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Anterior cervical discectomy and fusion versus hybrid surgery in multilevel cervical spondylotic myelopathy

A meta-analysis

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Abstract

Objective: A meta-analysis was performed to compare the radiographic and surgical outcomes between anterior cervical discectomy and fusion (ACDF) and hybrid surgery (HS, corpectomy combined with discectomy) in the treatment for multilevel cervical spondylotic myelopathy (mCSM).

Summary of background data: Both ACDF and HS are used to treat mCSM, however, which one is better treatment for mCSM remains considerable controversy.

Methods: An extensive search of literature was searched in PubMed/Medline, Embase, the Cochrane library, CNKI, and WANFANG databases on ACDF versus HS treating mCSM from January 2011 to December 2017. The following variables were extracted: blood loss, operation time, fusion rate, Cobb angles of C2–C7, total complications, dysphagia, hoarseness, C5 palsy, infection, cerebral fluid leakage, epidural hematoma, and graft subsidence. Data analysis was conducted with RevMan 5.3 and STATA 12.0.

Results: A total of 4 studies including 669 patients were included in our study. The pooled analysis showed that there were no significant difference in the operation time, fusion rate, Cobb angles of C2–C7, dysphagia, hoarseness, C5 palsy, infection, cerebral fluid leakage, epidural hematoma, and graft subsidence. However, there were significant difference between 2 groups in blood loss [$P<.00001$, SMD = −30.29 (−45.06, −15.52); heterogeneity: $P=.38$, $I^2=0\%$= and total complications [$P=.04$, OR = 0.66 95%CI (0.44, 0.98); heterogeneity: $P=.37$, $I^2=4\%$].

Conclusions: Based on our meta-analysis, except for blood loss and total complications, both ACDF and hybrid surgery are effective options for the treatment of multilevel cervical spondylotic myelopathy.

Abbreviations: ACCF = anterior cervical corpectomy and fusion, ACDF = anterior cervical discectomy and fusion, CSM = cervical spondylotic myelopathy, HS = hybrid surgery, corpectomy combined with discectomy, SMD = standardized mean difference.

Keywords: anterior cervical discectomy and fusion, hybrid surgery, multilevel cervical spondylotic myelopathy

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1. Introduction

Cervical spondylotic myelopathy (CSM) is a common clinical degenerative disease, seriously impacting quality of life and even causing disability for the elderly population.[1,2] CSM is usually caused by narrowing of the cervical spinal canal due to degenerative and congenital changes.[3–5] The selection of optimal surgical treatment for CSM, especially for multilevel cervical spondylotic myelopathy (mCSM), remains debated.[1–4,6–8] Surgeries mainly involved anterior and posterior approaches, including ACDF,[9] anterior cervical corpectomy and fusion (ACCF),[10–12] hybrid surgery,[13,14] laminoplasty,[15] laminectomy,[16] and laminectomy with fusion.[17,18] ACDF was firstly introduced to treat CSM by Smith and Robinson[19] and Cloward,[20] then the anterior procedure has become the most widely used surgical choice.[21] Among the anterior approaches, ACDF can decompress the anterior spinal cord and preserve the stability of the spinal column,[22–24] however, ACDF may have a high risk of incomplete decompression, limited visual exposure and injury to the cord.[23–27] In recent years, hybrid surgery (HS), corpectomy combined with discectomy, provides a good option for nerve tissue decompression and spinal reconstruction while reducing complications.[28–32]

Previous[32–34] meta-analysis mainly focused on the comparison between ACCF and ACDF or between ACCF and combining cervical disc arthroplasty with fusion in treatment for mCSM. However, no meta-analysis focused on the comparison of outcomes between ACDF and HS, corpectomy combined with discectomy, treating mCSM. The purpose of this meta-analysis is to compare radiographic and surgical outcomes of ACDF compared with HS in treatment for mCSM.

2. Materials and methods

2.1. Ethics statement

There is no need to seek informed consent from patients, since this is a meta-analysis based on the published data, without any potential harm to the patients; this is approved by Ethics Committee of The Affiliated Taizhou People's Hospital of Nantong University.

2.2. Search strategy

An extensive search of literature was performed in PubMed, Embase, the Cochrane library, CNKI, and WANFANG databases. The following keywords were used for search: "anterior cervical discectomy and fusion," "hybrid surgery," "corpectomy combined with discectomy," "multilevel cervical spondylotic myelopathy" from January 2011 to December 2017, with various combinations of the operators "AND" and "OR." Language was restricted to Chinese and English.

2.3. Inclusion criteria

Studies were included if they met the following criteria: randomized or nonrandomized controlled study; age greater than or equal to 18 years old; studies compared ACDF with HS in treatment of CSM; HS was defined as corpectomy combined with discectomy; 3 or 4 levels cervical spondylotic myelopathy; follow-up more than 2 years

2.4. Exclusion criteria

Studies were excluded if they met the following criteria: dealt only with ACDF or HS alone for treatment of CSM; had an average follow-up time of less than 2 years; had repeated data; did not report outcomes of interest; in vitro human cadaveric biomechanical studies; earlier trial, reviews, and case-reports have ossification of posterior longitudinal ligament

2.5. Selection of studies

Two reviewers independently reviewed all subjects, abstracts, and the full text of articles. Then the eligible trials were selected according to the inclusion criteria. When consensus could not be reached, a third reviewer was consulted to resolve the disagreement.

2.6. Data extraction and management

Two reviewers extracted data independently. The data extracted including the following categories: study ID, study design, study location, total patients, follow-up, mean age, gender, radiographic outcomes: preoperation and at the final follow-up Cobb angles of C2–C7, fusion rate, graft subsidence, and surgical outcomes: blood loss, operation time, total complications, dysphagia, hoarseness, C5 palsy, infection, cerebral fluid leakage, and epidural hematoma.

2.7. Statistical analysis

Data analysis was performed with RevMan 5.3 (The Nordic Cochrane Center, The Cochrane Collaboration, Copenhagen, Denmark) and STATA 12.0 (Stata Corporation, College Station, TX). Odds ratio (OR) was used as a summary statistic to analyze dichotomous variables, and the standardized mean difference (SMD) was used to analyze continuous variables. Both were reported with 95% confidence intervals (CI), and a P value of .05 was used as the level of statistical significance. Assessment for statistical heterogeneity was calculated using the I^2 tests, which described the proportion of the total variation in meta-analysis assessments from 0% to 100%. The random effects model was used for the analysis when an obvious heterogeneity was observed among the included studies ($I^2 >$ 50%). The fixed-effects model was used when there was no significant heterogeneity between the included studies ($I^2 \leq 50\%$).[35,36]

2.8. Test for risk of publication bias

We performed a visual inspection of the funnel plot for publication bias. The funnel plot should be asymmetric when there is publication bias and symmetric in the case of no publication bias. We performed Egger and Begg tests to measure the funnel plot asymmetry by using a significance level of $P < .05$. The trim and fill computation was used to estimate the effect of publication bias.

3. Results

3.1. Search results

We had searched 96 English studies in MEDLINE, Embase, 51 Chinese studies in WANFANG, and CNKI. Of these, 49 English articles and 44 Chinese after duplicates removed, 31 English articles and 5 Chinese articles were excluded due to unrelated studies. Around 13 English articles and 1 Chinese article were excluded due to eligibility criteria. As a result, a total of 4 studies were identified for this meta-analysis. The literature search procedure was shown in Figure 1.

3.2. Baseline characteristics and quality assessment

In total, 669 patients who suffered from mCSM from 4 studies were included in our study. Table 1 showed the baseline feature of included articles in our study.

All included studies were retrospective studies, Newcastle Ottawa Quality Assessment Scale (NOQAS) with a maximum of 9 points was applied for evaluating the quality of each study. There were 3 aspects for the quality: selection, comparability, exposure, and outcomes. Three studies scored 8 points and 1 studies scored 7 points, hence, the quality of each study was relatively high (Table 2).

3.3. Radiographic outcomes

3.3.1. The angle of C2-C7. Two studies[37,39] reported preoperative and at the final follow-up angle of C2–C7 between ACDF and HS. The meta-analysis showed that there were no difference between ACDF and HS in preoperative and the final

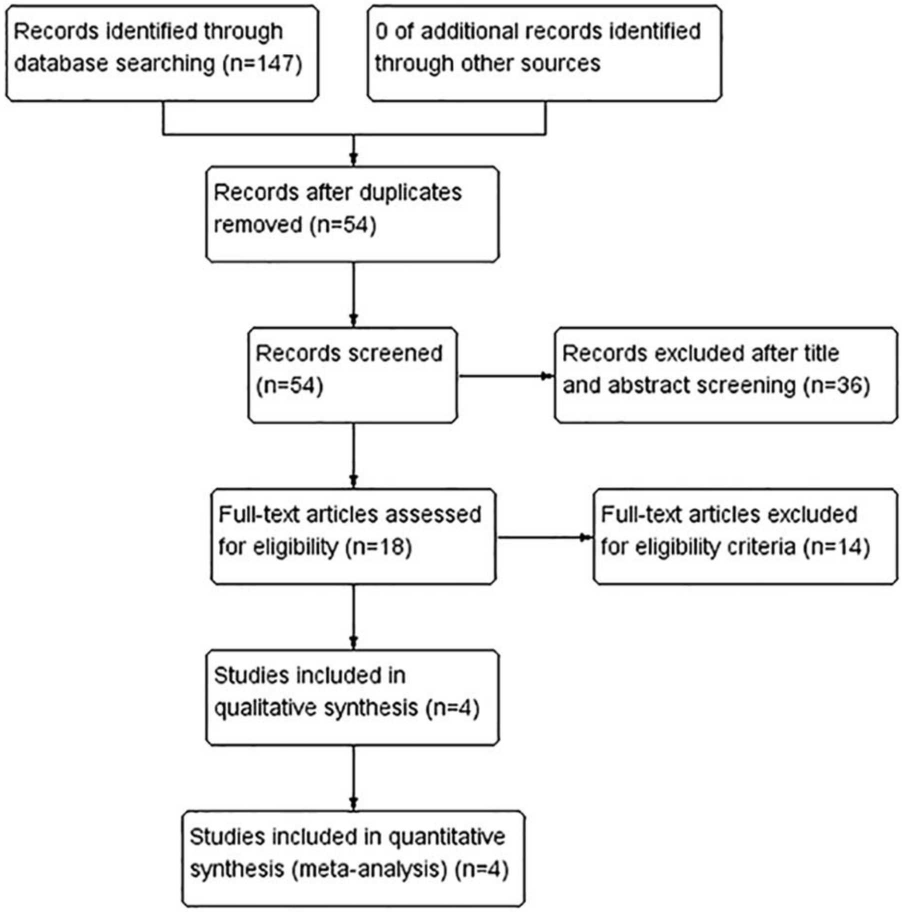

Figure 1. Flow diagram of study selection.

Table 1

Characteristics of included studies.

			No. participants			Mean Age, years (range)		Gender (M/F)		Follow-up, months (range)	
First author	Year	Country	ACDF	HS	Study type	ACDF	HS	ACDF	HS	ACDF	HS
Yang Liu[37]	2012	China	69	72	Retrospective study	46.1±6.8	46.9±7.1	39/30	44/28	26.8	25.6
Yang Liu[38]	2012	China	103	96	Retrospective study	53.48±8.50	54.36±7.82	57/46	58/38	24	24
Qunfeng Guo[39]	2011	China	43	53	Retrospective study	52.7±9.4	53.4±9.5	24/19	35/18	37.7±7.2	37.3±7.0
Qi Min[40]	2012	China	124	109	Retrospective study	53.48±8.5	53.68±7.8	69/55	61/48	24	24
Total			339	330							

ACDF = anterior cervical discectomy and fusion, HS = hybrid surgery.

follow-up angle of C2-C7 [$P = .15$, SMD = −5.75 (−13.51, 2.01); heterogeneity: $P = .007$, $I^2 = 86\%$, random-effect model, Fig. 2; $P = .62$, SMD = −0.98 (−4.85, 2.90); heterogeneity: $P = .08$, $I^2 = 68\%$, random-effect model, Fig. 3].

Table 2

The quality assessment according to the Newcastle–Ottawa Quality Assessment Scale (NOQAS) of each study.

Study	Selection	Comparability	Exposure	Total score
Yang Liu[37]	3	2	3	8
Yang Liu[38]	3	2	3	8
Qunfeng Guo[39]	2	2	3	7
Qi Min[40]	2	3	3	8

3.3.2. Fusion rate. Two studies[37,39] reported fusion rate between ACDF and HS. The meta-analysis showed that there was no significant difference between ACDF and HS in fusion rate [$P = .78$, OR = 1.66 95%CI (0.05, 54.51); heterogeneity: $P = .11$, $I^2 = 61\%$, random-effect model, Fig. 4].

3.3.3. Graft subsidence. Two studies[37,39] reported graft subsidence between ACDF and HS. The meta-analysis showed that there was no significant difference between ACDF and HS in graft subsidence [$P = .09$, OR = 0.16 95%CI (0.02, 1.30); heterogeneity: $P = .58$, $I^2 = 0\%$, fixed-effect model, Fig. 5].

3.4. Surgical outcomes

3.4.1. Blood loss. Two studies[37,39] reported blood loss between ACDF and HS. The meta-analysis showed that there

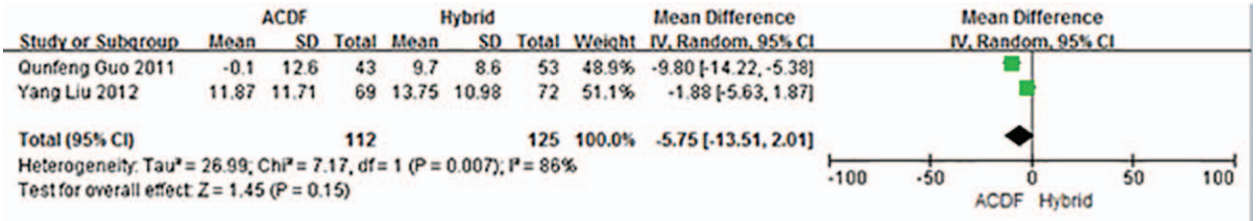

Figure 2. The standardized mean difference (SMD) estimate preoperative angle of C2–C7 in 2 groups. CI = confidence interval, df = degrees of freedom, M-H = Mantel–Haenszel, SMD = standardized mean difference.

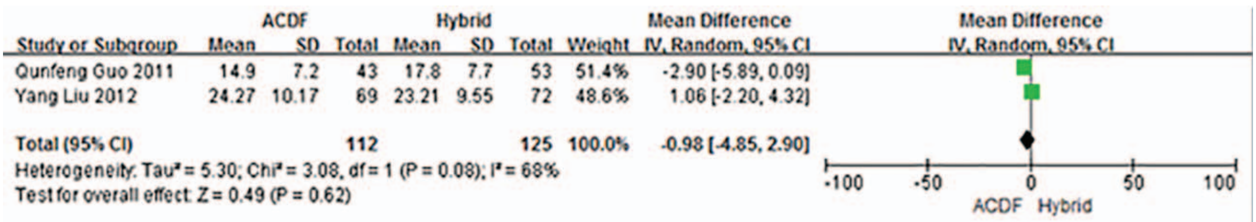

Figure 3. The standardized mean difference (SMD) estimate at the final follow-up angle of C2–C7 in 2 groups. CI = confidence interval, df = degrees of freedom, M-H = Mantel–Haenszel, SMD = standardized mean difference.

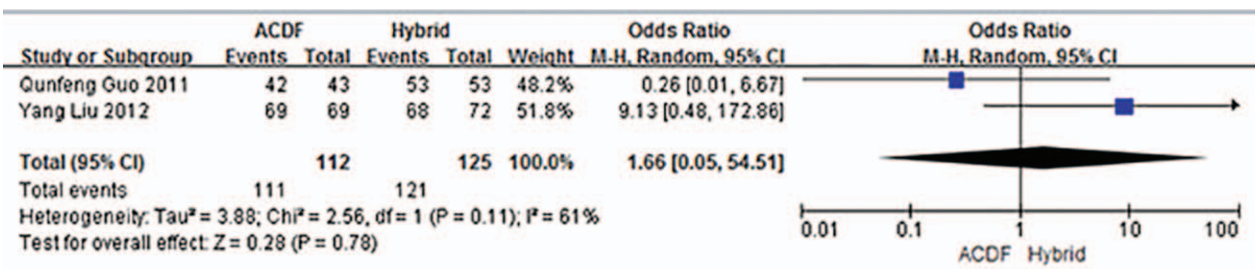

Figure 4. Forest plot showing fusion rate in 2 groups. CI = confidence interval, df = degrees of freedom, M-H = Mantel–Haenszel.

was significant difference between ACDF and HS in blood loss [$P < .00001$, SMD = −30.29 (−45.06, −15.52); heterogeneity: $P = .38$, $I^2 = 0\%$, fixed-effect model, Fig. 6].

3.4.2. Operation time. Two studies[37,39] reported operation time between ACDF and HS. The meta-analysis showed that there was no significant difference between ACDF and HS in operation time [$P = .82$, SMD = 2.63 (−19.62, 24.87); heterogeneity: $P = .0002$, $I^2 = 93\%$, random-effect model, Fig. 7].

3.4.3. Total complications. Four studies[37–40] reported number of total complications between ACDF and HS. The meta-analysis showed that there was significant difference between ACDF and HS in number of total complications [$P = .04$, OR = 0.66 95%CI (0.44, 0.98); heterogeneity: $P = .37$, $I^2 = 4\%$, fixed-effect model, Fig. 8].

3.4.4. C5 plasy. Four studies[37–40] reported C5 plasy between ACDF and HS. The meta-analysis showed that there was no

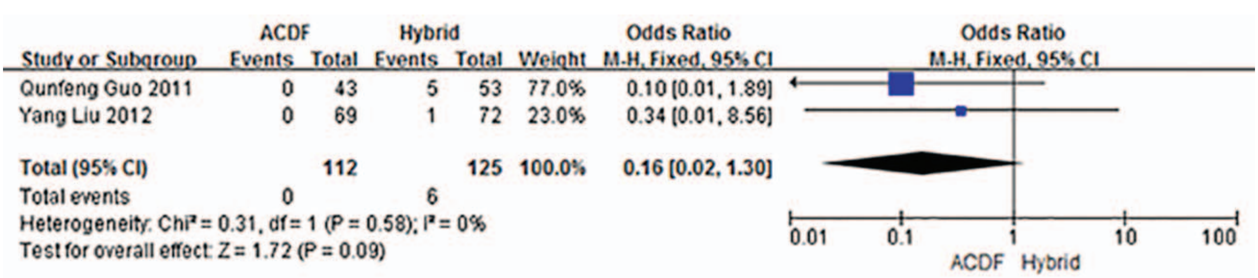

Figure 5. Forest plot showing graft subsidence in 2 groups. CI = confidence interval, df = degrees of freedom, M-H = Mantel–Haenszel.

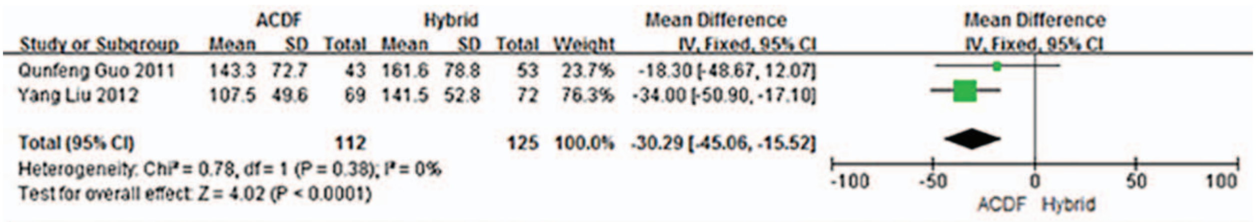

Figure 6. The standardized mean difference (SMD) estimate blood loss in 2 groups. CI = confidence interval, df = degrees of freedom, M-H = Mantel–Haenszel, SMD = standardized mean difference.

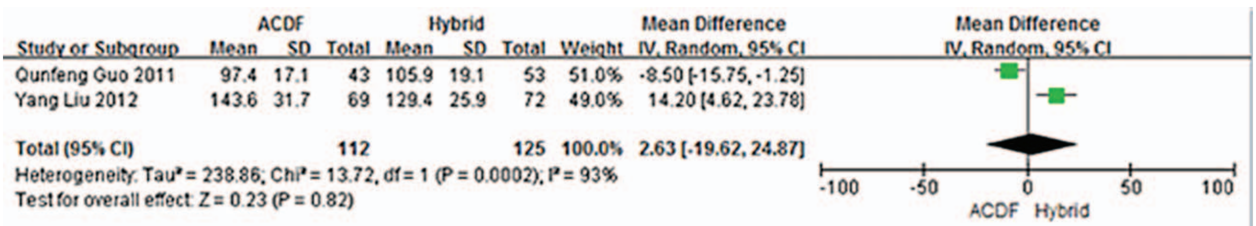

Figure 7. The standardized mean difference (SMD) estimate operation time in 2 groups. CI = confidence interval, df = degrees of freedom, M-H = Mantel–Haenszel, SMD = standardized mean difference.

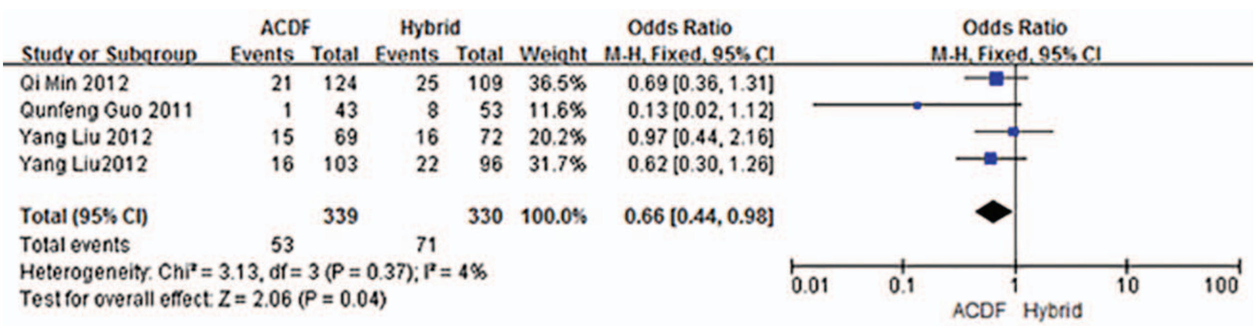

Figure 8. Forest plot showing total complications in 2 groups. CI = confidence interval, df = degrees of freedom, M-H = Mantel–Haenszel.

significant difference between ACDF and HS in C5 plasy [P = .09, OR = 0.48 95%CI (0.21, 1.11); heterogeneity: P = .85, I^2 = 0%, fixed-effect model, Fig. 9].

3.4.5. Infection. Three studies[37,38,40] reported infection between ACDF and HS. The meta-analysis showed that there was no significant difference between ACDF and HS in infection [P = .14, OR = 0.25 95%CI (0.04, 1.55); heterogeneity: P = .95, I^2 = 0%, fixed-effect model, Fig. 10].

3.4.6. Cerebral fluid leakage. Four studies[37–40] reported cerebral fluid leakage between ACDF and HS. The meta-analysis

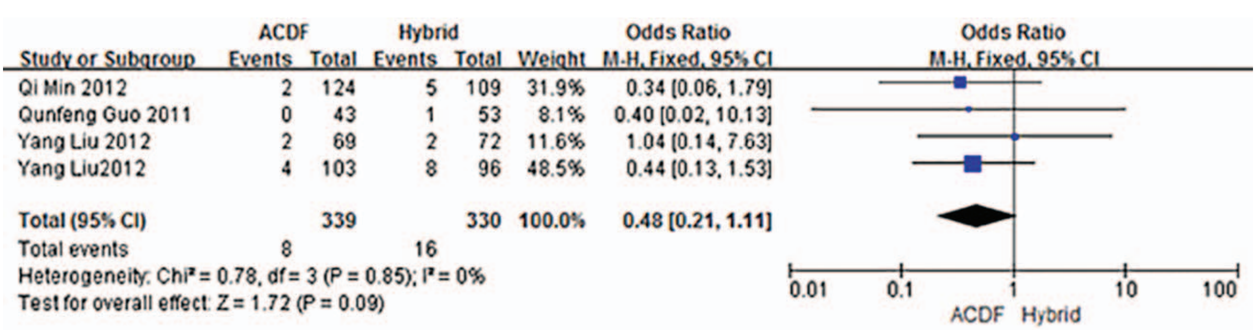

Figure 9. Forest plot showing C5 plasy in 2 groups. CI = confidence interval, df = degrees of freedom, M-H = Mantel–Haenszel.

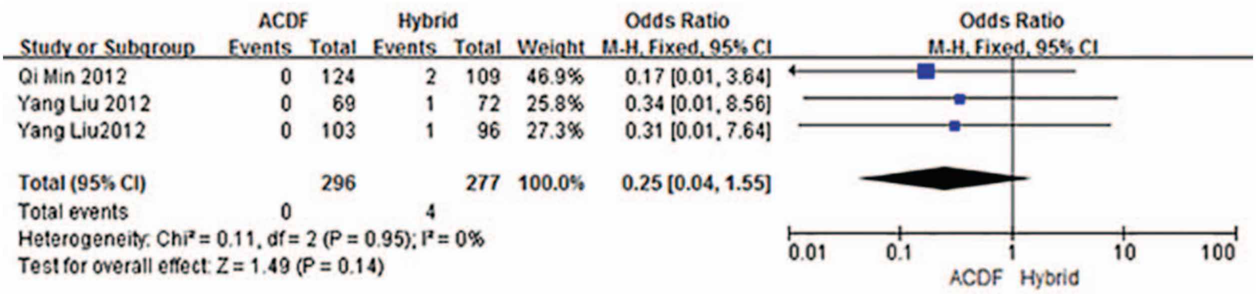

Figure 10. Forest plot showing infection in 2 groups. CI=confidence interval, df=degrees of freedom, M-H=Mantel–Haenszel.

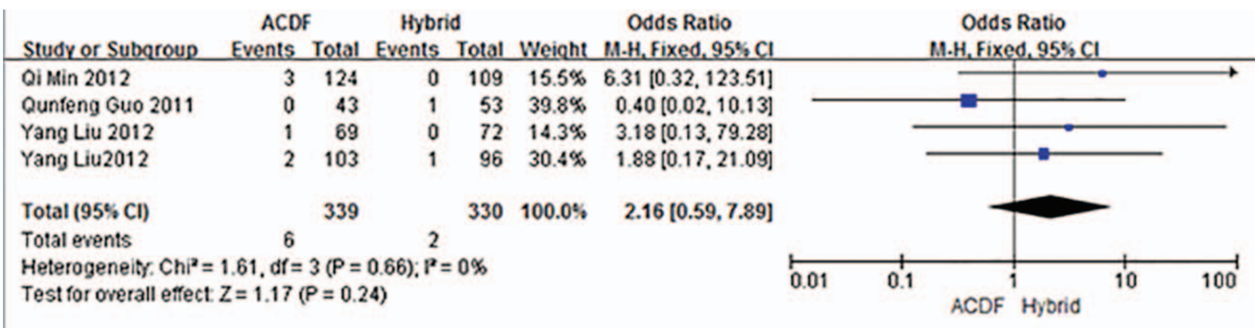

Figure 11. Forest plot showing cerebral fluid leakage in 2 groups. CI=confidence interval, df=degrees of freedom, M-H=Mantel–Haenszel.

showed that there was no significant difference between ACDF and HS in cerebral fluid leakage [$P=.24$, OR=2.16 95%CI (0.59, 7.89); heterogeneity: $P=.66$, $I^2=0\%$, fixed-effect model, Fig. 11].

3.4.7. Hoarseness. Three studies[37,38,40] reported hoarseness between ACDF and HS. The meta-analysis showed that there was no significant difference between ACDF and HS in hoarseness [$P=.45$, OR=1.42 95%CI (0.57, 3.53); heterogeneity: $P=.98$, $I^2=0\%$, fixed-effect model, Fig. 12].

3.4.8. Dysphagia. Three studies[37,38,40] reported dysphagia between ACDF and HS. The meta-analysis showed that there was no significant difference between ACDF and HS in dysphagia [$P=.45$, OR=1.27 95%CI (0.68, 2.37); heterogeneity: $P=.96$, $I^2=0\%$, fixed-effect model, Fig. 13].

3.4.9. Epidural hematoma. Two studies[37,39] reported epidural hematoma between ACDF and HS. The meta-analysis showed that there was no significant difference between ACDF and HS in epidural hematoma [$P=.90$, OR=1.14 95%CI (0.15, 8.34); heterogeneity: $P=.37$, $I^2=0\%$, fixed-effect model, Fig. 14].

3.4.10. Publication bias. After a detection of publication bias by STATA 12.0, but there was no publication bias found for all included studies (all $P>.05$).

4. Discussion

Up to now, surgical methods treated CSM for more than half a century. Regarding single-level CSM, the surgical option tends to agreement. however, as for multilevel, it remains debated.[41] In the 1960s, posterior approaches included laminectomy and laminoplasty as popular surgical option for mCSM.[24–26,42] But, the anterior approaches were widely used in recent years, which can provide directly decompression.[3–7,43] Nevertheless, it is difficult to avoid complications like graft migration, dysphagia, and so on.[44,45]

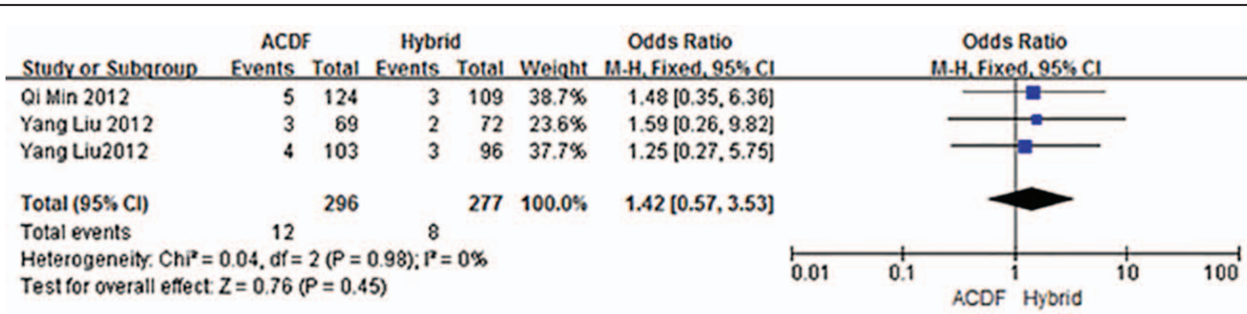

Figure 12. Forest plot showing hoarseness in 2 groups. CI=confidence interval, df=degrees of freedom, M-H=Mantel–Haenszel.

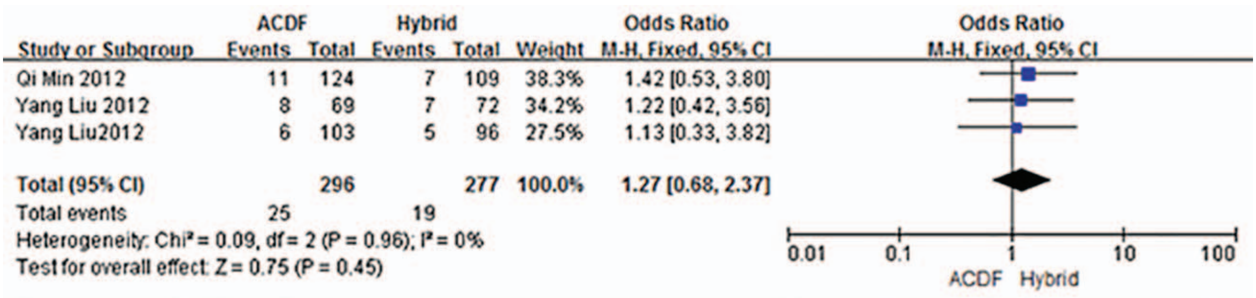

Figure 13. Forest plot showing dysphagia in 2 groups. CI=confidence interval, df=degrees of freedom, M-H=Mantel–Haenszel.

Recently, Liu et al[37] reported the comparison of 3 reconstructive techniques in the treatment for mCSM. In term of clinical outcomes, radiological parameters, and complication incidence, Liu believed that the hybrid surgery (1-level corpectomy plus 1-level discectomy) was the best alternative compared with ACDF and ACCF. Shamji et al[46] reviewed studies on the same topic, but concluded that all 3 operative approaches are effective strategies for the anterior surgical option of multilevel CSM. However, which surgery is the best option in the treatment of multilevel CSM remains unclear. Wen et al[33] and Han et al[34] performed a meta-analysis on comparison of surgical treatment for mCSM between ACDF and ACCF. They had the same conclusion that both ACDF and ACCF are effective option in treatment for mCSM. Nevertheless, no meta-analysis focused on the comparison between ACDF and HS for mCSM. The purpose of this meta-analysis is to compare radiographic outcomes and surgical outcomes of ACDF compared with HS in treatment for mCSM.

In this meta-analysis, we carried on strict eligibility criteria. Although no RCT studies were included in our study, all included studies had high quality according to the Newcastle Ottawa Quality Assessment Scale (NOQAS) and the baseline variables were similar. Thus, we considered the included reports suitable for meta-analysis. We assessed radiographic outcomes (Cobb angles of C2–C7, fusion rate and graft subsidence) and surgical outcomes (blood loss, operation time, dysphagia, hoarseness, C5 palsy, infection, cerebral fluid leakage, epidural hematoma and total complications) in the meta-analysis. The pooled results showed that there were no marked difference in radiographic outcomes, Cobb angles of C2–C7, fusion rate and graft subsidence between the 2 groups. Although in total complications and blood loss, ACDF were better than these of HS, both ACDF and HS were similar in operation time, dysphagia, hoarseness, C5 palsy, infection, cerebral fluid leakage and epidural hematoma.

In our meta-analysis of radiographic outcomes, we found that preoperative and the final follow-up Cobb angles of C2–C7 in ACDF and HS were similar. Cobb angles of C2–C7 at the final follow-up were significantly increased in 2 groups. Both could provide enough points of distraction and fixation except for the graft and interbody space shaping and restore alignment by pulling the involved vertebral bodies toward the lordotic ventral plate.[22–26,47–49]

We selected blood loss, operation time, and complication-related outcomes to evaluate surgical outcomes and found that ACDF were better in blood loss and total complications, while other variables including operation time, C5 plasy, dysphagia, hoarseness, infection, cerebral fluid leakage, and epidural hematoma were similar between the 2 groups. C5 palsy is considered as an important complication after cervical decompression surgery. Sakaura et al[50] reported the average incidence was 4.6% (range from 0 to 30%). But pathogenesis of C5 palsy remains unclear still now, multilevel corpectomy may lead to significant drift of spinal cord away ventral side. But both ACDF and HS had the same result in C5 plasy. There were similar rates of dysphagia and hoarseness in 2 groups. Dysphagia and hoarseness were common complications after multilevel anterior cervical surgery,[51] which may be caused by trachea and esophagus traction.[52]

There are several limitations of this study. First, no RCT study was included in our article; Second, we were unable to analyze some parameters, such as Japanese Orthopedic Association scores, because of small number of included studies, which may cause a high heterogeneity. We need more included articles in further study. Third, the follow-up of all included article is up to 2 years, which is not enough to observe the long-term recovery and complications. Fourth, we just searched English and Chinese articles on this topic. However, other articles could not be included in other languages due to difficulty in language translation.

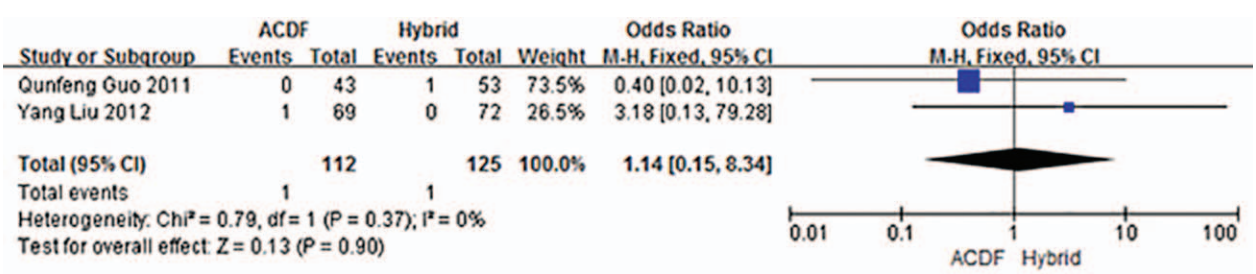

Figure 14. Forest plot showing epidural hematoma in 2 groups. CI=confidence interval, df=degrees of freedom, M–H=Mantel-Haenszel.

In summary, although, in term of total complications and blood loss, ACDF have more satisfactory efficacy in our meta-analysis. However, both ACDF and HS for multilevel CSM have effective surgical option. Future more studies with high methodological quality and long-term follow-up periods are needed to evaluate the 2 procedures for multilevel CSM treatment.

Author contributions

Authors' contributions—conceived and designed the study: ZCM; collected data: CQ, ZY; analyzed the data: HAB, ZW; wrote the paper: CQ and ZY.
Data curation: Wen-Yuan Ding, Qian Chen.
Formal analysis: Wen-Yuan Ding.
Methodology: Yu Zhang.
Visualization: Wen-Yuan Ding.
Writing – original draft: Chun-Ming Zhao, Ai-Bing Huang, Wei Zhang.

References

[1] Goffin J, Van LJ, Van CF, et al. A clinical analysis of 4- and 6-year follow-up results after cervical disc replacement surgery using the Bryan Cervical Disc Prosthesis. J Neurosurg Spine 2010;12:261–9.
[2] Lee SB, Cho KS, Kim JY, et al. Hybrid surgery of multilevel cervical degenerative disc disease: review of literature and clinical results. J Korean Neurosurg Soc 2012;52:452–8.
[3] Kang L, Lin D, Ding Z, et al. Artificial disk replacement combined with midlevel ACDF versus multilevel fusion for cervical disk disease involving 3 levels. Orthopedics 2013;36:e88–94.
[4] Hey HWD, Hong CC, Long AS, et al. Is hybrid surgery of the cervical spine a good balance between fusion and arthroplasty? Pilot results from a single surgeon series. Eur Spine J 2013;22:116–22.
[5] Shen C, Shen Y, Ding W, et al. Contrastive analysis of neck axial symptoms after hybrid surgery or traditional anterior cervical discectomy and fusion fortreatment of two-level cervical disease. Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi 2013;27:58–61.
[6] Grasso G. Clinical and radiological features of hybrid surgery in multilevel cervical degenerative disc disease. Eur Spine J 2015;24(suppl 7):842–8.
[7] Mao N, Wu J, Zhang Y, et al. A comparison of anterior cervical corpectomyand fusion combined with artificial disc replacement and cage fusion in patients with multilevel cervical spondylotic myelopathy. Spine (Phila Pa 1976) 2015;40:1277–83.
[8] Ding F, Jia Z, Wu Y, et al. Fusion-nonfusion hybrid construct versus anterior cervical hybrid decompression and fusion: a comparative study for 3-level cervical degenerative disc diseases. Spine (Phila Pa1976) 2014;39:1934–42.
[9] Cho BY, Lim J, Sim HB, et al. Biomechanical analysis of the range of motion after placement of a two-level cervical ProDisc-C versus hybrid construct. Spine (Phila Pa 1976) 2010;35:1769–76.
[10] Lee MJ, Dumonski M, Phillips FM, et al. Disc replacement adjacent to cervical fusion: a biomechanical comparison of hybrid construct versus two-level fusion. Spine (Phila Pa 1976) 2011;36:1932–9.
[11] Barrey C, Campana S, Persohn S, et al. Cervical disc prosthesis versus arthrodesis using one-level, hybrid and two-level constructs: an in vitro investigation. Eur Spine J 2012;21:432–42.
[12] Burkus JK, Traynelis VC, Haid RW, et al. Clinical and radiographic analysis of an artificial cervical disc: 7-year follow-up from the Prestige prospective randomized controlled clinical trial. J Neurosurg Spine 2014;21:516–28.
[13] Dan X, Ma XL, Ma JX, et al. A meta-analysis of cervical arthroplasty compared to anterior cervical discectomy and fusion for single-level cervical disc disease. J Clin Neurosci 2013;20:970–8.
[14] Fallah A, Akl EA, Ebrahim S, et al. Anterior cervical discectomy with arthroplasty versus arthrodesis for single-level cervical spondylosis: a systematic review and meta-analysis. PLoS One 2012;7:e43407.
[15] Stang A. Critical evaluation of the Newcastle–Ottawa scale for the assessment of the quality of nonrandomized studies in meta-analyses. Eur J Epidemiol 2010;25:603–5.
[16] Lian XF, Xu JG, Zeng BF, et al. Noncontiguous anterior decompression and fusion for multilevel cervical spondylotic myelopathy: a prospective randomized control clinical study. Eur Spine J 2010;19:713–9.
[17] Lawrence BD, Shamji MF, Traynelis VC, et al. Surgical management of degenerative cervical myelopathy: a consensus statement. Spine (Phila Pa 1976) 2013;38(22 Suppl 1):S171–2.
[18] Lawrence BD, Jacobs WB, Norvell DC, et al. Anterior versus posterior approach for treatment of cervical spondylotic myelopathy: a systematic review. Spine (Phila Pa 1976) 2013;38:S173–82.
[19] Smith GW, Robinson RA. The treatment of certain cervical-spine disorders by anterior removal of the intervertebral disc and interbody fusion. J Bone Joint Surg Am 1958;40-A:607–24.
[20] Cloward RB. The anterior approach for removal of ruptured cervical disks. J Neurosurg 2007;6:496–511.
[21] Lawrence BD, Brodke DS. Posterior surgery for cervical myelopathy: indications, techniques, and outcomes. Orthop Clin North Am 2012;43:29–40.
[22] Fengbin Y, Jinhao M, Xinyuan L, et al. Evaluation of a new type of titanium mesh cage versus the traditional titanium mesh cage for single-level, anterior cervical corpectomy and fusion. Eur Spine J 2013;22:2891–6.
[23] Gao R, Yang L, Chen H, et al. Long term results of anterior corpectomy and fusion for cervical spondylotic myelopathy. PLoS One 2012;7:e34811.
[24] Miyamoto H, Maeno K, Uno K, et al. Outcomes of surgical intervention for cervical spondylotic myelopathy accompanying local kyphosis (comparison between laminoplasty alone and posterior reconstruction surgery using the screw-rod system). Eur Spine J 2013;23:341–6.
[25] Sah S, Wang L, Dahal M, et al. Surgical management of cervical spondylotic myelopathy. JNMA J Nepal Med Assoc 2012;52:172–7.
[26] Umeda M, Sasai K, Kushida T, et al. A less-invasive cervical laminoplasty for spondylotic myelopathy that preserves the semispinalis cervicis muscles and nuchal ligament. J Neurosurg Spine 2013;18:545–52.
[27] Uehara M, Takahashi J, Ogihara N, et al. Cervical pedicle screw fixation combined with laminoplasty for cervical spondylotic myelopathy with instability. Asian Spine J 2012;6:241–8.
[28] Yang HL, Chen GD, Zhang HT, et al. Open-door laminoplasty with plate fixation at alternating levels for treatment of multilevel degenerative cervical disease. J Spinal Disord Tech 2013;26:E13–8.
[29] Kode S, Gandhi AA, Fredericks DC, et al. Effect of multilevel open-door laminoplasty and laminectomy on flexibility of the cervical spine: an experimental investigation. Spine (Phila Pa 1976) 2012;37:E1165–70.
[30] Mitsunaga LK, Klineberg EO, Gupta MC. Laminoplasty techniques for the treatment of multilevel cervical stenosis. Adv Orthop 2012;2012:307916.
[31] Hardman J, Graf O, Kouloumberis PE, et al. Clinical and functional outcomes of laminoplasty and laminectomy. Neurol Res 2010;32:416–20.
[32] Zhang J, Meng F, Ding Y, et al. Hybrid surgery versus anterior cervical discectomy and fusion in multilevel cervical disc diseases: a meta-analysis. Medicine (Baltimore) 2016;95:e3621.
[33] Wen ZQ, Du JY, Ling ZH, et al. Anterior cervical discectomy and fusion versus anterior cervical corpectomy and fusion in the treatment of multilevel cervical spondylotic myelopathy: systematic review and a meta-analysis. Ther Clin Risk Manag 2015;11:161–70.
[34] Han YC, Liu ZQ, Wang SJ, et al. Is anterior cervical discectomy and fusion superior to corpectomy and fusion for treatment of multilevel cervicalspondylotic myelopathy? A systemic review and meta-analysis. PLoS One 2014;9:e87191.
[35] Higgins JP, Thompson SG, Deeks JJ, et al. Measuring inconsistency in meta-analyses. BMJ 2003;327:557–60.
[36] Mantel N, Haenszel W. Statistical aspects of the analysis of data from retrospective studies of disease. J Natl Cancer Inst 1959;22:719–48.
[37] Liu Y, Hou Y, Yang L, et al. Comparison of 3 reconstructive techniques in the surgical management of multilevel cervical spondyloticmyelopathy. Spine (Phila Pa 1976) 2012;37:E1450–8.
[38] Liu Y, Qi M, Chen H, et al. Comparative analysis of complications of different reconstructive techniques following anterior decompression for multilevel cervical spondylotic myelopathy. Eur Spine J 2012;21:2428–35.
[39] Guo Q, Bi X, Ni B, et al. Outcomes of three anterior decompression and fusion techniques in the treatment of three-level cervical spondylosis. Eur Spine J 2011;20:1539–44.
[40] Min QI, Xinwei WANG, Yang LIU, et al. Comparative analysis of complications of different anterior decompression procedures for treating multilevel cervical spondylotic myelopathy. Chin J Spine Spinal Cord 2012;22:963–8.

[41] Papadopoulos EC, Huang RC, Girardi FP, et al. Three-level anterior cervical discectomy and fusion with plate fixation: radiographic and clinical results. Spine 2006;31:897–902.

[42] Chang SW, Kakarla UK, Maughan PH, et al. Four-level anterior cervical discectomy and fusion with plate fixation: radiographic and clinical results. Neurosurgery 2010;66:639–46.

[43] Bapat MR, Chaudhary K, Sharma A, et al. Surgical approach to cervical spondylotic myelopathy on the basis of radiological patterns of compression: prospective analysis of 129 cases. Eur Spine J 2008;17:1651–63.

[44] Anakwenze OA, Auerbach JD, Milby AH, et al. Sagittal cervi-cal alignmentafter cervical disc arthroplasty and anterior cervical discec-tomy and fusion: results of a prospective, randomized, con-trolled trial. Spine (Phila Pa 1976) 2009;34:2001–7.

[45] Liu T, Xu W, Cheng T, et al. Anterior versus posterior surgery for multilevel cervical myelopathy, which one is better? A systematic review. Eur Spine J 2011;20:224–35.

[46] Shamji MF, Massicotte EM, Traynelis VC, et al. Comparison of anterior surgical options for the treatment of multilevel cervical spondylotic myelopathy: asystematic review. Spine (Phila Pa 1976) 2013;38(22 suppl 1):S195–209.

[47] Park Y, Maeda T, Cho W, et al. Comparison of anterior cervical fusion after two-level discectomy or single-level corpectomy: sagittal alignment, cervical lordosis, graft collapse, and adjacent-level ossification. Spine J 2010;10:193–9.

[48] Uribe JS, Sangala JR, Duckworth EA, et al. Comparison between anterior cervical discectomy fusion and cervical corpectomy fusion using titanium cages for reconstruction: analysis of outcome and long-term follow-up. Eur Spine J 2009;18:654–62.

[49] Grob D, Luca A. Surgery for cervical stenosis: anterior cervical decompression, corpectomy, and fusion. Eur Spine J 2010;19: 1801–2.

[50] Sakaura H, Hosono N, Mukai Y, et al. C5 palsy after decompression surgery for cervical myelopathy: review of the literature. Spine (Phila Pa 1976) 2003;28:2447–51.

[51] Edwards CC, Heller JG, et al. Corpectomy versus laminoplasty for multilevelcervical myelopathy: an independent matched-cohort analysis. Spine 2002;27:1168–75.

[52] Apfelbaum RI, Kriskovich MD, Haller JR. On the incidence, cause, and prevention of recurrent laryngeal nerve palsies during anterior cervical spine surgery. Spine 2000;25:2906–12.