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How Common is Dysphagia After Anterior Cervical Spine Surgery, What Drives it, and Can it be Prevented? An Umbrella Review of Systematic Evidence

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Abstract

Study Design: Umbrella systematic review.

Objective: To critically appraise and synthesise the existing systematic review evidence regarding incidence, risk factors, management strategies, and prognostic impact of dysphagia in patients undergoing anterior cervical spine surgery(ACSS), with interpretation explicitly weighted by methodological confidence.

Methods: A systematic search (inception-November 2025) of PubMed, Embase, Scopus, Web of Science, and the Cochrane Database identified systematic reviews and meta-analyses evaluating dysphagia after ACDF, ACCF, CDA, or multilevel ACSS. Two reviewers independently screened and extracted data. Methodological quality was appraised using AMSTAR-2. Findings were synthesised narratively at the umbrella level and interpreted proportionate to the confidence of evidence.

Results: Thirty-two systematic reviews (>3.6 million patients) were included. Dysphagia incidence ranged from 1%-79% (variations largely driven by heterogeneous definitions and timepoints). Early postoperative (≤2 weeks) dysphagia was common (up to 71%); whereas persistent dysphagia (≥12 months) was reported in 12-14% in selected analyses. Female sex, multilevel procedures, C3-C4 involvement, anterior plating, and rhBMP-2 exposure were recurrently associated with increased risk. In contrast, zero-profile implants, cuff-pressure control, and perioperative steroids were associated with reduced early dysphagia in low-confidence reviews. However, 31/32 reviews were rated critically low confidence by AMSTAR-2 grading, limiting certainty. Only one RCT-based steroid meta-analysis achieved low confidence.

Conclusion: Dysphagia is frequently reported following ACSS, particularly in the early postoperative period. No preventive or therapeutic strategy can currently be recommended as standard of care based on high-certainty evidence. Most findings remain hypothesis-generating and require validation in high-quality prospective studies.

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Keywords
dysphagia, ACDF, anterior cervical spine surgery, complication, spine surgery, systematic review

Introduction

The anterior approach to the cervical spine was initially described by Cloward, Robinson and Smith[1–3] in the 1950s. Since then, it has become a widely employed approach for central and foraminal decompressions. Since the overall morbidity rates for anterior cervical spine surgery (ACSS) are acknowledged to be relatively low,[4] surgeons have been considering the safety and efficacy of performing this approach on an outpatient basis.[5–7] Given the complex vascular, neural, and aerodigestive anatomy, the anterior approach carries a diverse array of potential complications; some of which (such as vertebral artery pseudoaneurysm and oesophageal perforation) can be fatal, if not correctly identified.[3]

Among the diverse complications, dysphagia remains a poorly understood and underappreciated consequence following ACSS.[8] The etiopathogenesis of this condition is still largely unclear and has been purported to be multifactorial in nature.[9–11] Esophageal denervation, prevertebral soft tissue edema, nerve root injuries [such as hypoglossal nerve injury at spinal levels proximal to C3, superior laryngeal nerve (SLN) injury at C3-C4, pharyngeal plexus injury at levels C2-C5, and recurrent laryngeal nerve (RLN) injury during surgery between C5 and T1 levels]; and hematoma formation are some of the causes potentially associated with this condition.[12–16] Despite being a well-recognised clinical problem, there has been no universally accepted definition or technique to identify the presence of post-surgical dysphagia.[8,17] Partly attributable to the lack of a clear definition (or criteria for diagnosis), the incidence of dysphagia in the literature has been reported to vary between 1 and 79%.[18–21] Some of the risk factors for the development of post-surgical dysphagia include use of plate fixation, plate design or its physical prominence, revision surgery, female sex, multilevel procedures, pain severity and use of recombinant human bone morphogenetic protein-2 (rh-BMP-2).[8,22–24] Prior studies have recommended the use of peri-operative corticosteroids, endotracheal tube (ETT) cuff pressure monitoring, use of favourable or low-profile plate designs, use of anchored spacers (instead of traditional cage plate constructs); and diverse modifications to surgical techniques as preventative strategies to reduce the incidence as well as mitigate the severity of this potentially debilitating post-operative adverse event after ACSS.[16,25] However, with such a significant variation in the reported incidence and prevalence of dysphagia, lack of a clear definition, and often contradictory conclusions (from a relatively large-volume, yet lower-quality evidence) regarding the risk factors and preventative measures, the need for a clearer perspective on our current understanding of this significant clinical problem cannot be understated.[3,16,26,27]

The current umbrella review was thus planned to comprehensively summarise the systematic reviews hitherto published on this subject, and attempt to answer the following critically important questions: a. What is the incidence or prevalence of post-operative dysphagia after ACSS? b. What are the predisposing factors (modifiable versus non-modifiable) for the development of this complication, and what is the underlying pathophysiology? c. What are the recommendations to mitigate the incidence (or prevalence) or reduce the severity of this relatively common adverse event? d. What are the management strategies, and how do they impact the overall outcome and surgical prognosis?

Methods

Study Design

This study was conducted as an umbrella systematic review synthesising evidence from published systematic reviews and meta-analyses on dysphagia following ACSS. The primary objective was to provide a comprehensive overview of the incidence, risk factors, management strategies, and prognostic impact of dysphagia in ACSS. The methodology adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[28] Although a protocol was not prospectively registered, the review question, eligibility criteria, and analytic framework were established before data extraction. To minimize post hoc decisions, eligibility criteria and analytic framework established prior to data extraction were consistently adhered at all stages of review.

Search Strategy

A systematic search was performed across PubMed, Embase, Scopus, Web of Science, and Cochrane Database of Systematic Reviews from inception to November 2025. Reference lists of included reviews were hand-searched to identify additional eligible studies. The search terms combined controlled vocabulary and keywords related to *"anterior cervical spine surgery," "ACDF," "cervical disc arthroplasty," "corpectomy," "zero-profile," "plate," "BMP," "steroids,"* and *"dysphagia."* We used the following search strategy for the PubMed database: [("Anterior Cervical Discectomy and Fusion"[MeSH] OR "ACDF" OR "Anterior Cervical Corpectomy" OR "ACCF" OR "Cervical Disc Arthroplasty" OR "CDA" OR "Anterior Cervical Spine Surgery" OR "ACSS") AND ("Dysphagia"[Mesh] OR "Swallowing Disorders" OR "Swallowing Difficulty" OR "Bazaz" OR "SWAL-QOL" OR

"MDADI" OR "EAT-10") AND ("Systematic Review" OR "Meta-Analysis" OR "Review")]. A similar search strategy was used for other databases with database-specific search parameters.

Eligibility Criteria

We followed the PICOS strategy for inclusion of reviews into the analysis. The criteria were as follows: *Population:* Patients undergoing anterior cervical spine surgery (ACDF, ACCF, CDA, multilevel procedures); *Intervention/Exposure*: Surgical techniques, implant types, biologics (BMP), perioperative measures (steroids, cuff pressure control); *Comparator*: Alternative surgical techniques or perioperative strategies; *Outcomes*: Dysphagia incidence, severity, risk factors, management efficacy, and long-term prognosis; *Study type:* Systematic reviews, and meta-analyses. Case reports, individual primary studies of prospective and retrospective nature, along with their narrative reviews, were excluded.

Study Selection and Data Extraction

Two reviewers independently screened titles, abstracts, and full texts. Discrepancies were resolved through consensus. Data were extracted into a structured spreadsheet capturing: author, year, number of studies, sample size, study designs and surgery types, dysphagia definitions and assessment tools, incidence rates and subgroup analyses, key findings and limitations. For consistency, dysphagia incidence was categorised into three time-windows: early (≤2 weeks post-surgery), intermediate (2 weeks-3 months), and persistent (≥12 months).

Quality Assessment

The methodological quality of included systematic reviews was assessed using the AMSTAR-2 (A Measurement Tool to Assess Systematic Reviews) instrument.[29] This tool evaluates 16 critical domains, including protocol registration, comprehensiveness of the search, duplicate study selection and data extraction, justification of exclusions, risk-of-bias assessment, funding transparency, heterogeneity, and publication bias. Each domain was judged as Yes, Partial Yes, No, or Not Applicable. Based on critical flaws, overall confidence in each review was categorised as High, Moderate, Low, or Critically Low. Two reviewers independently applied AMSTAR-2, with disagreements resolved by consensus. It is important to note that AMSTAR-2 evaluates methodological rigour of systematic reviews, but does not directly assess certainty of evidence for specific outcomes (as GRADE does). Our interpretations are therefore limited to review-level confidence rather than outcome-level certainty.

Interpretation Framework and Methodological Considerations

Interpretation of findings in this umbrella review was explicitly weighted according to AMSTAR-2 confidence ratings. Reviews rated as critically low confidence were considered hypothesis-generating and were not used to support definitive clinical recommendations. Findings supported by higher methodological confidence, specifically the RCT-based meta-analysis of perioperative corticosteroid use, were given proportionately greater interpretive emphasis. Although a protocol was not prospectively registered, the review question, eligibility criteria, and analytic framework were established before data extraction. The absence of protocol registration is acknowledged as a limitation.

Given the umbrella design, overlap of primary studies across included systematic reviews was anticipated. However, formal quantification of overlap (e.g., corrected covered area) was not feasible because most reviews did not provide complete lists of included primary studies. This limitation may inflate the denominator of reported patient entries and lead to overrepresentation of certain large registry studies, thereby biasing pooled incidence and effect estimates. We therefore interpret these figures cautiously as approximate patient entries rather than unique individuals.

Data Synthesis

Given the umbrella review design and substantial heterogeneity in definitions, outcome measures, and overlapping primary studies, quantitative aggregation was not appropriate. We therefore employed a narrative synthesis to preserve methodological transparency. Where available, pooled incidence and risk ratios were extracted. Subgroup analyses were summarised by surgical technique, implant type, biologic use, and perioperative interventions.

Results

Study Selection and Characteristics

The systematic search identified 425 records. After screening, 32 systematic reviews and meta-analyses published between 2010 and 2025 were included, as shown in Figure 1. The characteristics of the reviews included in the study are given in Table 1. These reviews encompassed diverse study designs: randomised controlled trials (RCTs), prospective and retrospective cohort studies, and extensive database analyses, with sample sizes ranging from a small case-series of 31 patients to registry-based studies involving more than 3.6 million individuals. Due to the overlap of primary studies, this figure should be interpreted as approximate aggregated entries rather than unique individuals. While the reviewed surgical procedures included anterior cervical discectomy and fusion (ACDF), anterior cervical corpectomy and fusion (ACCF),

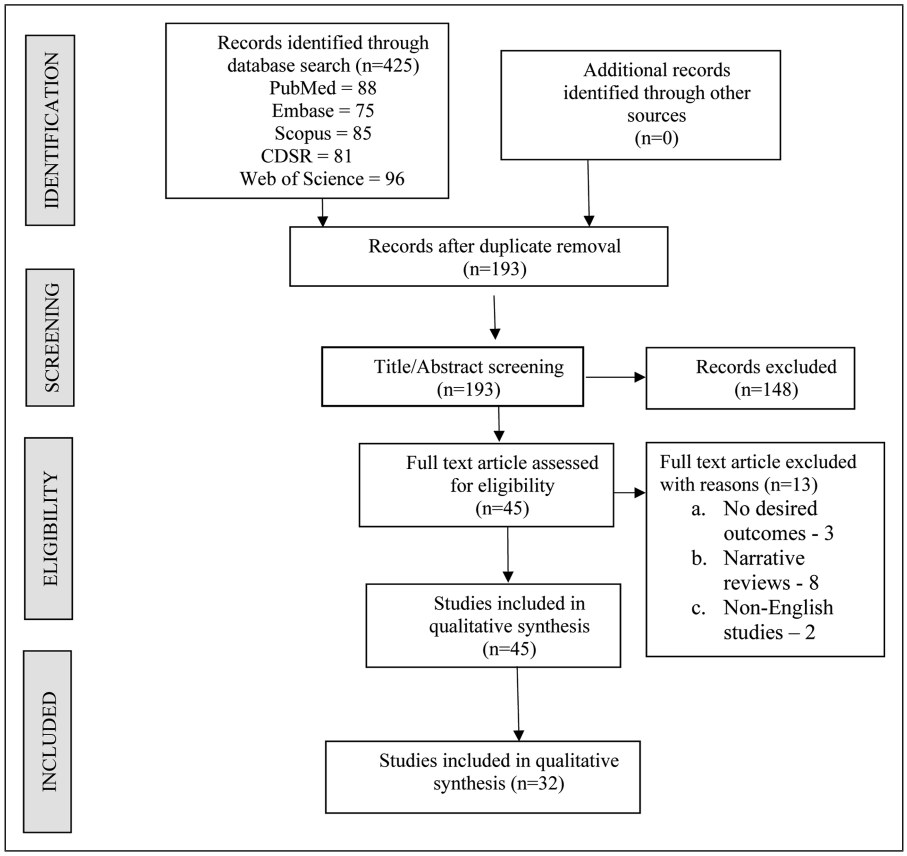


Figure 1. PRISMA flow diagram of inclusion of studies

cervical disc arthroplasty (CDA), and multilevel procedures, diverse implant systems such as zero-profile constructs (or other anchored spacers), cage-plate systems, and stand-alone cages were compared.

Methodological Quality of Included Reviews

The methodological quality of the included reviews was generally poor. AMSTAR-2 grading revealed that 31 reviews were of critically low confidence, primarily due to a lack of protocol registration, incomplete search strategies, absence of duplicate study selection and data extraction, failure to provide lists of excluded studies, and inadequate risk-of-bias assessment. Only one review (Zhang et al,[30] 2022) achieved a rating of low confidence, with strengths in protocol registration, duplicate extraction, and structured risk-of-bias analysis. The predominance of critically low ratings underscores limitations of the current evidence base and highlights the need for more rigorous systematic reviews (Table 2). The most frequently violated AMSTAR-2 domains included lack of protocol registration, incomplete search strategies, absence of duplicate study selection and extraction, and inadequate risk-of-bias assessment. These recurring flaws explain why most reviews were rated critically low. Findings derived from RCT-based meta-analyses were weighted more heavily than those from observational meta-analyses or registry-based studies, which carry greater risk of bias.

Incidence of Dysphagia

Dysphagia was reported as the most frequent complication following ACSS, though the incidence varied widely. Dysphagia incidence ranged from 1%-79%, reflecting highly heterogeneous definitions, timepoints, and assessment tools across anterior cervical spine surgery (ACSS) procedures. When applying standardised time-windows, early dysphagia (≤2 weeks) was reported in up to 71% of patients, while persistent dysphagia (≥12 months) was reported in 12-14%. These figures should be interpreted cautiously, given definitional heterogeneity and potential inflation of denominators due to unquantified overlap of primary studies across reviews.[3,16,26,27] The variability in incidence was primarily attributable to differences in definitions and assessment tools [ranging from patient-reported symptoms to validated instruments such as the Bazaz Dysphagia Score (BDS), Swallowing Quality-of-Life (SWAL-QOL), Dysphagia Disability Index (DDI), Dysphagia Numerical rating Scale, MD Anderson Dysphagia Inventory (MDADI), Functional Outcome Swallowing Scale (FOSS), and Eating Assessment Tool (EAT-10)].[8,22–24,31] In addition, radiographic indices like

Table 1. Characteristics of Reviews Included in the Study

Author name (year)	No. of studies	Sample size	Study types	Surgery type	Dysphagia definition	Assessment method	Dysphagia incidence	Subgroup Dysphagia incidence	Key findings	Limitations
Joaquim et al. (2014)	20	215140	RCT, PCS, RCS, DBS	ACDF, CDA, Zero-profile, Plating	Varied (swallowing difficulties, neck swelling, sore throat)	BSS, SWAL-QOL, MD Anderson Dysphagia Inventory, VAS for odynophagia	1.7%-71%; persistent 12%-14% ≥1 year	BMP higher (37.2/1000 vs 22.5/1000); Atlantis plate 14% vs Zephir 0%; Zero-profile lower (>3 mo: 20% plating vs 1 case zero-profile); Arthroplasty lower at 6-24 mo; Approach: LEO better C3-C4, MEO better C6-C7	Zero-profile implants, avoiding BMP, shorter operative time, and cuff-pressure control reduce dysphagia; CDA shows lower dysphagia than ACDF.	Heterogeneous literature; varied designs/definitions; limited evidence (Levels II–IV); Medline-only search.
Cabrera et al. (2023)	4	269	RCS	Multilevel ACDF (3-level / 4-level)	Symptomatic	None	2-34%	Papadopoulos 24% (11/46); Laratta 2.2% (1/46); Kim 3-level 34% (18/54), 4-level 27.5% (14/51); Wewel 11% (8/72)	Dysphagia was the most frequent complication across the included studies.	Substantial heterogeneity; few studies; retrospective designs; no validated tools; unable to stratify by osteobiologic type.
Martin et al. (2024)	27	591583	RCTS, PCS, RCS	ACDF (with vs without BMP2)	Inadequate neural control or impairment of soft tissue/bony structures, or patient-reported swallowing difficulties	PROM	NR	BMP2 increases dysphagia/dysphonia (RR 1.43, CI 1.25-1.64)	BMP2 significantly increases dysphagia/dysphonia risk.	High heterogeneity; inconsistent complication definitions; retrospective data; variable BMP dosing.
Liu et al. (2017)	18	2891	RCT, PCS, RCS	ACDF, ACCF, CDA, Multilevel surgery	BYS, Oswestry Neck Disability Questionnaire, MDADI, Dysphagia Disability Index	PROM	1%-79%	Female = 24.0%, Male = 13.9%; Plate = 20.2%, No plate = 12.4%; Multilevel = 44.4%, Single level = 22.8%; C3/4 = 23.4%, Lower levels = 9.1%; rhBMP-2 = 64.0%, Control = 27.8%	Major dysphagia risk factors: female sex, anterior plate, multilevel surgery, C3/4, rhBMP-2.	Non-uniform dysphagia grading; unmeasured confounders; variable follow-up; mostly non-randomised.
Shao et al. (2015)	7	560	RCT, PCS, RCS	ACDF (Zero-profile vs Conventional Cage-Plate)	Not explicitly standardised in meta-analysis; relied on primary study definitions	BSS, Modified Swallowing Quality of Life, VAS	NR	Zero-profile reduced dysphagia at 2w (P = 0.0002), 6 m (P = 0.008), 1 y (P = 0.001)	Zero-profile implants significantly reduce dysphagia vs cage-plate.	Mixed study designs, small samples, inconsistent secondary outcomes, and two different Zero-profile devices.
Yu et al. (2021)	8	632	RCT	ACDF (single or multilevel)	BSS, MDSS	BSS, MDSS, PSTSI (radiographic), VAS, EAT-10, SWAL-QOL	NR	PSTSI lower day 1 and 14; Bazaz improved at 2 weeks	Retropharyngeal steroids significantly reduce dysphagia at 2 weeks.	Variable steroid types/doses; subjective assessment tools; short–medium follow-up; few studies.

(continued)

Table 1. (continued)

Author name (year)	No. of studies	Sample size	Study types	Surgery type	Dysphagia definition	Assessment method	Dysphagia incidence	Subgroup Dysphagia incidence	Key findings	Limitations
Liu et al. (2018)	59	3662629	RCT, PCS, RCS	ACDF, ACCF, CDA, Multilevel surgery	Dysphagia, swallowing disorders	BSS, SWAL-QOL, MDADI	Upto 88%	Operative time ↑ risk (P = 0.009-0.017); rhBMP-2 use ↑ risk (OR 1.3-1.5); ET cuff pressure ↑ risk; dC2-C7 angle >9° ↑ risk ($P < 0.05$); Female gender OR ≈2.3; Plate use OR ≈1.66; ≥2 levels OR ≈2.07; C3/4 level OR ≈3.08; rhBMP-2 OR ≈5.52	Identified preventable risk factors are:[prolonged op time, BMP use, high cuff pressure, plate profile, dC2-C7 angle] and unpreventable factors [age, gender, multilevel, revision]	Contradictory findings; heterogeneous designs; no Level I evidence.
Liu et al. (2019)	6	550	RCT	ACDF	Dysphagia, odynophagia, or swallowing disorder	FOSS, BSS, VAS for odynophagia, MDSS, Nasofibroscopic ENT exam	NR	IV and local steroids are effective for reducing dysphagia incidence/ severity in multilevel ACSS; Local Depo-Medrol is effective specifically with BMP use; IV steroids are not effective for severity in 1-level ACDF (one study).	Steroids reduce dysphagia, especially in multilevel surgery.	Small samples; heterogeneous assessment; variable steroid dose/route; no IV vs local comparison.
Song et al. (2022)	8	615	RCT, PCS, RCS	ACDF	BSS, EAT-10, SWAL-QOL, DSQ, FOSS, Swelling Index	BSS, EAT-10, SWAL-QOL, DSQ, FOSS, VAS score	NR	Fewer moderate/severe cases (SMD 0.18; CI 0.08-0.44); Fusion ↑ (P = 0.01); No ↑ in op time or complications	Retropharyngeal steroids significantly reduce dysphagia rate and severity without increasing operating time or blood loss.	Small sample size (<100); variable steroid protocols; heterogeneity in operative factors; varied assessment tools.
Wang et al. (2023)	10	246433	RCT, PCS, RCS	ACDF	BSS, EAT-10 scores, ICD-9 codes, SWAL-QOL thresholds	EAT-10, BSS, SWAL-QOL, MDSS, ICD-9 codes	NR	PSTS ↓ ($P < 0.05$); VAS ↓; Moderate/severe dysphagia OR 0.12-0.17; Hospital stay −1.0 days	Local steroids reduce dysphagia and prevertebral swelling early postop.	Large heterogeneity (steroid protocol/ assessment/follow-up); limited level comparison; possible underdiagnosis of mild dysphagia.
Cheng et al. (2022)	5	246052	RCT, PCS, RCS	ACDF	BYS, SWAL-QOL, EAT-10, MDS	MDSS, SWAL-QOL, BSS, EAT-10	NR	Local steroids reduced severity/incidence; possible delayed complications (e.g., pseudarthrosis)	Local corticosteroid application reduces the incidence and severity of dysphagia following ACSS without increasing early complications.	Heterogeneity (protocol/ assessment/follow-up); no standardised dysphagia instrument; inconsistent evidence level.
Oh et al. (2020)	10	4018	PCS, RCS	ACDF (single-level vs multiple-level)	BSS, Self-reported outcomes	BSS, PROM	Single-level = 4.0%, Multiple-level = 6.6%; 12-24 months: Single 3.7% vs Multi 12%	Multiple-level ACDF has statistically higher dysphagia rates than single-level at 12-24 months; 3-level procedures are significantly higher than single-level (13.7% vs 4.4%)	Multiple-level ACDF has statistically higher dysphagia rates than single-level at 12-24 months.	Mostly retrospective; unreported confounders; subjective self-reports; few studies.

(continued)

Table 1. (continued)

Author name (year)	No. of studies	Sample size	Study types	Surgery type	Dysphagia definition	Assessment method	Dysphagia incidence	Subgroup Dysphagia incidence	Key findings	Limitations
Shen et al. (2023)	7	486	RCT	ACDF, ACCF, CDA	BSS, MDSS classification, EAT-10 scores >3	BSS, MDSS, EAT-10, Swallowing VAS, SWAL-QOL, PSTSI	NR	Local steroid use reduces early postoperative dysphagia (POD 4) and soft tissue swelling; no difference in non-fusion rates; no serious steroid-related complications.	Local steroids reduce early dysphagia and soft-tissue swelling.	Variable steroid types/doses; insufficient level-based data; variable follow-up; heterogeneous assessments.
Riley III et al. (2010)	15	2802	PCS, DBS	ACDF; AC corpectomy; ADR; BMP-2	BSS; WHO grade; MD Anderson Inventory; Dysphagia disability index	Telephone interview; BSS; MDADI; Barium swallow; ENT fiberoptic exam; Nurse/physician interview	1 week: 33.1%; 1 month: 53.2%; 6 months: 19.8%; 12 months: 16.8%; 24 months: 12.9%	Incidence declines over time but plateaus at 1 year (13-21%); Risk factors: female sex and multilevel surgery; Evidence for steroids, cuff pressure, and plate design is very low	Dysphagia declines over time; female sex and multilevel surgery increase risk.	No standardised definition; only two studies used validated PROs; wide incidence range.
Yin et al. (2016)	5	472	PCS, RCS	ACDF (Zero-P implant vs Cage and Plate)	Difficulty swallowing	BSS	NR	At last follow-up: Zero-P dysphagia incidence markedly lower (RR = 0.19; 95% CI 0.06-0.58; $P = 0.004$); Early post-op dysphagia also reduced (RR = 0.76; $P = 0.04$)	Zero-P reduces dysphagia risk vs plating.	Low-quality evidence (no RCTs); small samples; selection bias; short follow-up.
Gabr et al. (2020)	14	1173	RCT	ACDF (Stand-alone anchored spacers vs Cage with plate)	BSS	BSS; SQOL	NR	Immediate & long-term dysphagia reduced; less blood loss & op time; fusion similar.	Anchored spacers reduce immediate and long-term dysphagia.	High-risk studies excluded; incomplete reporting; no level-count stratification.
Shriver et al. (2017)	14	1336	RCT, PCS	ACDF with plating (autograft vs allograft)	BSS	BSS; NRS; PROM; Questionnaire	8.50%	Moderate/severe 4.4%; <12 m ~20%, >24 m ~7% Standardized Bazaz score gave higher rates	Dysphagia decreases after 12 months; the Bazaz score detects more cases.	Few studies, inconsistent controls, inconsistent level reporting, and diagnostic heterogeneity.
Carr et al. (2025)	25	31	RCS, CS, CR	ACDF (Screw back-out complications)	Symptomatic	Clinical presentation; Imaging evidence of migration	51.60%	52% had dysphagia; Asymptomatic cases likely underreported	Dysphagia commonly accompanies delayed screw back-out.	Mostly case reports/series; high risk of bias; symptomatic reporting bias; non-surgical literature excluded.
Anderson et al. (2017)	8	3027	RCT	ACDF vs CDA	Dysphagia/Dysphonia	Clinical Events Committee review, adverse event reporting	ACDF = 10.7%; TDR = 10.2%	No sig. difference (RR 1.16); TDR is likely as safe as ACDF	ACDF and TDR have similar dysphagia rates.	Non-standard definitions; variable data collection; incomplete follow-up; grouped minor/major events.

(continued)

Table 1. (continued)

Author name (year)	No. of studies	Sample size	Study types	Surgery type	Dysphagia definition	Assessment method	Dysphagia incidence	Subgroup Dysphagia incidence	Key findings	Limitations
Rodrigues-Pinto et al. (2024)	21	2463	RCT, PCS, RCS	1- or 2-level ACDF using allograft	Symptomatic	PROM	0.5%-14.4%	Plated ACDF = 5%-14.4%; No plate = 6.4%-8.8%; Most resolved <3 m; higher with plates Persistent dysphagia rare	Dysphagia most common postop complication; higher with plates.	No appropriate controls; inconsistent definitions/ reporting; unclear symptom resolution; limited allograft specificity; substantial heterogeneity.
Adenikinju et al. (2017)	7	246298	RCT, RCS	ACDF	BSS, EAT-10 (score >3), FOSS, VAS (0-10)	BSS, EAT-10, FOSS, VAS, PROM	9.50%	Steroid cohort = 7.88%, Control = 9.52%; Pedram study: steroid = 71.79%, control = 82.28%	Steroids reduce early dysphagia, especially in multilevel cases.	Heterogeneous assessment methods (Bazaz/FOSS/VAS); variable steroid protocols; low power for rare events.
Zadegan et al. (2018)	9	246414	RCT, PCS, RCS	ACDF, ACCF	BSS, EAT-10, FOSS, VAS for odynophagia	BSS, EAT-10, FOSS, VAS, Subjective sensation	1% to 79%	Steroids significantly reduce dysphagia severity/ incidence in the early post-op period; Effect most pronounced in multilevel procedures (>2 levels).	Steroids significantly reduce early dysphagia severity/incidence.	High risk of bias; few studies reporting key outcomes; heterogeneity prevented meta-analysis; poor-quality outcome measures.
Xiao et al. (2017)	16	1066	RCT, PCS, RCS	ACDF, ACCF	BYS	BYS	Immediate (ZPC = 24.5%, CP = 33.0%); 2 weeks (ZPC=15.8%, CP = 40.5%); 3 months (ZPC = 2.6%, CP = 19.4%); 12 months (ZPC = 1.1%, CP = 10.8%)	ZPC associated with lower dysphagia incidence immediately, 2 weeks, 2, 3, 6, and 12 months; No significant difference at 1 week, 1 month, or 24 months.	Zero-profile constructs significantly lower dysphagia.	Heterogeneous diagnoses/graft types; retrospective selection bias; clinical heterogeneity; geography/language bias.
Cho et al. (2013)	22	2598	RCT, PCS, RCS	ACDF, ACCF	BSS; Dysphagia Disability Index; SWAL-QOL; Dysphagia NRS	Videofluoroscopy (VSE); BSS; Dysphagia Disability Index; SWAL-QOL; Dysphagia NRS	Overall immediate = 71%; 1 month = 50.2-54.2%; 12 months = 12.5-13.6%; 1 year=12-14%	Risk: female, multilevel, revision, bulky plate, rhBMP-2; zero-profile may reduce risk	Dysphagia is common early; reduced with zero-profile plates.	No Level I evidence; unvalidated questionnaires; multifactorial aetiology; poor survey–record correlation.
Yee et al. (2020)	240 (67 for dysphagia)	737,041 (dysphagia subset)	PCS, RCS, CS, CR	ACDF, ACCF, CDA	Chronic dysphagia is defined as lasting >3 months; Specific scoring criteria are not standardised across all included studies.	Fluoroscopic swallow studies; BYS; Patient reporting; Hospital readmission data	5.30%	Prospective > retrospective; chronic dysphagia has a low overall	Risk factors: BMP>2 levels, female sex, and revision surgery.	Predominantly case reports; heterogeneous populations; retrospective bias; potential reporting bias.
Rai et al. (2024)	79 (28 for dysphagia)	4,270 (dysphagia subset)	PCS, RCS	ACDF, ACCF	Chronic dysphagia is defined as lasting >3 months	Patient complaints/ reporting	7.90%	Risk ↑: BMP, 3-4 levels, plate; Zero-profile reduces incidence	Dysphagia is common; zero-profile reduces risk; cuff-pressure is important.	Retrospective design; reporting bias; heterogeneous study designs.

(continued)

Table 1. (continued)

Author name (year)	No. of studies	Sample size	Study types	Surgery type	Dysphagia definition	Assessment method	Dysphagia incidence	Subgroup Dysphagia incidence	Key findings	Limitations
Zhang et al. (2022)	14	1181	RCT	ACDF, ACCF, CDA	BSS; MDSS	BSS; MDSS; SWAL-QOL; Dysphagia Symptom Questionnaire; EAT-10	NR	Control 51.4% vs Steroid 32%; VAS ↓; Hospital stay ↓; no effect on fusion or op time	Steroids significantly reduce dysphagia for up to 1 year.	Variable steroid types/doses; limited quantitative data; variable fusion levels; low–moderate evidence quality.
Yang et al. (2016)	30	1062	PCS, RCS	ACDF with Zero-profile Implant System	Transient (<30 days); Persistent (>90 days); BSS	BSS	Transient 15.6% (0-76%); Persistent 0-7%	Zero-profile lower dysphagia; country variation (China < USA/Germany)	Zero-profile systems have low dysphagia rates.	Low-level evidence; very high heterogeneity; publication bias; selection bias (English/Chinese); non-validated Bazaz scale.
Cheung et al. (2019)	19	1170 (dysphagia analysis subset)	PCS, RCS	ACDF (Stand-alone cage vs Cage-plate)	Varied/Clinical reporting (outcomes included dysphagia, hoarseness)	VAS, NDI, SF-36, Odom's, Clinical reporting	NR	Cage-only <3 m OR 0.32; >3 m OR 0.27; ↓ ASD; ↑ subsidence	Stand-alone cages reduce dysphagia vs cage-plate.	Significant heterogeneity, observational bias, variable outcomes, surgeon variability, and publication bias.
Yang et al. (2017)	12	3500 (1948 CDR, 1552 ACDF)	RCT	ACDF vs CDR	Varied; studies used BSS, DSQ, or unspecified clinical reporting	BSS, DSQ, EAT-10, Voice Handicap Index, Dysphonia Severity Index, Clinical reporting	NR	CDR < ACDF for dysphagia; 12 RCTs; "non-profile" devices avoid irritation	CDR reduces dysphagia compared with plated ACDF.	No gold-standard criteria; limited severity/duration reporting; population differences; selection bias; small samples.
Yu et al. (2023)	11	849	RCT, RCS	ACDF vs ACCF (2 and 3 levels)	Clinical reporting of symptomatic dysphagia	Clinical reporting/observation	ACDF 7.1% vs ACCF 6.3%	ACDF has fewer total complications; multilevel ACDF is favourable in the 3-level subgroup	No dysphagia difference between ACDF and ACCF.	High heterogeneity (pseudarthrosis/complications); only two RCTs; language restriction; varied etiologies unassessed.
Zhong et al. (2016)	10	2711	RCT	CDA vs ACDF	BSS, DSQ, FOSS, or clinical reporting	BSS, Functional Outcome Swallowing Scale, DSQ, VAS Hoarseness, Cervical Spine Outcomes Questionnaire, SWAL-QOL	CDA 9.46% vs ACDF 12.09%	CDA significantly lowers dysphagia due to reduced retraction/plate profile	CDA results in lower dysphagia due to less retraction or plate profile.	Inadequate blinding; high dropout (>30%); inconsistent evaluation intervals; varied prosthesis types; publication bias.

ACCF: Anterior Cervical Corpectomy and Fusion; ACDF: Anterior Cervical Discectomy and Fusion; ACSS: Anterior Cervical Spine Surgery; ADR/CDA/CDR: Artificial Disc Replacement/Cervical Disc Arthroplasty/Cervical Disc Replacement; BMP/rhBMP-2: Bone Morphogenetic Protein/Recombinant Human Bone Morphogenetic Protein-2; BSS: Bazaz Dysphagia Score; COI: Conflict of Interest; CR/CS: Case Report/Case Series; DBS: Database Study; EAT-10: Eating Assessment Tool-10; FOSS: Functional Outcome Swallowing Scale; MDADI: MD Anderson Dysphagia Inventory; MDSS: Modified Dysphagia Symptom Score; NRS: Numeric Rating Scale; PCS: Prospective Cohort Study; PROM: Patient-Reported Outcome Measure; PSTS/PSTSI: Prevertebral Soft Tissue Swelling/Prevertebral Soft Tissue Swelling Index; RCS: Retrospective Cohort Study; RCT: Randomized Controlled Trial; RoB: Risk of Bias; SWAL-QOL: Swallowing Quality of Life Questionnaire; VAS: Visual Analog Scale.

Table 2. Methodological Quality of the Included Reviews Based on AMSTAR-2 Grading (Confidence Ratings: High, Moderate, Low, or Critically Low)

Author name (Year)	PICO	Protocol priori	Design rationale	Search	Selection	Extraction	Exclusion	Summary of findings	RoB analysis	Funding	Meta-analysis	RoB impact on results	RoB in discussion	Heterogeneity	Publication bias	COI	Grading
Joaquim et al. (2014)	Yes	No	Partial Yes	No	No	No	No	Yes	Partial Yes	No	N/A	N/A	Partial Yes	Yes	N/A	Yes	Critically Low
Cabrera et al. (2023)	Yes	No	Yes	Partial Yes	Yes	Yes	No	Yes	Yes	No	N/A	N/A	Partial Yes	Yes	No	Yes	Critically Low
Martin et al. (2024)	Yes	No	No	No	No	No	No	Yes	No	No	N/A	N/A	No	Yes	No	Yes	Critically Low
Liu et al. (2017)	Yes	No	No	Partial Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Critically Low
Shao et al. (2015)	Yes	No	No	Partial Yes	Yes	Yes	No	Yes	No	No	Yes	No	No	Yes	No	Yes	Critically Low
Yu et al. (2021)	Yes	No	Yes	Partial Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	Partial Yes	Yes	Yes	Yes	Critically Low
Liu et al. (2018)	Yes	No	Yes	Partial Yes	No	No	No	Partial Yes	No	No	N/A	No	No	Yes	N/A	Yes	Critically Low
Liu et al. (2019)	Yes	No	Yes	Partial Yes	No	No	No	Yes	No	No	N/A	No	No	Yes	N/A	Yes	Critically Low
Song et al. (2022)	Yes	No	Yes	Partial Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Critically Low
Wang et al. (2023)	Yes	No	Yes	Partial Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	Yes	Yes	No	Yes	Critically Low
Cheng et al. (2022)	Yes	No	Yes	Partial Yes	Yes	No	No	Yes	No	No	N/A	N/A	No	Yes	N/A	Yes	Critically Low
Oh et al. (2020)	Yes	No	Yes	Partial Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Critically Low
Shen et al. (2023)	Yes	No	Yes	Partial Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	No	Yes	No	Yes	Critically Low
Riley III et al. (2010)	Yes	No	Yes	Partial Yes	Yes	No	No	Yes	No	No	No	No	Partial Yes	No	No	Yes	Critically Low
Yin et al. (2016)	Yes	No	Yes	Yes	Partial Yes	Yes	No	Yes	Yes	No	Yes	No	Yes	Yes	No	Yes	Critically Low
Gabr et al. (2020)	Yes	Yes	Yes	Partial Yes	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Critically Low
Shriver et al. (2017)	Yes	No	Yes	Yes	Partial Yes	Yes	No	Yes	Yes	No	Yes	No	Yes	Yes	No	Yes	Critically Low
Carr et al. (2025)	Yes	No	Yes	Yes	No	No	No	Yes	No	No	N/A	No	Partial Yes	N/A	No	Yes	Critically Low
Anderson et al. (2017)	Yes	No	Yes	No	No	No	No	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes	Critically Low

(continued)

Table 2. (continued)

Author name (Year)	PICO	Protocol priori	Design rationale	Search	Selection	Extraction	Exclusion	Summary of findings	RoB analysis	Funding	Meta-analysis	RoB impact on results	RoB in discussion	Heterogeneity	Publication bias	COI	Grading
Rodrigues-Pinto et al. (2024)	Yes	Partial Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	N/A	N/A	Yes	Yes	N/A	Yes	Critically Low
Adenikinju et al. (2017)	Yes	No	Yes	No	Yes	No	No	Yes	Partial Yes	No	No	N/A	Partial Yes	Yes	No	Yes	Critically Low
Zadegan et al. (2018)	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No	N/A	N/A	Yes	Yes	N/A	Yes	Critically Low
Xiao et al. (2017)	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	Partial Yes	Yes	No	Yes	Critically Low
Cho et al. (2013)	Yes	No	Yes	Yes	Yes	No	No	Yes	No	No	N/A	N/A	No	Yes	N/A	Yes	Critically Low
Yee et al. (2020)	Yes	No	Yes	No	Yes	No	No	No	No	No	N/A	N/A	Partial Yes	Yes	N/A	Yes	Critically Low
Rai et al. (2024)	Yes	No	Yes	Yes	Yes	No	No	Yes	No	No	N/A	N/A	No	Yes	N/A	Yes	Critically Low
Zhang et al. (2022)	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Low
Yang et al. (2016)	Yes	No	Yes	Yes	Yes	Yes	No	Yes	No	No	Yes	No	Partial Yes	Yes	Yes	Yes	Critically Low
Cheung et al. (2019)	Yes	No	Yes	Partial Yes	Yes	Partial Yes	No	Yes	Yes	No	Yes	No	Yes	Yes	No	Yes	Critically Low
Yang et al. (2017)	Yes	No	Yes	Partial Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Critically Low
Yu et al. (2023)	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	Partial Yes	Yes	Yes	Yes	Critically Low
Zhong et al. (2016)	Yes	No	Yes	Partial Yes	Yes	Yes	No	Yes	Yes	No	Yes	Partial Yes	Yes	Yes	Yes	Yes	Critically Low

AMSTAR-2: A Measurement Tool to Assess Systematic Reviews, version 2; COI: Conflict of Interest; MA: Meta-analysis; N/A: Not Applicable; PICO: Population, Intervention, Comparator, Outcome; RoB: Risk of Bias.

prevertebral soft tissue swelling (PSTS) and prevertebral soft tissue index (PSTSI), as well as video-fluoroscopic evaluations, were also employed.[16] Rates were most frequently reported for ACDF, but broader ACSS procedures (ACCF, CDA, multilevel constructs) demonstrated similar heterogeneity. Distinguishing ACDF-only data from broader ACSS findings is important.

Risk Factors for Dysphagia

Risk factor analyses identified both patient-related and surgical determinants.[8,16,22–24,31] Female sex was associated with a higher risk [with odds ratios (OR)¸2.3]. While multilevel procedures were associated with a 2-fold greater risk of dysphagia (as compared with single-level surgeries), involvement of the C3-C4 level carried a particularly enhanced risk (OR>3.0).[23–25,31] Prolonged operative time was also associated with increased dysphagia risk. Based on our analysis, implant design may be associated with differences in dysphagia rates: while anterior cage-plate constructs (CPC) were associated with higher dysphagia rates (OR = 1.66), use of zero-profile (or anchored spacer) constructs may be associated with reduced risk.[32–37] Biologic use, especially recombinant human bone morphogenetic protein-2 (rhBMP-2), was associated with increased dysphagia risk [relative risk (RR): 1.43 and OR: 5.52].[38–40] Peri-operative factors such as high endotracheal cuff pressure and excessive changes in cervical alignment (C2–C7 lordosis>9°) were also implicated in the occurrence of dysphagia.[3,8,22–25] These associations were primarily reported in observational meta-analyses and registry data, and therefore must be interpreted with caution compared to the limited RCT-based evidence. Further, these associations should be interpreted cautiously, as they are derived predominantly from critically low-confidence reviews and may reflect confounding rather than causal relationships.

Management (Preventive) Strategies

Among several preventive and therapeutic measures that were evaluated, perioperative corticosteroids were the most consistently studied intervention.[30,41–48] Both intravenous and local administrations were associated with reduced early postoperative dysphagia incidence and severity, particularly in multilevel ACDF. Local depo-medrol® (methyl-prednisolone acetate injectable suspension) administration was associated with reduced dysphagia in patients exposed to rhBMP-2; while retropharyngeal steroid application was associated with reduced PSTSI and improved Bazaz scores at 2 weeks without increasing complications. Steroid use was associated with reduced early dysphagia and shorter hospital stay in one RCT-based meta-analysis (low confidence). Findings from other reviews were critically low in confidence and therefore remain hypothesis-generating. However, this represents the only RCT-based meta-analysis available, and its findings carry greater evidentiary weight than observational syntheses.

Implant design modifications may also be associated with differences in dysphagia rates. Zero-profile constructs were associated with lower dysphagia rates compared with cage-plate systems. Still, these observations arise from critically low-confidence reviews and should be interpreted as hypothesis-generating signals [relative risk (RR) ranging between 0.19 and 0.76 across different timepoints].[32–37] Anchored spacers were associated with lower dysphagia rates and operative time. Still, these findings are derived from critically low-confidence reviews and should be interpreted as preliminary, hypothesis-generating signals rather than definitive recommendations. On a similar note, stand-alone cages were associated with lower dysphagia incidence (than cage-plate constructs), with OR: 0.32 during the early postoperative period and 0.27 beyond 3 months. Cervical disc arthroplasty (CDA) was associated with potentially lower dysphagia rates compared with ACDF (9.5% vs 12.1%), possibly attributable to limited oesophageal retraction and avoidance of anterior plating (inherent to fusion procedure).[9,49,50]

Prognostic Impact and Outcomes

Although dysphagia was common, most cases were transient. Persistent dysphagia (beyond 12 months) affected 12 to 14% patients, impairing the quality of life (QoL) and functional recovery.[3,8,16,22–24,26,27,42] Severe dysphagia correlated with prolonged hospital stays, higher readmission rates, and reduced patient satisfaction. Despite its frequency, dysphagia seldom influenced fusion rates or long-term surgical outcomes; however, chronic cases exerted a meaningful negative influence over postoperative recovery trajectories.

Discussion

During the early postoperative period following ACSS, dysphagia is considered to be one of the most common, albeit consistently bothersome, adverse events.[23,24,42] It has been reported to complicate the immediate postoperative course in up to 88% of individuals in some series—compared with up to 71% in other analyses—with variations largely attributable to heterogeneous definitions and assessment timepoints (sometimes, with a severe clinical course).[23,24,42] In a certain proportion of patients, it has been observed to follow a persistent and complicated course. Being aware of contributory factors and preventative strategies, treating surgeons may be better positioned to anticipate and potentially mitigate early, severe or persistent dysphagia in patients undergoing ACSS. This umbrella review provides a structured appraisal of existing systematic reviews, explicitly weighted by methodological confidence. While similar syntheses exist, our contribution lies in integrating AMSTAR-2 grading into the interpretive framework. To provide a structured umbrella-

Table 3. Structured Umbrella-Level Synthesis of Evidence on Dysphagia After Anterior Cervical Spine Surgery, Stratified by AMSTAR-2 Confidence Rating and Evidence Type (Observational vs. RCT-Based), Distinguishing Hypothesis-Generating From More Reliable Findings

Risk Factor	Direction of Association	Consistency Across Reviews	Confidence (AMSTAR-2)
Modifyable risk factors			
Prolonged operative time	↑ Risk of dysphagia	Reported in several reviews, moderate consistency	Critically low confidence
Use of rhBMP-2	↑ Risk of dysphagia	Consistently associated across multiple reviews	Critically low confidence
Endotracheal tube (ETT) cuff pressure	↑ Risk is high when cuff-pressure control	Reported in multiple reviews, consistent	Critically low confidence
Cervical plate type/position (prominent implant)	↑ Risk with thicker/prominent plates	Mixed findings; some reviews consistent, others inconclusive	Critically low confidence
Over-exaggeration of C2–C7 lordosis (>9° change)	↑ Risk of dysphagia	Reported in several reviews, moderate consistency	Critically low confidence
Psychiatric factors	↑ risk (association with symptom perception and persistence)	Reported in a few reviews, limited consistency	Critically low confidence
Tobacco usage	↑ risk of dysphagia and impaired healing	Reported sporadically, low consistency	Critically low confidence
Prevertebral soft tissue swelling (PSTS)	↑ Risk of early dysphagia	Consistently reported across reviews	Critically low confidence
Superior laryngeal nerve (SLN) / recurrent laryngeal nerve (RLN) / branch injuries	↑ Risk of dysphagia	Consistently reported across reviews	Critically low confidence
Non-modifyable risk factors			
Old age	↑ Risk of dysphagia	Reported in several reviews, moderate consistency	Critically low confidence
Female gender	↑ Risk of dysphagia	Consistently reported across multiple reviews	Critically low confidence
Multilevel surgery (≥2 levels)	↑ Risk of dysphagia	Consistently reported across reviews	Critically low confidence
Revision surgery	↑ Risk of dysphagia	Reported in multiple reviews, moderate consistency	Critically low confidence
High BMI	↑ Risk of dysphagia	Reported sporadically, with limited consistency	Critically low confidence
Intervention strategy			
Preoperative tracheal/oesophageal traction exercises	↓ dysphagia by improving tissue mobility and reducing postoperative oedema	Reported in a single review; limited evidence	Critically low confidence
Avoiding prolonged operative time	↓ dysphagia risk by minimising soft tissue retraction and ischemia	Reported in multiple reviews; moderate consistency	Critically low confidence
Avoiding routine use of rhBMP-2	↓ dysphagia risk by preventing soft tissue swelling and inflammatory response	Consistently reported across reviews	Critically low confidence
Small and smoother cervical plates	↓ dysphagia risk by reducing oesophageal impingement	Reported in several reviews; moderate consistency	Critically low confidence
Use of anchored spacers instead of plates	↓ dysphagia risk by eliminating plate prominence and reducing retraction	Consistently reported across reviews	Critically low confidence
Application of a steroid before wound closure	↓ early dysphagia by reducing inflammation and oedema	Consistently reported; one RCT-based meta-analysis supports	Low confidence
Considering cervical disc arthroplasty (CDA)	↓ dysphagia risk compared to ACDF due to less oesophageal retraction and no plate	Reported in several reviews; moderate consistency	Critically low confidence
Changing/reducing endotracheal cuff pressure (ETCP) during medial retraction	↓ dysphagia risk by reducing oesophageal compression	Consistently reported across reviews	Critically low confidence
Changing profile of retractors	↓ dysphagia risk by minimising soft tissue trauma	Reported in a few reviews; limited consistency	Critically low confidence
Changing the plane of dissection	↓ dysphagia risk by reducing oesophageal manipulation	Reported in a few reviews; limited consistency	Critically low confidence

Note. All findings are weighted by AMSTAR-2 confidence. Critically low confidence findings are hypothesis-generating only and should not be interpreted as practice-changing recommendations.

level synthesis weighted by methodological confidence, the key findings are summarised in Table 3 under 4 domains: *what is reliably known, what remains uncertain, what may be clinically actionable, and research priorities.*

Definition and Measurement Heterogeneity as a Driver of Incidence Variability

It is important to distinguish that most incidence estimates arise from observational reviews and registry data, whereas the few RCT-based syntheses provide more reliable but narrower insights. The wide range in the reported dysphagia incidence across the literature may be attributed to definitional and measurement heterogeneity, rather than true epidemiological divergence. For structured synthesis, dysphagia time windows were categorised as early (≤2 weeks), intermediate (2 weeks-3 months) and persistent (≥12 months). However, many included reviews did not standardise the time points, and primary studies frequently used inconsistent follow-up intervals.

Additionally, diagnoses varied considerably, including clinician-reported symptoms, retrospective registry coding and validated patient-reported outcome measures such as the Bazaz score, EAT-10, SWAL-QOL, MDADI, and FOSS. Reviews incorporating structured PROMs generally reported higher dysphagia detection rates compared with those relying on unstructured chart documentation. This heterogeneity in definitions and assessment methods substantially limits comparability across reviews and contributes to imprecision in pooled incidence estimates.

Risk Factors

Yee et al[3] observed that the occurrence of dysphagia was a predictor of a longer hospital stay and multiple readmissions. Among the different risk factors considered, they observed that use of BMP, multi-level (≥3) ACDF, female sex, and revision surgery were associated with higher dysphagia. These risk factors are supported predominantly by low-quality observational evidence. In contrast, RCT-based analyses remain scarce, underscoring the need for higher-quality trials.

Cho et al[16] demonstrated that prevertebral soft tissue swelling (secondary to haemorrhage, iatrogenic peri-oesophagal trauma), cervical plate prominence, impingement secondary to fibrosis, adhesions or osteophytes, and prolonged oesophagal retraction (causing high intraluminal pressures, ischemia-reperfusion injury) could be associated with the etiopathogenesis of dysphagia. They demonstrated that female sex, older age, severe neck pain, multilevel/revision surgeries, longer operative time, prominent cervical plate, and rhBMP-2 use were significant risk factors. In the meta-analysis by Liu et al,[23] female sex ($P < 0.001$), use of anterior cervical plate ($P < 0.001$), multi-level (≥2 levels) surgery ($P < 0.001$), upper surgical level at C3-C4 ($P = 0.004$) and rhBMP-2 ($P < 0.001$) were correlated with dysphagia.

Biologic use. Among the biologics, BMP has been most commonly correlated with increased dysphagia. In the meta-analysis by Martin et al,[40] While rhBMP-2 was associated with improved arthrodesis, dysphagia and anterior soft tissue complications were enhanced. In another review,[25] based on data from 4 studies (level II-IV evidence),[10,51–53] BMP was correlated with significantly enhanced risk of dysphagia. Shriver et al[26] demonstrated statistically insignificant difference in dysphagia rate between autograft and allograft implantation during ACDF.

Prominence of cervical plates. Zeng et al[54] observed a higher dysphagia rate with a prominent plate profile (thickness>1.4 mm). Similarly, Lee et al[55] demonstrated a lower incidence of early and persistent dysphagia with plates carrying a smoother and smaller profile. On the other hand, studies by Liu et al,[24] Jain et al[56] and Chin et al[11] reported an unclear correlation between the profile prominence of the plate and dysphagia.

Multilevel surgery. Generally, multi-level surgeries have been correlated with higher dysphagia rates. The meta-analysis by Oh et al[27] showed statistically higher dysphagia rate for multilevel ACDF *(6.6% versus 4%* at 12-24 months follow-up). However, studies have not demonstrated any significant difference in dysphagia between ACCF and ACDF surgeries in multilevel pathologies.[3,31,41]

Screw migration. Although usually self-limiting, dysphagia can be associated with serious pathologies. Carr et al[57] described dysphagia and pharyngoesophageal injury rates of 52% and 61%, respectively, following screw migration. A proportion of these patients required implant removal and surgical oesophageal or hypopharyngeal repair.

Yee et al[3] reported an incidence of oesophageal injury in 0.46% (pooled incidence: 0.2%). Such patients presented with dysphagia, odynophagia, sepsis, wound drainage, implant failure and neurological deficits. The timing of recognition of injury ranged from intraoperative to delayed discovery at 20 years, and mortality ranged between 0 and 33%.

Preventive Measures

Jaoquim et al[25] evaluated the role of diverse pre- and intra-operative preventive measures [such as tracheal traction exercises (TTE), avoidance of prolonged operative time, avoidance of BMP, considering CDA in appropriate situations, using modified retractors, control of tracheal cuff pressures, modifying dissection planes, use of plates with smaller profile, use of anchored spacers, and local steroid use] to mitigate dysphagia. They concluded that although evidence regarding these preventive measures was limited, these interventions did not appear to increase complications;

however, their incorporation into routine surgical practice should be considered cautiously, pending validation in higher-quality prospective studies.

Anchored cages. In the study by Shao et al,[34] the zero-profile cage (ZPC) was associated with a lower dysphagia rate at 2 weeks ($P = 0.0002$), 6 months ($P = 0.008$), and 1 year ($P = 0.001$), as compared with the cage-plate construct (CPC). On a similar note, studies by Yin[33], Gabr,[32] Xiao et al,[35] Yang et al[36] and Cheung[37] also reported lower dysphagia rates with stand-alone anchored spacers compared with CPC at different postoperative time points.

Cervical disc arthroplasty (CDA). There have been contrasting reports regarding the association between CDA and dysphagia. While Anderson et al[9,49] did not observe any significant correlation; Yang et al[36] and Zhong et al.[50] reported statistically significant associations with reduced dysphagia rates ($P = 0.022$ and 0.01, respectively) after CDA.

Corticosteroid use. Among the diverse preventive measures, the impact of corticosteroid administration (systemically or locally) on dysphagia has remained the most widely assessed. In the meta-analysis by Liu,[23,24,42] perioperative intravenous (dexamethasone/methylprednisolone) and local steroid use were associated with reduced incidence and severity of early dysphagia (especially for multilevel surgeries). In the meta-analysis by Adenikinju,[47] patients receiving systemic and local steroids had better reductions in the severity of postoperative dysphagia (with no added risk of infections or pseudoarthrosis). In a meta-analysis of RCTs (Zhang et al[30]), steroids administered locally or systemically were associated with reduced dysphagia (within 1 year), VAS (2 weeks) and length of hospital stay.

A majority of other reviews have focused on the effectiveness of local steroid application. Yu et al[41] demonstrated that perioperative retropharyngeal steroid administration mitigated the severity of postoperative dysphagia ($P < 0.0001$), ameliorated PSTSI ($P < 0.0001$), and improved VAS score ($P < 0.001$). In patients undergoing revision surgery or those requiring BMP application for pseudoarthrosis, locally-administered depomedrol on collagen sponge was shown to reduce dysphagia. On a similar note, reviews by Song et al,[43] Cheng et al,[44] and Shen et al[46] also reported the beneficial effect of local steroid application (in different formulations and dosages) in mitigating dysphagia-related complications. Among these, only perioperative corticosteroid use has been evaluated in an RCT-based meta-analysis, which provides relatively stronger evidence compared to the critically low-confidence observational reviews.

Endotracheal cuff pressure. The evidence regarding the role of endotracheal tube cuff pressure (ETTCP) and preoperative TTE is still largely unclear. Yee et al[3] observed that by limiting or monitoring endotracheal tube cuff pressure (ETTCP) to 15 mmHg, there was no change in dysphagia rates. In contrast, they observed that preoperative TTE significantly mitigated dysphagia (especially after multilevel ACDF). On the other hand, the meta-analysis by Cho et al[16] also did not demonstrate any significant benefit of ETTCP control or reduction in postoperative dysphagia incidence.

Quality of Evidence and Limitations

A significant finding of this umbrella review is the uniformly low methodological quality of existing systematic reviews. Overall, 31/32 reviews were rated as critically low on AMSTAR-2. The key recurring flaws included: a. lack of protocol registration, b. inadequate search strategies, c. absence of duplicate screening and extraction, d. inconsistent risk-of-bias assessment, e. failure to report excluded studies, f. inability to address publication bias. These flaws undermine confidence in pooled incidence estimates and effect sizes. Additionally, heterogeneity in dysphagia definitions, outcome time points, and assessment tools makes the comparison across studies challenging. Since most reviews synthesised retrospective data, under-reporting of dysphagia is likely, particularly in chronic cases or in registries lacking validated PROMs. Although the review question, eligibility criteria, and analytic framework were established before data extraction, the absence of formal registration of the study protocol may introduce bias by allowing post-hoc methodological decisions, particularly in study selection and synthesis. This limitation is acknowledged and underscores the need for protocol registration in future umbrella reviews.

How AMSTAR Ratings Informed Interpretation

Interpretation of findings in this umbrella review was explicitly weighted according to AMSTAR-2 confidence ratings. Reviews rated as critically low confidence were considered hypothesis-generating and were not used to support definitive clinical recommendations (Table 4). Findings supported by higher methodological confidence, especially the RC-based meta-analysis of perioperative steroid use, were given proportionately greater interpretive emphasis. Where possible, signals derived primarily from observational meta-analyses were distinguished from those based on RCTs. This structured weighing framework was applied consistently across all domains of synthesis.

Evidence Certainty Statement

The overall certainty of evidence regarding dysphagia after ACSS is low. The predominance of critically low-confidence systematic reviews substantially limits confidence in pooled incidence estimates and effect size interpretations. Most identified associations, particularly those relating to implant design, rhBMP-2 exposure, and perioperative techniques,

Table 4. Interpretation of the Evidence From the Structured Umbrella-Level Synthesis, Highlighting AMSTAR-2 Confidence Ratings, Distinctions Between Observational and RCT-Based Evidence, and Areas of Clinical Uncertainty

A. What is reliably known?

Domain	Summary of Evidence	Consistency	AMSTAR-2 Confidence	Interpretation
Early postoperative dysphagia (≤2 weeks)	Frequently reported; incidence varies widely (1-79%)	Consistent presence; magnitude variable	Predominantly Critically Low	Common but definition-dependent; true magnitude uncertain
Female sex	Associated with increased dysphagia risk	Consistent direction across reviews	Critically Low	Recurrent association; effect size imprecise
Multilevel surgery	Associated with increased risk	Consistent	Critically Low	Likely contributory factor
Upper cervical exposure (C3-C4)	Associated with increased risk	Moderately consistent	Critically Low	Anatomically plausible; low certainty
Perioperative corticosteroids	Reduced early dysphagia incidence/severity	Consistent	One Low-confidence (RCT-based) review; others Critically Low	Most methodologically supported preventive strategy

B. What Remains Uncertain?

Domain	Nature of Uncertainty	Methodological Drivers
Persistent dysphagia (≥12 months)	True long-term incidence unclear	Heterogeneous definitions Inconsistent follow-up Retrospective data
Implant design effects (zero-profile vs plating)	Independent magnitude of effect uncertain	Confounding Heterogeneous primary studies
Cervical disc arthroplasty (CDA) vs ACDF	Mixed findings regarding dysphagia reduction	Heterogeneous primary studies Varying follow-up Predominance of critically low-confidence reviews
rhBMP-2 dose-response	Strength and dose relationship unclear	Variable dosing Mixed indications Low-quality reviews
Endotracheal cuff pressure control	Conflicting findings	Limited prospective data Inconsistent methodology
Preoperative tracheal/oesophageal traction exercises (TTE)	Limited and inconsistently reported benefit on postoperative dysphagia	A few primary studies Heterogeneous protocols Variable outcome measures/timepoints Reviews are largely critically low in confidence
Review overlap	Degree of primary-study duplication unknown	Lack of a corrected covered area analysis

C. What May Be Clinically Actionable (With Caution)?

Potential Strategy	Evidence Signal	Confidence	Clinical Interpretation
Minimise plate prominence	Reduced the early dysphagia signal	Critically Low	Consider in high-risk cases
Cervical disc arthroplasty (vs ACDF)	Some analyses suggest lower dysphagia rates	Critically Low	Inconclusive Not sufficient for dysphagia-driven indication
Use zero-profile constructs	Reduced early dysphagia	Critically Low.	Suggestive benefit Long-term effect uncertain
Limit rhBMP-2 in high-risk individuals.	Increased dysphagia signal	Critically Low	Consider individualised risk assessment
Perioperative corticosteroids	Reduced early dysphagia	Low (RCT-based subset)	Most evidence-supported strategy
Limit operative duration/retraction time.	Increased dysphagia signal	Critically Low	Biologically plausible precaution

D. Research Priorities

Priority Area	Rationale
Core outcome set for ACSS dysphagia	Improve comparability across studies.
Standardised timepoints (≤2 weeks, 3 months, ≥12 months)	Reduce incidence variability
Routine use of validated PROMs (EAT-10, MDADI)	Improve detection precision
Dose-stratified prospective trials for rhBMP-2	Clarify the causal relationship.
Mechanistic imaging correlates (PSTS, alignment change)	Define pathophysiology
Multicenter prospective cohorts	Adjust for surgical and implant confounders.

Abbreviations: AMSTAR-2: A Measurement Tool to Assess Systematic Reviews 2; CDA: Cervical disc arthroplasty; ACDF: Anterior cervical discectomy and fusion; ACSS: Anterior cervical spine surgery; TTE: Tracheal traction exercises; PROM: Patient-reported outcome measures; BMP: Bone morphogenic protein; RCT: Randomised controlled trial; PSTS: Prevertebral Soft Tissue Swelling; EAT-10: Eating Assessment Tool-10; MDADI: MD Anderson Dysphagia Inventory.

should therefore be interpreted as hypothesis-generating signals rather than definitive causal relationships.

Perioperative corticosteroid administration represents the most methodologically supported intervention, based on the only review synthesising RCTs; however, even this evidence is limited by heterogeneity in dosing, administration route, and follow-up duration. Accordingly, clinical decisions should be individualised, evidence-informed, and tempered by recognition of the current methodological constraints within the reviewed literature.

Future Research Directions

High-quality, prospective, standardised research is urgently needed. Priority areas include: a. Uniform definitions and validated assessment tools, including routine use of Bazaz scores, EAT-10, MDADI, and standardised radiographic markers, b. Prospective multicenter cohort studies: enabling robust adjustment for confounders and stratification by surgical approach, implant type, alignment correction, and intraoperative variables. Dose-response data for rhBMP-2 and optimised steroid protocols, d. Mechanistic imaging studies investigating PSTS, soft tissue oedema, cervical alignment shifts and pharyngeal biomechanics, etc. Development of individualised risk-prediction models, f. Long-term functional outcomes, including swallowing-related QoL, nutritional status, and health-care utilisation. These priorities are essential to move beyond hypothesis-generating signals toward reliable, practice-informing evidence.

Conclusion

Dysphagia is commonly reported after ACSS, particularly in the early postoperative period. However, the reported incidence substantially varies due to inconsistent definitions, assessment tools, and follow-up intervals. Female sex and multilevel surgery demonstrated association with increased risk, while perioperative corticosteroid administration represents the most methodologically supported strategy for reducing early dysphagia. However, no preventive or therapeutic strategy can currently be recommended as standard of care based on high-certainty evidence. Most findings remain hypothesis-generating and require validation in high-quality prospective studies. Future progress depends on standardised outcome definitions, validated patient-reported measures, and high-quality prospective multicenter studies capable of clarifying modifiable risk factors and preventive strategies.

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Data Availability Statement

Data generated in the study will be made available upon reasonable request to the authors.

References

1. Cloward RB. The anterior approach for removal of ruptured cervical disks. *J Neurosurg*. 1958;15:602-617. doi:10.3171/jns.1958.15.6.0602.
2. Smith GW, Robinson RA. The treatment of certain cervical-spine disorders by anterior removal of the intervertebral disc and interbody fusion. *J Bone Joint Surg Am*. 1958;40-A:607-624.
3. Yee TJ, Swong K, Park P. Complications of anterior cervical spine surgery: a systematic review of the literature. *J Spine Surg*. 2020;6:302-322. doi:10.21037/jss.2020.01.14.
4. Memtsoudis SG, Hughes A, Ma Y, Chiu YL, Sama AA, Girardi FP. Increased in-hospital complications after primary posterior versus primary anterior cervical fusion. *Clin Orthop Relat Res*. 2011;469:649-657. doi:10.1007/s11999-010-1549-4.
5. Yerneni K, Burke JF, Chunduru P, et al. safety of outpatient anterior cervical discectomy and fusion: a systematic review and meta-analysis. *Neurosurgery*. 2020;86:30-45. doi:10.1093/neuros/nyy636.
6. Fu MC, Gruskay JA, Samuel AM, et al. Outpatient anterior cervical discectomy and fusion is associated with fewer short-term complications in one- and two-level cases: a propensity-adjusted analysis. *Spine (Phila Pa 1976)*. 2017;42:1044-1049. doi:10.1097/BRS.0000000000001988.
7. Adamson T, Godil SS, Mehrlich M, Mendenhall S, Asher AL, McGirt MJ. Anterior cervical discectomy and fusion in the outpatient ambulatory surgery setting compared with the in-patient hospital setting: analysis of 1000 consecutive cases. *J Neurosurg Spine*. 2016;24:878-884. doi:10.3171/2015.8.SPINE14284.
8. Riley LH, Vaccaro AR, Dettori JR, Hashimoto R. Postoperative dysphagia in anterior cervical spine surgery. *Spine (Phila Pa 1976)*. 2010;35:S76-S85. doi:10.1097/BRS.0b013e3181d81a96.
9. Anderson PA, Sasso RC, Riew KD. Comparison of adverse events between the Bryan artificial cervical disc and anterior cervical arthrodesis. *Spine (Phila Pa 1976)*. 2008;33:1305-1312. doi:10.1097/BRS.0b013e31817329a1.

10. Buttermann GR. Prospective nonrandomized comparison of an allograft with bone morphogenic protein versus an iliac-crest autograft in anterior cervical discectomy and fusion. *Spine J*. 2008;8:426-435. doi:10.1016/j.spinee.2006.12.006.
11. Chin KR, Eiszner JR, Adams SB. Role of plate thickness as a cause of dysphagia after anterior cervical fusion. *Spine (Phila Pa 1976)*. 2007;32:2585-2590. doi:10.1097/BRS.0b013e318158dec8.
12. Kang SH, Kim D-K, Seo KM, Kim KT, Kim YB. Multi-level spinal fusion and postoperative prevertebral thickness increase the risk of dysphagia after anterior cervical spine surgery. *J Clin Neurosci*. 2011;18:1369-1373. doi:10.1016/j.jocn.2011.02.033.
13. Kepler CK, Rihn JA, Bennett JD, et al. Dysphagia and soft-tissue swelling after anterior cervical surgery: a radiographic analysis. *Spine J*. 2012;12:639-644. doi:10.1016/j.spinee.2012.03.024.
14. Mendoza-Lattes S, Clifford K, Bartelt R, Stewart J, Clark CR, Boezaart AP. Dysphagia following anterior cervical arthrodesis is associated with continuous, strong retraction of the esophagus. *J Bone Joint Surg Am*. 2008;90:256-263. doi:10.2106/JBJS.G.00258.
15. Papavero L, Heese O, Klotz-Regener V, Buchalla R, Schröder F, Westphal M. The impact of esophagus retraction on early dysphagia after anterior cervical surgery: does a correlation exist? *Spine (Phila Pa 1976)*. 2007;32:1089-1093. doi:10.1097/01.brs.0000261627.04944.cf.
16. Cho SK, Lu Y, Lee D-H. Dysphagia following anterior cervical spinal surgery: a systematic review. *Bone Joint J*. 2013;95-B:868-873. doi:10.1302/0301-620X.95B7.31029.
17. Bazaz R, Lee MJ, Yoo JU. Incidence of dysphagia after anterior cervical spine surgery: a prospective study. *Spine (Phila Pa 1976)*. 2002;27:2453-2458. doi:10.1097/00007632-200211150-00007.
18. Smith-Hammond CA, New KC, Pietrobon R, Curtis DJ, Scharver CH, Turner DA. Prospective analysis of incidence and risk factors of dysphagia in spine surgery patients: comparison of anterior cervical, posterior cervical, and lumbar procedures. *Spine (Phila Pa 1976)*. 2004;29:1441-1446. doi:10.1097/01.brs.0000129100.59913.ea.
19. Ratnaraj J, Todorov A, McHugh T, Cheng MA, Lauryssen C. Effects of decreasing endotracheal tube cuff pressures during neck retraction for anterior cervical spine surgery. *J Neurosurg*. 2002;97:176-179. doi:10.3171/spi.2002.97.2.0176.
20. Pedram M, Castagnera L, Carat X, Macouillard G, Vital JM. Pharyngolaryngeal lesions in patients undergoing cervical spine surgery through the anterior approach: contribution of methylprednisolone. *Eur Spine J*. 2003;12:84-90. doi:10.1007/s00586-002-0495-6.
21. Mummaneni PV, Burkus JK, Haid RW, Traynelis VC, Zdeblick TA. Clinical and radiographic analysis of cervical disc arthroplasty compared with allograft fusion: a randomized controlled clinical trial. *J Neurosurg Spine*. 2007;6:198-209. doi:10.3171/spi.2007.6.3.198.
22. Rai V, Sharma V, Kumar M, Thakur L. A systematic review of risk factors and adverse outcomes associated with anterior cervical discectomy and fusion surgery over the past decade. *J Craniovertebr Junction Spine*. 2024;15:141-152. doi:10.4103/jcvjs.jcvjs_168_23.
23. Liu F-Y, Yang D-L, Huang W-Z, et al. Risk factors for dysphagia after anterior cervical spine surgery: A meta-analysis. *Medicine (Baltimore)*. 2017;96:e6267. doi:10.1097/MD.0000000000006267.
24. Liu J, Hai Y, Kang N, Chen X, Zhang Y. Risk factors and preventative measures of early and persistent dysphagia after anterior cervical spine surgery: a systematic review. *Eur Spine J*. 2018;27:1209-1218. doi:10.1007/s00586-017-5311-4.
25. Joaquim AF, Murar J, Savage JW, Patel AA. Dysphagia after anterior cervical spine surgery: a systematic review of potential preventative measures. *Spine J*. 2014;14:2246-2260. doi:10.1016/j.spinee.2014.03.030.
26. Shriver MF, Lewis DJ, Kshettry VR, Rosenbaum BP, Benzel EC, Mroz TE. Dysphagia rates after anterior cervical discectomy and fusion: a systematic review and meta-analysis. *Global Spine J*. 2017;7:95-103. doi:10.1055/s-0036-1583944.
27. Oh LJ, Ong S, Ghozy S, et al. Dysphagia rates in single- and multiple-level anterior cervical discectomy and fusion surgery: a meta-analysis. *J Spine Surg*. 2020;6:581-590. doi:10.21037/jss-20-506.
28. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. 2021;372:n71. doi:10.1136/bmj.n71.
29. Shea BJ, Reeves BC, Wells G, et al. AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. *BMJ*. 2017;358:j4008. doi:10.1136/bmj.j4008.
30. Zhang X, Yang Y, Shen Y-W, Zhang KR, Ma LT, Liu H. Effect of perioperative steroids application on dysphagia, fusion rate, and visual analogue scale (VAS) following anterior cervical spine surgery: A meta-analysis of 14 randomized controlled trials (RCTs). *Front Surg*. 2022;9:1040166. doi:10.3389/fsurg.2022.1040166.
31. Yu Z, Shi X, Yin J, Jiang X, Xu N. Comparison of complications between anterior cervical diskectomy and fusion versus anterior cervical corpectomy and fusion in two- and three-level cervical spondylotic myelopathy: a meta-analysis. *J Neurol Surg A Cent Eur Neurosurg*. 2023;84:343-354. doi:10.1055/s-0042-1747926.
32. Gabr MA, Touko E, Yadav AP, et al. Improved dysphagia outcomes in anchored spacers versus plate-screw systems in anterior cervical discectomy and fusion: a systematic review. *Global Spine J*. 2020;10:1057-1065. doi:10.1177/2192568219895266.
33. Yin M, Ma J, Huang Q, et al. The new zero-P implant can effectively reduce the risk of postoperative dysphagia and complications compared with the traditional anterior cage and plate: a systematic review and meta-analysis. *BMC Musculoskelet Disord*. 2016;17:430. doi:10.1186/s12891-016-1274-6.
34. Shao H, Chen J, Ru B, et al. Zero-profile implant versus conventional cage-plate implant in anterior cervical discectomy and fusion for the treatment of degenerative cervical

spondylosis: a meta-analysis. *J Orthop Surg Res*. 2015;10:148. doi:10.1186/s13018-015-0290-9.
35. Xiao S, Liang Z, Wei W, Ning J. Zero-profile anchored cage reduces risk of postoperative dysphagia compared with a cage with plate fixation after anterior cervical discectomy and fusion. *Eur Spine J*. 2017;26:975-984. doi:10.1007/s00586-016-4914-5.
36. Yang Y, Ma L, Liu H, Xu M. A Meta-analysis of the incidence of patient-reported dysphagia after anterior cervical decompression and fusion with the zero-profile implant system. *Dysphagia*. 2016;31:134-145. doi:10.1007/s00455-015-9681-7.
37. Cheung ZB, Gidumal S, White S, et al. Comparison of anterior cervical discectomy and fusion with a stand-alone Interbody cage versus a conventional cage-plate technique: a systematic review and meta-analysis. *Global Spine J*. 2019;9:446-455. doi:10.1177/2192568218774576.
38. Cabrera JP, Agarwal N, Mesregah MK, et al. Analysis of complications in multilevel anterior cervical discectomy and fusion using osteobiologics other than bone morphogenetic protein: a systematic review. *Global Spine J*. 2024;14:86S-93S. doi:10.1177/21925682231168083.
39. Rodrigues-Pinto R, Muthu S, Diniz SE, et al. Complications of the use allograft in 1- or 2-level anterior cervical discectomy and fusion: a systematic review. *Global Spine J*. 2024;14:70S-77S. doi:10.1177/21925682231173358.
40. Martin CT, Holton K, Broida SE, et al. Comparative complications associated with BMP use in patients undergoing ACDF for degenerative spinal conditions: systematic review and meta-analysis. *Global Spine J*. 2024;14:94S-109S. doi:10.1177/21925682231166325.
41. Yu H, Dong H, Ruan B, Xu X, Wang Y. Intraoperative use of topical retropharyngeal steroids for dysphagia after anterior cervical fusion: a systematic review and meta-analysis. *Dis Markers*. 2021;2021:7115254. doi:10.1155/2021/7115254.
42. Liu J, Zhang Y, Hai Y, Kang N, Han B. Intravenous and local steroid use in the management of dysphagia after anterior cervical spine surgery: a systematic review of prospective randomized controlled trails (RCTs). *Eur Spine J*. 2019;28:308-316. doi:10.1007/s00586-018-5840-5.
43. Song J, Yi P, Wang Y, et al. The retropharyngeal steroid use during operation on the fusion rate and dysphagia after ACDF? A systematic review and meta-analysis. *Eur Spine J*. 2022;31:288-300. doi:10.1007/s00586-021-06727-1.
44. Cheng L, Guan J, Zhang C, et al. The effect of local intraoperative corticosteroid application on postoperative dysphagia following anterior cervical spine surgery. *Neurosurg Rev*. 2022;45:63-70. doi:10.1007/s10143-019-01207-z.
45. Wang J-W, Shi P-Z, Li K, et al. Safety and efficacy of local steroid application on dysphagia following anterior cervical discectomy and fusion: a systematic review and meta-analysis. *Clin Spine Surg*. 2023;36:265-279. doi:10.1097/BSD.0000000000001433.
46. Shen L, Lu L, Si C, et al. Impact of local steroid application on dysphagia after anterior cervical spine surgery: a meta-analysis. *Arch Orthop Trauma Surg*. 2023;143:3015-3024. doi:10.1007/s00402-022-04513-2.
47. Adenikinju AS, Halani SH, Rindler RS, Gary MF, Michael KW, Ahmad FU. Effect of perioperative steroids on dysphagia after anterior cervical spine surgery: A systematic review. *Int J Spine Surg*. 2017;11:9. doi:10.14444/4009.
48. Zadegan SA, Jazayeri SB, Abedi A, Bonaki HN, Vaccaro AR, Rahimi-Movaghar V. Corticosteroid administration to prevent complications of anterior cervical spine fusion: a systematic review. *Global Spine J*. 2018;8:286-302. doi:10.1177/2192568217708776.
49. Anderson PA, Nassr A, Currier BL, et al. Evaluation of adverse events in total disc replacement: a meta-analysis of FDA summary of safety and effectiveness data. *Global Spine J*. 2017;7:76S-83S. doi:10.1177/2192568216688195.
50. Zhong Z-M, Li M, Han Z-M, et al. Does cervical disc arthroplasty have lower incidence of dysphagia than anterior cervical discectomy and fusion? A meta-analysis. *Clin Neurol Neurosurg*. 2016;146:45-51. doi:10.1016/j.clineuro.2016.04.002.
51. Tumialán LM, Pan J, Rodts GE, Mummaneni PV. The safety and efficacy of anterior cervical discectomy and fusion with polyetheretherketone spacer and recombinant human bone morphogenetic protein-2: a review of 200 patients. *J Neurosurg Spine*. 2008;8:529-535. doi:10.3171/SPI/2008/8/6/529.
52. Lu DC, Tumialán LM, Chou D. Multilevel anterior cervical discectomy and fusion with and without rhBMP-2: a comparison of dysphagia rates and outcomes in 150 patients. *J Neurosurg Spine*. 2013;18:43-49. doi:10.3171/2012.10.SPINE10231.
53. Fineberg SJ, Ahmadinia K, Oglesby M, Patel AA, Singh K. Hospital outcomes and complications of anterior and posterior cervical fusion with bone morphogenetic protein. *Spine (Phila Pa 1976)*. 2013;38:1304-1309. doi:10.1097/BRS.0b013e31828f494c.
54. Zeng J-H, Zhong Z-M, Chen J-T. Early dysphagia complicating anterior cervical spine surgery: incidence and risk factors. *Arch Orthop Trauma Surg*. 2013;133:1067-1071. doi:10.1007/s00402-013-1773-y.
55. Lee MJ, Bazaz R, Furey CG, Yoo J. Influence of anterior cervical plate design on Dysphagia: a 2-year prospective longitudinal follow-up study. *J Spinal Disord Tech*. 2005;18:406-409. doi:10.1097/01.bsd.0000177211.44960.71.
56. Jain A, Hassanzadeh H, Strike SA, Skolasky RL, Riley LH. rhBMP use in cervical spine surgery: associated factors and in-hospital complications. *J Bone Joint Surg Am*. 2014;96:617-623. doi:10.2106/JBJS.M.00666.
57. Carr MT, Steinberger J, Houten JK. Delayed Screw Migration Following Anterior Cervical Discectomy and Fusion. *World Neurosurgery*. 2025;194:123555. doi:10.1016/j.wneu.2024.12.014.