensive retrieval strategy was used for the reduction of publication bias possibility; 3) direct and indirect evidence of the effectiveness and safety of treatment strategies was used for overcoming the major limitation that is observed in conventional pairwise meta-analysis; and 4) subtle differences among the 4 interventions were distinguished by SUCRA and posterior probabilities of outcomes.

However, this study has a few limitations that are discussed in the following sections. First, we included both RCTs and case–control studies in this analysis, because only 4 RCTs were included, the case–control studies may have attenuated the significance of the conclusions. Second, these interventions (ACDF, ACCF, CTDR, and HS) may have different indications that may have affected the effectiveness and safety of each intervention. Third, the lack of double-blind studies may have introduced detection bias, for the evaluators may have given the study group higher marks. Fourth, the length of follow-up period in the included studies varied, which may make deviations in graded NDI score and calculated complications. Finally, the clinical heterogeneity might be caused by different implants, the extent of degenerated disc, and surgical technologies used at different facilities, which is a unavoidable deviation in performing NMA to evaluate effectiveness and safety of multiple surgical interventions. Despite these weaknesses, to our knowledge, this was the first meta-analysis comparing 4 anterior approaches for treating multilevel CSM, which might provide useful information for clinical references.

A previous meta-analysis (34) reported that CTDR had similar operation time and NDI score compared to ACDF, but CTDR could reduce incidences of ASD and adverse events. Gao et al (37) also conducted a meta-analysis and found that ACDF was associated with shorter operative time, but similar NDI score and incidence of complications that was further validated by the Ma et al (33) study. Zou et al (35) performed a meta-analysis of CTDR versus ACDF for 2 contiguous levels of cervical disc disease and found that CTDR had significant superiorities in NDI score and incidence of complications with similar operative time. Findlay et al (36) demonstrated that CTDR achieved better recovery of NDI score and less dysphagia, adjacent segment disease compared to ACDF at 4 and 7 years follow-up. When compared to HS, Zhang et al (32) reported that HS achieved better recovery of NDI score and reduced the risk of adjacent disc degeneration compared to ACDF at 2 years follow-up. Also, Liu et al (29) stated that HS was associated with lower incidences of complications, similar duration of surgery, and NDI score. Further, Wang et al (31) performed a meta-analysis of ACDF versus ACCF for 3 or 4 level multilevel CSM and found that ACDF did not lead to significant differences in operation time or NDI score, but led to a lower incidence of total complications compared to ACCF. Wen et al (30) also indicated that numbers of complications in ACDF was significantly less than in ACCF, and operation time between ACDF and ACCF for multilevel CSM were not significantly different.

This NMA provided ample outcomes to evaluate effectiveness and safety of several surgical interventions for treating multilevel CSM. NDI score is the first and the most widely used instrument for assessing self-rated disability in patients with neck pain (38), which could also estimate the effectiveness of surgical interventions for multilevel CSM. Meanwhile, operation time and incidence rate of complications could be strong evidence to assess the safety of surgical interventions. Our network analysis showed that CTDR resulted in better recovery of NDI score compared with the other 3 interventions. We also found that CTDR resulted in lower total incidence of complications than ACDF, ACCF, and HS. ACDF resulted in shorter operation time than ACCF, CTDR, and HS. Furthermore, we also used the SUCRA and posterior probabilities of outcomes to distinguish the subtle differences among the 4 interventions. For achieving better recovery of NDI score, the rank on treatments was: CTDR, HS, ACDF, and ACCF with CTDR being the best. For reducing operation time, the rank on treatments in decreasing order was: ACDF, HS, ACCF and CTDR. For lowering incidence of complications, the rank on treatments was: CTDR, ACDF, HS, and ACCF in which CTDR showed lowest complication list.

Conclusions

This NMA demonstrated that in the anterior surgical management of multilevel CSM, CTDR has the highest probability of improving the functional outcome and reducing the total incidence of complications. However, further high-quality, RCTs are required to confirm and update these results.

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