Original Article
Comparison of anterior cervical discectomy and fusion versus anterior cervical corpectomy and fusion for the treatment of contiguous two-level cervical spondylotic myelopathy

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Abstract: Purpose: The purpose of this study is to evaluate the clinical effectiveness and safety of anterior cervical discectomy and fusion (ACDF) and anterior cervical corpectomy and fusion (ACCF) for treating contiguous two-level cervical spondylotic myelopathy (CSM). Methods: The authors searched electronic databases for relevant studies that compared the clinical effectiveness of ACDF and ACCF for the treatment of patients with contiguous two-level CSM. Data extraction and quality assessment were conducted, and RevMan 5.2 was used for data analysis. The random effects model was used if there was heterogeneity between studies; otherwise, the fixed effects model was used. Results: A total of six studies were included in our meta-analysis. No statistical difference was observed with regard to complications, degeneration of the level adjacent to the fusion, fusion rate, arm and neck VAS score, postoperative JOA score between ACCF and ACDF. Compared with ACDF group, the blood loss and operation time were significantly higher in the ACCF group, however, Cobb and fused segment height were significantly lower. Conclusions: Our meta-analysis reveals that surgical treatments of contiguous two-level CSM are similar in terms of most clinical outcomes using ACDF or ACCF. However, owing to the limitations of the current study, high-quality clinical studies with larger sample sizes are still needed to confirm our results.

Keywords: ACDF, ACCF, CSM

Introduction
Cervical spondylotic myelopathy (CSM) is a clinically symptomatic condition caused by compression of the spinal cord due to degeneration. The degeneration of the intervertebral disc, uncovertebral joint, facet joint, posterior longitudinal ligament, and ligamentum flavum cause spinal cord compression and cervical myelopathy [1]. At present, patients diagnosed with symptomatic CSM were often recommended to receive anterior cervical decompression and fusion (ACDF) for patients diagnosed with CSM [2-5].

There are two representative surgical approaches for CSM: anterior and posterior. Anterior approaches usually involve ACDF or anterior cervical corpectomy with fusion (ACCF). ACDF is a surgical procedure removing the intervertebral disc, replaced by a small plug of bone or other graft substitute, which usually applied for treating the compression of nerve root or spinal cord [6-8], while ACCF refers to a procedure removing part of the vertebra and adjacent intervertebral discs to decompress. Cervical spinal cord and nerves. ACDF and ACCF can establish a solid cervical stability that is conducive to relieving pressure on the level of compressed spinal cord. One recent meta-analysis by Huang Z-Y et al have shown that ACDF has more advantages compared to ACCF between the two surgeries to treat two-adjacent-level CSM [9]. Additionally, Guan L et al provided evidence that ACDF may be more effective than ACCF with respect to the operation time, blood loss as well as hospital time for CSM treatment [10]. However, Han YC et al reported that
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Although complications and increased lordosis are significantly better in the ACDF group, there is no strong evidence to support the routine use of ACDF over ACCF in CSM [11].

At present, no standards or guidelines exist for the treatment of contiguous two-level CSM. We performed a meta-analysis to evaluate the clinical outcomes between ACDF and ACCF for the treatment of CSM.

Materials and methods

Search strategy and study selection

We searched for studies in electronic databases including PubMed (1966 to Dec 2015), MEDLINE (1966 to Dec 2015), EMBASE (1974 to Dec 2015), Cochrane Controlled Trial Register (Cochrane library 2015) and Google Scholar (1966 to Dec 2015). We restricted the language to English. The following search terms were used: (1) cervical spondylosis myelopathy OR CSM; (2) ACDFOR anterior cervical discectomy and fusion; (3) ACCF OR anterior cervical corpectomy and fusion. (1) and (2) or (3). Reference lists of all included studies were scanned to identify additional potentially relevant studies. Two reviewers independently screened the titles and abstracts of identified papers, and full text copies of all potentially relevant studies were obtained.

Inclusion criteria

All comparative studies that adopted ACCF and ACDF to treat two-adjacent-level cervical spondylosis were identified, and the reference lists of identified articles were searched to identify other potentially eligible studies. Studies were included if they met the following criteria: (1) ACCF with titanium mesh, cage or autologous ilium bone grafting; ACDF with inter body cage devices or autologous ilium bone grafting; and the two surgeries used anterior cervical plate and screw fixation. (2) All patients included had a confirmed CSM at two adjacent segments, and surgical intervention was recommended. (3) The trials were followed up for more than 12 months. Studies did not meet the above criteria were excluded from selection.

Exclusion criteria

(1) The studies did not meet the inclusion criteria. (2) The intraoperative outcome data (amount of bleeding and operation time), clinical outcomes (Japanese Orthopaedic Association (JOA) score and visual analogue scale (VAS) score for neck and arm pain), radiological outcomes (C2-C7 Cobb, fused segment height, fusion rate and degeneration of the adjacent level) or complications were not reported. (3) The number of samples was less than 30 cases. (4) The patients evaluated were treated at the same hospital.
Quality assessment of included studies

The 3-item scale of Jadad was used to assess the quality of included studies [12]. This instrument is referred to as the ‘Jadad scale’. Scale scores can range from 0 to 5 points, with higher scores indicating better quality (Table 1).

Data extraction

Two reviewers independently extracted the data using a standardised form, which covered the following items: (1) basic characteristics, including the year of publication, study design, inclusion/exclusion criteria, age, sex, enrolled number and follow-up rate; (2) intraoperative outcomes, consisting of operation time and amount of bleeding; (3) clinical outcomes, including Japanese Orthopaedic Association (JOA) score and visual analogue scale (VAS) score for neck and arm pain; (4) radiological outcomes, such as cervical lordosis for total cervical, fused segment height, segmental height, fusion rate, degeneration of the adjacent level and (5) complications, including short-term and long-term complications.

Data analysis

We performed all meta-analyses with the Review Manager software (RevMan Version 5.2; (Cochrane Collaboration, Oxford, UK)). 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.

Results

The process of identifying relevant studies is summarized in Figure 1. From the selected databases, 636 references were obtained. By screening the titles and abstracts, 611 references were excluded due to duplicates, irrelevant studies, case reports, not comparative studies and review. The remaining 25 studies underwent a detailed and comprehensive evaluation. Finally, 6 studies were included in our meta-analysis [13-18]. Tables 2 and 3 summarise the baseline characteristics assessment and quality of included studies, respectively.

Clinical outcome

Operation time: Two studies provided operation time at the last follow-up. Random-effect model was used as the pooling method. The operation time was significant higher in the ACCF group compared with the ACDF group [$P=0.03$, WMD: 46.35 (4.00, 88.70); Figure 2].

Blood loss: Two studies provided blood loss at the last follow-up. Fixed-effect model was used as the pooling method. The blood loss was significant higher in the ACCF group compared with the ACDF group [$P<0.00001$, WMD: 474.90 (411.92, 537.87); Figure 3].
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Table 2. Characteristics of included studies

<table>
<thead>
<tr>
<th>Study ID</th>
<th>Design</th>
<th>Country</th>
<th>Sample size</th>
<th>Age (years)</th>
<th>Follow up (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burkhardt JK [13]</td>
<td>Retrospective</td>
<td>Switzerland</td>
<td>Total: 118</td>
<td>ACDF: 60.9±9.9</td>
<td>ACDF: N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ACDF: 80</td>
<td>ACCF: 38</td>
</tr>
<tr>
<td>Jeffrey C [14]</td>
<td>Retrospective</td>
<td>USA</td>
<td>Total: 54</td>
<td>ACDF: N/A</td>
<td>ACCF: 60.1±11.1</td>
</tr>
<tr>
<td>Park Y [16]</td>
<td>Retrospective</td>
<td>South Korea</td>
<td>Total: 97</td>
<td>ACDF: 22</td>
<td>ACCF: 46</td>
</tr>
<tr>
<td>Kim M [17]</td>
<td>Retrospective</td>
<td>Korea</td>
<td>Total: 70</td>
<td>ACDF: 24</td>
<td>ACCF: 45</td>
</tr>
</tbody>
</table>
| ACDF: anterior cervical discectomy with fusion | ACCF: anterior cervical corpectomy with fusion | N/A = not available.

Table 3. Quality assessment of included studies

<table>
<thead>
<tr>
<th>Study (year)</th>
<th>Randomization</th>
<th>Double-blind</th>
<th>Withdrawals/dropouts</th>
<th>Jadad Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jeffrey C [14]</td>
<td>Inappropriate</td>
<td>Not clear</td>
<td>Yes</td>
<td>1</td>
</tr>
<tr>
<td>Liu J [15]</td>
<td>Inappropriate</td>
<td>Not clear</td>
<td>Yes</td>
<td>1</td>
</tr>
<tr>
<td>Park Y [16]</td>
<td>Inappropriate</td>
<td>Not clear</td>
<td>Yes</td>
<td>1</td>
</tr>
<tr>
<td>Kim M [17]</td>
<td>Not clear</td>
<td>Not clear</td>
<td>Yes</td>
<td>1</td>
</tr>
<tr>
<td>Oh MC [18]</td>
<td>Appropriate</td>
<td>Not clear</td>
<td>Yes</td>
<td>3</td>
</tr>
</tbody>
</table>

Postoperative JOA score: Two studies provided the postoperative JOA score at the last follow-up. Fixed-effect model was used as the pooling method. There was no significant difference between the two groups [P=0.15, WMD: -0.61 (-1.43, 0.22); Figure 4].

Neck VAS: Studies reported a postoperative neck VAS score. Fixed-effect model was used as the pooling method and the pooled data revealed no significant difference [P=0.95, WMD: -0.03 (-1.02, 0.95); Figure 5], with low heterogeneity (I²=6%).

Arm VAS: Two studies reported a postoperative arm VAS score. Fixed-effect model was used as the pooling method and the pooled data from the two relevant studies did not reveal any significant difference [P=0.14, WMD: -0.74 (-1.72, 0.24); Figure 6], with low heterogeneity (I²=0%).

C2-C7 Cobb: Four studies reported C2-C7 Cobb at the final follow-up. Fixed-effect model was used as the pooling method and the pooled data from the four relevant studies revealed that ACCF group had a significantly lower Cobb than the ACDF group [P=0.002, WMD: -3.15 (-5.13, -1.17); Figure 7], with low heterogeneity (I²=38%).

Fused segment height: Two studies reported the fused segment height data at the final follow-up. Random-effect model was used as the pooling method. The pooled results demonstrated that the ACCF group had a significantly lower fused segment height than the ACDF group [P=0.02, WMD: -3.73 (-6.96, -0.53); Figure 8], with low heterogeneity (I²=38%).

Fusion rate: Four studies reported the fusion rate at the final follow-up. Fixed-effect model was used as the pooling method and the pooled results demonstrated that there was no significant difference in the fusion rate between the two groups [P=0.75, OR: 1.27 (0.29, 5.50); Figure 9], with low heterogeneity (I²=40%).

Degeneration: Two studies reported the degeneration of the level adjacent to the fusion at the final follow-up. Fixed-effect model was used as the pooling method and the pooled results revealed that there was no significant difference in the degeneration of the level adjacent to the fusion between the two groups [P=0.66, OR: 1.36 (0.36, 5.17); Figure 10], with no heterogeneity (I²=0%).

Complications: Five studies reported the complications at the final follow-up. Fixed-effect
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<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>ACCF</th>
<th>ACDF</th>
<th>Mean Difference</th>
<th>Mean Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Total</td>
<td>Mean</td>
</tr>
<tr>
<td>Liu J[15]</td>
<td>123</td>
<td>21</td>
<td>47</td>
<td>17</td>
</tr>
<tr>
<td>Oh MC[18]</td>
<td>210</td>
<td>6</td>
<td>140.71</td>
<td>44.5</td>
</tr>
<tr>
<td>Total</td>
<td>41</td>
<td>36</td>
<td>100.0%</td>
<td>46.35 [4.00, 88.70]</td>
</tr>
</tbody>
</table>

Heterogeneity: Tau² = 649.47; Chi² = 10.70, df = 1 (P = 0.001); I² = 91%
Test for overall effect: Z = 2.15 (P = 0.03)

Forest plot of operation time between the ACCF group and ACDF group.

Forest plot of blood loss between the ACCF group and ACDF group.

Forest plot of postoperative JOA score between the ACCF group and ACDF group.

Forest plot of neck VAS score between the ACCF group and ACDF group.

model was used as the pooling method and the pooled results showed that there was no significant difference in the complications between the two groups [P=0.99, OR: 1.01 (0.50, 2.02); Figure 11], with low heterogeneity (I²=6%). Of 52 patients, pseudarthrosis was reported in only 1 patient after ACCF [14]. Liu Jetal reported that four patients (18.2%) in group ACDF and five (20.8%) in group ACCF suffered from perioperative complications [15].
Comparison of ACDF versus ACCF for treating CSM

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>ACDF</th>
<th>ACCF</th>
<th>Mean Difference</th>
<th>Mean Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Total Mean</td>
<td>Total</td>
</tr>
<tr>
<td>Burkhardt JK[13]</td>
<td>1.4</td>
<td>3.2</td>
<td>38</td>
<td>2.4</td>
</tr>
<tr>
<td>Oh MC[19]</td>
<td>2.63</td>
<td>2.7</td>
<td>17</td>
<td>2.79</td>
</tr>
<tr>
<td>Total (95% CI)</td>
<td>55</td>
<td></td>
<td>94</td>
<td>100.0% -0.74 [-1.72, 0.24]</td>
</tr>
<tr>
<td>Heterogeneity: Chi² = 6.00, df = 1 (P = 0.44); I² = 0%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test for overall effect: Z = 1.48 (P = 0.14)</td>
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</tbody>
</table>

Figure 6. Forest plot of arm VAS score between the ACCF group and ACDF group.

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>ACDF</th>
<th>ACCF</th>
<th>Mean Difference</th>
<th>Mean Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Total Mean</td>
<td>Total</td>
</tr>
<tr>
<td>Burkhardt JK[13]</td>
<td>9.7</td>
<td>7.7</td>
<td>38</td>
<td>13.6</td>
</tr>
<tr>
<td>Kim M[17]</td>
<td>15.7</td>
<td>8.6</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Oh MC[18]</td>
<td>14.59</td>
<td>10.6</td>
<td>17</td>
<td>23.43</td>
</tr>
<tr>
<td>Park Y[16]</td>
<td>9.6</td>
<td>9.1</td>
<td>52</td>
<td>11.2</td>
</tr>
<tr>
<td>Total (95% CI)</td>
<td>123</td>
<td></td>
<td>193</td>
<td>100.0% -3.15 [-5.13, -1.17]</td>
</tr>
<tr>
<td>Heterogeneity: Chi² = 4.83, df = 3 (P = 0.18); I² = 38%</td>
<td></td>
<td></td>
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<tr>
<td>Test for overall effect: Z = 3.11 (P = 0.002)</td>
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</tbody>
</table>

Figure 7. Forest plot of C2-C7 Cobb between the ACCF group and ACDF group at the final follow-up.

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>ACDF</th>
<th>ACCF</th>
<th>Mean Difference</th>
<th>Mean Difference</th>
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<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Total Mean</td>
<td>Total</td>
</tr>
<tr>
<td>Burkhardt JK[13]</td>
<td>37.3</td>
<td>4.3</td>
<td>38</td>
<td>39.9</td>
</tr>
<tr>
<td>Oh MC[18]</td>
<td>49.9</td>
<td>5</td>
<td>17</td>
<td>56</td>
</tr>
<tr>
<td>Total (95% CI)</td>
<td>55</td>
<td></td>
<td>94</td>
<td>100.0% -3.74 [-6.96, -0.53]</td>
</tr>
<tr>
<td>Heterogeneity: Tau² = 3.28; Chi² = 2.15, df = 1 (P = 0.14); I² = 54%</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Test for overall effect: Z = 2.28 (P = 0.02)</td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

Figure 8. Forest plot of fused segment height between the ACCF group and ACDF group at the final follow-up.

two patients in group ACDF and three in group ACCF suffered from wound infection [15], C5 nerve root palsy occurred in one patient in group ACDF [15], one patient in group ACDF and two in group ACCF suffered dysphagia [15]. Kim Metal reported that Graft-related complications were developed in 2 patients in ACDF-AP, 5 patients in ACDF-CA, 3 patients in ACDF-CP, 3 patients in ACCF groups [17]. Oh MCetal reported that the ACCF group had 3 surgery-related complications including hoarseness, dura laceration, and postoperative upper extremity weakness [18].

Discussion

Cervical spondylotic myelopathy (CSM) is a common spinal disease caused by narrowing of the cervical spinal canal as a result of degenerative and congenital changes, and leads to significant neurological disability [19, 20]. Various approaches have been used to treat CSM, such as multilevel discectomy, corpectomy, laminectomy with/without fusion, laminoplasty, and laminectomy [21-25]. Anterior approach appears to be more suitable when the pathologies of anterior involve only 1 or 2.
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vertebral body levels, while if more than 2 levels usually proceed using an posterior approach clinically [26]. ACDF can remove the compressive pathology and reconstruct the alignment of the cervical spine, yielding good clinical results. Surgeries involving anterior approaches include ACDF and ACCF. Although some relevant studies comparing the ACDF and ACCF
have been reported, the evidence regarding whether ACDF is superior to ACCF remains ambiguous. We therefore conducted a meta-analysis to determine whether ACDF is associated with better clinical outcomes compared with ACCF.

Our meta-analysis showed that there was no significant difference in terms of complications, degeneration of the level adjacent to the fusion, fusion rate, arm and neck VAS score, postoperative JOA score between ACCF and ACDF. Compared with ACDF group, the blood loss and operation time were significant higher in the ACCF group, however, Cobb and fused segment height were significantly lower.

Previous study has stated that compared ACDF and ACCF to treat contiguous two-level CSM, ACDF has some advantages such as less blood loss, a shorter operation time, greater cervical lordosis in the total cervical and fused segments, a higher segmental height and less graft subsidence [9]. No significant differences in JOA, VAS, ROM or complications were found [9]. Our results are consistent with previous study [9]. Recent a meta-analysis reveals no significant difference in efficacy comparison between ACDF and ACCF, but the safety of ACDF was superior to ACCF with respect to the operation time, blood loss as well as hospital time [27]. However, another meta-analysis suggest that surgical treatments of multilevel CSM are similar in terms of most clinical outcomes using ACDF or ACCF [28]. Wen ZQ et al found that blood loss and complications during surgery in ACDF were significantly less that in ACCF; while other clinical outcomes were not significantly different [28].

We discovered that the safety of ACDF was significantly superior as compared to ACCF with regard to the operation time as well as blood loss. It has also been evidenced that 2-level ACDF was found to be superior to 1-level ACCF in terms of operation times, bleeding amounts, and radiologic results [18]. Furthermore, Liu J et al reported that two-level ACDF was found with less operation duration and blood loss, better cervical lordosis than those of single-level ACCF according to a long-term follow-up. ACDF requires less exposure of the spinal cord than does corpectomy [29]; therefore, less damage to the spinal column occurs. Accordingly, ACDF might result in less blood loss than ACCF. In terms of ACCF, a15-19 mm anterior midline trough should be performed in the vertebral body down to the posterior longitudinal ligament or dura, with removal of the cephalad and caudal discs [29], which would require more time to be removed; similarly it will cost more time to obtain a graft material to fit the trough. Consequently, ACDF had a significantly shorter operation time.

Our study shown that there was no statistically difference in JOA scores as well as VAS scores for neck and arm pain significantly improved between ACDF and ACCF. These results suggest that both procedures effectively treat contiguous two-level CSM and improve the patients’ neurological function. Our results was in line with a previous study confirming that surgical managements of 2 segmental CSM by ACDF or ACCF showed no significant differences in terms of achieved clinical symptom improvements [18]. Recent study reported by Liu J et al also found that no significant different was noted between group ACDF and group ACCF in both the preoperative mJOA scores and postoperative mJOA scores [15]. These results were similar to previous studies [13, 30].

Meta-analysis revealed that as compared to ACDF group, Cobb were significantly lower in the ACCF group. Consistent with our findings, previous studies demonstrated that ACCF was inferior to ACDF in terms of C2-7 angle improvement and segmental angle improvement [13, 16-18]. This may be associated with the following reason: Single-level ACCF takes out the vertebral body and two discs, while two-level ACDF just removes the two discs [29]; thus, ACDF allows the construction of an almost normal spinal column after surgery. As a result, the loss of Cobb is less common in ACDF. In other words, ACDF preserves the sagittal alignment somewhat better than does ACCF.

Compared with ACDF group, fused segment height were significantly lower in the ACCF group. With ACDFs, screws are placed in the intervening segment and two caudal end plates share the load of the construct [16]. In contrast, with a single-level corpectomy, screw purchase is only at the cranial and caudal vertebral segments and the caudal end plate bears the full load of the construct [16]. This may help to explain why single-level ACCF causes a significant reduction compared to ACDF.
Concerning the fusion rate, the data showed that there is no significant difference between the two groups. Previous study reported higher fusion rates after ACCF than multi-level ACDF [31]. However, other studies demonstrated the opposite results [32, 33]. The fusion rate of two groups is quite high, it may be considered all patients used anterior plate fixation; which can provide a stable biomechanics environment for bone healing [34, 35].

In terms of complications, we found that there was no significant difference between the two groups. Liu J et al found that 18.2% of patients in group ACDF and 20.8% in group ACCF suffered perioperative complication [15]. However, the incidence of complications was not significantly different between the two groups [15]. This is consistent with our findings.

A previous report found that ACDF may alter the natural history of cervical spondylosis and hasty the development of degenerative changes at levels immediately above and below fused regions [36]. However, another study reported by Oh MC et al, showed that among the 31 patients, 2 in the ACDF group and 3 in the ACCF group showed adjacent degeneration, without a significant intergroup difference [18]. We also found that there was no significant difference in degeneration of the level adjacent to the fusion.

We believe that our result of meta-analysis is affected by several reasons. Firstly, in this meta-analysis, most the studies selected were not RCT, while it did not influence the credibility of the results. Secondly, there was variability among the studies in the choice of indicators to evaluate the postoperative clinical effect. This clearly reflects the lack of a gold standard outcome measure. Finally, clinical heterogeneity might be caused by the various indications for surgery and the surgical technologies used at the different treatment centers. Due to these limitations, the combined results of this meta-analysis should be cautiously accepted, and high-quality RCTs with long term follow-up and large sample size are needed.

Based on this meta-analysis, we conclude that although ACDF was significantly superior as compared to ACCF with regard to the operation time as well as blood loss, in terms of other clinical outcomes, such as complications, degeneration of the level adjacent to the fusion, fusion rate, arm and neck VAS score, postoperative JOA score, there is no statistically significant difference between ACDF and ACCF for contiguous two-level CSM.

Conclusions

In conclusion, our meta-analysis reveals that surgical treatments of contiguous two-level CSM are similar in terms of most clinical outcomes using ACDF or ACCF. However, owing to the limitations of the current study, high-quality clinical studies with larger sample sizes are still needed to confirm our results.

Disclosure of conflict of interest

None.

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