Is Anterior Cervical Discectomy and Fusion Superior to Corpectomy and Fusion for Treatment of Multilevel Cervical Spondylotic Myelopathy? A Systemic Review and Meta-Analysis

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Abstract

Objective: Both anterior cervical discectomy with fusion (ACDF) and anterior cervical corpectomy with fusion (ACCF) are used to treat cervical spondylotic myelopathy (CSM), however, there is considerable controversy as to whether ACDF or ACCF is the optimal treatment for this condition. To compare the clinical outcomes, complications, and surgical trauma between ACDF and ACCF for the treatment of CSM, we conducted a meta-analysis.

Methods: We conducted a comprehensive search in MEDLINE, EMBASE, PubMed, Google Scholar and Cochrane databases, searching for relevant controlled trials up to July 2013 that compared ACDF and ACCF for the treatment of CSM. We performed title and abstract screening and full-text screening independently and in duplicate. A random effects model was used for heterogeneous data; otherwise, a fixed effect model was used to pool data, using mean difference (MD) for continuous outcomes and odds ratio (OR) for dichotomous outcomes.

Results: Of 2157 citations examined, 15 articles representing 1372 participants were eligible. Overall, there were significant differences between the two treatment groups for hospital stay (MD = –5.60, 95% CI = –7.09 to –4.11), blood loss (MD = –151.35, 95% CI = –253.22 to –49.48), complications (OR = 0.50, 95% CI = 0.35 to 0.73) and increased lordosis of C2–C7 (MD = 3.70, 95% CI = 0.96 to 6.45) and fusion segments angles (MD = 3.38, 95% CI = 2.54 to 4.22). However, there were no significant differences in the operation time (MD = –9.34, 95% CI = –42.99 to 24.31), JOA (MD = 0.24, 95% CI = –0.10 to 0.57), VAS (MD = –0.06, 95% CI = –0.81 to 0.70), NDI (MD = –1.37, 95% CI = –3.17 to 0.43), Odom criteria (OR = 0.88, 95% CI = 0.60 to 1.30) or fusion rate (OR = 1.17, 95% CI = 0.34 to 4.11).

Conclusions: Based on this meta-analysis, 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.

Introduction

Cervical spondylotic myelopathy (CSM) is a clinically symptomatic condition caused by compression of the spinal cord due to degeneration. It is a significant cause of disability in the adult population [1–3], notably causing progressive degenerative changes in the cervical spine of patients over 55 years of age [4,5]. CSM is a common cause of neurological morbidity, and can substantially decrease quality of life [6]. The principal indication for surgery for CSM is the development of progressive spinal cord type symptoms and signs [7]. Surgical treatment has been advocated for CSM by many authors, however, the optimal surgical approach remains controversial. Anterior, posterior and combined anterior and posterior surgical approaches for CSM have all been proposed and encouraged. Anterior approaches usually involve anterior cervical disectomy with fusion (ACDF) or anterior cervical corpectomy with fusion (ACCF), whereas posterior cervical canal decompression approaches typically involve laminoplasty and laminectomy. In terms of anterior procedures, there is considerable controversy as to which reconstruction technique is best after anterior cervical decompression. The anterior approach to the cervical spine was developed in the 1950s by Smith [8] and Cloward [9]. ACDF can decompress the anterior spinal cord, preserve the stability of the spinal column and is associated with a low prevalence of graft extrusion or migration. However, some authors argue that ACDF may not be the optimal surgical approach for CSM due to the risk of incomplete decompression, limited visual exposure, and a high
| Study         | Publition year | Sample Size | Mean age(years) | Sex(male/female) | Followup(months,years) | Graft                                      |
|--------------|----------------|-------------|-----------------|------------------|------------------------|--------------------------------------------|
| Li et al.[22]| 2013           | 47          | 51.3 ± 6.5      | 58M/31F          | 79.6 ± 20.5m           | Autograft,cage                            |
| Liu et al.[21]| 2012           | 69          | 46.1 ± 6.8      | 39M/30F          | 26.8m(12–29m)          | Cages,Atlantis plate, Titanium mesh cage   |
| Kyung et al.[23]| 2012         | 25          | 50.3 ± 7.5      | 19M/6F           | 87.3 ± 21.7m           | 94.3 ± 25.3m, Autograft                    |
| Lin et al.[24]| 2012           | 57          | 58.74 ± 9.7     | 38M/19F          | 24m                    | Autograft,TMC                            |
| Guo et al.[25]| 2011           | 43          | 52.7 ± 9.4      | 24M/19F          | 37.7 ± 7.2m            | 37.3 ± 7.3m, Titanium cage                |
| Park et al.[26]| 2010           | 45          | 49.3 ± 9.7      | 28M/17F          | 25.7 ± 6.2m            | Allograft, cages                         |
| Oh et al.[10]| 2009           | 14          | 54.45 ± 11.6    | 16M/15F          | 26.23 ± 15.0m         | Cage, allograft                          |
| Uribe et al.[27]| 2009          | 42          | 46.2 ± 0.0      | 21M/21F          | 2.3 years              | 2.2 years, Titanium mesh cages            |
| Hwang et al.[28]| 2007          | 27          | 54.2 ± 52.2     | 13M/14F          | 24m                    | Titanium mesh cages, Autograft            |
| Nirala et al.[29]| 2004           | 69          | 55 ± 44         | 40M/29F          | 54m                    | 48m, Titanium mesh cages, Autograft       |
| Hilibrand et al.[30]| 2002          | 131         | 53 ± 58         | 66M/65F          | 57m                    | 73m, Titanium mesh cages, Autograft       |
| Jeffrey et al.[31]| 2001           | 32          | 51.5(17–80)     | 27M/25F          | 3.6 years (2–7Y)       | Allograft, Titanium mesh cages            |
| Emery et al.[32]| 1998           | 45          | 58(27–88)       | 69M/38F          | > 2 years              | Allograft, Titanium mesh cages, Autograft |
| Swank et al.[33]| 1997           | 38          | 51(30–78)       | 37M/27F          | 39m(12–81m)            | Allograft, Titanium mesh cages, Autograft |
| Yonenobu et al.[34]| 1985           | 50          | 51.4 ± 8.6      | 46M/4F           | 54m(14–157m)           | Autograft, Titanium mesh cages, Autograft |

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| Study            | Hospital Stay | Operation Time | Blood Loss | JOA | VAS | NDI | Odom Criteria | Fusion Rate | Cobb angles of C2–C7 | Segmental angle | Complications |
|------------------|---------------|----------------|------------|-----|-----|-----|----------------|-------------|-----------------------|----------------|---------------|
| Li et al.[22]    | NA            | NA             | NA         | YES | NA  | NA  | NA             | YES         | YES                   | NA             | NA            |
| Liu et al.[21]   | NA            | YES            | YES        | YES | NA  | YES | NA             | YES         | YES                   | NA             | YES           |
| Kyung et al.[23] | YES           | YES            | YES        | YES | YES | NA  | NA             | YES         | YES                   | NA             | YES           |
| Lin et al.[24]   | NA            | YES            | YES        | NA  | YES | NA  | NA             | YES         | YES                   | NA             | YES           |
| Guo et al.[25]   | NA            | YES            | YES        | YES | NA  | NA  | NA             | YES         | YES                   | NA             | YES           |
| Park et al.[26]  | NA            | NA             | NA         | NA  | NA  | NA  | NA             | NA         | YES                   | NA             | NA            |
| Oh et al.[10]    | YES           | YES            | YES        | YES | NA  | YES | NA             | YES         | NA                   | NA             | YES           |
| Uribe et al.[27] | NA            | YES            | NA         | NA  | NA  | NA  | NA             | YES         | NA                   | NA             | YES           |
| Hwang et al.[28] | YES           | NA             | NA         | YES | YES | NA  | NA             | YES         | NA                   | YES           | YES           |
| Nirala et al.[29]| NA            | NA             | NA         | NA  | NA  | NA  | NA             | YES         | YES                   | NA             | NA            |
| Hilibrand et al.[30]| NA           | NA             | NA         | NA  | NA  | NA  | NA             | YES         | YES                   | NA             | NA            |
| Jeffrey et al.[31]| NA            | NA             | NA         | NA  | NA  | NA  | NA             | YES         | YES                   | NA             | NA            |
| Emery et al.[32] | NA            | NA             | NA         | NA  | NA  | NA  | NA             | YES         | NA                   | NA             | NA            |
| Swank et al.[33] | NA            | NA             | NA         | NA  | NA  | NA  | NA             | YES         | NA                   | NA             | NA            |
| Yonenobu et al.[34]| NA            | NA             | NA         | NA  | NA  | NA  | NA             | NA         | YES                   | NA             | YES           |
| Number of patients involved | 133 | 446 | 446 | 517 | 133 | 228 | 805 | 1140 | 432 | 295 | 749 |

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rate of non-union due to graft–host interfaces [10,11]. An alternate means of improving the fusion rate after multi-level decompression is the use of ACCF [12]. In addition to improving the fusion rate, ACCF also provides for a more extensive decompression and serves as a source for autografting. Unfortunately, ACCF is a more difficult spinal surgery to perform and is also associated with a higher incidence of complications, such as increased risk of damage to the spinal cord or nerve roots.

Table 3. Details of complications of the included studies.

| Study               | Dysphagia | Hoarseness | Cerebral fluid leakage | Donor site pain | Epidural hematoma | CS palsy | Infection |
|---------------------|-----------|------------|------------------------|-----------------|-------------------|----------|-----------|
| Liu et al. [21]     | YES       | NA         | NO                     | YES             | YES               | YES      | NA        |
| Kyung et al. [23]   | YES       | NA         | NA                     | NA              | NA                | NA       | NA        |
| Lin et al. [24]     | YES       | NA         | NA                     | NA              | NA                | NA       | NA        |
| Guo et al. [25]     | YES       | NA         | NA                     | NA              | NA                | NA       | NA        |
| Uribe et al. [27]   | YES       | NA         | NA                     | NA              | NA                | NA       | NA        |
| Nirala et al. [29]  | YES       | NA         | NO                     | YES             | YES               | YES      | NA        |
| Yonenobu et al. [34]| NA        | NA         | NO                     | NA              | NA                | NA       | NA        |

Table 4. Quality assessment according to the Newcastle–Ottawa scale of the included studies.

| Study               | Selection | Comparability | Exposure | Total score |
|---------------------|-----------|---------------|----------|-------------|
| Li et al. [22]      | 3         | 2             | 3        | 8           |
| Liu et al. [21]     | 3         | 2             | 3        | 8           |
| Kyung et al. [23]   | 3         | 2             | 3        | 8           |
| Lin et al. [24]     | 3         | 2             | 3        | 8           |
| Guo et al. [25]     | 3         | 2             | 3        | 8           |
| Park et al. [26]    | 2         | 2             | 3        | 7           |
| Oh et al. [10]      | 2         | 2             | 3        | 7           |
| Uribe et al. [27]   | 2         | 2             | 3        | 7           |
| Hwang et al. [28]   | 3         | 2             | 3        | 8           |
| Nirala et al. [29]  | 2         | 2             | 3        | 7           |
| Hillbrand et al. [30]| 2        | 2             | 3        | 7           |
| Jeffrey et al. [31] | 2         | 2             | 3        | 7           |
| Emery et al. [32]   | 2         | 2             | 3        | 7           |
| Swank et al. [33]   | 2         | 2             | 3        | 7           |
| Yonenobu et al. [34]| 2         | 2             | 3        | 7           |

Figure 1. Flow diagram detailing study inclusion.

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excessive bleeding, graft displacement or extrusion, and others.

The results of previous studies comparing the clinical effects of ACDF to ACCF for the treatment of CSM vary considerably. It is still uncertain whether ACDF is safer and more effective than ACCF. Therefore, to clarify these ambiguous findings we performed a meta-analysis to compare ACDF with ACCF for the treatment of CSM.

Methods

2.1 Search strategies

To assemble all of the relevant literature, a search of relevant systematic reviews on CSM in the Cochrane Library (Cochrane library 2013), observational cohort studies (with and without control groups), systematic reviews, and clinical trials was conducted in MEDLINE (1966 to July 2013), EMBASE (1974 to July 2013), PubMed (1966 to July 2013) and Google Scholar (1966 to July 2013). The following search terms were used: cervical spondylotic myelopathy, cervical spine, discectomy, corpectomy, cervical spondylosis, surgical decompression, spinal fusion, and complications, with various combinations of the operators “AND”, “NOT”, and “OR”. We restricted the language to English. References cited in relevant articles and reviews were checked to identify additional studies. The full search strategy is available upon request from the corresponding authors (Wang and Tan).

The quality of the studies was independently assessed by two authors (Han and Liu), and the level of agreement between them was recorded. The decision on whether to include an article was made by manual screening of titles and abstracts, followed by full-text screening by the same reviewers. If additional data or clarification were necessary, we contacted the study authors. Any disagreements between reviewers were resolved by discussion with another reviewer (Wang).

2.2 Eligibility criteria

Studies were included if they met the following criteria: (1) adult patients over 18 years of age of both genders with CSM; (2) randomized or non-randomized controlled clinical studies; (3) studies compared ACDF with ACCF for treatment of CSM; (4) post-operative follow-up with included patients was for a minimum of 24 months; and (5) outcome assessment was based on the primary and secondary outcomes. The primary outcome was defined as major surgical complications, radiographic outcomes, fusion rate, or patient-related outcome measures regarding pain and quality of life using various validated questionnaires, such as the Japanese Orthopedic Association score (JOA), the Visual Analogue Score (VAS), the Neck Disability Index (NDI), and Odom criteria, among others. The secondary outcome included surgical data, such as the operation time, blood loss and length of hospital stay.

2.3 Exclusion criteria

Studies were excluded if they (1) had an average follow-up time of less than 24 months; (2) were uncontrolled; (3) described case reports or were systematic reviews; (4) dealt only with combined ACDF and ACCF surgery versus ACDF or ACCF alone for treatment of CSM.

2.4 Data extraction and management

Data were extracted independently by two reviewers (Han and Liu). Discussions were conducted to deal with disagreements, and when necessary, discussions included another independent expert (Wang). The following information was collected from each study: (1) general characteristics, including the authors, the year of publication, the study location, the number of patients, and the mean age; (2) surgical characteristics, such as the type of surgery, the type of fusion, the surgical approach, the duration of surgery, and the blood loss; (3) post-operative outcomes, such as the JOA score, the VAS score, the NDI score, the Odom score, the fusion rate, and the rate of complications.

Figure 2. The forest plot for hospital stay between ACDF group and ACCF group, CI = confidence interval, df = degrees of freedom, IV = independent variable, SD = standard deviation.
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Figure 3. The forest plot for blood loss between ACDF group and ACCF group, CI = confidence interval, df = degrees of freedom, IV = independent variable, SD = standard deviation.
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publication, sample size, age, gender, duration of follow-up and the type of graft (Table 1); and (2) details of the clinical outcome measurement: the length of hospital stay, blood loss, operation time, JOA, VAS, NDI, Odom criteria, fusion rate, Cobb angles of C2–C7, segmental angle complications, and the type of complications, such as dysphagia, hoarseness, C5 palsy, infection, cerebral fluid leakage, donor site pain, epidural hematoma, graft related and hardware-related complications (Tables 2 and 3). All included studies met the inclusion and exclusion criteria. The extracted data were rechecked for accuracy or against the inclusion criteria by Wang.

2.5 Statistical analysis

All statistical tests were performed using the Review Manager software (RevMan Version 5.1; The Cochrane Collaboration, Copenhagen, Denmark). Assessment for statistical heterogeneity was done using the Chi-squared and I-squared tests [16]. Values of I² greater than 50% were considered to indicate substantial heterogeneity. A probability of p<0.05 was considered to be statistically significant. The results were expressed in terms of mean difference (MD) and 95% CI for continuous outcomes and in terms of odds ratio (OR) and 95% confidence interval (95% CI) for dichotomous outcomes. A random effects model was used for heterogeneous data; otherwise, a fixed effect model was used. Collected data were checked and entered into the computer by the two reviewers (Han and Liu).

3.1 Search results

Initial electronic database searches yielded 2157 relevant titles. Of these, 2075 were excluded after review of the abstract and title for being unrelated to the topic at hand, not human studies, not comparative studies, or for being case reports or review articles. A further 63 studies were subsequently excluded due to failure to meet the inclusion criteria after review of the full text. One article were excluded due to insufficient follow-up [17]. An additional two studies were excluded due to other interventions [18,19]. Two articles identified were written by the same author [20,21], and we selected the one most recently published [21]. As a result, fifteen studies fulfilled the eligibility criteria [10,21–34]. Study inclusion is detailed in Fig 1. A meta-analysis was conducted using these fifteen studies.

3.2 Demographic characteristics and quality assessment

The demographic characteristics of the included studies are presented in Tables 1–3. The 15 studies included a total of 1372 patients: 734 who underwent ACDF and 638 who underwent ACCF with various grafts, including autografts, allografts, and cage and/or plate systems. All participants in the fifteen studies had undergone follow-up for at least 2 years. No randomized controlled trials were identified; all fifteen studies included were retrospective studies. The quality of each study was assessed using the Newcastle Ottawa Quality Assessment Scale (NOQAS). This scale for non-randomized case controlled studies and cohort studies was used to allocate a maximum of nine points for the

Figure 4. The forest plot for operation time between ACDF group and ACCF group, CI = confidence interval, df = degrees of freedom, IV = independent variable, SD = standard deviation.
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Figure 5. The forest plot for JOA score between ACDF group and ACCF group, CI = confidence interval, df = degrees of freedom, IV = independent variable, SD = standard deviation, JOA = the Japanese Orthopedic Association scores.
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quality of selection, comparability, exposure, and outcomes for study participants. Of the studies, six scored 8 points and nine scored 7 points. Hence, the studies were of a relatively high quality (Table 4).

### 3.3 Clinical outcome analysis

#### 3.3.1 Hospital stay, blood loss and operation time

Three studies were selected for the meta-analysis for hospital stay [10,23,27]. A total of 133 patients from 3 studies (66 patients for ACDF and 67 patients for ACCF) were included in this comparison. The available data demonstrated low heterogeneity ($I^2 = 27\%$). The hospital stay in the ACDF group was superior to the ACCF group ($MD = -5.60, 95\% CI = -7.09 to -4.11; p<0.00001; Fig 2$). Six studies reported intraoperative blood loss and operation time; a total of 446 patients from 6 studies (250 patients for ACDF and 196 patients for ACCF) were included. Blood loss was significantly higher in the ACCF group compared with ACDF ($MD = -151.35, 95\% CI = -253.22 to -49.48; p = 0.004; Fig 3$). There was no significant difference in operation time between the two treatment groups ($MD = -9.34, 95\% CI = -42.99 to 24.31; p = 0.59; Fig 4$). There was significant heterogeneity in blood loss and operation time between the studies ($I^2 = 98\%$, which can not be explained by our predefined subgroup analysis. Therefore, the quality of evidence for this outcome is low.

#### 3.3.2 JOA, VAS, NDI and Odom criteria

The clinical outcome for 571 patients from seven studies was assessed using the JOA score (282 in the ACDF group and 235 in the ACCF group). There was no significant difference in the final follow-up JOA score between the two groups ($MD = 0.24, 95\% CI = -0.10 to 0.57; p = 0.16$, with low heterogeneity ($I^2 = 7\%$; Fig 5$)$. Three studies included reports of neck pain in the VAS scores (66 in the ACDF group and 67 in the ACCF group). There was no difference in neck VAS score between ACDF and ACCF ($MD = -0.06, 95\% CI = -0.81 to 0.70; p = 0.88$, with no heterogeneity ($I^2 = 0\%$; Fig 6$). Two studies reported a final follow-up NDI score; there was no significant difference between the two treatment groups ($MD = -1.37, 95\% CI = -3.17 to 0.43; p = 0.14; Fig 7$). Seven trials reported the Odom criteria (428 in the ACDF group and 377 in the ACCF group). The patients with excellent or good clinical outcomes were similar in the two groups ($OR = 0.86, 95\% CI = 0.60 to 1.30; p = 0.53$) and the available data demonstrated low heterogeneity ($I^2 = 5\%$; Fig 8).

#### 3.3.3 Radiographic assessment (fusion rate, Cobb angle of C2-C7, and segmental angle)

Twelve studies used radiographs to assess the consolidation of the fusion ($n = 1140$ patients, 601 in the ACDF group and 539 in the ACCF group). The incidence of fusion was not different between the two groups ($OR = 1.17, 95\% CI = 0.34 to 4.11; p = 0.80$, with moderate heterogeneity ($I^2 = 72\%$; Fig 9$)). Six trials reported the Cobb angle of C2-C7 ($243$ in the ACDF group and $109$ in the ACCF group) and three trials reported the segmental angle ($169$ in the ACDF group and $126$ in the ACCF group). Statistical analysis showed significant differences between the ACDF and ACCF groups for changes of the angle of the Cobb angle ($MD = -3.70, 95\% CI = 0.96 to 6.45; p = 0.008; Fig 10$ and the segmental angle ($MD = -2.54, 95\% CI = 4.22; p<0.00001; I^2 = 6\%; Fig 11$).

#### 3.3.4 Complications

Eight studies reported complications ($n = 749$ patients, 382 in the ACDF group and 367 in the ACCF group), however, the records of post-operative complications were variable. Some studies described all complications, whereas some provided only the major complications. The incidence of complications was significantly higher in the ACCF group than in the ACDF group ($OR = 0.50, 95\% CI = 0.35 to 0.73; p = 0.0003$, with no heterogeneity ($I^2 = 0\%$; Fig 12$). There was a significant difference in graft-related complications, however, there were no differences in dysphagia, hoarseness, C5 palsy, infection, cerebral fluid leakage, donor site pain, epidual hematoma, or hardware-related complications (Fig 13).

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**Figure 6.** The forest plot for VAS score between ACDF group and ACCF group, CI = confidence interval, df = degrees of freedom, IV = independent variable, SD = standard deviation, VAS = visual analogue score of neck.

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**Figure 7.** The forest plot for NDI score between ACDF group and ACCF group, CI = confidence interval, df = degrees of freedom, IV = independent variable, SD = standard deviation, NDI = neck disability index.

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Discussion

Although the surgical treatment for cervical spondylotic myelopathy (CSM) has a history going back sixty years, the selection of surgical procedures remains controversial and challenging. The common surgical procedures used include the anterior, posterior, and combined anteroposterior approaches. Anterior approaches to the cervical spine are recognized as a reliable and effective method to treat CSM and they have been widely accepted as an appropriate operative procedure. Anterior decompression and fusion can remove the compressive pathology and reconstruct the alignment of the cervical spine, yielding good clinical results. The type of decompression and reconstruction technique are the two important decisions to be made. Anterior decompression and fusion include cervical discectomy with fusion (ACDF) and anterior cervical corpectomy with fusion (ACCF) [35–37], however, the ideal anterior decompression method is controversial.

Although some relevant studies comparing the ACDF and ACCF have been reported, the evidence regarding whether ACDF is superior to ACCF remains insufficient, owing to ambiguous results. We therefore conducted a meta-analysis to determine whether ACDF is associated with better clinical outcomes compared with ACCF. In this meta-analysis, we used strict eligibility criteria. Although no RCT studies were included in our study, all selected studies were of high quality according to the Newcastle Ottawa Quality Assessment Scale (NOQAS) and the baseline variables were similar. Thus, we considered the included reports suitable for meta-analysis. Clinical outcomes (hospital stay, JOA, VAS, NDI score and Odom criteria), surgical outcomes (operation time, blood loss, and perioperative complications), and radiographic outcomes (rate of fusion, Cobb angle of C2–C7, and segmental angle) were assessed in the meta-analysis.

There was a significant difference in hospital stay between ACDF and ACCF. A shorter hospital stay makes ACDF a better proposition than ACCF. In the meta-analysis of JOA, VAS and NDI, scores were similar in the two groups. However, both groups demonstrated a significant post-operative increase in JOA scores and decrease in VAS scores, an increase that was maintained at the final follow-up. There was also no difference in Odom criteria.
between the two groups. These findings indicate that both groups achieved adequate decompression of the spinal cord and nerve roots that were compressed by herniated discs or osteophytes, and that these patients benefited from reconstruction of the spinal column.

In the meta-analysis, operation time and blood loss were selected to evaluate surgical trauma. Both the overall and subgroup analyses revealed that although blood loss was significantly higher in the ACCF group than in the ACDF group, the operation time was similar in the two groups. This indicates that,

### Table: Odds Ratio of Complications

| Study or Subgroup | ACDF Events | ACDF Total | ACCF Events | ACCF Total | Weight | M-H, Random, 95% CI | M-H, Random, 95% CI |
|-------------------|-------------|------------|-------------|------------|--------|---------------------|---------------------|
| Guo 2011          | 1           | 43         | 6           | 24         | 2.3%   | 0.07 [0.01, 0.64]   |                     |
| Hwang 2007        | 8           | 27         | 19          | 35         | 9.6%   | 0.35 [0.12, 1.02]   |                     |
| Kyung 2012        | 10          | 25         | 7           | 15         | 6.5%   | 0.76 [0.21, 2.77]   |                     |
| Lin 2012          | 11          | 57         | 20          | 63         | 15.1%  | 0.51 [0.22, 1.20]   |                     |
| Liu 2012          | 15          | 69         | 17          | 39         | 14.8%  | 0.36 [0.15, 0.84]   |                     |
| Nirala 2004       | 16          | 69         | 39          | 132        | 23.8%  | 0.72 [0.37, 1.41]   |                     |
| Uribe 2009        | 1           | 42         | 3           | 38         | 2.0%   | 0.28 [0.03, 2.86]   |                     |
| Yang 2012         | 16          | 103        | 23          | 87         | 21.1%  | 0.51 [0.25, 1.05]   |                     |
| Yonenobu 1985     | 6           | 50         | 3           | 21         | 4.9%   | 0.82 [0.18, 3.63]   |                     |
| Subtotal (95% CI) |             | 485        | 454         | 100.0%     |        | 0.51 [0.36, 0.70]   |                     |

Total events: 84

Heterogeneity: Tau² = 0.00; Chi² = 6.22, df = 8 (P = 0.62); I² = 0%
Test for overall effect: Z = 4.08 (P < 0.0001)

Total events: 485

Heterogeneity: Tau² = 0.00; Chi² = 6.22, df = 8 (P = 0.62); I² = 0%
Test for overall effect: Z = 4.08 (P < 0.0001)
| Study or Subgroup | ACDF Events | ACDF Events | Odds Ratio | Odds Ratio |
|------------------|-------------|-------------|------------|------------|
|                  | Total Weight | Total Weight | M-H Random | 95% CI Year |
|                  | Weight      | Weight      | M-H Random | 95% CI      |
| Dysphagia        | 3 69 7 132 | 69 7 132 6.5% | 0.81 [0.20, 3.24] | 2004 |
|                  |             |             |            |            |
|                  | 2 27 3 35 | 27 3 35 3.6% | 0.63 [0.13, 5.50] | 2007 |
|                  | 8 69 4 39 | 69 4 39 7.7% | 1.15 [0.32, 4.49] | 2012 |
|                  | 3 25 3 15 | 25 3 15 4.1% | 0.55 [0.09, 3.13] | 2012 |
|                  | 4 57 5 63 | 57 5 63 6.7% | 0.88 [0.22, 3.43] | 2012 |
|                  | 247 95 284 | 284 284 28.5% | 0.86 [0.45, 1.67] | 2012 |

Total events

Subtotal (95% CI)

Heterogeneity: Tau^2 = 0.00; Chi^2 = 0.47, df = 4 (P = 0.98); P = 0%
Test for overall effect: Z = 0.44 (P = 0.66)

Hbarness

Nirsat 2004 | 2 69 3 132 3.6% | 1.28 [0.21, 7.67] | 2004 |

Hwong 2007 | 2 27 3 35 4.4% | 1.30 [0.25, 7.19] | 2007 |

Khwong 2012 | 4 57 3 63 3.7% | 0.73 [0.12, 4.61] | 2012 |

Liu 2012 | 4 57 3 63 3.7% | 0.73 [0.12, 4.61] | 2012 |

Subtotal (95% CI)

Heterogeneity: Tau^2 = 0.00; Chi^2 = 0.63, df = 1 (P = 0.43); P = 0%
Test for overall effect: Z = 1.33 (P = 0.18)

CS palsy

Liu 2012 | 2 57 3 63 3.7% | 0.73 [0.12, 4.52] | 2012 |

Liu 2012 | 2 57 3 63 3.7% | 0.73 [0.12, 4.52] | 2012 |

Subtotal (95% CI)

Heterogeneity: Tau^2 = 0.00; Chi^2 = 0.63, df = 1 (P = 0.43); P = 0%
Test for overall effect: Z = 1.33 (P = 0.18)

Infection

Yononbu 1985 | 1 50 0 21 1.2% | 1.30 [0.05, 33.28] | 1985 |

Nirsat 2004 | 2 69 5 132 4.2% | 0.76 [0.14, 4.01] | 2004 |

Liu 2012 | 0 69 1 39 1.2% | 0.18 [0.01, 4.94] | 2012 |

Subtotal (95% CI)

Heterogeneity: Tau^2 = 0.00; Chi^2 = 0.80, df = 2 (P = 0.67); P = 0%
Test for overall effect: Z = 0.63 (P = 0.53)

Cerebral fluid leakage

Guo 2011 | 0 43 1 24 1.2% | 0.18 [0.01, 4.60] | 2011 |

Khwong 2012 | 0 25 1 15 1.2% | 0.19 [0.01, 4.96] | 2012 |

Liu 2012 | 2 57 1 63 2.1% | 0.03 [0.02, 7.25] | 2012 |

Liu 2012 | 1 69 0 39 1.2% | 1.73 [0.07, 43.49] | 2012 |

Subtotal (95% CI)

Heterogeneity: Tau^2 = 0.00; Chi^2 = 2.48, df = 3 (P = 0.48); P = 0%
Test for overall effect: Z = 0.37 (P = 0.71)

Donor site pain

Nirsat 2004 | 3 69 8 132 6.7% | 0.70 [0.28, 2.75] | 2004 |

Hwong 2007 | 0 27 8 35 1.5% | 0.06 [0.01, 1.07] | 2007 |

Khwong 2012 | 1 25 4 15 2.3% | 0.11 [0.01, 1.15] | 2012 |

Subtotal (95% CI)

Heterogeneity: Tau^2 = 0.00; Chi^2 = 3.50, df = 2 (P = 0.17); P = 0%
Test for overall effect: Z = 1.74 (P = 0.08)

Epidural haematoma

Yononbu 1985 | 1 50 0 21 1.2% | 1.30 [0.05, 33.28] | 1985 |

Guo 2011 | 0 43 1 24 1.2% | 0.18 [0.01, 4.60] | 2011 |

Liu 2012 | 1 57 2 63 2.1% | 0.54 [0.05, 6.17] | 2012 |

Liu 2012 | 1 69 1 39 1.6% | 0.56 [0.03, 9.11] | 2012 |

Subtotal (95% CI)

Heterogeneity: Tau^2 = 0.00; Chi^2 = 0.72, df = 3 (P = 0.87); P = 0%
Test for overall effect: Z = 0.69 (P = 0.38)

Graft related

Yononbu 1985 | 3 50 3 21 4.4% | 0.38 [0.07, 2.08] | 1985 |

Nirsat 2004 | 1 69 5 132 2.6% | 0.37 [0.04, 3.26] | 2004 |

Khwong 2012 | 0 42 1 38 1.2% | 0.29 [0.01, 7.44] | 2006 |

Khwong 2012 | 0 25 2 15 1.3% | 0.11 [0.02, 1.37] | 2012 |

Liu 2012 | 0 57 6 63 1.5% | 0.08 [0.00, 1.40] | 2012 |

Liu 2012 | 0 69 2 39 1.3% | 0.11 [0.01, 2.31] | 2012 |

Subtotal (95% CI)

Heterogeneity: Tau^2 = 0.00; Chi^2 = 1.64, df = 5 (P = 0.90); P = 0%
Test for overall effect: Z = 2.64 (P = 0.005)

Hardware related

Guo 2011 | 0 43 1 24 1.2% | 0.18 [0.01, 4.60] | 2011 |

Liu 2012 | 0 69 3 39 1.4% | 0.08 [0.00, 1.49] | 2012 |

Khwong 2012 | 1 25 0 15 1.3% | 0.30 [0.15, 7.43] | 2012 |

Subtotal (95% CI)

Heterogeneity: Tau^2 = 1.50; Chi^2 = 3.19, df = 2 (P = 0.20); P = 0%
Test for overall effect: Z = 0.91 (P = 0.36)

Total (95% CI)

1791 1718 100.0% | 0.58 [0.41, 0.83] | 2012 |

Total events

55 98

Heterogeneity: Tau^2 = 0.00; Chi^2 = 1.70, df = 34 (P = 0.96); P = 0%
Test for overall effect: Z = 3.01 (P = 0.003)
in the treatment of CSM, the surgical trauma associated with ACCF is higher than with ACDF. We selected the total complications for meta-analysis to evaluate complication-related outcomes, and found a higher incidence of complications with ACCF than with ACDF (OR = 0.50, 95% CI = 0.35 to 0.73, \( p = 0.0003 \)). Subgroup analysis observed apart from graft related complications is significantly higher in the ACCF group (\( p = 0.005 \)), while other subgroups, namely dysphagia, hoarseness, C5 palsy, infection, cerebral fluid leakage, donor site pain, epidural hematoma and hardware-related complications, were similar between the two groups. There was no heterogeneity between the two groups for total complications for all subgroups (\( I^2 = 0 \)). Considering the most significantly different complications were graft-related, this seemed to be due to technical reasons. Some authors consider that ACDF offers more fixation points to hold the construct rigidly in place, but ACCF provide only two points of fixation. The lack of fixation points may therefore be the reason for the higher graft-related complication rates in the ACCF group [15,38]. There were similar rates of dysphagia and hoarseness between the two groups in this meta-analysis; and they are the most common sequelae. Some studies have reported that post-operative dysphagia occurs in 2–48% of patients [39] and post-operative hoarseness occurs in 3–11% of patients [40,41], but these symptoms are frequently transient. The etiology of dysphagia may be multifactorial, including hematoma formation and prolonged retraction and denervation of the upper esophagus by injury to the pharyngeal plexus [42]. The etiology of post-operative hoarseness has been postulated to be related to direct injury to the recurrent or superior laryngeal nerves.

Regarding the fusion rate, in the current meta-analysis, patients who underwent ACDF were not significantly different from those who underwent ACCF (\( p = 0.63 \)). However, some studies have reported that ACDF has a high rate of non-union, because they consider that ACCF can not only easily resolve retro-vertebral compressive pathology but also reduce the graft-host interface [23,25,29,30]. However, meta-analysis is a statistical analysis of data collected from several different studies on the same problem, pooling outcomes in order to arrive at a more unbiased and scientific conclusion [43,44], so we regard the fusion rate to be similar between the two groups. In this meta-analysis, both the ACDF and ACCF groups had significantly increased lordosis of C2–C7 and fusion segments, but the increase was greater in the ACCF group than in those with ACCF. Some studies have reported that ACDF can provide multiple points of distraction and fixation in addition to the graft and interbody space shaping, and can also restore alignment by pulling the involved vertebral bodies toward the lordotic ventral plate. However, ACCF grafts may straighten the cervical spinal column between the remaining vertebral bodies [24].

There are several limitations to this meta-analysis. Firstly, none of the studies included in the meta analysis were RCTs. Secondly, there was a variable length of follow-up between the studies and this is particularly important for evaluating surgery results. Thirdly, clinical heterogeneity might be caused by the various indications for surgery and the surgical technologies used at the different treatment centers. Finally, these studies lack a gold standard outcome to evaluate the post-operative clinical effect.

### Conclusion

Based on a systematic review of the literature and meta-analysis of ACDF and ACCF for the treatment of CSM, the following conclusions may be drawn. The clinical outcomes of ACDF are superior to ACCF for hospital stay, blood loss, complications and increased cervical lordosis, but the outcomes of operation time, fusion rate, Odom criteria and JOA, VAS, and NDI scores are equivalent between the two groups. This meta-analysis highlights the surgical and outcome differences between ACDF and ACCF in the treatment of CSM. Due to the varying pathoanatomy of spinal cord compression leading to CSM, individualized treatment decisions should be based upon the location of the compressive pathology. If significant retrovertebral compression on the spinal cord is present then ACCF is the preferred treatment. In the absence of significant retrovertebral disease, ACDF is the preferred treatment. However future studies with high methodological quality and long-term follow-up periods are needed for updated meta-analyses, in order to better evaluate the two procedures for CSM treatment.

### Supporting Information

**Checklist S1 PRISMA Checklist.**

(DOC)

**Author Contributions**

Conceived and designed the experiments: SJW JT. Performed the experiments: YCH ZQL. Analyzed the data: YCH ZQL. Contributed reagents/materials/analysis tools: LJL. Wrote the paper: YCH ZQL.

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