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Unilateral biportal endoscopy versus anterior cervical discectomy and fusion for cervical radiculopathy: a meta-analysis

T. MARTINS DA SILVA[1], M. F. L. ALMEIDA NEGRELI[2], R. C. DINIZ DE SOUZA[2], S. B. GUAZZELLI[1], A. M. MIRANDA[3]

[1]Federal University of Minas Gerais, Minas Gerais,Alfredo Balena Avenue, 190 - MG, 30130-100, Brazil; [2]State University of Maranhao, Alecrim Hill, w/n, 656000-000, Maranhao, Brazil; [3]Federal University of São Paulo, Sena Madureira street, 1500, 04021-001,São Paulo, Brazil.

Correspondence at: Alesson Marinho Miranda, M.D. Anesthesiologist and Pain management, Cel. Auris Coelho street, 285, Natal, Brazil, 59075-050. E-mail: alesson.mar@gmail.com

The gold standard treatment for cervical radiculopathy is anterior cervical discectomy and fusion (ACDF). Our study compared ACDF with unilateral biportal endoscopy (UBE) to determine whether or not there is an advantage of the minimally invasive technique. PubMed, Embase, and Cochrane databases were searched for studies that compared UBE to ACDF for cervical radiculopathy. Statistical analysis was performed using Review Manager 5.4. Heterogeneity was examined with I^2 statistics and a random-effects model was used for all outcomes. Three studies comprising 509 patients with cervical radiculopathy were included. Of the participants studied, 255 underwent UBE (50.1%). There were no significant differences observed across the two groups in the change from baseline of NDI scores (MD: -0.17; 95% CI: -2.50 to 2.17), neck pain (SMD: -0.10; 95% CI: -0.53 to 0.33), and upper limb pain (SMD: -0.19; 95% CI: -0.43 to 0.06; p = 0.13). The UBE group showed a significant increase in operating time (MD: 19.78 min; 95% CI: 13.57 to 25.98 min) and a lower incidence of complications (0.051% vs. 0.094%; OR 0.52; 95% CI 0.25-1.08). UBE is an effective and safe alternative to ACDF, with no significant differences between the two approaches in terms of NDI scores or neck and arm pain. While the UBE group had a longer operating time, it exhibited a lower incidence of postoperative complications.

Keywords: UBE, ACDF, Cervical Radiculopathy, Unilateral biportal endoscopy, Anterior cervical Decompression and fusion, Discectomy, Spine surgery.

INTRODUCTION

Cervical spondylotic radiculopathy (CSR) is a common manifestation of cervical spondylosis characterized by neck pain, arm pain, finger numbness, and arm weakness[1]. While most CSR patients achieve relief through conservative treatments, such as oral non-steroidal anti-inflammatory drugs (NSAIDs), epidural steroid injections, cervical traction, acupuncture, or cervical collars, surgical intervention becomes necessary for those with unremitting radicular pain despite 6 to 12 weeks of conservative treatment, progressive motor weakness, or the presence of myelopathy[2,3].

ACDF is the gold-standard surgical treatment due to its efficacy in nerve decompression and stabilizing the cervical spine by removing pathological tissues and achieving bone graft fusion[4–6]. However, ACDF may cause damage to nearby structures and is associated with dysphagia, hematoma, recurrent laryngeal nerve palsy, adjacent segment disease, and reduced cervical range of motion[7].

Over the past three decades, minimally invasive spine surgery has advanced significantly, aiming to preserve normal spinal structures, as invasiveness affects hospital stay duration and postoperative pain[8]. Endoscopic spine surgery, initially limited to posterolateral disc herniations via a transforaminal approach, faced challenges like limited instruments, poor visibility, high radiation exposure, and a steep learning curve[9].

Posterior cervical foraminotomy (PCF) can be performed endoscopically or openly[10]. Endoscopic PCF often provides better pain relief but raises concerns about instability[11], especially without arthrodesis. Unilateral biportal endoscopy (UBE) is an emerging minimally invasive surgical technique that employs two independent channels for visualization

and instrument manipulation, allowing for enhanced surgical flexibility, a magnified field of view, and a broad decompression range[9]. UBE has demonstrated promising outcomes in treating various spinal conditions, including lumbar and thoracic disorders, and has recently been applied to the treatment of CSR[12,13].

Despite the increasing adoption of UBE in cervical spine surgery, evidence directly comparing its efficacy and safety to ACDF in CSR treatment remains limited. Therefore, we aimed to conduct a systematic review and meta-analysis to compare these two strategies.

MATERIALS AND METHODS

This systematic review and meta-analysis was performed and reported in accordance with the Cochrane Collaboration Handbook for Systematic Review of Interventions and the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) Statement guidelines.

Eligibility Criteria

We restricted our analysis to studies that met all the following inclusion criteria: (1) randomized controlled trials and observational studies; (2) inclusion of patients with cervical radiculopathy with treatment groups for both UBE and ACDF and (3) analysis of any of the following outcomes of interest: neck pain, upper limb pain, and Neck Disability Index (NDI). In case of studies with overlapping patient populations, the study with the largest number of patients was included.

Search Strategy

Two authors performed an electronic search independently using PUBMED, EMBASE, and Cochrane Library. The results were last updated on Dec 26, 2024. The following algorithm was developed as a search strategy: (cervical OR "cervical radiculopathy" OR "disc herniation" OR "herniated disc") AND (discectomy OR "foraminotomy" OR ACDF OR laminoforaminotomy OR decompression OR "Anterior cervical discectomy and fusion") AND (UBE OR "Unilateral biportal endoscopy" OR "biportal endoscopy" OR BESS OR "two portal endoscopy" OR "two portal endoscopic surgery"). Data were extracted from qualified studies and independently tested in detail by the M.N. and T.M. researchers. Disagreements between these authors were resolved by consensus among the three authors. The review protocol has been registered on PROSPERO (CRD42024627489).

Endpoints

The outcomes assessed included upper limb pain, neck pain, NDI, duration of hospitalization, blood loss, operation time, and postoperative complications.

Quality assessment

We evaluated the risk of bias in randomized studies using version 2 of the Cochrane Risk of Bias assessment tool (RoB 2). Non-randomized studies were assessed with the Risk of Bias in Non-randomized Studies of Interventions tool (ROBINS-I). Two independent authors completed the risk of bias assessment (T.M. and R.D.). Disagreements were resolved through a consensus after discussing reasons for discrepancy. The RCT was assigned a score for "high risk", "low risk", or "unclear risk" in each of the five domains: selection, performance, detection, attrition, and reporting biases. Non-randomized studies were evaluated for bias across seven domains: confounding, selection of participants, classification of interventions, deviations from intended interventions, missing data, measurement of outcomes, and reporting outcomes. Funnel plots of individual study weights against point estimates were used to check for evidence of publication bias.

Statistical Analysis

Mean difference (MD) and standardized mean difference (SMD) with 95% confidence intervals (CI) were computed to compare continuous outcomes. Odds ratios (OR) with 95% CI were calculated to compare the incidence of binary endpoints between the two treatment arms. We used Cochran's Q test and I^2 statistics to evaluate for heterogeneity. An I^2 value greater than 75% is considered indicative of high heterogeneity[14]. For all outcomes, pooled estimates were computed with DerSimonian and Laird random-effects models. P-values of < 0.05 were considered statistically significant. Statistical analyses were performed with Review Manager 5.4 (Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark).

The standard deviation (SD) of the mean changes from baseline is a common missing outcome data and difficulties for running a meta-analysis without missing SDs explained by previous systematic reviews. For calculating missing SDs, a formula was defined:

$$SD_{change} = \sqrt{(SD^2_{baseline} + SD^2_{final} - (2 \,.\, r \,.\, SD_{baseline} \,.\, SD_{final})}$$

SD_{change} means the SD of the mean changes from baseline, and the r symbolizes the correlations between the baseline and final measurements; this correlation value is not generally presented in the

studies. For instance, among the studies eligible for this systematic review, none demonstrate this r-value. This systematic review attempted to estimate missing SD changes from baseline using additional data (e.g., confidence intervals, p-values, t-values, F-values, and standard errors) with RevMan. However, this could not be applied due to the lack of information in the included studies. Afterward, corresponding authors of the included studies were contacted to request their data or the mean and SDchange from baseline values, as previously recommended[14,15]. Finally, if the corresponding authors did not share their data with this systematic review, and the $SD_{baseline}$ and SD_{final} values were known, the SD_{change} value was calculated by assigning a value of 0.7 to the r in the formula[16,17] to provide a conservative estimate as undertaken by previous systematic reviews[18,19].

RESULTS

Study selection and baseline characteristics

The primary search yielded 273 results. After the removal of duplicate records and ineligible studies, 35 remained and were fully reviewed based on inclusion criteria. Of those, 3 met the criteria of this review, comprising 509 patients (337 males) from one randomized controlled trial (RCT) and two non-randomized cohorts (Figure 1). Population characteristics are presented in Table I. A total of 255 patients underwent UBE (50.1%) and the follow-up ranged from 1 to 1.5 years.

Pooled analysis of all included studies

There were no significant differences observed across the two groups in the change from baseline of NDI scores (MD: -0.17; 95% CI: -2.50 to 2.17; p = 0.89; I^2 = 73%) (Figure 2A), neck pain (SMD: -0.10; 95% CI: -0.53 to 0.33; p = 0.66; I^2 = 78%) (Figure 2B), upper limb pain (SMD: -0.19; 95% CI: -0.43 to 0.06; p = 0.13; I^2 = 37%) (Figure 2C), and duration of hospitalization (MD: -0.68 days; 95% CI: -2.69 to 1.33 days; p = 0.51; I^2 = 98%) (Figure 2D). Furthermore, no significant difference was found in blood loss between the two studies included in the analysis (MD: -24.27ml; 95% CI: -93.33 to 44.79ml; p = 0.49; I^2 = 99%) (Figure 2E). Compared with the ACDF group, the UBE group had a significantly longer operating time (MD: 19.78 min; 95% CI: 13.57 to 25.98 min; p < 0.00001; I^2 = 58%) (Figure 3).

A total of 24 complications were reported in the ACDF group, while 13 complications were reported in the UBE group. The UBE group had a lower incidence of complications than the ACDF group (0.051% vs. 0.094%; OR 0.52; 95% CI: 0.25 to 1.08; p = 0.08; I^2 = 0%) (Figure 4).

In the ACDF group, the complications included dysphagia, neck and shoulder pain, C5 paralysis, and hoarseness. In contrast, the UBE group reported upper

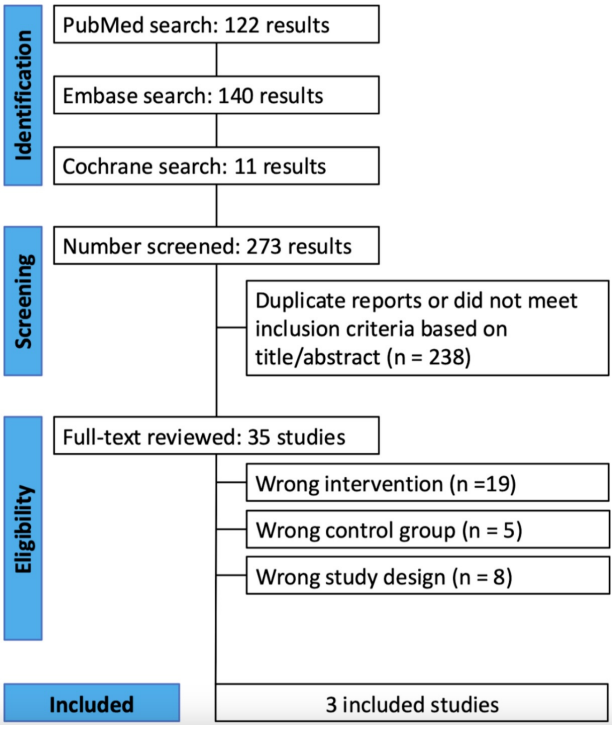

Fig. 1 — PRISMA flow diagram of study screening and selection.

Table I. — Baseline characteristics of included studies. Values are mean ± standard deviation and median (range).

Study	Study design	Follow-up (years)	Study population	Number of participants		Mean age		% Male		Distribution of diseased intervertebral space segments	
				UBE	ACDF	UBE	ACDF	UBE	ACDF	UBE	ACDF
Wen[26]	Retrospective cohort	1,5	Single-segment CSR	30	30	56.69 ± 5.86	56.8 ± 6.5	60	56	C3/4: 3 C4/5: 8 C5/6: 10 C6/7: 9	C3/4: 4 C4/5: 8 C5/6: 11 C6/7: 7
Jung[27]	Retrospective cohort	1	Single-level cervical disc herniation	162	156	54 (29–81)	52 (34–83)	69.75	64.8	C3/4: 6 C4/5: 19 C5/6: 85 C6/7: 35 C7/T1: 7	C3/4: 3 C4/5: 30 C5/6: 94 C6/7: 29 C7/T1: 0
Peng[28]	RCT	1	Unilateral CSR induced by cervical disc herniation	63	68	56.26 ± 12.31	58.31 ± 13.96	65.07	69.11	C3/4: 7 C4/5: 5 C5/6: 13 C6/7: 10 C4-6: 12 C5-7: 11 C6-T1: 5	C3/4: 5 C4/5: 13 C5/6: 15 C6/7: 9 C4-6: 9 C5-7: 14 C6-T1: 3

UBE: unilateral biportal endoscopy; ACDF: anterior cervical decompression and fusion; RCT: Randomized controlled trial; CSR: Cervical spondylotic radiculopathy.

extremity numbness, motor weakness, heat injury, and neck and shoulder pain.

Quality assessment

The randomized trial was classified as low risk of bias. Nonetheless, the non-randomized studies were classified as critical risk of bias, mainly due retrospective nature of both studies. The analysis performed with ROBINS-I and RoB 2 tools for the individual studies is summarized in Figures 5A and 5B.

Although limited by the small number of studies, there was no evidence of publication bias by funnel plot analyses on the main outcomes of neck pain at 12 months and upper limb pain at 12 months (Figures S1 and S2).

DISCUSSION

In this systematic review and meta-analysis of 3 studies and 509 patients, we compared ACDF and UBE to manage cervical radiculopathy. There were no significant differences between UBE and ACDF in improving patient-reported outcomes, including the change from baseline in NDI scores, neck pain, and upper limb pain. The incidence of complications was lower in the UBE group compared to the ACDF group, though this difference did not reach statistical significance.

ACDF is the gold standard surgical strategy for treating CSR. However, its superiority over other established approaches, such as PCF, remains uncertain [20]. UBE and endoscopic PCF are the primary minimally invasive approaches for treating CSR. Previous meta-analyses have compared UBE to PE, with evidence suggesting no significant differences in efficacy and safety between these techniques[21]. However, no meta-analysis has yet compared UBE to the gold standard ACDF.

The UBE procedure was first reported in 2016 for the treatment of lumbar spinal stenosis and has since been widely used for lumbar disorders[22]. UBE combines the advantages of interlaminar endoscopy and microscopic surgery using independent channels for instruments. The combination of observation channel and operation channel enables the instrument to move more widely, thus obtaining a better range of decompression and exploration. However, balancing adequate decompression with preserving the facet joint is essential to maintain segmental stability[23,24]. UBE is a minimally invasive spinal technique that has advanced significantly recently due to its high efficiency, extensive decompression, clear vision, and less damage to the paraspinal musculature[25].

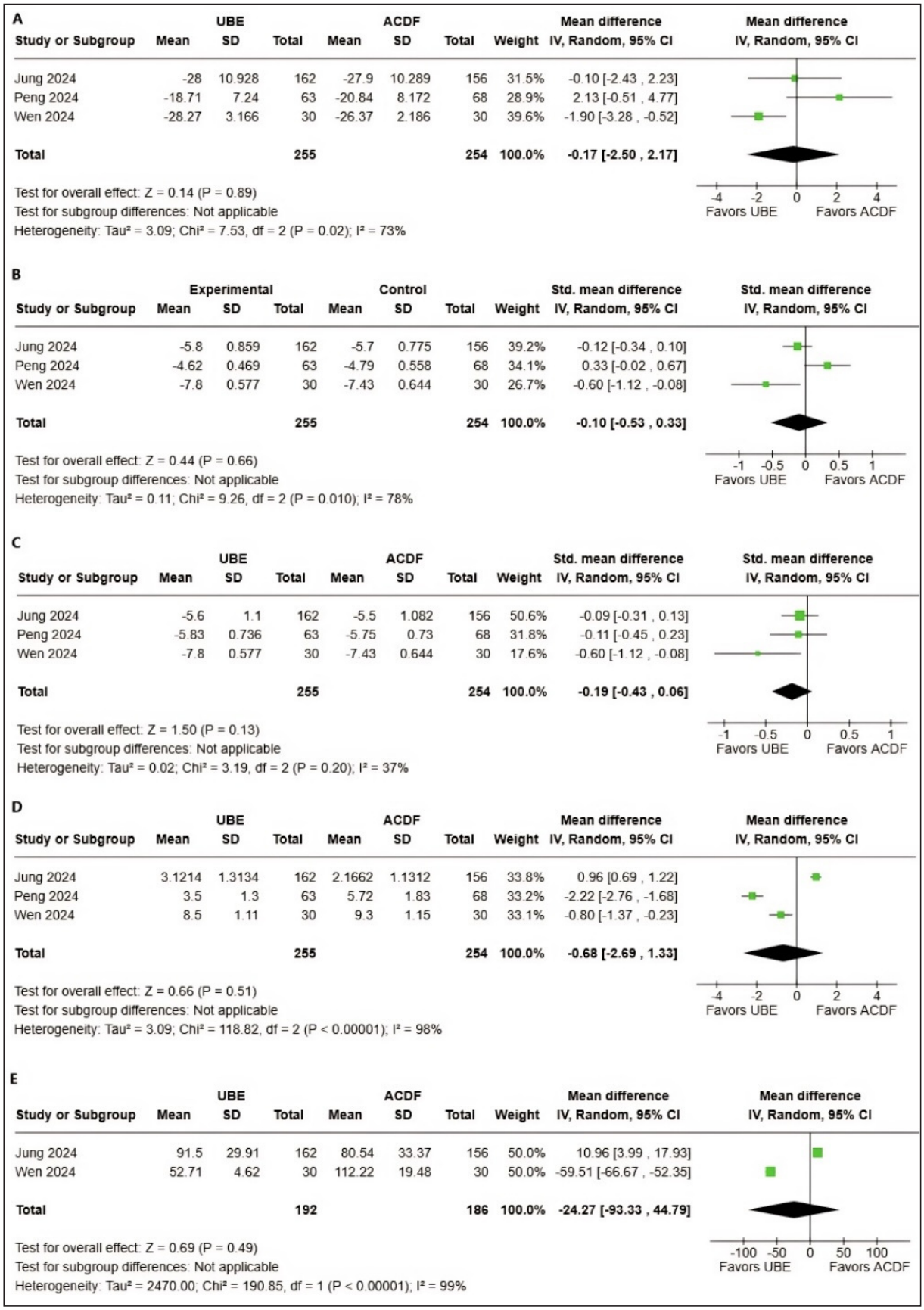

Fig. 2 — No significant differences were observed across the three studies in the change from baseline of NDI scores (A), neck pain (B), upper limb pain (C), and duration of hospitalization (D). Furthermore, no significant difference was found in blood loss between the two studies included in the analysis (E).

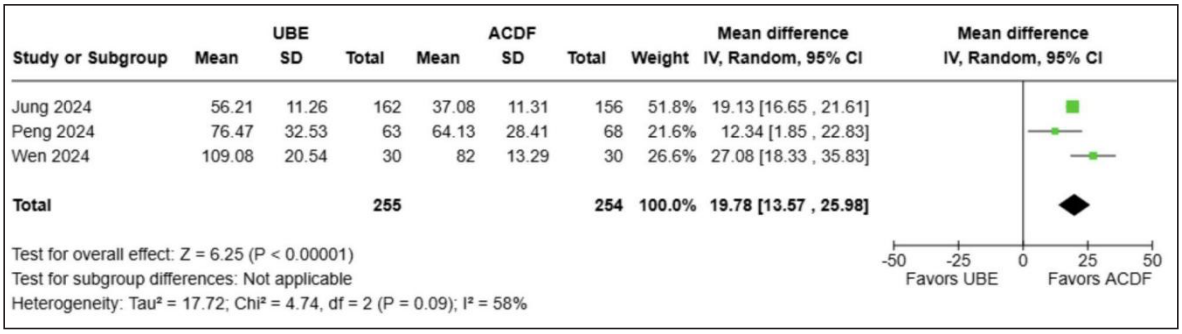

Fig. 3 — Operating time was significantly higher in the UBE group compared to the ACDF group.

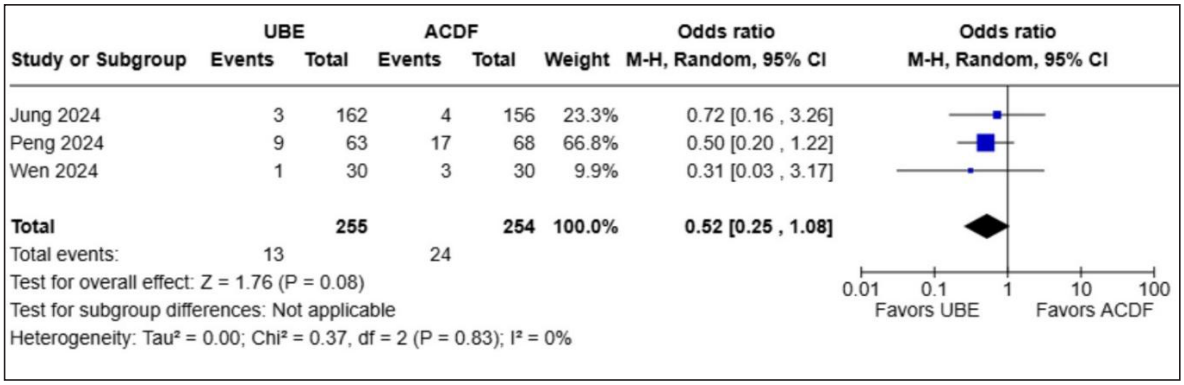

Fig. 4 — The incidence of complications was lower in the UBE group.

A

Study	Bias from randomization process	Bias due to deviations from intended interventions	Bias due to missing outcome data	Bias in measurement of the outcomes	Bias in selection of the reported result	Overall risk of bias
Peng 2024	Low	Low	Low	Low	Low	Low

B

Study	Bias due to confounding	Bias in selection of participants	Bias in classification of interventions	Bias due to deviations from intended interventions	Bias due to missing data	Bias in measurement of outcomes	Bias in selection of the reported result	Overall risk of bias judgement
Wen 2024	Critical	Low	Low	Low	Low	Low	Low	Critical
Jung 2024	Critical	Low	Low	Low	Low	Low	Low	Critical

Fig. 5 — Risk of bias summary for randomized studies: RoB 2 (A) and for non-randomized studies: ROBINS-I (B).

We found that ACDF had a higher complication rate than UBE, including dysphagia, hematoma, recurrent laryngeal nerve palsy, and a higher risk of pseudarthrosis in multi-level fusions, as documented in the literature 6. Operating time was significantly longer in the UBE group compared to the ACDF group, which may be attributed to an initial lack of experience with cervical UBE, as hypothesized by Wen et al and Jung et al[26,27].

Our study has important limitations: (1) two studies were not randomized (2) the follow-up time might not be long enough to evaluate long-term effects of surgical approaches and (3) the learning curve of UBE may have influenced early outcomes.

Another limitation is that Wen et al. used the same Visual Analog Scale (VAS) score to assess both neck and upper limb pain, which may reduce the specificity in identifying the pain source.

There was high heterogeneity in neck pain, duration of hospitalization, and blood loss. Unlike the study by Peng et al., the studies by Jung et al. and Wen et al. are non-randomized which may overestimate or underestimate not only the effect of different interventions but also select distinct patient populations with varying prognoses. Meta-regression was not conducted for this article, as it is generally not recommended to perform meta-regression when fewer than 10 studies are included in a meta-analysis.

CONCLUSION

UBE is an effective and safe alternative to ACDF, with no significant differences between the two approaches in terms of NDI scores or neck and arm pain. While the UBE group had a longer operating time, it exhibited a lower incidence of postoperative complications.

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Data sharing agreement: Because this meta-analysis was based on data extracted from previously published research, all data and study materials are available in the public domain. The authors of this meta-analysis did not have access to patient-level data of the included studies, and researchers interested in these data are encouraged to contact the corresponding authors of each study.

Declaration of interest statement: All authors report no relationships that could be construed as a conflict of interest. All authors take responsibility for all aspects of the reliability and freedom from bias of the data presented and their discussed interpretation.

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