Joint Diseases and Related Surgery

Jt Dis Relat Surg
2026;37(1):1-8

ORIGINAL ARTICLE

Hidden blood loss in anterior cervical discectomy and fusion versus single-level anterior cervical corpectomy and fusion with adjacent discectomy for two-level cervical spondylotic myelopathy

Yin-xiao Peng, MD[1], Bo Xiao, MD[2], Rui Zhong, MD[1], Xiao-ping Xu, MD[3]

[1]Department of Orthopaedics, The Third People's Hospital of Chengdu, Sichuan, China
[2]Department of Orthopaedics, Pidu District People's Hospital of Chengdu, Sichuan, China
[3]Department of Orthopaedics, The First Affiliated Hospital of Chengdu Medical College, Sichuan, China

ABSTRACT

Objectives: This study aims to evaluate hidden blood loss (HBL) in patients undergoing anterior cervical surgery for two-level cervical spondylotic myelopathy (CSM) and to compare the HBL between anterior cervical discectomy and fusion (ACDF) and single-level anterior cervical corpectomy and fusion (ACCF) with adjacent discectomy.

Patients and methods: Between January 2019 and December 2023, a total of 100 patients (55 males, 45 females; mean age: 49.4±11.4 years; range, 43 to 84 years) who underwent anterior cervical surgeries were retrospectively analyzed. Data collection encompassed demographic information, laboratory findings, and clinical records. Patients treated with ACDF were classified as Group A, while those receiving ACCF were assigned to Group B. Total blood loss (TBL) was calculated using the Gross formula, and HBL was determined based on TBL, postoperative drainage volume, and intraoperative blood loss.

Results: The most frequently affected segments were C3/4 and C4/5. The mean operative time was 135.5±13.4 min in Group A versus 139.5±12.8 min in Group B, indicating no statistically significant difference (p=0.130). The mean intraoperative blood loss and HBL were 42.5±9.2 mL and 231.5±55.0 mL in Group A, respectively, compared to 53.4±9.02 mL and 262.8±53.3 mL in Group B. Both parameters showed statistically significant intergroup differences (intraoperative blood loss: p<0.001; HBL: p=0.005). Hemoglobin (Hb) loss was significantly lower in Group A than in Group B, demonstrating a statistically significant difference (p<0.001).

Conclusion: In the perioperative period of anterior cervical surgery for two-level CSM (primarily C3/4-C4/5), HBL represents a clinically significant factor which should not be overlooked. Compared to ACDF, greater attention should be paid to postoperative anemia and HBL in patients undergoing ACCF.

Keywords: Anterior cervical corpectomy and fusion, anterior cervical discectomy and fusion, cervical spondylotic myelopathy, hidden blood loss.

Cervical spondylotic myelopathy (CSM) is a spinal cord dysfunction syndrome caused by degenerative changes in cervical intervertebral discs.[1] Approximately 10% of individuals aged 55 years and above exhibit clinical manifestations of CSM.[2] The two-level adjacent segment variant represents the most prevalent subtype, accounting for 56% of cases.[3] With advancing age, both the incidence and severity of disc herniation increase, exacerbating spinal cord compression.[4] Clinical presentations

Received: June 18, 2025
Accepted: August 05, 2025
Published online: September 23, 2025

Correspondence: Yin-xiao Peng, MD. Department of Orthopaedics, The Third People's Hospital of Chengdu, 610031 Sichuan, China.

E-mail: pengyx31@126.com

Correspondence: Xiao-ping Xu, MD. Department of Orthopaedics, The First Affiliated Hospital of Chengdu Medical College, 610500 Sichuan, China

E-mail: xpxudoct@cmc.edu.cn

Doi: 10.52312/jdrs.2026.2445

Citation: Peng YX, Xiao B, Zhong R, Xu XP. Hidden blood loss in anterior cervical discectomy and fusion versus single-level anterior cervical corpectomy and fusion with adjacent discectomy for two-level cervical spondylotic myelopathy. Jt Dis Relat Surg 2026;37(1):1-8. doi: 10.52312/jdrs.2026.2445.

of CSM include neck pain along with sensory and motor deficits in the upper extremities. Without timely intervention, the condition may progress to limb paralysis and significantly impair daily functioning.[5]

Current therapeutic strategies encompass conservative management and surgical intervention. When conservative measures fail to yield improvement within three months, surgical decompression via anterior, posterior, or combined approaches is recommended to prevent neurological deterioration.[6] Among these, anterior approaches such as anterior cervical discectomy and fusion (ACDF) and anterior cervical corpectomy and fusion (ACCF) are considered minimally invasive yet effective, with favorable clinical outcomes.[7] While both techniques demonstrate efficacy for two-level CSM, recent evidence suggests ACCF may carry higher complication risks in multi-level procedures compared to ACDF or hybrid approaches.[8] Nevertheless, their application remains prevalent for specific pathologies such as retrovertebral compression.

However, the minimally invasive nature of anterior cervical surgery often leads spine surgeons to overlook potential perioperative bleeding-related complications. Clinical observations have shown that, despite minimal intraoperative and postoperative visible blood loss (VBL), a significant proportion of patients develop postoperative anemia. We hypothesize that hidden blood loss (HBL) may underlie this phenomenon. Anemia can delay functional recovery, prolong wound healing, increase infection risks, and extend hospitalization.[9] Moreover, many CSM patients are elderly with multiple comorbidities and reduced tolerance to blood loss. Therefore, accurate assessment of total blood loss (TBL) is crucial for optimizing perioperative management and ensuring patient safety. While ACCF carries higher overall complication risks in multi-level surgery,[8] quantifying its specific blood loss burden remains clinically imperative as: *(i)* HBL-driven anemia independently worsens outcomes (delayed recovery, infection) regardless of other complications;[9] *(ii)*Surgeons frequently select ACCF for critical indications (e.g., retrovertebral stenosis, ossification of posterior longitudinal ligament [OPLL]) where direct decompression is non-negotiable; and iii) No prior study has isolated HBL differences between these techniques despite its significant contribution to postoperative morbidity. Thus, comparing HBL in ACDF versus ACCF addresses a distinct clinical question: optimizing blood conservation for high-risk procedures where ACCF is unavoidable.

Existing research has identified substantial HBL in spinal surgeries,[10,11] including minimally invasive procedures such as percutaneous vertebroplasty.[12] Yet, few studies have investigated HBL in anterior cervical surgeries[13,14] or compared the impact of different surgical approaches on HBL. Although Yin et al.[15] confirmed substantial HBL in 219 mixed-level anterior cervical fusion cases, their analysis neither stratified by surgical levels nor directly compared ACDF versus ACCF. In the present study, we specifically aimed to address this gap by conducting a focused head-to-head analysis of HBL between ACDF and ACCF in the most prevalent subtype (two-level adjacent segment CSM) and to refine perioperative risk assessment for distinct surgical approaches.

PATIENTS AND METHODS

This single-center, retrospective cohort study was conducted at The Third People's Hospital of Chengdu and Department of Orthopaedics between January 2019 and December 2023. Patients who underwent anterior cervical surgery at our institution were included. Inclusion criteria were as follows: *(i)* CSM diagnosis confirmed through clinical and radiological evaluation; *(ii)* imaging evidence of two-level adjacent segment spinal cord compression; *(iii)* persistent symptoms after ≥3 months of conservative management; and *(iv)* treatment with either ACDF or ACCF. Exclusion criteria were as follows: *(i)* multi-level cervical spondylosis (≥3 segments); *(ii)* previous cervical spine surgery; *(iii)* cervical deformities, fractures, tumors, or infections; *(iv)* coagulation disorders or chronic use of antiplatelet/anticoagulant medications; *(v)* incomplete medical records; and *(vi)* documented objection to secondary data use in research. Finally, a total of 100 patients (55 males, 45 females; mean age: 49.4±11.4 years; range, 43 to 84 years) who met the inclusion criteria were recruited. Written informed consent was obtained from each patient. Ethical Review Committee Statement: This study was observational in nature. The Ethics Committee of The Third People's Hospital of Chengdu confirmed that ethical approval was not required.

Surgical indication and technique selection

The choice between ACDF and ACCF was determined preoperatively based on: *(i)* Compression characteristics: ACCF was preferred for central canal stenosis >50% (measured via midsagittal magnetic resonance imaging [MRI] T2-weighted images) or when pathology spanned the vertebral body (e.g., large retrovertebral osteophytes, OPLL). The ACDF was indicated for foraminal stenosis or disc-level pathology without significant vertebral body involvement; *(ii)* Sagittal alignment: ACCF was selected when local kyphosis >10° required correction through vertebral body resection; *(iii)* Surgeon's assessment: Final decisions incorporated symptom patterns and intraoperative accessibility considerations. Both ACDF and ACCF were compared within their respective indications. This study evaluated the differences of HBL between the two surgical techniques rather than the procedural superiority. No cases required conversion between techniques intraoperatively.

Surgical technique

No patients received tranexamic acid (TXA) or other antifibrinolytic agents during the study period in accordance with the institutional protocols. Hemostasis was achieved solely through bipolar electrocautery and absorbable gelatin sponge (Surgicel™, Ethicon Inc., Somerville, NJ, USA) application.

All operations were performed under general anesthesia by two senior spine surgeons (each with >10 years of experience in cervical surgery). Both surgeons adhered to identical protocols for hemostasis (bipolar cautery + Surgicel™ application) and drain placement (subfascial 3.0-mm closed-suction drain). Patients undergoing ACDF were designated as group A, while those receiving ACCF constituted group B. Surgical levels were determined based on symptoms, physical signs, and imaging findings. Preoperatively, all patients underwent tracheoesophageal traction training to prevent postoperative expectoration difficulties and dysphagia.

The patients were positioned supine with head fixation and shoulder elevation. A transverse incision of 5 cm was made along the right anterior cervical approach. Following platysma incision, meticulous dissection was performed to separate the vascular sheath and visceral fascia, fully exposing the prevertebral fascia and target segments. Target intervertebral spaces were localized using C-arm fluoroscopy, followed by Caspar (Aesculap, Inc., Center Valley, PA, USA) retractor placement.

Group A (ACDF protocol)

After disc space distraction: *(i)* The annulus fibrosus and anterior longitudinal ligament were incised, with subsequent discectomy; *(ii)* Osteophytes at posterior vertebral margins and adjacent endplates were meticulously debrided; *(iii)* Hypertrophic posterior longitudinal ligament was elevated and resected using cervical nerve dissectors to expose the dura mater; *(iv)* Complete decompression of posterior borders, dural sac, and nerve root canals was achieved; *(v)* Cartilaginous endplates were curetted, and locally harvested osteophytes (from posterior vertebral margins) were morselized as autograft. Interbody cages were packed with this autograft and implanted to restore cervical height; and *(vi)* Final fixation with screws through interbody cages was conducted under fluoroscopic confirmation of stability and physiological curvature.

Group B (ACCF protocol)

Following disc space distraction: *(i)* Mid-portion corpectomy of the pathological vertebra and adjacent discectomy were performed until posterior longitudinal ligament exposure; *(ii)* Osteophytes and disc materials were completely removed, ensuring thorough decompression of the dural sac and bilateral nerve root canals; *(iii)* Cartilaginous endplates at rostral/caudal vertebral borders were curetted; *(iv)* After measuring the defect, the resected vertebral body bone and excised osteophytes were morselized as autograft. The titanium mesh cage was filled with this autograft and implanted to restore cervical height; and *(v)* After the retractor was removed, an anterior locking plate was fixed with screws under fluoroscopic verification.

All patients initiated ambulatory mobilization with cervical orthosis support on postoperative Day (POD)1. Drainage was discontinued within 48 h after surgery, and cervical immobilization was maintained for three months.

Data collection

Epidemiological data were documented, encompassing age, sex, height, body weight, body mass index (BMI), smoking status, underlying comorbidities, affected segments, symptom duration, intramedullary hyperintensity on MRI, and preoperative Cobb angle measurements at the surgical segments (C2-C7) from neutral lateral radiographs (Cobb angle measurement protocol: The angle between parallel lines drawn along the inferior endplates of C2 and C7 vertebrae was quantified using PACS imaging software [Sectra AB, Sweden]). Laboratory metrics comprised fasting blood glucose, hematocrit (Hct) levels, serum albumin concentration, and hemoglobin (Hb) values. These parameters were derived from preoperative and POD3 blood analyses covering complete blood count and liver function tests. Clinical records included the American Society of Anesthesiologists (ASA) classification, operative duration, intraoperative blood loss, postoperative drainage volume, length of hospital stay, and follow-up time. Perioperative blood transfusion was documented.

Calculation of blood loss

Patient blood volume (PBV) was calculated using the Nadler formula:[16] PBV (L) = k1 × height (m)3 + k2 × weight (kg) + k3, where coefficients differed by sex:

1. Males: k1=0.3669, k2=0.03219, k3=0.6041;
2. Females: k1=0.3561, k2=0.03308, k3=0.1833.

TBL was derived via the Gross equation:[17] TBL (L) = PBV (L) × (Hct_{pre} - Hct_{post})/ Hctave; where Hct_{pre} was the preoperative Hct, Hct_{post} was the Hct on POD3, and Hctave was the average of Hct_{pre} and Hct_{post}.

The HBL was defined as: HBL=TBL-VBL, where VBL encompassed intraoperative blood loss (quantified gravimetrically after irrigation fluid correction and Hb mass in surgical gauzes) plus postoperative drainage volume. Anemia diagnosis followed the World Health Organization (WHO) sex-specific Hb thresholds (<130 g/L males; <120 g/L females).[18]

Statistical analysis

Statistical analysis was performed using the SPSS version 26.0 software (IBM Corp., Armonk, NY, USA). Continuous variables were presented in mean±standard deviation (SD) or median (min-max), while categorical variables were presented in number and frequency. Inter-group comparisons employed independent t-tests for continuous data and chi-square tests for categorical variables. Subgroup analysis was carried out to assess potential surgeon-related variability between surgeons. A p value of <0.05 was considered statistically significant.

RESULTS

The most frequently affected segments were C3/4 and C4/5. No significant differences existed in

TABLE I
Patients' demographics

	Group A		Group B		
Variables	n	Mean±SD	n	Mean±SD	*p*
Age (year)		62.5±10.5		61.7±8.1	0.661
Sex					0.546
Male	26		29		
Female	24		21		
Height (m)		1.66±0.05		1.67±0.05	0.507
Weight (kg)		63.4±6.4		64.6±7.3	0.411
BMI (kg/m²)		23.0±2.1		23.2±2.1	0.625
Smoking	10		13		0.476
Comorbidities					0.418
Hypertension	6		6		
DM	14		16		
CHD	5		7		
Affected segments					0.869
C3/4, C4/5	33		32		
C4/5, C5/6	12		14		
C5/6, C6/7	5		4		
Symptom duration (mo)		13.8±6.4		12.7±6.4	0.400
Intramedullary hyperintensity on MRI	8		5		0.372
Preoperative Cobb angle		26.6±6.1		26.7±5.7	0.973
Total	50		50		

SD: Standard deviation; BMI: Body mass index; DM: Diabetes mellitus; CHD: Coronary heart disease; MRI: Magnetic resonance imaging.

TABLE II
Comparison of intraoperative and postoperative parameters between the two groups

	Group A		Group B		
Variables	n	Mean±SD	n	Mean±SD	*p*
ASA classification					0.098
I	7		8		
II	33		23		
III	10		19		
Operative duration (min)		135.5±13.4		139.5±12.8	0.130
Intraoperative blood loss (mL)		42.5±9.2		53.4±9.0	<0.001
Postoperative drainage (mL)		27.9±5.3		29.0±5.9	0.336
Length of hospital stay (days)		7.4±2.4		7.2±1.2	0.628
Follow-up time (mo)		19.0±5.3		19.3±5.0	0.755
Total	50		50		

SD: Standard deviation; ASA: American Society of Anesthesiologists.

demographic characteristics between the groups (Table I).

All surgical plans were executed as preoperatively determined, with no intraoperative conversions between ACDF and ACCF techniques. The mean operative duration was 135.5±13.4 min for Group A versus 139.5±12.8 min for Group B, showing no statistically significant disparity ($p=0.130$). Intraoperative blood loss significantly differed between the groups (Group A: 42.5±9.2 mL; Group B: 53.4±9.0 mL; $p<0.001$). Comparable outcomes were observed for ASA classification, postoperative drainage volume, hospital stay, and follow-up time (Table II). Cases were evenly distributed between surgeons (Surgeon 1: 52 cases; Surgeon 2: 48 cases), with comparable ACDF/ACCF allocation

TABLE III
Laboratory and HBL-related parameters

	Group A		Group B		
Variables	n	Mean±SD	n	Mean±SD	*p*
Preoperative blood glucose (mmol/L)		6.4±0.9		6.6±1.2	0.201
Preoperative serum albumin (g/L)		36.7±2.4		37.0±2.0	0.528
Preoperative Hb (g/L)		130.4±6.7		131.2±5.8	0.548
Postoperative Hb (g/L)		119.3±7.3		114.2±8.9	0.003
Hb loss (g/L)		11.1±4.0		16.9±8.1	<0.001
Preoperative Hct (%)		37.8±3.2		36.9±2.7	0.126
Postoperative Hct (%)		35.1±3.0		33.9±2.5	0.037
Hct loss (%)		2.7±0.6		3.0±0.6	0.056
Anemia					
Preoperative anemia	6		5		0.749
Postoperative anemia	37		42		0.220
PBV (L)		4.1±0.4		4.2±0.5	0.170
VBL (mL)		70.4±9.7		85.3±12.1	<0.001
HBL (mL)		231.5±55.0		262.8±53.3	0.005
TBL (mL)		301.9±54.8		348.2±54.6	<0.001
Total	50		50		

HBL: Hidden blood loss; SD: Standard deviation; Hb: Hemoglobin; Hct: Hematocrit; (Hb loss referred to preoperative Hb minus postoperative Hb; Hct loss referred to preoperative Hct minus postoperative Hct); PBV: Patient blood volume; VBL: Visible blood loss; TBL: Total blood loss.

ratios (p=0.597). Drain removal followed a uniform protocol, when output was <30 mL/24 h. No patients received blood transfusions during hospitalization.

Perioperative laboratory parameters and HBL are presented in Table III. The mean Hb loss was significantly lower in Group A (11.1±4.0 g/L) compared to Group B (16.9±8.1 g/L) (p<0.001). The mean TBL and HBL values were 301.9±54.8 mL and 231.5±55.0 mL in Group A, respectively, compared to 348.2±54.6 mL and 262.8±53.3 mL in Group B. Statistically significant intergroup differences were observed for both measures (TBL: p<0.001; HBL: p=0.005). Notably, while HBL constituted a comparable proportion of TBL in both groups (ACDF: 76.7% *vs.* ACCF: 75.3%; p=0.210), the absolute TBL difference (46.3 mL higher in ACCF) primarily drove the significant intergroup disparity in HBL (31.3 mL) (Table III).

The subgroup analysis which was conducted to assess potential surgeon-related variability, no significant inter-operator differences were observed (p=0.412).

DISCUSSION

This study establishes two key outcomes for two-level anterior cervical surgery: i) ACCF procedures generated significantly greater HBL (262.8±53.3 mL *vs.* 231.5±55.0 mL; p=0.005) and Hb reduction (16.9±8.1 g/L *vs.* 11.1±4.0 g/L; p<0.001) compared to ACDF; and ii) Despite comparable HBL-to-TBL ratios (76.7% *vs.* 75.3%; p=0.210), elevated TBL in the ACCF group directly amplified absolute HBL magnitude. These findings necessitate protocolized anemia management for ACCF cases, including strict postoperative Hb monitoring and targeted hemostatic interventions to mitigate transfusion requirements.

Both ACDF and ACCF are established surgical approaches for two-level cervical spondylosis.[19] ACDF, involving disc removal and fusion, preserves vertebral bodies and is associated with reduced structural disruption. In contrast, ACCF requires corpectomy for direct decompression, offering advantages in specific pathologies like ossified posterior longitudinal ligaments.[20] Despite their clinical efficacy, both procedures entail perioperative blood loss, traditionally focused on intraoperative VBL. However, emerging evidence underscores the significance of HBL, extravasation into tissues or hemolysis, which contributes substantially to postoperative anemia and complications.[21] While Yin et al.[15] established the clinical significance of HBL in a large cohort of mixed-level anterior cervical fusions, their study did not perform subgroup analyses by surgical levels or directly contrast ACDF and ACCF techniques. On the other hand, our study provided the first focused comparison of HBL specifically in two-level CSM, the most common pathological subtype-and directly quantified the differential impact of ACDF versus ACCF. This granular analysis addresses a critical gap in optimizing surgical strategy for this population. Our findings do not equate ACDF/ACCF safety, but instead provide actionable data for scenarios where ACCF is anatomically mandated. When surgeons must choose ACCF for severe central compression, protocolized HBL reduction, through TXA or preoperative optimization, becomes essential to mitigate its inherent hematological burden.

Critically, HBL represented a similarly dominant proportion of TBL in both groups (76.7% ACDF *vs.* 75.3% ACCF; p=0.210), underscoring that unseen hemorrhage dominates perioperative hematological burden regardless of surgical technique. This proportion aligned with spinal surgery literature where HBL typically accounts for >70% of TBL.[15] However, the significantly elevated TBL in ACCF (348.2±54.6 mL *vs.* 301.9±54.8 mL; p<0.001) directly amplified absolute HBL (262.8±53.3 mL *vs.* 231.5±55.0 mL; p=0.005). This indicates that more extensive bone resection of ACCF inherently increases TBL burden, which proportionally manifests as greater HBL.

In the current study, HBL/TBL proportions (ACDF: 76.7%; ACCF: 75.3%) exceed the ratio reported for single-level ACDF[13] and approach the upper limits of Yin et al.'s[15] mixed-level cohort. This elevated ratio may reflect: *(i)* pathological complexity: two-level disease requires extended dissection planes and larger dead space for blood sequestration; *(ii)* measurement timing: later Hct assessment (POD3 *vs.* POD1[15]) captured cumulative hemolysis; and *(iii)* exclusion bias: rigorous coagulation criteria excluded patients with enhanced clotting capacity. These factors collectively explain why our ratios sit at the spectrum's higher end, reinforcing that multi-level anterior surgery inherently maximizes the contribution of HBL to total erythrocyte loss.

The pronounced HBL in ACCF likely stems from multifactorial mechanisms: *(i)* extended operative exposure increasing capillary leakage, *(ii)* cytokine release triggering hemolysis, and *(iii)* residual oozing into dead space after wound closure. This explains ACCF's significantly higher Hb loss (16.9±8.1 g/L *vs.* 11.1±4.0 g/L; p<0.001) and Hct reduction (p=0.037), exacerbating postoperative anemia despite comparable VBL to literature benchmarks. Crucially, HBL accounted for 75.3% of TBL in ACCF versus 76.7% in ACDF, highlighting its dominance over VBL. These results emphasize that HBL is not merely a theoretical concern but a substantive contributor to TBL, necessitating procedure-specific risk assessment.

Compared with ACDF, clinicians should be aware of greater postoperative Hb loss and HBL in patients undergoing ACCF. While selecting a surgical strategy for two-level cervical spondylosis, HBL may be considered alongside traditional factors (e.g., spinal stability). For high-risk patients (e.g., elderly or those with cardiopulmonary comorbidities), ACDF could be a relatively favorable option to potentially mitigate HBL-related complications. Conversely, if ACCF is indicated (e.g., for severe central stenosis), perioperative monitoring for anemia remains prudent. Future research should validate HBL-reduction protocols and explore correlations with long-term outcomes.

The significantly elevated HBL and Hb reduction observed in ACCF procedures necessitate implementation of standardized blood conservation protocols. We recommend the following evidence-based strategies: *(i)* preoperative optimization: administer intravenous ferric carboxymaltose (500 to 1,000 mg) to patients with baseline Hb <130 g/L (males) or <120 g/L (females) and consider erythropoiesis-stimulating agents for renally impaired patients; *(ii)* intraoperative management: implement routine TXA infusion for ACCF cases (15 mg/kg bolus followed by 1 mg/kg/h maintenance) and employ meticulous layered hemostasis utilizing bipolar electrocautery; and *(iii)* postoperative vigilance: adhere to restrictive transfusion thresholds: Hb <80 g/L for asymptomatic patients; <100 g/L for those with cardiorespiratory comorbidities, conduct daily Hb monitoring through POD3 and initiate early ambulation to enhance erythropoietic activity. These tiered interventions, particularly targeted TXA prophylaxis in corpectomy cases, may effectively mitigate HBL-associated anemia while minimizing transfusion-related risks.[22]

The absence of significant differences in hospital stay between ACDF and ACCF groups in our cohort diverges from prior reports of prolonged hospitalization for ACCF in multi-level procedures.[8] This discrepancy likely stems from key methodological distinctions: *(i)* Our strict inclusion of only two-level pathology (excluding ≥3-level cases), whereas Badhiwala et al.[8] analyzed multi-level surgeries (3 to 4 segments) where ACCF's inherent complexity may delay discharge; *(ii)* Standardized enhanced recovery protocols in our institution (ambulation POD1, uniform collar use, fixed drain removal criteria) minimized perioperative variability; and *(iii)* Comparable baseline comorbidity burden (ASA scores, p=0.098) and absence of transfusion requirements in both groups eliminated confounding factors that prolong hospitalization.

Nevertheless, several limitations warrant acknowledgment in this study. First, the retrospective design and limited cohort size constrained generalizability, necessitating future validation through large-scale prospective studies. Second, Hct and Hb measurements were confined to preoperative and POD3 assessments without long-term anemia monitoring, potentially resulting in underestimation of HBL. Third, postoperative fluid resuscitation may introduce hemodilution bias in HBL calculations. Fourth, the absence of TXA administration, a known modulator of HBL in spinal surgery, may have elevated absolute blood loss values in both groups. However, this uniformity ensures unbiased comparison between ACDF and ACCF. Finally, our homogeneous rehabilitation protocol may have attenuated intergroup differences in hospital stay observed in heterogenous cohorts.[8]

In conclusion, in anterior cervical surgery for two-level CSM, perioperative HBL constitutes a critical consideration which warrants close attention. Compared to ACDF, ACCF procedures demonstrate significantly greater Hb loss and more HBL, necessitating heightened clinical vigilance. Therefore, in scenarios where ACCF is anatomically indicated including retrovertebral pathology, awareness of its amplified HBL burden should prompt protocolized blood conservation strategies, such as TXA or Hb optimization, to mitigate anemia-related sequelae, thereby complementing broader risk-benefit assessments.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Wrote the draft of the manuscript, were major contributors in design and revising: Y.X.P., B.X.; Critically reviewed and revised the manuscript for important intellectual content: X.P.X.; Were involved in collecting data and design of the study; Y.X.P., R.Z.; Approved the final manuscript and agree to be accountable for all aspects of the work: X.P.X.

Conflict of Interest: The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding: The authors received no financial support for the research and/or authorship of this article.

REFERENCES

1. Nouri A, Tetreault L, Singh A, Karadimas SK, Fehlings MG. Degenerative cervical myelopathy: Epidemiology, genetics, and pathogenesis. Spine (Phila Pa 1976) 2015;40:E675-93. doi: 10.1097/BRS.0000000000000913.
2. Chen L, Zhang Z, Li J, Tong P, Xu T. Meta-analysis of treatment for adjacent two-segment cervical spondylotic myelopathy: A comparison between anterior cervical corpectomy and fusion and anterior cervical discectomy and fusion. Global Spine J 2025;15:1839-48. doi: 10.1177/21925682241297586.
3. Toledano M, Bartleson JD. Cervical spondylotic myelopathy. Neurol Clin 2013;31:287-305. doi: 10.1016/j.ncl.2012.09.003.
4. Tu J, Vargas Castillo J, Das A, Diwan AD. Degenerative cervical myelopathy: Insights into its pathobiology and molecular mechanisms. J Clin Med 2021;10:1214. doi: 10.3390/jcm10061214.
5. Ouyang P, Li J, He X, Dong H, Zang Q, Li H, et al. Biomechanical comparison of 1-level corpectomy and 2-level discectomy for cervical spondylotic myelopathy: A finite element analysis. Med Sci Monit 2020;26:e919270. doi: 10.12659/MSM.919270.
6. McCormick JR, Sama AJ, Schiller NC, Butler AJ, Donnally CJ 3rd. Cervical spondylotic myelopathy: A guide to diagnosis and management. J Am Board Fam Med 2020;33:303-13. doi: 10.3122/jabfm.2020.02.190195.
7. Wen Z, Lu T, Wang Y, Liang H, Gao Z, He X. Anterior cervical corpectomy and fusion and anterior cervical discectomy and fusion using titanium mesh cages for treatment of degenerative cervical pathologies: A literature review. Med Sci Monit 2018;24:6398-404. doi: 10.12659/MSM.910269.
8. Badhiwala JH, Leung SN, Ellenbogen Y, Akbar MA, Martin AR, Jiang F, et al. A comparison of the perioperative outcomes of anterior surgical techniques for the treatment of multilevel degenerative cervical myelopathy. J Neurosurg Spine 2020;33:433-40. doi: 10.3171/2020.4.SPINE191094.
9. Phan K, Wang N, Kim JS, Kothari P, Lee NJ, Xu J, et al. Effect of preoperative anemia on the outcomes of anterior cervical discectomy and fusion. Global Spine J 2017;7:441-7. doi: 10.1177/2192568217699404.
10. Yang JH, Kim HJ, An M, Suh SW, Chang DG. Hidden blood loss and its risk factors for oblique lumbar interbody fusion. J Clin Med 2024;13:1454. doi: 10.3390/jcm13051454.
11. Raitio A, Heiskanen S, Soini V, Helenius L, Syvänen J, Helenius I. Hidden blood loss and bleeding characteristics in children with congenital scoliosis undergoing spinal osteotomies. Int Orthop 2024;48:1569-77. doi: 10.1007/s00264-024-06090-y.
12. Tang L, Zhang H, Yang Y, Huang HQ. Hidden blood loss of percutaneous vertebroplasty for osteoporotic vertebral compression fractures. Jt Dis Relat Surg 2025;36:240-7. doi: 10.52312/jdrs.2025.2201.
13. Xiao B. Hidden blood loss in anterior cervical discectomy and fusion with zero-profile anchored spacer for the treatment of cervical radiculopathy. Jt Dis Relat Surg 2025;36:555-61. doi: 10.52312/jdrs.2025.2371.
14. Cai T, Chen D, Wang S, Shi P, Wang J, Wang P, et al. Perioperative hidden blood loss in elderly cervical spondylosis patients with anterior cervical discectomy fusion and influencing factors. Geriatr Orthop Surg Rehabil 2021;12:21514593211002164. doi: 10.1177/21514593211002164.
15. Yin H, He X, Luo Z, Chen J, Zhou W, Wang A. Analysis of related risk factors of hidden blood loss after anterior cervical fusion. Orthopade 2019;48:618-25. doi: 10.1007/s00132-018-3652-2.
16. Nadler SB, Hidalgo JH, Bloch T. Prediction of blood volume in normal human adults. Surgery 1962;51:224-32.
17. Gross JB. Estimating allowable blood loss: Corrected for dilution. Anesthesiology 1983;58:277-80. doi: 10.1097/00000542-198303000-00016.
18. Beghé C, Wilson A, Ershler WB. Prevalence and outcomes of anemia in geriatrics: A systematic review of the literature. Am J Med 2004;116 Suppl 7A:3S-10. doi: 10.1016/j.amjmed.2003.12.009.
19. Galivanche AR, Gala R, Bagi PS, Boylan AJ, Dussik CM, Coutinho PD, et al. Perioperative outcomes in 17,947 patients undergoing 2-level anterior cervical discectomy and fusion versus 1-level anterior cervical corpectomy for treatment of cervical degenerative conditions: A propensity score matched national surgical quality improvement program analysis. Neurospine 2020;17:871-8. doi: 10.14245/ns.2040134.067.
20. Chen T, Wang Y, Zhou H, Lin C, Li X, Yang H, et al. Comparison of anterior cervical discectomy and fusion versus anterior cervical corpectomy and fusion in the treatment of localized ossification of the posterior longitudinal ligament. J Orthop Surg (Hong Kong) 2023;31:10225536231167704. doi: 10.1177/10225536231167704.
21. Sehat KR, Evans RL, Newman JH. Hidden blood loss following hip and knee arthroplasty. Correct management of blood loss should take hidden loss into account. J Bone Joint Surg Br 2004;86:561-5.
22. Lou Z, Jiang Y, Jiang K, Zhu J, Lai L, Huang Z, et al. Efficacy and safety of tranexamic acid use in elderly patients undergoing anterior cervical discectomy and fusion: A retrospective study. J Int Med Res 2024;52:3000605241285661. doi: 10.1177/03000605241285661.