Anterior corpectomy versus posterior laminoplasty for multilevel cervical myelopathy: a systematic review and meta-analysis

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Abstract

Background Surgical strategy for multilevel cervical myelopathy resulting from cervical spondylotic myelopathy (CSM) or ossification of posterior longitudinal ligament (OPLL) still remains controversial. There are still questions about the relative benefit and safety of direct decompression by anterior corpectomy (CORP) versus indirect decompression by posterior laminoplasty (LAMP).

Objective To perform a systematic review and meta-analysis evaluating the results of anterior CORP compared with posterior LAMP for patients with multilevel cervical myelopathy.

Methods Systematic review and meta-analysis of cohort studies comparing anterior CORP with posterior LAMP for the treatment of multilevel cervical myelopathy due to CSM or OPLL from 1990 to December 2012. An extensive search of literature was performed in Pubmed, Embase, and the Cochrane library. The quality of the studies was assessed according to GRADE. The following outcome measures were extracted: pre- and postoperative Japanese orthopedic association (JOA) score, neurological recovery rate (RR), surgical complications, reoperation rate, operation time and blood loss. Two reviewers independently assessed each study for quality and extracted data.

Subgroup analysis was conducted according to the mean number of surgical segments.

Results A total of 12 studies were included in this review, all of which were prospective or retrospective cohort studies with relatively low quality. The results indicated that the mean JOA score system for cervical myelopathy and the neurological RR in the CORP group were superior to those in the LAMP group when the mean surgical segments were <3, but were similar between the two groups in the case of the mean surgical segments equal to 3 or more. There was no statistical difference in the surgical complication rate between the two groups when the mean surgical segments <3, but were significantly higher incidences of surgical complications and complication-related reoperation in the CORP group compared with the LAMP group in the case of the mean surgical segments equal to 3 or more. Besides, the operation time in the CORP group was longer than that in the LAMP group, and the average blood loss was significantly more in the CORP group compared with the LAMP group.

Conclusion Based on the results above, anterior CORP and fusion is recommended for the treatment of multilevel cervical myelopathy when the involved surgical segments were <3. Given the higher rates of surgical complications and complication-related reoperation and the higher surgical trauma associated with multilevel CORP, however, it is suggested that posterior LAMP may be the preferred method of treatment for multilevel cervical myelopathy when the involved surgical segments were equal to 3 or more. In addition, taking the limitations of this study into consideration, it was still not appropriate to draw a strong conclusion claiming superiority for CORP or LAMP. A well-designed, prospective, randomized controlled trial is necessary to provide objective data on the clinical results of both procedures.

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Introduction

Multilevel cervical myelopathy is frequently related to the multilevel constriction of cervical cord due to CSM or OPLL. The natural course without surgical treatment is generally poor in the neurological deficit. On the contrary, a stabilization of neurological deficit or even recovery may be obtained through surgical decompression in majority of patients [1]. The two main surgical strategies used for the treatment of multilevel cervical myelopathy are anterior decompression via CORP and posterior decompression via LAMP. However, there is considerable controversy over which surgical approach will receive the best clinical outcome for the minimum cost.

With respect to anterior CORP, it has been advocated in the situation that the ventral constriction of spinal cord should be removed to obtain sufficient decompression, especially when the spinal canal is narrow severely or the local protrusion is massive [2]. The anterior CORP can receive a direct decompression of myelopathy levels by resecting the ventral constriction. Besides, anterior intervertebral fusion after CORP can establish a cervical stability that is conducive to relieve pressure on the level of compressed cervical cord. However, results of anterior CORP have varied due to insufficient decompression resulting from ossification of the dura or massive bleeding from the epidural space. Moreover, the difficulties for anterior approach not only lie in decompression process, but also in the reconstruction of cervical spine after multilevel CORP, which requires high skill level for surgeon and more bone grafts for fusion. Besides, the surgical trauma and incidence of complications significantly increase with the number of involved segments when anterior surgical approaches are used. [3].

As for posterior LAMP, it was first described by Tsuji [4] and had been developed to address multilevel cervical compressive myelopathy caused by CSM or OPLL. Compared with anterior CORP, the posterior LAMP is less technically demanding. The indirect decompression via posterior LAMP and the cervical lordosis alignment allow the spinal cord floating away from ventral compression. Whereas, if posterior shift of the cord is not sufficient, ventral constriction of the cord may persist, leading to diminished recovery from myelopathy. In particular, it does not always produce the expected space for a massive ossified protrusion, which causes a highly narrowed spinal canal. In addition, the problem of postoperative cervical

malalignment and axial pain symptom remains to be solved after LAMP [5, 6].

On account of no standards or guidelines existing for the treatment of multilevel cervical myelopathy due to CSM or OPLL, this systematic review and meta-analysis was performed according to MOOSE guidelines [7] to assess the clinical results of anterior CORP compared with posterior LAMP for patients with multilevel cervical myelopathy in terms of neurological recovery, surgical complications, reoperation rate and surgical trauma.

Materials and methods

Search strategy

An extensive search of literature was performed in Pubmed, Embase, and the Cochrane library with medical subject headings (MeSH) complemented with a free text search. MeSH of Pubmed and EMBASE used the following terms: cervical myelopathy and CORP, cervical myelopathy and LAMP, cervical myelopathy and decompression, cervical myelopathy and surgical, cervical stenosis and CORP, cervical stenosis and LAMP, cervical stenosis and decompression, cervical stenosis and surgical, OPLL and CORP, OPLL and LAMP, OPLL and decompression, OPLL and surgical. A similar search was performed in the Cochrane library. The aim at first was to find randomized, controlled trials and later also observational studies comparing anterior CORP with posterior LAMP from 1990 to December 2012. Reference lists from the studies selected by searching were checked to identify additional articles meeting the inclusion in this systematic review.

Inclusion criteria and quality evaluation

The following inclusion criteria were adopted: (1) study design: randomized, controlled trials (RCTs) or cohort studies; (2) study population: patients with cervical compressive myelopathy (≥ 2 segments) due to CSM or OPLL, excluding tumors, trauma, soft disc herniation or previous surgery; (3) purpose of interventions: to compare clinical outcome differences between anterior CORP and posterior LAMP; (4) outcome measurements: neurological recovery outcomes, surgical complications, reoperation rate, operation time and blood loss. Studies did not meet the above criteria were excluded from selection. Two review authors independently assessed titles and abstracts for possible inclusion. If they could not reach an agreement, the opinion of a third reviewer was adopted. Only articles published in English and free to access were included. The risk of bias was assessed

using the criteria proposed by the Cochrane back review group [8]. The level of evidence was assessed according to the guidelines of the GRADE working group [9].

Data extraction and subgroup analysis

The following outcome measurements were extracted as primary outcomes: pre- and postoperative JOA score and neurological RR, which was first described by Hirabayashi [10]. Secondary outcomes were surgery-related complications, reoperation rate and surgical trauma including the operation time and evaluated blood loss. The studies included were divided into two subgroups according to the mean number of surgical segments: subgroup A included the studies in which the mean number of surgical segments was between 2 and 3, whereas subgroup B included the studies in which the mean number of surgical segments was equal to 3 or more.

Data analysis

A systematic review and meta-analysis of cohort studies was performed to determine which surgical strategy is more effective for the treatment of multilevel cervical myelopathy due to CSM or OPLL. Heterogeneity was tested using Chi square test and quantified by calculating I^2 statistic, for which $P < 0.1$ and $I^2 > 50\%$ was considered to be statistically significant. For the pooled effects, weighted mean difference (WMD) or standard mean difference (SMD) was calculated for continuous variables according to the consistency of measurement units, and odds ratio (OR) was calculated for dichotomous variables. Continuous variables are presented as mean differences and 95 % confidence intervals (CI), whereas dichotomous variables are presented as odds ratios and 95 % CI. Random-effects or fixed-effects models were used depending on the heterogeneity of the studies included. All statistical tests were performed with SPSS software (Version 18.0, IBM Corporation, USA) and Review Manager (Version 5.1, The Cochrane Collaboration).

Results

Search results

There were 695 citations found in Pubmed and 374 in Embase and 3 citations in the Cochrane library. These articles were reviewed and a total of 712 titles and abstracts were screened after removing duplicates. Secondary stage screening of abstracts was based on study design,

Fig. 1 Results of search in Pubmed, EmBase and the Cochrane library

population, purpose of interventions, and outcome index, and a total of 23 articles were obtained in full and screened, yielding a total of 12 articles [5, 11–21] for this systematic review and meta-analysis (Fig. 1).

Quality assessment

No randomized controlled trial was identified. All studies included were prospective or retrospective cohort studies with relatively low quality (Table 1). The quality of evidence using GRADE was not upgraded and remained low due to the unspecific description of study design and the less rigorous methodology in observational studies [22].

Baseline characteristics

These 12 studies contained 12 cohorts with a total of 768 patients, of which 320 underwent anterior CORP and 448 underwent posterior LAMP. There were two articles [12, 14] that did not report the male to female ratio, and five articles [5, 14, 16, 19, 21] that did not report the preoperative duration of symptoms. There were no significant differences between the two groups in terms of surgical age, gender ratio, duration of symptoms and follow-up ($P < 0.05$). Baseline characteristics of the two treatment groups are presented in Table 2.

Table 1 Grading of quality of studies according to GRADE

References	Published year	Risk of bias	Indirectness	Imprecision	Publication bias	Large effect	Plausible residual confounding	Total	Quality of evidence
Yonenobu [11]	1992	−1	0	N/A	−1	0	0	−2	Very low
Hosono [5]	1996	−1	0	N/A	−1	0	0	−2	Very low
Wada [12]	2001	−1	0	N/A	−1	0	0	−2	Very low
Edwards [13]	2002	−1	0	N/A	−1	0	0	−2	Very low
Wang [14]	2006	−1	0	N/A	−1	0	0	−2	Very low
Masaki [15]	2007	−1	0	N/A	−1	0	0	−2	Very low
Iwasaki [16]	2007	−1	0	N/A	−1	0	0	−2	Very low
Lee [17]	2008	−1	0	N/A	−1	0	0	−2	Very low
Shibuya [18]	2010	−1	0	N/A	−1	0	0	−2	Very low
Gandhoke [19]	2011	−1	0	N/A	−1	0	0	−2	Very low
Hiraia [20] ^a	2011	−1	0	N/A	−1	0	0	−1	Very low
Sakaia [21] ^a	2012	−1	0	N/A	−1	0	0	−1	Very low

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

Table 2 Baseline characteristics of the different treatment groups

	Corpectomy	Laminoplasty
Number of patients	320	448
Male/female	181/89	294/115
Mean age (minimum–maximum)/year	56.1 (51.8–60.4)	59.3 (54–64.8)
Mean duration of symptoms (minimum–maximum)/month	19.2 (9–37.4)	21.6 (9–50)
Mean follow-up (minimum–maximum)/month	67.2 (12–180)	63.5 (12–140.4)

Clinical outcome

Nine studies used the JOA score to assess the clinical outcome, seven of which provided pre- and postoperative JOA score with standard deviation. There was no significant difference in the preoperative JOA score between the two groups in either subgroup A or B, indicating that the preoperative neurological function was similar between the CORP group and the LAMP group (Fig. 2). By contrast, there was a significant difference in the postoperative JOA score between the two groups in subgroup A [WMD = 1.03 (0.46, 1.61), $P < 0.01$]. But in subgroup B, there was no significant difference in the postoperative JOA score between the two groups (Fig. 3).

Nine studies used RR to assess the degree of neurological function improvement, six of which provided the mean with standard deviation. There was a significant difference in the neurological RR between the two groups in subgroup A [WMD = 12.77 (6.57, 18.97), $P < 0.01$]. However, although it showed significant heterogeneity among the studies in subgroup B (heterogeneity: $P = 0.01$;

$I^2 = 84\%$), there was no apparent difference in the neurological RR between the two groups. Since meta-analysis was impractical, only descriptive analysis was performed (Fig. 4).

All the results above demonstrated that the postoperative neurological recovery in the CORP group was superior to that in the LAMP group when the mean involved surgical segments were <3 , but was similar between the two groups when the mean involved surgical segments were equal to 3 or more.

There were three articles [5, 14, 15] that did not report any complication related to surgery. Therefore, only nine studies provided a list of the postoperative complications. There was no significant difference in the surgical complication rate between the two groups in subgroup A. But in subgroup B, there was a significant difference in the surgical complication rate between the two groups [OR 1.84 (1.09, 3.12), $P < 0.05$], which indicated that the incidence of surgery-related complication was significantly higher in the CORP group than that in the LAMP group when the mean involved surgical segments were equal to 3 or more (Fig. 5). In addition, the primary complications for the CORP group were the graft and surgical approach-related complications and the higher rate of adjacent deterioration that required reoperation, and for the LAMP group were the higher rates of postoperative C5 radiculopathy, axial neck pain and cervical kyphotic change (Table 3).

There were nine studies that reported the complication-related reoperation rates. The reoperation rate was significantly higher in the CORP group compared with the LAMP group in either subgroup A or B [OR 6.99 (2.11, 23.13), $P < 0.01$ and OR 12.13 (3.92, 37.54), $P < 0.01$] (Fig. 6). Besides, in the patients treated with anterior CORP, a total

Fig. 2 Weighted mean difference of preoperative JOA between the CORP group and the LAMP group

Fig. 3 Weighted mean difference of postoperative JOA between the CORP group and the LAMP group

of 41 (16.5 %) required reoperation, of which 23 (56.1 %) were for pseudoarthrosis, 7 (17.1 %) for adjacent deterioration and 7 (17.1 %) for graft malposition. In the patients treated with posterior LAMP, on the other hand, only 3 (1 %) required reoperation, of which one was for

neurological deterioration due to new disc herniation, one for restenosis caused by collapsed laminoplasty segment and one for posterior hematoma.

A total of five studies reported the operation time and blood loss. Operation time and blood loss were

Fig. 4 Weighted mean difference of neurological RR between the CORP group and the LAMP group

Fig. 5 Odds ratio of surgical complication rates between the CORP group and the LAMP group

apparently higher in the CORP group compared with the LAMP group in either subgroup A or B, although there was significant heterogeneity among the studies in the

two subgroups (Figs. 7, 8). This indicated that the surgical trauma in the CORP group was obviously higher than that in the LAMP group.

Table 3 Number of complications (percentage of included patients)

Complication	Corpectomy (N = 248)	Laminoplasty (N = 321)
Dysphagia/dysphonia	15 (6.0 %)	–
Hardware fail	6 (2.4 %)	–
Graft malposition	9 (3.6 %)	–
Pseudarthrosis	25 (10.1 %)	–
Adjacent deterioration	30 (12.1 %)	–
Esophageal fistula	2 (0.8 %)	–
CSF leakage	1 (0.4 %)	2 (0.6 %)
Hematoma	1 (0.4 %)	1 (0.3 %)
C5 paralysis/ radiculopathy	9 (3.6 %)	31 (9.6 %)
Axial neck pain	11 (4.4 %)	29 (9.0 %)
Kyphotic change	14 (5.6 %)	38 (11.8 %)
Deterioration neurologic deficit	9 (3.6 %)	7 (2.2 %)
Reoperation	41 (16.5 %)	3 (0.9 %)

Discussion

Limitations of systematic review

The results of anterior CORP and posterior LAMP in the treatment of multilevel cervical myelopathy due to CSM or

OPLL had been compared in the studies included. Whereas, these studies have been limited by marked heterogeneity of the patient groups and the inclusion of patients undergoing decompression of fewer than three motion segments except for the study by Edwards et al. [13], which had strictly included the patients undergoing decompression of three or more motion segments. Since lack of peer to peer comparisons of multilevel CORP versus LAMP, the optimal surgical strategy for multilevel cervical myelopathy remains controversial. Therefore, we performed a systematic review and meta-analysis with two subgroups divided according to the mean number of surgical segments, with the expectation to diminish the effect of plausible confounding from these studies as possible and to evaluate the effectiveness of anterior CORP compared with posterior LAMP for patients with multilevel cervical myelopathy.

However, there are some limitations in our study that warrant mention. First, none of the studies included in the meta-analysis were RCTs and we had to rely upon the data from observational studies of which the quality was very low. Second, all the articles included were published in English, which may lead to a potential publication bias. Third, the population that underwent CORP may be inconsistent with the LAMP group in some studies included, for example more kyphotic deformity preoperatively,

Fig. 6 Odds ratio of reoperation rates between the CORP group and the LAMP group

Fig. 7 Weighted mean difference of operation time between the CORP group and the LAMP group

Fig. 8 Standard mean difference of blood loss between the CORP group and the LAMP group

which certainly may have an effect on the results of this study. Furthermore, most of the studies focused on the evaluation of neurological function improvement, but neglected to evaluate the overall quality of life. Finally, follow-up time varied between the studies and thus may have influenced our results.

Surgery-related considerations

The results from this study indicated that the postoperative neurological recovery in the CORP group was superior to that in the LAMP group when the mean involved surgical segments were <3 , but was similar between the two groups

in the case of the mean involved surgical segments equal to 3 or more. There was no statistical difference in the surgical complication rate between the two groups when the mean involved surgical segments were <3 , but were significantly higher incidence of surgical complications and complication-related reoperation in the CORP group compared with the LAMP group in the case of the mean involved surgical segments equal to 3 or more. In addition, the surgical trauma in the CORP group was obviously higher than that in the LAMP group.

However, it was not appropriate to draw a strong conclusion about one procedure superior to the other on clinical outcomes considering the limitations of this systematic

review and meta-analysis. We have to assess the patient's age and health status, the number of compressed levels, adjacent segment degeneration, the severity of cervical stenosis, cervical sagittal alignment and stability when we make a decision about which surgical approach to be adopted for the treatment of multilevel cervical myelopathy due to CSM or OPLL.

Masaki et al. [15] reported that elderly patients treated with laminoplasty showed an especially poor surgical outcome. Inversely, Shibuya et al. [18] recommended the application of laminoplasty for elderly patients. It is generally acknowledged that posterior LAMP was less invasive compared with anterior CORP and was more appropriate for the elderly patients with multilevel cervical myelopathy, especially for elderly patients with poor health status preoperatively.

Wada et al. [12] noted a significant correlation between pseudarthrosis and number of fused segments, demonstrating that the incidence of pseudarthrosis was augmented with the increased number of fused segments. In particular, according to a meta-analysis involving 2,682 patients by Fraser et al. [23], the fusion rate for the anterior procedure with plating was 97.1 % at the one-disc level, 94.6 % at the two-disc level, and 82.5 % at the three-disc level. All of these suggested that reconstruction of cervical spine after multilevel CORP was highly technically demanding with a high incidence of pseudarthrosis requiring revision surgery when the number of fusion segments was equal to three or more.

Yonenobu et al. [11], Wada et al. [12] and Shibuya et al. [18] reported a higher rate of adjacent segment degeneration in the CORP group compared with the LAMP group, respectively, indicating that anterior long-segment intervertebral fusion may be a potential risk factor for the development of adjacent segment degeneration. Besides, adjacent deterioration is one of the main causes of reoperation, which accounted for 17.1 % in this study. Therefore, to prevent the incidence of reoperation due to deteriorated degeneration in adjacent segments, the disc degeneration and instability of segments adjacent to compressed levels should be taken into serious consideration when anterior CORP and fusion are applied.

Kyphotic change in the cervical spine after LAMP is well known. In this study, there was a higher rate of cervical kyphotic change observed in the patients treated with posterior LAMP compared with that treated with anterior CORP. So here comes a question that whether instrumented fusion is necessary if posterior LAMP is alternatively used. Kimura et al. [24] reported that LAMP did not provide a good outcome in the presence of kyphotic or S-shaped malalignment, indicating that progressive kyphosis was responsible for delayed neurologic deterioration. Besides, Masaki et al. [15] compared the clinical

results between a good outcome group (recovery rate ≥ 40 %, $n = 27$) and a poor outcome group (recovery rate < 40 %, $n = 13$), suggesting that instability of vertebrae at the cord compression level was a risk factor for poor surgical outcome after LAMP. From a biomechanical point of view, anterior CORP and fusion can receive strong spine stability and maintain the cervical lordotic alignment. However, posterior LAMP has limitations in terms of stabilization of the cervical spine and preventing development of kyphosis, which could have a deleterious effect on long-term outcome. Thus, it is generally believed that instrumented fusion may be helpful to restore cervical lordosis and produce better results when LAMP is alternatively used for the treatment of multilevel cervical myelopathy.

Axial symptom is another problem needed to be resolved after LAMP. It remains unclear about the causes resulting in postoperative axial symptoms. Loss of cervical range of motion and injury to posterior extensor musculature after LAMP may be the potential risk factors for postoperative axial symptoms. Modified LAMP, such as improved method preserving the posterior tension band or extensor musculature inserted into C2 and C7 spinous process, was proved to be helpful for reducing the incidence of postoperative axial symptoms [25–27]. In addition, findings from a study by Asano et al. [28] indicated that the incidence of axial pain after LAMP might be a byproduct of the method and duration of postoperative immobilization. Consequently, shortening the period of external fixation and early range of motion training can reportedly decrease the incidence of axial symptoms after LAMP [29].

Making a decision about whether a surgical treatment to be performed or not largely depends on the severity of cervical stenosis or the extent of spinal cord compression. Although anterior CORP is technically demanding and has a higher incidence of surgery-related complications, it is preferable to posterior LAMP in the postoperative neurological recovery for patients with severe extent of cervical stenosis or cord compression (occupying rate ≥ 50 or 60 %) [16, 21, 30]. However, it was actually very difficult to remove massive ossification through anterior CORP as a result of ossification of the dura or massive bleeding from the epidural space. In most cases, the anterior floating method without completely resection of ossification was usually used to avoid dural tears and injury to spinal cord. Posterior LAMP is often selected as an alternative option for such patients when anterior decompression is fraught with iatrogenic deterioration of the neurologic status.

So, here comes another question that how much benefits could be achieved by anterior direct decompression with higher risk of secondary injury to spinal cord. From a standpoint of the result of neurological recovery, anterior CORP is preferable to posterior LAMP for patients with

severe extent of cervical stenosis or cord compression. From a standpoint of the safety of surgical decompression, however, posterior LAMP is superior to anterior CORP for patients with severe extent of cervical stenosis or cord compression. Therefore, we have to weigh cautiously between the clinical benefit and the safety of surgery, and occasionally combined anterior and posterior approach may be an effective and safe method of treatment when necessary.

Conclusion

Based on this study, anterior CORP and fusion are recommended for the treatment of multilevel cervical myelopathy when the involved surgical segments were <3 . Given the higher rates of surgical complications and complication-related reoperation and the higher surgical trauma associated with multilevel CORP, however, it is suggested that posterior LAMP may be the preferred method of treatment for multilevel cervical myelopathy when the involved surgical segments were equal to 3 or more. In addition, taking the limitations of this study into consideration, it was still not appropriate to draw a strong conclusion claiming superiority for CORP or LAMP. A well-designed, prospective, randomized controlled trial is necessary to provide objective data on the clinical results of both procedures.

Conflict of interest None.

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