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ORIGINAL ARTICLE

Anterior versus posterior surgery for multilevel cervical myelopathy, which one is better? A systematic review

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Abstract The objective of the study is to perform a systematic review to compare the clinical outcomes and complications of anterior surgery with posterior surgery for multilevel cervical myelopathy (MCM). MEDLINE, EMBASE databases and other databases were searched for all the relevant original articles published from January 1991 to November 2009 comparing anterior with posterior surgery for MCM. Subgroup analysis was performed according to the follow-up years. The following end points were mainly evaluated: final follow-up JOA (Japanese Orthopaedic Association) scale, recovery rate and complication outcomes. Ten articles fulfilled all inclusion criteria. For multilevel CSM patients, the final follow-up JOA score for the anterior group was significantly higher than the posterior group ($p < 0.05$, WMD 0.83 [0.24, 1.43]) in the 'follow-up time $\leq$5 years' subgroup, but had no significant differences in the 'follow-up time >5 years' subgroup ($p > 0.05$). The recovery rate for the anterior group was significantly higher than the posterior group ($p < 0.05$, WMD 10.08 [1.39, 18.78]) in the 'follow-up time $\leq$5 years' subgroup. No study reported the recovery rate for the follow-up time >5 years. For multilevel OPLL patients, the final follow-up JOA score and recovery rate for the anterior group were both significantly higher than the posterior group in the 'follow-up time $\leq$5 years' subgroup ($p < 0.05$, WMD 2.50 [0.16, 4.85]; $p < 0.05$, WMD 29.48 [29.09, 29.87], respectively). One study [31] which mean follow-up time was 6 years was enrolled in the 'follow-up time >5 years' subgroup. The results showed there was no significant difference in final follow-up JOA score and recovery rate between anterior and posterior group for patients with occupying ratio of OPLL <60% ($p > 0.05$), while in patients with occupying ratio $\geq$60%, the final follow-up JOA score and recovery rate of anterior surgery were both superior to that of posterior surgery ($p < 0.05$). For both multilevel CSM and OPLL patients, the complications for the anterior group were significantly more than the posterior group in the 'follow-up time $\leq$5 years' subgroup ($p < 0.05$, OR 7.33 [2.96, 18.20] for CSM patients; $p < 0.05$, OR 4.44 [1.80, 10.98] for OPLL patients), but were similar to the posterior group in the 'follow-up time >5 years' subgroup ($p > 0.05$). In conclusion, anterior surgery had better clinical outcomes and more complications at the early stage after operation for both multilevel CSM and OPLL patients. At the late stage, posterior surgery had similar clinical outcomes and complications to anterior surgery for CSM patients, and OPLL patients with occupying ratio of OPLL <60%. While for

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OPLL patients with occupying ratio ≥60%, anterior surgery had superior clinical outcome to posterior surgery.

Keywords Multilevel cervical myelopathy · Surgery · Systematic review · Meta-analysis

Introduction

Cervical myelopathy is a common cause of spinal cord dysfunction in older persons all over the world. The treatment options of cervical myelopathy include conservative treatment or operative management. Operative management is indicated for most of the patients with clinically evident cervical myelopathy and it is recommended for patients who have either substantial or progressive impairment of neurological function without sustained remission [1, 2]. Surgery for cervical myelopathy involving one or two motion segments may be successfully performed with a low incidence of complications, and consensus favors anterior cervical decompression with fusion and instrumentation for this kind of patients [3], while surgical treatment for multilevel cervical myelopathy (MCM) of three or more levels is associated with less predictable outcomes and a higher frequency of complications [4–6].The optimal treatment for MCM continues to be the subject of considerable debate, and controversy always exists over using anterior or posterior surgery.

Although extensive research on the two approaches has been done [7–18], yet studies on the comparison of the two approaches are limited. Furthermore, a wide variation in patient population, study design and results exists. These factors make it difficult for workers in this field to know the exact value of the two approaches. Meta-analysis represents a powerful tool to summarize findings in the literature by taking into consideration and enabling analysis of differences between studies [19, 20]. Thus, the purpose of our study is to perform a systematic review to compare the anterior surgery with the posterior surgery for MCM by comparing the surgical outcomes, radiographic changes and complications of these two approaches.

Materials and methods

Literature search

A comprehensive computer literature search of abstracts about studies in human subjects was performed to identify articles about anterior and posterior surgery for MCM. The MEDLINE, EMBASE databases, from January 1991 to November 2009, were searched with the following keywords: ("cervical spondylotic myelopathy OR cervical myelopathy OR cervical spondylosis OR cervical stenosis OR ossification of the posterior longitudinal ligament") AND ("multisegment OR multilevel OR multi-level OR multi-segment") AND ("anterior OR posterior OR laminoplasty OR laminectomy OR corpectomy OR discectomy OR vertebrectomy OR spondylectomy OR surgical OR surgery OR dorsal OR ventral"). No language restrictions were applied.

Other databases, such as Web of Knowledge, EBSCO, Sciencedirect, Springlink, Scopus and The Cochrane Library, were also checked for relevant articles with the same keywords. We also searched the abstracts of American Academy of Orthopaedic Surgeons Annual Meeting (2006–2008: http://www.aaos.org/education/anmeet/libscip.asp). The list of articles was supplemented with extensive cross-checking of the reference lists of all retrieved articles.

Selection of studies

Two reviewers (L.T, X.W) independently assessed potentially eligible studies. The study selection was accomplished through two levels of study screening. At level 1 screening, abstracts were reviewed for the following exclusion criteria: case reports, letters, editorial, comments, reviews and articles that did not include raw data; follow-up period <30 days; no surgical intervention. Full articles were then obtained for all studies accepted at level 1 screening and for any citations for which a determination could not be made from the abstract. If the study was not reported in full journal publications, we contacted the authors for full text or additional information needed. For level 2 screening, the inclusion criteria were any randomized or quasi-randomized controlled clinical trials of anterior versus posterior surgery for MCM in adults. When data or subsets of data were presented in more than one article, the article with the most details or the most recent article was chosen. The studies were excluded when the results were presented in combination and could not be differentiated for performance assessment.

Data extraction

The same observers independently extracted relevant data from each article by using a standardized form. Observers were not blinded with regard to the information about the journal name, the authors, the authors' affiliation or year of publication, since this had been shown to be unnecessary [22]. To resolve disagreement between reviewers, a third reviewer (C.T.) assessed all discrepant items, and the majority opinion was used for analysis.

Common characteristics about studies: Author's country; year of publication; type of patient's disease; the number of patients for each group; the number of operative levels.

Study design characteristics about studies: A methodological quality assessment scheme used by Handoll [21] was used to extract relevant study design characteristics of each study. In this scheme, each item was graded either 'Y', '?', or 'N', respectively indicating that the quality criteria were met for the item ("yes"), or possibly or only partially met for the item ("Possible, partial"), or not met ("No").

Clinical characteristics about studies:

1. Baseline characteristics for each group: preoperative JOA score, age, duration of the symptoms, and others.
2. Outcome measures: we analyzed multilevel CSM and OPLL patients separately in perioperative data, clinical outcomes, and complication outcomes. For radiographic data, we analyzed them together.

(a) Perioperative data: operative time and blood loss. (b) Clinical outcomes: JOA scale [23] and recovery rate, which is defined according to the rationale of Hirabayashi [24] as recovery rate = (ε postoperative JOA scores-ε preoperative JOA scores/17-ε preoperative JOA scores) × 100%. The results were indicated by the recover rate as follows: 75% or more (excellent), 50–74% (good), 25–49% (fair), and <25% (poor) (we calculated excellent result and good result together as 'excellent to good' result, and fair result and poor result together as 'fair to poor' result). (c) Complication outcomes. (d) Radiographic outcomes: decrease rate of ROM (range of motion) from C2 to C7, alignment deterioration, change of anterior–posterior (AP) diameter of the narrowest spinal canal, change of regional Cobb's angle and change of overall Cobb's angle.

Timing of outcome assessment and subgroup analysis

The results were collected for the final follow-up time. Analysis of the outcomes was divided into two subgroups according to the time of outcome assessment if possible. One was the follow-up time ≤5 years and the other was the follow-up time >5 years.

Statistical analysis

Common characteristics were summarized using basic descriptive statistics (simple counts and means). Clinical characteristics were synthesized via meta-analytic pooling of each group results. Meta-analysis was performed in line with the recommendations from the Cochrane Collaboration and the Quality of Reporting of Meta-analyses Guidelines [25–27].

All analysis were performed using Microsoft Excel 2003 (Microsoft, Seattle, Wash), SPSS 13.0 for Windows (SPSS, Chicago, III), and RevMan5.0 (Review Manager (RevMan) [Computer program]. Version 5.0. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2008). RevMan5.0 is a freeware software produced by the Cochrane Collaboration, and could be downloaded from the website "http://www.cc-ims.net/RevMan/RevMan5".

Results

Literature search and selection of studies

After the computerized search was performed and reference lists were extensively cross-checked, about 370 abstracts were identified. Of these, 288 were rejected after level 1 screening (reviewing the abstracts).Of the remaining 82 articles, 72 relevant articles were excluded after we read the full texts or additional information of these articles because (1) the articles were not controlled clinical trails ($n = 48$), (2) the aim of the articles was not to compare the clinical outcome for anterior surgery with posterior surgery ($n = 12$), (3) the articles were about comparison for cervical myelopathy, but the clinical data of multi-level cervical myelopathy could not be extracted ($n = 8$), (4) the studies did not include raw data ($n = 4$). At last 10 articles [28–37] including 10 studies fulfilled all inclusion criteria and were selected for data extraction and analysis.

Common characteristics about studies

The studies took place in one of five countries [Japan (5), India (2), South Korea (1), Germany (1) and USA (1)]. They were mainly non-randomized controlled clinical trials except 1 cohort study. Five studies were focused on mutilevel cervical ossification of the posterior longitudinal ligament and the other five studies were focused on mutilevel cervical spondylotic myelopathy. Most operative techniques were corpectomy for anterior surgery and laminoplasty for posterior surgery. Table 1 presents specific operative techniques of anterior and posterior surgery in each study. There were total 561 patients in the selected studies and the age ranged from 30 to 75 years. Two hundred and twenty-one patients were treated by anterior surgery and 340 patients underwent posterior surgery. In five studies, the sex distribution was described: 201 patients were males and 97 patients were females. Table 2 presents the detail information about the common characteristics of the included data sets.

Study design characteristics

Most studies had a suboptimal design with regard to treatment concealment, the intention to treat analysis, and

Table 1 Specific operative techniques of anterior and posterior surgery in each study

Disease	Source	Anterior			Posterior		
		Type	Fusion	Instrumentation	Type	Fusion	Instrumentation
Operative technique							
CSM	Kristof et al. [28]	Ventral corpectomy	Autologous iliac crest	Yes	Laminectomy	Yes	Yes
CSM	Bapat et al. [30]	Discectomy or corpectomy or combination of the two	Iliac crest or cages	Partly	Laminectomy	Yes	NM
CM	Edwards et al. [34]	Corpectomy	Strut graft from iliac crest (1), allograft fibula (8) an autogenous fibula (4)	Anterior plate (11)	Open door laminoplasty (1), T-saw laminoplasty (10)	Yes	No
CSM	Wada et al. [35]	Subtotal corpectomy	Strut graft from iliac crest or fibula	No	Open door laminoplasty	Yes	No
CSM	Yonenobu et al. [37]	Subtotal corpectomy	Strut graft from iliac crest	No	Laminoplasty	Yes	No
OPLL	Lee et al. [29]	Corpectomy	Fibular bone allograft (15), cylindrically shaped mesh cages filled with cadaveric bone chips (5)	Yes	Laminoplasty	Yes	No
OPLL	Iwasaki et al. [31]	Subtotal corpectomy followed by total discectomy	Tricortical iliac crest autograft (9), fibular strut autograft (18)	Anterior plate (1)	Laminoplasty	Yes	No
OPLL	Jain et al. [32]	Corpectomy	Iliac crest bone graft	No	Laminectomy (12), open door laminoplasty (1)	N M	No
OPLL	Tani et al. [33]	Subtotal corpectomy and discectomy	Tricortical iliac crest autograft	Anterior plate (7)	Z-shaped laminoplasty (10), open door laminoplasty (1), spinous process splitting, laminoplasty (1)	Yes	No
OPLL	Goto and Gita [36]	Subtotal spondylectomy	Fibular grafting (partly)	No	Laminectomy laminoplasty	Yes	No

NM not mentioned

Table 2 Common characteristics about studies included in the systematic review

Source	Country	Published year	Study design	Disease	No. of patients			No. of levels (mean)	
					A	P	Total	A	P
Kristof et al. [28]	Germany	2009	NRCT	CSM	42	61	103	2	3
Bapat et al. [30]	India	2008	NRCT	CSM	20	25	45	3.0	3.2
Edwards et al. [34]	USA	2001	Cohort	CM	13	13	26	≥3	≥3
Wada et al. [35]	Japan	2001	NRCT	CSM	23	24	47	2.3	2.5
Yonenobu et al. [37]	Japan	1992	NRCT	CSM	41	42	83	2.5	2.6
Lee et al. [29]	South Korea	2008	NRCT	OPLL	20	27	47	3.4	5.5
Iwasaki et al. [31]	Japan	2007	NRCT	OPLL	27	66	93	3.0	5.7
Jain et al. [32]	India	2005	NRCT	OPLL	14	13	27	≥4	≥4
Tani et al. [33]	Japan	2002	NRCT	OPLL	14	12	26	3.2	5.6
Goto and Gita [36]	Japan	1995	NRCT	OPLL	7	57	64	≥3	≥3

NRCT non-randomized controlled clinical trial, *OPLL* multilevel cervical ossification of the posterior longitudinal ligament, *CSM* multilevel cervical spondylotic myelopathy, *MCM* multilevel cervical myelopathy, *No.* number

Table 3 Results of meta-analysis of baseline characteristics for anterior versus posterior surgery

Baseline characteristics	No. of studies	No. of patients	Statistical method	Effect of estimate (95% CI)	*P* value
1. Age	9	497	WMD	−2.73 [−4.81, −0.64]	<0.05[a]
2. Duration of the symptoms	8	404	WMD	0.81 [−1.80, 3.43]	>0.05
3. Preoperative JOA score	6	338	WMD	0.03 [−1.18,1.24]	>0.05
4. Follow-up time	9	404	WMD	0.08 [−0.12, 0.27]	>0.05

WMD weighted mean difference, *CI* confidence interval

[a] Statistically significant

double-blind (questions 1–3 and 5–6, 100% for "no" and "?"responses to these questions). However, as for baseline characteristics, inclusion and exclusion criteria and outcome measures, etc., most studies were optimally designed (100% for "yes" responses to question 9 and 10; 80% to question 4; 70% to question 7; 60% to question 8). Actually, questions 1–3 and 5–6 were more concerned with study method and questions 4 and 7–11 were more concerned with clinical data, so questions 4 and 7–11 were more important. If the studies were ideally designed according to these questions, the clinical result would be correct and credible.

Clinical characteristics about studies

Baseline characteristics

Most studies reported that the baseline characteristics, including age, duration of the symptoms, preoperative JOA score, and follow-up time, etc. were matched for each group. The results of the meta-analysis of these baseline characteristics showed that there was no significant difference between the anterior and posterior surgery in duration of the symptoms, preoperative JOA score and follow-up time. Although the age of the anterior group was significant younger than the posterior group ($p < 0.05$), the mean age for the two groups were both over 50 years, and the gap between the two groups for the majority of studies was <3 years. Therefore, it would not affect the clinical outcome. The results of the meta-analysis of the baseline characteristics for anterior versus posterior surgery were summarized in Table 3.

Outcome measures

For multilevel CSM patients (*a*) *Perioperative outcomes*: the operative time for the anterior group was significantly longer than the posterior group ($p < 0.05$, WMD 53.37, 95% CI [10.71, 96.04]). The operative blood loss for anterior group was significant more than the posterior group ($p < 0.05$, WMD 102.81 [42.46, 163.15]).

(*b*) *Clinical outcomes*: the final follow-up JOA score for the anterior group was significantly higher than the posterior group ($p < 0.05$, WMD 0.83 [0.24, 1.43]) in the 'follow-up time ≤5 years' subgroup, but had no significant differences in the 'follow-up time >5 years' subgroup ($p > 0.05$). In total, it was significantly higher for the anterior group than the posterior group too ($p < 0.05$, WMD 0.88 [0.31, 1.44]).

The recovery rate for the anterior group was significantly higher than the posterior group ($p < 0.05$, WMD 10.08 [1.39, 18.78]) in the 'follow-up time ≤5 years' subgroup. Because of no study reporting the recovery rate for the follow-up time >5 years, we could not analyse the recovery rate for the two groups in the 'follow-up time >5 years' subgroup.

Both the 'excellent to good' and 'fair to poor' result for the anterior group were not significantly different with the posterior group in the 'follow-up time ≤5 years' subgroup ($p > 0.05$). No study reporting the results for the follow-up time >5 years.

(*c*) *Complication outcomes*: the complications for the anterior group were significantly more than the posterior group in the 'follow-up time ≤5 years' subgroup ($p < 0.05$, OR 7.33 [2.96, 18.20]), but were similar to the posterior group ($p > 0.05$) in the 'follow-up time >5 years' subgroup. In total, it was significantly more than the posterior group too ($p < 0.05$, OR 2.97 [1.76, 5.00]).

The axial pain for the anterior group was similar to the posterior group ($p > 0.05$). As only two studies reported the result, we did not do subgroup analysis.

Table 4 shows the detail results of the meta-analysis of clinical and complication outcome measures for multilevel CSM patients.

For OPLL patients (*a*) *Perioperative outcomes*: only one study [31] reported the perioperative outcomes. The results showed mean operative time was 302 min (range 167–470 min) and mean blood loss was 513 g (range 70–1,730 g) for the anterior group. The corresponding values for the posterior group were 177 min (range 90-395 min) and 464 g (range 50-1,800 g), respectively. No direct comparison was done.

Table 4 Results of meta-analysis of clinical and complication outcome measures for anterior versus posterior surgery for multilevel CSM patients

Outcomes	No. of studies	No. of patients	Statistical method	Effect of estimate (95% CI)[b]	*P* value
1. Operative time	4	217	WMD	53.37 [10.71, 96.04]	0.05[a]
2. Operative blood loss	4	217	WMD	102.81 [42.46, 163.15]	0.05[a]
3. The final follow-up JOA score	4	222	WMD	0.88 [0.31, 1.44]	0.05[a]
3.1. Follow-up time <5 years	3	175	WMD	0.83 [0.24, 1.43]	0.05[a]
3.2. Follow-up time >5 years	1	47	WMD	1.20 [−0.46, 2.86]	0.05
4. Recovery rate (%) follow-up time <5 years	2	128	WMD	10.08 [1.39, 18.78]	0.05[a]
5. Excellent to good' result follow-up time <5 years	2	71	OR	1.14 [0.37, 3.49]	0.05
6. Fair to poor' result follow-up time < 5 year	2	71	OR	0.88 [0.28, 2.76]	0.05
7. The alignment deterioration	2	139	OR	0.68 [0.22, 2.06]	0.05
8. Complications	5	204	OR	2.97 [1.76, 5.00]	0.05[a]
8.1. Follow-up time < 5 year	3	154	OR	7.33 [2.96, 18.20]	0.05[a]
8.2. Follow-up time > 5 years	2	150	OR	1.66 [0.84, 3.27]	0.05
9. Axial pain	2	73	OR	0.49 [0.18, 1.33]	0.05

WMD weighted mean difference, *OR* odds ratio, *CI* confidence interval

[a] Statistically significant

[b] Effect estimate. If effect estimate is positive (>0), it means anterior group is more than posterior group. If it is negative (<0), it means anterior group is less than posterior group; whether it is significant lies on *P* value

(*b*) *Clinical outcomes*: the final follow-up JOA score and recovery rate for the anterior group were both significantly higher than the posterior group ($p < 0.05$, WMD 2.50 [0.16, 4.85]; $p < 0.05$, WMD 29.48 [29.09, 29.87], respectively) in the 'follow-up time ≤5 years' subgroup. One study [31] which mean follow-up time was 6 years was enrolled in the 'follow-up time >5 years' subgroup. The results showed there was no significant difference in final follow-up JOA score and recovery rate between anterior and posterior group for patients with occupying ratio of OPLL <60% ($p > 0.05$), while for patients with occupying ratio ≥60%, the final follow-up JOA score and recovery rate of anterior surgery was superior to that of posterior surgery ($p < 0.05$).

The 'excellent to good' result for the anterior group was significantly better than the posterior group in the 'follow-up time ≤5 years' subgroup ($p < 0.05$ OR 3.38 [1.06, 10.84]), but there were no significant differences between the two groups in the 'follow-up time >5 years' subgroup and in total ($p > 0.05$) too. The 'fair to poor' result for the anterior group was not significantly different with the posterior group in the 'follow-up time ≤5 years' subgroup, in the 'follow-up time > 5 years' subgroup and in total ($p > 0.05$).

(*c*) *Complication outcomes*: the complications for the anterior group were significantly more than the posterior group in the 'follow-up time ≤5 years' subgroup ($p < 0.05$, OR 4.44 [1.80, 10.98]), but were similar to the posterior group ($p > 0.05$) in the 'follow-up time >5 years' subgroup. In total, it was significantly more than the posterior group too ($p < 0.05$, OR 3.12 [1.60, 6.07]).

Table 5 shows the detail results of the meta-analysis of clinical and complication outcome measures for multilevel OPLL patients.

The main complications for the anterior group were graft complications, dysphagia and dysphonia for CSM patients and CSF leakage and graft complications for OPLL patients. The complications for the posterior group were similar between OPLL patients and CSM patients, which were mainly C5 root palsy (Table 6) displays complications for anterior and posterior surgery in each study.

(*d*) *Radiographic outcomes*: three studies [29, 34, 35] reported the mean decrease rate of ROM. However, as they all did not report the standard deviation, we could not do meta-analysis for it. Two studies [29, 34] which mean follow-up time were <50 months both showed that the decrease rate of ROM for the anterior group was more than the posterior group, while they also reported there were no statistic different ($p > 0.05$). However, the other study [35] which mean follow-up time was longer than 11 years showed that the decrease rate of ROM for the anterior group was significantly less than the posterior group ($p < 0.05$). Table 7 shows the detail result of mean decrease rate of ROM.

The alignment deterioration for the anterior group was similar to the posterior group ($p > 0.05$). However as only two studies [31, 35] reported the result, we did not do subgroup analysis.

Table 5 Results of meta-analysis of clinical and complication outcome measures for anterior versus posterior surgery for multilevel OPLL patients

Outcomes	No. of studies	No. of patients	Statistical method	Effect of estimate (95% CI)[b]	*P* value
1. The final follow-up JOA score follow-up time <5 years	2	126	WMD	1.99 [−1.23, 5.21]	0.05[a]
2. Recovery rate (%) follow-up time <5 years	3	117	WMD	29.48 [29.09, 29.87]	0.05[a]
3. Excellent to good' result	3	146	OR	1.27 [0.63, 2.54]	0.05
3.1 Follow-up time <5 years	2	53	OR	3.38 [1.06, 10.84]	0.05[a]
3.2 Follow-up time >5 years	1	93	OR	0.67 [0.27, 1.67]	0.05
4. Fair to poor result	3	146	OR	0.56 [0.13, 2.42]	0.05
4.1. Follow-up time <5 years	2	53	OR	0.29 [0.05, 1.58]	0.05
4.2. Follow-up time >5 years	1	93	OR	1.50 [0.60, 3.72]	0.05
5. Complications	3	193	OR	3.12 [1.60, 6.07]	0.05[a]
5.1. Follow-up time <5 years	2	100	OR	4.44 [1.80, 10.98]	0.05[a]
5.2. Follow-up time >5 years	1	93	OR	1.89 [0.67, 5.34]	0.05

WMD weighted mean difference, *OR* odds ratio, *CI* confidence interval

[a] Statistically significant

[b] Effect of estimate. If effect estimate is positive (>0), it means anterior group is more than posterior group. If it is negative (<0), it means anterior group is less than posterior group; whether it is significant lies on *P* value

Table 6 Complications for anterior and posterior surgery in each study

Source	Disease	Complications	
		Anterior	Posterior
Kristof et al. [28]	CSM	Overall complications (17), radiculopathy (5), hoarseness, dysphagia (3), wound infection (1), hardware failure (7), pneumonia (1), sepsis (2), irreversible sepsis (2), operative mortality (2)	Overall complications (22), radiculopathy (12), wound infection (4), hardware failure (4), pneumonia (3), renal failure (2), irreversible radiculopathy (4), operative mortality (1)
Bapat et al. [30]	CSM	Malpositioned implant (1), graft site pain (4), permanent r laryngeal nerve palsy (1), adjacent segment degeneration (1),(symptomatic), >3 months dysphagia (1), dysphonia (1)	C5 radiculopathy (1), transient deltoid paresis (1), postoperation death (myocardial infarction) (1)
Edwards et al. [34]	CM	Myelopathy progression (1), pseudarthrosis (1), subjacent ankylosis (1), persistent dysphagia (4), persistent dysphonia (2)	HNP/radiculopathy (1)
Wada et al. [35]	CSM	Graft dislodgement (2), fracture (1), pseudarthrosis (6), esophageal fistula (1)	C5 root palsy (4)
Yonenobu et al. [37]	CSM	Graft complication (10) (including dislodgement, fracture and nonunion), esophageal fistula (1), betralissbesis (1)	C5 root transient paralysis (3)
Lee et al. [29]	OPLL	Graft protrusion (1), screw backout (2), mesh cage and pedicle screw (2), mesh cage and CSF leakage (1), CSF leakage, C7 fracture, mesh cage and pedicle screw (1)	Right ulnar nerve radiculopathy (1), CSF leakage (1), C5–C6 radiculopathy (2), CSF leakage, right ulnar nerve radiculopathy (1)
Iwasaki et al. [31]	OPLL	Transient motor weakness in the left lower extremity (1), C5 segment palsy (1), graft extrusion (2), pseudarthrosis (2), late neurologic deterioration (2)	Transient motor paresis in the upper extremity (6), persistent neuropathic arm pain (5), transient deterioration of myelopathy (1)
Jain et al. [32]	OPLL	CSF leak (3), Graft-extrusion (1), Respiratory distress (1), Dysphagia (1), Deterioration in power in all limbs (2)	Worsen in power in all limbs but improved to preoperative status progressively (1)
Tani et al. [33]	OPLL	CSF leak (3), graft-extrusion (1), hoarseness (3), sensory symptoms in the distribution of the lateral femoral cutaneous nerve and gastrointestinal hemorrhage (2)	Late deterioration (1), unilateral deltoid pain (2), increased numbness of the hands (1)
Goto and Gita [36]	OPLL	Not mentioned	Not mentioned

Table 7 Mean decrease rate of ROM for anterior versus posterior surgery

Study	Edwards et al. [34]		Lee et al. [29]		Wada et al. [35]	
	Corpectomy and fusion with instrumentation	Laminoplasty and fusion	Corpectomy and fusion with instrumentation	Laminoplasty and fusion	Corpectomy and fusion without instrumentation	Laminoplasty and fusion
Item						
Follow-up time	49 months	40 months	21.8 months	29.1 months	15 years	11 years
Number of patients	13	13	20	27	23	24
Mean decrease rate of ROM	56.8	38.5	54.2	44.5	51.3	71.1
P value	>0.05		>0.05		<0.05[a]	

ROM range of motion from C2 to C7

[a] Statistically significant

Only one study [29], which follow-up time <50 months reported the mean change of anterior–posterior (AP) diameter of the narrowest spinal canal and mean change of regional Cobb's angle for the two groups. The mean change in the AP diameter was 9.1 mm for anterior surgery and 4.11 mm for posterior surgery ($p < 0.05$). The mean change in the regional Cobb's angle was 1.7° and −3.1°, respectively ($p > 0.05$). Two studies [28, 29] reported the mean change in the overall Cobb's angle was similar for the two groups ($p > 0.05$).

Discussion

The results of this systematic review have shown that for both multilevel CSM and OPLL patients compared with posterior surgery, anterior surgery had longer operative time, more operative blood loss. Anterior surgery had higher final follow-up JOA score and higher recovery rate with more complications in "follow-up time ≤5 years" subgroup. In "follow-up time >5 years" subgroup, complications were similar between the two groups. Anterior surgery had similar final follow-up JOA score with posterior surgery for CSM patients and OPLL patients with occupying ratio of OPLL <60%, while in OPLL patients with occupying ratio ≥60%, anterior surgery had superior final follow-up JOA score and recovery rate to posterior surgery.

In this systematic review, no language restrictions were applied and we chose lots of keywords and searched as more databases as possible to search all relevant articles in the world to avoid selection bias. To minimize bias in the selection of studies and data extraction, reviewers independently selected articles on the basis of inclusion criteria and extracted characteristics by using a standardized form. Any disagreement was resolved by discussion.

To do an ideal systematic review, we would better enroll randomized controlled trials (RCT) with homogeneity. However, in practice, RCT is very rare, especially for surgery [38, 39]. In this systematic review, all the studies selected were not RCT, while it did not influence the credibility of the results. Because almost all the studies reported the baseline characteristics were matched for each group and the results for the meta-analysis of baseline characteristics also showed no significant difference between the two groups.

Most patients with cervical myelopathy have pre-existing cervical spinal stenosis and then are affected by progressive cervical spondylosis or ossification of the posterior longitudinal ligament which compress the spinal cord anteriorly. When the cervical spinal canal diameter is reduced, the amount of room available for the spinal cord decreased. Then, when the cervical spine is in hyperextension, the result is buckling of the ligamentum flavum posteriorly, and the cord may become compressed against an anterior osteophyte or ossification lesion.

The advantage for anterior surgery is that it is more radical than posterior surgery in decompressing the nerve tissue by directly removing all of the anterior pathogenic structures such as protruded discs, osteophyte or ossification lesion. With grafting, immediate stability of cervical spine can be achieved. In addition, with anterior stabilization, there is no longer concern over buckling of ligamentum flavum posteriorly. In our systematic review, it was shown that during the early stage, the anterior surgery was significantly better than posterior in the final follow-up JOA score and the recovery rate. Anterior surgery had better clinical outcomes. However, we also found that during the late stage, there was no statistically difference in the final follow-up JOA score, "excellent to good" result, and "fair to poor" result between anterior surgery and posterior surgery except OPLL patients with occupying ratio ≥60%. It indicated that these two procedures were generally identical with respect to long-term clinical outcomes. That is possibly because late deterioration secondary to degenerative changes at the adjacent levels after anterior surgery [40, 41].

Another important disadvantage of anterior surgery is it leads to more surgical complications than posterior surgery at early stage after operation. For CSM patients, the main complications for anterior group were complications related to bone grafting, causing major concern during the postoperative course, dysphagia and dysphonia. For OPLL patients, the main complications for anterior group were CSF leakage and also complications related to bone grafting. The main complication for the posterior group between OPLL patients and CSM patients was both C5 root palsy. The cause of this complication maybe tethering of the nerve roots by fibrosis or spondylotic changes at the root canal and such tethering plus ventral or dorsal shift of the spinal cord after decompression would exert traction on the root or rootlet leading to intractable pain and paralysis [42].

As for posterior surgery, it is more concerned about "total decompression effect" resulting from posterior shift of spinal cord. It decompresses the nerve tissue indirectly. From this systematic review, we can see posterior surgery had identical long-term clinical outcomes to anterior surgery for CSM patients and OPLL patients with occupying ratio of OPLL <60%. While, in patients with occupying ratio ≥ 60%, it had inferior outcome. The results indicated the indirectly decompression was effective for most cervical myelopathy patients, but if anterior pathogenic structures were too big, the effectiveness was limited. In this condition, anterior surgery or combination of the two approaches is better. Preoperative cervical alignment is another important factor for selection of posterior surgery. In general, cervical kyphosis patients are not suitable for posterior surgery.

Besides anterior surgery and posterior surgery, anteroposterior surgery combining the anterior and posterior approaches is another option for MCM. Sometimes, it is optimal correction of deformity and fusion. The most appropriate use of this combined approach may be in the setting of severe multilevel spondylosis and stenosis requiring more than three inter-vertebral decompressions or two vertebrectomies, multilevel spondylosis and substantial kyphosis, and post-traumatic or post-laminectomy kyphosis [3]. As no controlled study is concerned with anteroposterior surgery for MCM, anteroposterior surgery was not included in this systematic review.

The limitation of this study is relatively small number of qualified studies, especially the studies with long follow-up time (>10 years). Another limitation is most studies did not report preoperative cervical alignment (kyphosis or lordosis) very clearly except Iwasaki [31], in whose study anterior group included 15 lordotic, 7 straight and 5 kyphotic patients and posterior group included 32 lordotic, 29 straight and 5 kyphotic patients. The other limitation of this study is although we used lots of methods to avoid selection bias, 5 of the 10 papers enrolled were from Japan, only 1 paper from the USA and 1 paper from Germany. Thus, this analysis may have regional bias.

On the basis of the results of this systematic review, we can conclude that anterior surgery had better clinical outcomes and more complications at the early stage after operation for both multilevel CSM and OPLL patients. At the late stage, posterior surgery had similar clinical outcomes and complications to anterior surgery for CSM patients, and OPLL patients with occupying ratio of OPLL <60%, while for OPLL patients with occupying ratio ≥60%, anterior surgery had superior clinical outcome to posterior surgery.

Appendix

See Tables 8 and 9.

Table 8 Methodological quality assessment scheme

Questions	Scores		
	Yes	?	N
(1) Was the assigned treatment adequately concealed prior to allocation	Method did not allow disclosure of assignment	Small but possible chance of disclosure of assignment or unclear	Quasi-randomised, or open list or tables
(2) Were the outcomes of participants who withdrew described and included in the analysis (intention to treat)?	Withdrawals well described and accounted for in analysis	Withdrawals described and analysis not possible, or probably no withdrawals	No mention, inadequate mention, or obvious differences and no adjustment

Table 8 continued

Questions	Scores		
	Yes	?	N
(3) Were the outcome assessors blinded to treatment status?	Effective action taken to blind assessors	Small or moderate chance of unblinding of assessors, or some blinding of outcomes attempted	Not mentioned or not possible
(4) Were important baseline characteristics reported and comparable?	Good comparability of groups, or confounding adjusted for in analysis	Confounding small, mentioned but not adjusted for, or comparability reported in text without confirmatory data	Large potential for confounding, or not discussed
(5) Were the trial participants blind to assignment status after allocation?	Effective action taken to blind participants	Small or moderate chance of unblinding of participants	Not possible, or not mentioned (unless double-blind), or possible but not done
(6) Were the treatment providers blind to assignment status?	Effective action taken to blind treatment providers	Small or moderate chance of unblinding of treatment providers	Not possible, or not mentioned (unless double-blind), or possible but not done
(7) Were care programmes, other than the trial options, identical?	Care programmes clearly identical	Clear but trivial differences, or some evidence of comparability	Not mentioned or clear and important
(8) Were the inclusion and exclusion criteria for entry clearly defined?	Clearly defined (including type of fracture)	Inadequately defined	Not defined
(9) Were the outcome measures used clearly defined?	Clearly defined	Inadequately defined	Not defined
(10) Were the accuracy and precision, with consideration of observer variation, of the outcome measures adequate; and were these clinically useful and did they include active follow up?	Optimal	Adequate	Not defined, not adequate
(11) Was the timing (e.g. duration of surveillance) clinically appropriate?	Optimal. (>1 year)	Adequate. (6 months–1 year)	Not defined, not adequate (<6 months)

Table 9 Study design characteristics of the included data sets

Study	Scores												
	Wada et al. [35]	Lee et al. [29]	Edwards et al. [34]	Bapat et al. [30]	Yonenobu et al. [37]	Goto and Gita [36]	Tani et al. [33]	Jain et al. [32]	Iwasaki et al. [31]	Kristof et al. [28]	N	?	Y
Question													
Question (1)	N	N	N	N	N	N	N	N	N	N	10	0	0
Question (2)	?	?	?	?	?	?	?	?	?	?	0	10	0
Question (3)	N	N	N	N	N	N	N	N	N	N	10	0	0
Question (4)	Y	Y	Y	?	Y	?	Y	Y	Y	Y	0	2	8
Question (5)	N	N	N	N	N	N	N	N	N	N	10	0	0
Question (6)	N	N	N	N	N	N	N	N	N	N	10	0	0
Question (7)	Y	Y	Y	?	Y	?	Y	Y	Y	?	0	4	7
Question (8)	Y	?	Y	Y	Y	?	Y	?	Y	?	0	4	6

Table 9 continued

Study	Scores											
	Wada et al. [35]	Lee et al. [29]	Edwards et al. [34]	Bapat et al. [30]	Yonenobu et al. [37]	Goto and Gita [36]	Tani et al. [33]	Jain et al. [32]	Iwasaki et al. [31]	Kristof et al. [28]	N	?	Y
Question (9)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	0	0	10
Question (10)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	0	0	10
Question (11)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	0	0	10

Questions 1–11 was the 11 questions in the methodological quality assessment scheme [21]

Data were the responses to these questions for each article and the number of response “N”, “?”, “Y” for each question

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