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EXPERT CONSENSUS

Expert consensus on the prevention and treatment of asphyxia and anterior cervical hematoma after anterior cervical surgery

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Abstract

Background: Asphyxia caused by an anterior cervical hematoma compressing the airway is one of the most catastrophic complications of anterior cervical surgery. This consensus formulates recommendations on the key issues in the prevention and treatment of asphyxia and anterior cervical hematoma after anterior cervical surgery, providing a reference for standardized clinical management. **Methods:** Following the modified Delphi method and the standards of the WHO Handbook for Guideline Development and the Guiding Principles for the Development/Revision of Clinical Practice Guidelines in China (2022 Edition), a panel of 67 experts (predominantly spinal surgeons) from across China was convened. Nineteen clinical questions (items 6 to 24 of the questionnaire) were developed using the PICO (Population, Intervention, Comparison, Outcome) framework. An agreement rate of 70% or higher was defined as consensus, ≥50% and <70% as majority preference, and below 50% as divergent opinions. **Results:** Nineteen recommendations were formulated (12 strong and 7 weak; 10 supported by level B evidence and 9 by level D evidence). Anterior cervical hematoma compressing the airway was identified as the primary risk factor (6.47/7 points); progressive neck swelling as the primary early warning sign (4.77/6 points); the first 24 hours after surgery as the key monitoring window (91.0%); and drain placement (100%) with a single drain (92.5%) as the preferred drainage strategy. Anesthesiologist judgment on the safety of extubation was the primary indication for ICU transfer (80.6%), and small, thin dressings exposing the operative field were preferred (73.1%). Bedside wound opening for decompression was rated the first-line emergency measure (4.64/5 points), and a rapid coordinated response involving the surgical, anesthesiology, and nursing teams was the preferred collaboration model (3.98/5 points). **Conclusions:** This consensus provides evidence-based recommendations informed by expert experience for the prevention and treatment of asphyxia and anterior cervical hematoma after anterior cervical surgery. Consensus was not reached on several issues, which warrant further research, including drain position, routine monitoring intensity and setting, and the timing of high-flow oxygen therapy.

Keywords: Anterior cervical surgery, Anterior cervical hematoma, Airway obstruction, Asphyxia, Expert consensus

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1 INTRODUCTION

Anterior cervical surgery, including anterior cervical discectomy and fusion (ACDF), anterior cervical corpectomy and fusion (ACCF), and anterior cervical disc replacement, is one of the most commonly used surgical approaches for the treatment of degenerative diseases, trauma, tumors, and deformities of the cervical spine. Anterior cervical hematoma is one of the most devastating complications after anterior cervical surgery; once it forms and compresses the airway, it can rapidly lead to asphyxia and even death. The reported incidence of hematoma after anterior cervical surgery is approximately 0.4%–5.6% [1]. A retrospective study of 13,523 patients from Peking University Third Hospital reported a postoperative hematoma incidence of 0.4% (55/13,523). Among patients who developed postoperative hematoma, 29% experienced difficult intubation before hematoma evacuation [2]. A British study of 1,938 ACDF cases showed a reoperation rate for hematoma of 0.62% [3].

Because of the low incidence of hematoma and the limited sample sizes of single-center studies, high-quality evidence is currently lacking regarding the prevention, monitoring, and emergency management of postoperative asphyxia and anterior cervical hematoma [4].

2 METHODS

This consensus was developed in accordance with the WHO Handbook for Guideline Development and the Guiding Principles for the Development and Revision of Clinical Practice Guidelines in China (2022 edition), using the modified Delphi method [5, 6]. A multidisciplinary working group comprising a steering committee, a consensus panel, a secretariat, and an external expert review group was established. The consensus panel consisted of 67 experts from hospitals at all levels nationwide, predominantly specializing in spinal surgery.

Literature search and evidence grading: Clinical questions were formulated according to the PICO (Population, Intervention, Comparison, Outcome) framework. The secretariat systematically searched PubMed, Web of Science, CNKI, Wanfang Data, VIP, and the China Biology Medicine database from the inception of each database to April 2025. Systematic reviews and meta-analyses, randomized controlled trials, and observational studies were included, whereas narrative reviews, case series, and conference abstracts were excluded. The level of evidence was classified into four grades: grade A, high-quality evidence from systematic reviews or randomized controlled trials; grade B, moderate-quality evidence from cohort or case-control studies; grade C, low-quality evidence from case series or other observational studies; and grade D, very low-quality evidence based on expert opinion. The strength of each recommendation (strong/weak) was determined by combining the level of evidence with the expert consensus.

Survey and voting: The questionnaire comprised 19 clinical questions (items 6–24), including nine ranking questions, five single-choice questions, and five multiple-choice questions. The multiple-choice questions corresponded to Clinical Questions 6, 7, 8, 9, and 19 and allowed experts to select more than one option. For multiple-choice questions, the number of experts selecting each option was reported under the heading "mentioned by", and the corresponding percentage was calculated by dividing this number by the total number of experts. Because experts could select more than one option, the percentages across options could sum to more than 100%.

Data analysis and recommendation grading: For the ranking questions, the mean composite score of each option was calculated by rank weighting. In a question with m options, the option ranked first received m points, the second received m - 1 points, and so on, with the last-ranked option receiving 1 point; options that were not ranked received 0 points. The mean composite score of each option was the sum of the points awarded by all experts divided by the total number of experts, with a higher score indicating greater importance. For the single- and multiple-choice questions, an agreement rate of 70% or higher was defined as consensus, ≥50% and <70% as majority preference, and below 50% as divergent opinions. The strength of each recommendation (strong or weak) was determined by jointly considering the level of evidence, the degree of expert consensus, and the balance of clinical benefit and risk. A strong recommendation was assigned when the clinical benefits clearly outweighed the risks and the recommendation addressed a critical patient-safety issue, even when the level of evidence was low (grade C or D), provided that expert consensus was high. A weak recommendation was assigned when the evidence was limited, the benefit-risk balance was uncertain, or expert agreement reflected only a majority preference or expert opinions remained divergent.

3 CLINICAL QUESTIONS AND RECOMMENDATIONS

Question 1: The most important risk factor

Clinical question: Among the multiple risk factors for asphyxia after anterior cervical surgery, which should serve as the primary target for prevention and control?

Literature evidence: Airway obstruction caused by postoperative hematoma is the most catastrophic complication. Epstein reported a hematoma incidence of approximately 0.4%–5.6% after ACDF [1]. Tian et al. included 13,523 patients and identified ACCF (odds ratio [OR] 2.459) and peak mean arterial pressure during emergence from anesthesia (OR 1.030); the rate of difficult intubation among patients with hematoma was as high as 29%, and retropharyngeal hematoma was an independent risk factor for difficult airway (OR 10.435) [2]. A study of 1,938 ACDF patients by Geldart et al. also showed that hematoma-related symptoms were predominantly neck swell-

ing and dysphagia [3]. Song et al. reported that hematoma-induced acute airway obstruction occurred in 9 of 785 patients (1.15%) after anterior cervical fusion [7]. Wang et al. included 1,150 patients undergoing anterior cervical decompression and fusion and reported a postoperative hematoma incidence of 1.0%, with smoking (OR 5.193), prolonged preoperative thrombin time (OR 1.643), and antiplatelet therapy (OR 15.070) as independent risk factors [8]. In a review of 11 studies (44,030 cases), Epstein also showed a postoperative hematoma incidence of 0.4%–1.2% [4].

Expert survey results: In the survey of 67 experts, the risk factors were ranked by mean composite score (maximum score, 7 points): airway compression by anterior cervical wound hematoma, 6.47 points; laryngeal edema, 4.89 points; thick sputum obstructing the airway, 2.58 points; the combined effects of multiple factors, 2.34 points; glossoptosis, 1.94 points; respiratory depression related to anesthetic/analgesic agents, 1.51 points; and mucosal injury and edema of the pharynx and larynx, 1.51 points.

Airway compression by anterior cervical hematoma received the highest mean composite score, ranking first among the identified risk factors.

Recommendation 1: Airway compression by anterior cervical hematoma should be prioritized as the primary target for prevention and control, and contributing factors such as laryngeal edema and sputum-related airway obstruction should be managed comprehensively. (Level of evidence: B; Strength of recommendation: strong).

Question 2: High-risk time window

Clinical question: When is the high-incidence time window for airway crisis after anterior cervical surgery?

Literature evidence: Geldart et al. reported that hematoma-related symptoms appeared at a mean of 36.9 hours after surgery, and the median time to reoperation was 48 hours after surgery (range, 0–144 hours) [3]. Tian et al. also found that some hematomas occurred during the period of blood pressure fluctuations associated with emergence from anesthesia [2]. Song et al. reported that 67% of acute airway obstructions occurred within 24 hours after surgery, whereas the remaining 33% occurred later, with a median onset time of 72 hours; Wang et al. also reported that 45.5% of hematomas occurred within 24 hours after surgery, whereas 54.5% were delayed (mean, 4 days) [7, 8]. Risk appears to be concentrated in the first 24–48 hours after surgery; however, delayed hematomas indicate that monitoring should not be limited to the first postoperative day.

Expert survey results: Among the 67 experts, 42 (62.7%) identified 6–24 hours after surgery as the high-risk window, 19 (28.4%) selected the first 6 hours, 5 (7.5%) selected 24–72 hours, and 1 (1.5%) selected the first 30 minutes after emergence from anesthesia as a distinct category. Overall, 61 experts (91.0%), i.e., the sum of those selecting the first 6 hours and 6–24 hours, identified the first 24 hours after surgery as the high-risk window.

Recommendation 2: The period within 24 hours after surgery (particularly 6 to 24 hours) should be regarded as the key monitoring time window for airway obstruction, and observation should be appropriately extended for high-risk patients. (Level of evidence: B; Strength of recommendation: strong).

Question 3: Early warning clinical manifestations of airway obstruction

Clinical question: Which early clinical manifestations are most useful for providing early warning of postoperative airway obstruction?

Literature evidence: Geldart et al. showed that the most common symptoms in patients with hematoma requiring reoperation were neck swelling (28%), dysphagia (24%), and focal neurological deficits (16%), with stridor and hoarseness in some patients [3]. Song et al. reported that the typical manifestations of hematoma-induced airway obstruction were inspiratory stridor, neck swelling, and facial edema, subsequently progressing to respiratory distress [7]. As the hematoma enlarges progressively, neck swelling and compression symptoms appear before the decline in oxygen saturation.

Expert survey results: In the survey of 67 experts, the clinical manifestations were ranked by mean composite score (maximum score, 6 points): progressive neck swelling, 4.77 points; chest tightness and breathlessness with subjective breathing difficulty, 3.85 points; persistent decline in peripheral oxygen saturation, 3.45 points; rapidly expanding ecchymosis of the neck skin, 2.91 points; copious sputum with difficulty expectorating, 1.47 points; and severe sore throat with blood-streaked sputum, 0.91 points.

Recommendation 3: Progressive neck swelling should be regarded as the foremost early warning sign, and an early warning system incorporating chest tightness and breathlessness, subjective breathing difficulty, and persistent decline in peripheral oxygen saturation should be established; the emergency protocol should be activated upon the appearance of any of these manifestations. (Level of evidence: B; Strength of recommendation: strong).

Question 4: Choice of wound dressing

Clinical question: Should the cervical wound dressing be a large, thick dressing with full coverage, or a small, thin dressing that exposes the operative field?

Literature evidence: Direct clinical studies are currently lacking. From the perspective of hematoma monitoring, a thick, full-coverage dressing may mask early signs of swelling.

Expert survey results: Among the 67 experts, 49 (73.1%) preferred a small, thin dressing exposing the operative field and surrounding skin, 8 (11.9%) preferred no fixed standard, with dressing choice determined as needed, 6 (9.0%) preferred a large, thick dressing with full coverage, and 4 (6.0%) preferred coverage with a sterile adhesive film only.

Recommendation 4: A small, thin dressing that covers the incision while leaving the surrounding skin visible should be used so that early signs of hematoma, such as neck swelling and ecchymosis, can be detected promptly. (Level of evidence: D; Strength of recommendation: weak).

Question 5: Timing of wound inspection

Clinical question: When should inspection of the cervical wound be performed after surgery?

Literature evidence: Postoperative hematomas may develop suddenly and progress rapidly, and routine inspections at fixed time points may fail to detect hematomas that develop and progress between scheduled assessments. Geldart et al. showed that hematoma symptoms can appear at any time from immediately after surgery to several days later, indicating that both symptom-driven and time-driven observation are indispensable [3].

Expert survey results: In the survey of 67 experts, the timing options were ranked by mean composite score (maximum score, 5 points): immediate inspection when the patient reports neck discomfort or breathing difficulty, 4.15 points; routine inspection at each nursing handover, 3.40 points; inspection during daily routine ward rounds, 2.26 points; inspection at the first dressing change after surgery, 1.62 points; and inspection only when oxygen saturation declines, 0.23 points.

Recommendation 5: A combined symptom- and time-driven wound inspection strategy should be established, with immediate inspection when the patient reports discomfort and routine inspection of the cervical incision and surrounding neck for swelling at each nursing shift handover. Although this recommendation is based on level D evidence, it was graded as strong because it addresses the early detection of wound hematoma and airway compromise, which are critical patient-safety concerns. The expected clinical benefits of prompt inspection clearly outweigh its minimal risks, and the recommendation was supported by a high level of expert consensus. (Level of evidence: D; Strength of recommendation: strong).

Question 6: Choice of drainage device

Clinical question: Should a drainage tube be used, or should passive drainage devices such as rubber strip drains and half-tube drains be used?

Literature evidence: A cohort study of 7,943 ACDF patients by Lim et al. and a systematic review by Lerch and Chau both found that drainage did not significantly reduce the incidence of hematoma or infection [9, 10]. Geldart et al. showed no significant differences between the drainage and non-drainage groups in the rates of reoperation for hematoma and infection or in the length of hospital stay [3]. In a review of 11 studies (44,030 cases), Epstein also pointed out that drainage cannot prevent hematoma formation and does not increase the rates of infection and reoperation [4]. The value of drainage lies in facilitating the detection of postoperative bleeding and the removal of blood from the surgical site.

Expert survey results (multiple-choice question): Among the 67 experts, drainage tubes were selected by all 67 (100%), while rubber strip drains and half-tube drains were selected by 7 (10.4%) and 6 (9.0%) experts, respectively.

Recommendation 6: A drain tube should be routinely placed after anterior cervical surgery, especially in patients with obvious oozing or concomitant bleeding risk, and the volume and characteristics of the drainage should be closely observed. Although the available literature does not demonstrate that routine drainage significantly reduces the incidence of postoperative hematoma or infection, drain placement is still recommended because it facilitates early detection of postoperative bleeding through monitoring of drainage volume and characteristics and allows blood to be drained from the surgical site. This provides an additional safety measure against a low-probability but potentially high-consequence complication. The recommendation was supported by unanimous expert agreement; however, its weak recommendation strength reflects the limited direct evidence that drainage reduces complication rates. (Level of evidence: B; Strength of recommendation: weak).

Question 7: Choice of drainage pressure

Clinical question: Should negative-pressure (suction) drainage or gravity drainage be used?

Literature evidence: High-quality studies directly comparing negative-pressure and gravity drainage after anterior cervical spine surgery are currently lacking. Negative-pressure drainage facilitates the evacuation of oozing blood and reduces dead space, but excessively strong suction may induce or aggravate bleeding; gravity drainage is relatively gentle.

Expert survey results (multiple-choice question): Among the 67 experts, 44 (65.7%) mentioned negative-pressure drainage, and 26 (38.8%) mentioned gravity drainage.

Negative-pressure drainage was the majority preference, although the 70% consensus threshold was not reached.

Recommendation 7: Negative-pressure drainage should generally be performed at a moderate suction level; gravity drainage is also acceptable. The choice depends on the condition of the operative field and the surgeon's experience. Although negative-pressure drainage did not reach the 70% consensus threshold (65.7%, a majority preference), this recommendation was formulated based on that majority preference combined with the mechanistic advantage of negative pressure in evacuating oozing blood and reducing dead space, while recognizing that gravity drainage remains acceptable depending on the operative field and the surgeon's judgment. (Level of evidence: D; Strength of recommendation: weak).

Question 8: Number of drains

Clinical question: Should one or two drain tubes be placed?

Literature evidence: Relevant studies are extremely limited. The anterior incision is narrow, and a single drain tube is usually sufficient to drain the operative area; increasing the number of drains does not necessarily confer additional benefit and may instead increase the risk of infection and incisional discomfort.

Expert survey results (multiple-choice question): Among the 67 experts, 62 (92.5%) mentioned a single drain tube, while 12 (17.9%) mentioned two drain tubes.

Recommendation 8: A single drain tube should be routinely placed after anterior cervical spine surgery. Although the available evidence is limited and does not demonstrate that routine drainage reduces the incidence of postoperative hematoma or infection, a single drain tube is recommended because it facilitates the early detection and evacuation of postoperative bleeding, providing an additional safety measure against a low-probability but potentially high-consequence complication. The recommendation was supported by a high level of expert agreement (92.5%) and was graded as strong despite the limited direct evidence. (Level of evidence: D; Strength of recommendation: strong).

Question 9: Position of drain placement

Clinical question: Should the drain tube be placed beneath the deep cervical fascia, beneath the prevertebral fascia, or in the superficial fascial layer?

Literature evidence: High-quality studies comparing clinical outcomes across different drain positions are currently lacking. Both positions—beneath the deep cervical fascia and beneath the prevertebral fascia—are close to the main bleeding area, whereas the superficial fascial layer offers limited drainage efficacy.

Expert survey results (multiple-choice question): Among the 67 experts, 38 (56.7%) selected placement beneath the deep cervical fascia, 35 (52.2%) selected placement beneath the prevertebral fascia, and 4 (6.0%) selected placement in the superficial fascial layer.

The two main positions were selected at similar frequencies, and neither reached the 70% consensus threshold.

Recommendation 9: The drain tube should be placed beneath the deep cervical fascia or beneath the prevertebral fascia, in a layer close to the bleeding area; the superficial fascial layer is not routinely recommended. No single drainage position reached the 70% consensus threshold; the two majority preferences (beneath the deep cervical fascia, 56.7%; beneath the prevertebral fascia, 52.2%) both place the drain close to the bleeding area. Accordingly, either of these two positions is considered acceptable, whereas placement in the superficial fascial layer (6.0%) is not routinely recommended. (Level of evidence: D; Strength of recommendation: weak).

Question 10: Timing of high-flow oxygen therapy

Clinical question: When signs of dyspnea appear, should "high-flow oxygen be administered immediately while simultaneously evaluating the cause", or should "the cause be assessed first to rule out mechanical obstruction before administering oxygen"?

Literature evidence: In cases of partial airway obstruction, high-flow oxygen therapy can maintain oxygenation and provide time for further assessment and intervention; however, it cannot relieve mechanical airway obstruction and carries the risk of masking clinical deterioration and delaying definitive management. Direct research evidence is currently lacking.

Expert survey results: Among the 67 experts, 38 (56.7%) favored immediate administration of high-flow oxygen while the underlying cause was promptly assessed; 20 (29.9%) favored administering high-flow oxygen only after mechanical airway obstruction had been definitively excluded; 5 (7.5%) favored prioritizing assessment to avoid masking the condition; and 4 (6.0%) favored administering oxygen according to oxygen saturation without a unified principle.

Immediate administration of high-flow oxygen while assessing the underlying cause was the most frequently selected option (56.7%), but did not reach the 70% consensus threshold.

Recommendation 10: When dyspnea occurs, high-flow oxygen should be administered while the cause is evaluated immediately; for compressive obstruction caused by hematoma, high-flow oxygen cannot replace decompression, and the need for urgent airway intervention should be determined as soon as possible. Immediate administration of high-flow oxygen received a majority preference (56.7%) but did not reach the consensus threshold. This recommendation reflects the importance of maintaining oxygenation during the prompt assessment of impending airway compromise, while emphasizing that oxygen therapy cannot replace decompression in cases of mechanical airway obstruction. (Level of evidence: D; Strength of recommendation: weak).

Question 11: Examinations for early assessment

Clinical question: When airway obstruction or hematoma is suspected, which bedside assessment methods should be prioritized for early evaluation?

Literature evidence: Bedside ultrasound can rapidly and noninvasively assess the extent of cervical hematoma and airway compression; continuous pulse oximetry reflects changes in oxygenation in real time; arterial blood gas analysis clarifies ventilation and acid-base status. Tian et al. emphasized that patients with hematoma are at high risk of difficult airway, and that the airway should be addressed simultaneously during assessment [2].

Expert survey results: In the survey of 67 experts, the assessment methods were ranked by mean composite score (maximum score, 5 points), with continuous pulse oximetry receiving 3.87 points, arterial blood gas analysis 3.42 points, bedside cervical ultrasound 3.28 points, chest imaging 0.98 points, and complete blood count and coagulation profile 0.38 points.

Recommendation 11: Continuous pulse oximetry, arterial blood gas analysis, and bedside cervical ultrasound should be adopted as the three core examinations for early assessment of airway crisis, with additional tests, such as coagulation studies, performed when necessary. (Level of evidence: B; Strength of recommendation: strong).

Question 12: Prioritization of emergency measures

Clinical question: When an anterior cervical hematoma is suspected to be rapidly expanding and compressing the airway, how should bedside management and transfer to the operating room be prioritized?

Literature evidence: Airway compression by an anterior cervical hematoma progresses rapidly, and delayed decompression can lead to irreversible injury. The literature unanimously recommends that when a hematoma is progressively enlarging and threatening the airway, bedside wound opening (suture removal) for decompression should be performed immediately. Anesthesiologists should be summoned simultaneously to secure the airway, and the patient should be transferred to the operating room for wound exploration and hemostasis. For patients with marked dyspnea, bag-valve-mask (BVM)-assisted ventilation may be provided before the airway is secured. Tian et al. reported that the rate of difficult intubation in patients with hematoma is as high as 29% [2].

Expert survey results: In the survey of 67 experts, the emergency measures were ranked by mean composite score (maximum score, 5 points), with bedside wound opening (suture removal) for decompression receiving 4.64 points, immediately summoning anesthesiologists for emergency airway management receiving 2.74 points, BVM-assisted ventilation receiving 1.87 points, transfer to the operating room for wound exploration and hemostasis receiving 1.77 points, and high-flow oxygen via face mask receiving 1.25 points.

Recommendation 12: When rapid enlargement of an anterior cervical hematoma threatening the airway is suspected, bedside wound opening (suture removal) for decompression should be performed immediately, while simultaneously summoning anesthesiologists to establish the airway (with BVM assisted ventilation if necessary) and transferring the patient to the operating room for hemostasis. (Level of evidence: B; Strength of recommendation: strong).

Question 13: Management of analgesic-related respiratory depression

Clinical question: When opioids and other analgesic agents are used, how should drug-related respiratory depression be prevented and managed?

Literature evidence: Opioids can depress the respiratory center and may increase the risk of airway obstruction in patients whose airways are already vulnerable following anterior cervical spine surgery. High-quality randomized controlled studies are currently lacking; nevertheless, individualized dosing, combination with non-opioid analgesics, and intensified respiratory monitoring after drug administration are widely accepted principles.

Expert survey results: Among the 67 experts, the analgesic management measures were ranked by mean composite score (maximum score, 5 points) as follows: individualized dose adjustment of analgesic agents: 4.00 points; intensified respiratory and oxygen saturation monitoring after drug administration: 3.34 points; combination with non-opioid analgesics: 1.53 points; strict restriction of opioid use: 1.34 points; routine prophylactic use of respiratory stimulants: 0.15 points.

Recommendation 13: Postoperative analgesics should be administered with individualized dose adjustment, and respira-

tory status and oxygen saturation should be closely monitored after drug administration. Opioids may be combined with non-opioid analgesics, whereas routine prophylactic use of respiratory stimulants is not recommended. (Level of evidence: B; Strength of recommendation: strong).

Question 14: Emergency team collaboration model

Clinical question: What team collaboration model should be established for the emergency management of an airway crisis?

Literature evidence: An airway crisis caused by anterior cervical hematoma involves surgical decompression, anesthetic airway management, and nursing support, and cannot be adequately managed by a single discipline working alone. Tian et al. emphasized that patients with hematoma are at high risk of a difficult airway and require early involvement of the anesthesiology team [2]. Rapid multidisciplinary coordination and standardized protocols are considered essential components of critical airway management.

Expert survey results: Among the 67 experts, the collaboration models were ranked by mean composite score (maximum score, 5 points) as follows: rapid coordinated response involving the surgical, anesthesiology, and nursing teams: 3.98 points; preoperative development of standardized emergency protocols: 3.58 points; regular emergency simulation drills: 2.40 points; coordinated management by the surgical and emergency department teams: 0.72 points; independent management by the on-duty physician: 0.19 points.

Recommendation 14: Establish a rapid coordinated response model involving the surgery, anesthesiology, and nursing teams, develop standardized emergency protocols preoperatively, and conduct regular drills. Although this recommendation is based on level D evidence, it was graded as strong because rapid multidisciplinary coordination is essential for managing airway emergencies and offers clear clinical benefits with minimal associated risks. The recommendation was also supported by a high level of expert consensus. (Level of evidence: D; Strength of recommendation: strong).

Question 15: Preoperative preventive measures

Clinical question: What preoperative measures should be taken to reduce the risk of postoperative laryngeal edema and airway obstruction?

Literature evidence: Preoperative tracheal retraction exercise improves intraoperative tolerance of the tracheoesophageal complex and reduces traction injury, thereby lowering the risk of postoperative laryngopharyngeal complications such as dysphagia and laryngeal edema [11, 12]. Control of upper respiratory tract infections, smoking cessation, and other preventive measures also help reduce postoperative airway complications. A randomized controlled study by Jeyamohan et al. suggested a potential protective effect of glucocorticoids on swallowing and the airway, although strict indications are required [13].

Expert survey results: Among the 67 experts, the preoperative preventive measures were ranked by mean composite score (maximum score, 7 points) as follows: standardized preoperative tracheal retraction exercise: 5.34 points; control of upper respiratory tract infection/pharyngeal or laryngeal inflammation: 4.55 points; preoperative smoking cessation for ≥2 weeks but <1 month: 2.64 points; preoperative nebulized inhalation therapy: 2.30 points; preoperative smoking cessation for ≥1 month: 2.26 points; preoperative prophylactic use of glucocorticoids: 1.49 points; preoperative use of expectorants (mucolytics): 1.43 points.

Recommendation 15: Perform routine preoperative tracheal retraction exercises, control upper respiratory tract infections and pharyngeal or laryngeal inflammation, encourage patients to stop smoking at least 2 weeks before surgery, and consider nebulized therapy as appropriate. (Level of evidence: B; Strength of recommendation: strong).

Question 16: Postoperative preventive measures

Clinical question: What postoperative measures should be taken to prevent airway complications such as laryngeal edema and sputum obstruction?

Literature evidence: Postoperative continuous oxygen therapy helps maintain oxygenation, while continuous oxygen saturation monitoring facilitates the early detection of oxygenation abnormalities; nebulized inhalation, expectorants (mucolytics), and early expectoration help maintain airway patency; and appropriate head-of-bed elevation with neck immobilization helps reduce soft-tissue edema and venous congestion. Glucocorticoids for edema reduction have potential benefit in laryngeal edema, but risks such as infection should be weighed.

Expert survey results: Among the 67 experts, the postoperative preventive measures were ranked by mean composite score (maximum score, 8 points) as follows: postoperative continuous oxygen therapy and oxygen saturation monitoring: 5.91 points; routine postoperative nebulized inhalation: 5.00 points; postoperative positioning management: 3.98 points; standardized postoperative use of expectorants (mucolytics): 3.79 points; postoperative encouragement of early effective expectoration: 3.58 points; short-term postoperative glucocorticoids for edema reduction: 3.15 points; enhanced oral care and airway humidification: 2.32 points; postoperative transfer to the intensive care unit (ICU) for monitoring and observation: 1.77 points.

Recommendation 16: Implement the four core postoperative measures: continuous oxygen therapy with oxygen saturation

monitoring, nebulized therapy, appropriate positioning, and the use of expectorants (mucolytics). Early effective expectoration should also be encouraged, and short-term glucocorticoid therapy may be considered in patients at high risk of laryngeal edema. (Level of evidence: B; Strength of recommendation: strong).

Question 17: Routine monitoring intensity for high-risk patients

Clinical question: For patients at high risk of airway complications after anterior cervical spine surgery, what level of routine monitoring should be provided?

Literature evidence: Hematoma is rare but carries severe consequences, and no randomized controlled studies on stratification of monitoring levels currently exist. Geldart et al. and Tian et al. suggested that most patients can be safely managed in a general ward, whereas monitoring should be intensified for those with risk factors such as concurrent ACCF, blood pressure fluctuations during emergence from anesthesia, or an anticipated difficult airway [2, 3].

Expert survey results: Among the 67 experts, 22 (32.8%) selected routine postoperative transfer to the ICU for monitoring, 18 (26.9%) selected prolonged post-extubation observation with an emergency tracheostomy set kept ready at the bedside, 15 (22.4%) selected preoperative multidisciplinary assessment, and 12 (17.9%) selected intensified postoperative nebulization and glucocorticoid therapy for edema prevention. None of the options reached consensus; the highest proportion was only 32.8%.

Recommendation 17: The intensity of monitoring should be individualized according to each patient's risk of airway complications. High-risk patients should undergo prolonged post-extubation observation, have an emergency tracheostomy set kept ready at the bedside, or be transferred to the ICU, whereas low-risk patients should be closely observed in a general ward. Because no option reached consensus (the highest proportion was 32.8%), this recommendation adopts an individualized, risk-stratified approach, with monitoring measures selected according to each patient's risk profile. (Level of evidence: D; Strength of recommendation: weak).

Question 18: Choice of postoperative monitoring setting

Clinical question: Should patients be monitored in the ICU, a monitored ward, a post-anesthesia care unit (PACU), or a general ward?

Literature evidence: Direct studies comparing outcomes across different monitoring settings are lacking. The choice of monitoring setting is essentially a matter of risk stratification and should be determined after comprehensively considering factors such as surgical segments, bleeding risk, and airway assessment.

Expert survey results: Among the 67 experts, 20 (29.9%) selected direct transfer to the ICU for monitoring, 18 (26.9%) selected observation in a monitored ward or PACU for ≥6 to <24 hours, 17 (25.4%) selected routine monitoring in a general ward, and 12 (17.9%) selected observation in a monitored ward or PACU for ≥24 hours. Opinions were divergent, and no consensus was reached.

Recommendation 18: The monitoring setting should be selected according to individual risk stratification. High-risk patients should be transferred to the ICU or a monitored ward or PACU, whereas low-risk patients may be monitored in a general ward, provided that immediate emergency airway management can be performed when needed. Given the divergent expert opinions (the highest proportion was 29.9%), this recommendation adopts an individualized, risk-stratified approach. (Level of evidence: D; Strength of recommendation: weak).

Question 19: Indications for ICU transfer

Clinical question: What conditions should serve as indications for ICU observation after anterior cervical spine surgery?

Literature evidence: Tian et al. showed that ACCF (OR 2.459) and peak mean arterial pressure during emergence from anesthesia (OR 1.030) are independent risk factors for hematoma, and the rate of difficult intubation in patients with hematoma was 29%, suggesting that the level of monitoring should be escalated in patients with bleeding tendency, arterial injury, or risk of a difficult airway [2]. The anesthesiologist's judgment based on intraoperative airway conditions and extubation assessment is an important basis for determining whether safe extubation is possible and whether ICU observation is needed. Wang et al. showed that antiplatelet therapy (OR 15.070, 95% confidence interval 2.663–85.274) and prolonged preoperative thrombin time (OR 1.643) are independent risk factors for hematoma, further supporting escalation of the level of monitoring in patients with bleeding tendency [8].

Expert survey results (multiple-choice question): Among the 67 experts, 54 (80.6%) selected the anesthesiologist's judgment regarding the feasibility of safe extubation, reaching consensus; 41 (61.2%) selected bleeding tendency, such as an insufficient interval since discontinuation of anticoagulants, receiving majority support; 35 (52.2%) selected confirmed injury to the superior or inferior thyroid artery, also receiving majority support; 28 (41.8%) selected surgical involvement of ≥4 intervertebral levels; 19 (28.4%) selected an operative time of ≥4 hours; 19 (28.4%) selected cerebrospinal fluid leakage; and 17 (25.4%) selected other reasons. The latter four options did not reach consensus.

Recommendation 19: The anesthesiologist's judgment regarding the feasibility of safe extubation should serve as the primary indication for ICU transfer. ICU observation should also be considered for patients with a bleeding tendency or confirmed superior or inferior thyroid artery injury, while the number of surgical levels and operative duration should also be taken into account in the overall risk assessment. (Level of evidence: B; Strength of recommendation: strong).

4 SUMMARY

This consensus addressed 19 clinical questions concerning the prevention and management of asphyxia and anterior cervical hematoma after anterior cervical spine surgery and recruited 67 experts from hospitals at all levels nationwide, predominantly specializing in spinal surgery, to participate in the survey. Specialty: spinal surgery, 63 (94.0%); neurosurgery, 1 (1.5%); other/unknown, 3 (4.5%). Professional titles: chief physicians, 32 (47.8%); associate chief physicians, 26 (38.8%); attending physicians, 6 (9.0%); others, 3 (4.5%). Years of practice in cervical spine surgery: 10–20 years, 40 (59.7%); <10 years, 13 (19.4%); >20 years, 14 (20.9%). Based on the available evidence, 19 recommendations were formulated, including 10 supported by level B evidence and 9 by level D evidence. Of these, 12 were classified as strong recommendations and 7 as weak recommendations.

Among the 9 ranking questions, the items ranked first by mean composite score, constituting the core elements of each domain, included the following: anterior cervical hematoma compressing the airway as the most important risk factor (6.47/7 points); progressive neck swelling as the primary early warning sign (4.77/6 points); immediate wound inspection when the patient reports neck discomfort or dyspnea as the preferred timing for wound inspection (4.15/5 points); continuous pulse oximetry as the primary early assessment item (3.87/5 points); bedside wound opening (suture removal) for decompression as the primary emergency measure (4.64/5 points); individualized adjustment of analgesic dosing as the primary analgesic management measure (4.00/5 points); rapid coordinated response involving the surgery, anesthesiology, and nursing teams as the preferred collaboration model (3.98/5 points); preoperative tracheal retraction exercise as the primary preventive measure (5.34/7 points); and postoperative continuous oxygen therapy and oxygen saturation monitoring as the primary postoperative measure (5.91/8 points).

Among the single- and multiple-choice questions, the following items reached the consensus threshold: drain tube drainage as the preferred drainage medium (100%); single drain (92.5%); the first 24 hours after surgery as the high-risk period (91.0%); the anesthesiologist's judgment on whether the patient can be extubated as the primary indication for transfer to the ICU (80.6%); and small, thin dressing (73.1%).

Areas characterized by divergent opinions and warranting further investigation included: the position of drain tube placement (below the deep fascia vs. below the prevertebral fascia), the routine level and setting of postoperative monitoring, the timing of high-flow oxygen therapy, drainage pressure, and whether high-risk patients should be routinely transferred to the ICU. Given the low incidence of hematoma after anterior cervical spine surgery and the limited availability of high-quality evidence, the recommendations in this consensus are supported by level B or D evidence. Nevertheless, 12 of the 19 recommendations are strong and 7 are weak, reflecting the consideration of critical patient-safety issues, expert consensus, and the balance between clinical benefits and risks.

5 DISCUSSION

This consensus addressed two potentially life-threatening complications after anterior cervical spine surgery: asphyxia and anterior cervical hematoma. Following evidence-based guideline development standards and adopting the modified Delphi method, it convened 67 experts nationwide, predominantly specializing in spinal surgery, to formulate 19 recommendations addressing 19 clinical questions, systematically covering the entire continuum of care, including risk factor identification, early warning, observation and assessment, emergency management, anesthesia and perioperative management, and prevention. Ultimately, 12 strong and 7 weak recommendations were formulated, with 10 supported by level B evidence and 9 by level D evidence. Despite the varying levels of evidence, expert agreement was high on core patient-safety elements, including risk factor identification, early warning, and emergency airway management.

The characteristics and strengths of this consensus are mainly reflected in three aspects. First, it addresses key clinical challenges and provides highly actionable recommendations: it establishes "anterior cervical hematoma compressing the airway" as the primary target for prevention and control; proposes progressive neck swelling, chest tightness and breathlessness, and persistent decline in peripheral oxygen saturation as the core early warning signs; and emphasizes bedside wound opening (suture removal) for decompression as the primary emergency measure when the hematoma enlarges rapidly, thereby providing frontline clinicians with a clear and actionable decision pathway. Second, it covers the entire continuum of care in a systematic and comprehensive manner: from preoperative risk factor screening and prevention, to postoperative observation and assessment, and further to emergency management and airway management upon the onset of asphyxia, forming closed-loop recommendations. Third, it balances evidence with real-world clinical practice: although existing studies have not demonstrated significant benefits of routine drainage in reducing complications, expert consensus supports retaining drainage as an additional safety measure against rare but potentially life-threatening complications. The consensus further advo-

cates routinely keeping an emergency tracheostomy set at the bedside and establishing a rapid coordinated response involving the surgery, anesthesiology, and nursing teams to shorten the time required for airway crisis management.

This consensus also has limitations and deficiencies. With regard to evidence, the included literature consisted predominantly of retrospective cohort studies and systematic reviews and meta-analyses, lacking prospective randomized controlled trials. Moreover, the incidence of anterior cervical hematoma is low (0.4%–5.6%) and single-center sample sizes are limited, making it difficult to obtain high-level evidence in the short term; therefore, most recommendations are graded level B (10) or D (9) evidence. Nevertheless, 12 of the 19 recommendations are strong and 7 are weak, reflecting the consideration of critical patient-safety issues, high expert consensus, and a favorable balance between clinical benefits and risks. With regard to methodology, the surveyed experts were predominantly spinal surgeons, with limited participation from related disciplines such as anesthesiology, critical care medicine, and otolaryngology, and the response options for some questions may not have covered all clinical scenarios. With regard to content, expert opinions remain divergent on detailed management issues such as drainage pressure, drain position, and level of monitoring, reflecting considerable heterogeneity in clinical practice. In the future, with the accumulation of multicenter prospective studies and real-world data, these divergent areas are expected to gain more definitive evidence-based support, and this consensus will be updated and refined accordingly.

DECLARATIONS

Author contributions

Jingchuan Sun, Liuyu Ouyang, and Xiaoming Li contributed equally to this work and drafted the manuscript. Kaiqiang Sun, Shuqiang Wang, and Mengchen Yin contributed to the literature review, data analysis, and critical revision of the manuscript. Jiangang Shi conceived and supervised the study and is the corresponding author. All authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests.

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SUPPLEMENTARY MATERIAL

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