Expert Consensus

Multidisciplinary international expert consensus on perioperative airway management

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Background: Perioperative airway management is critical for patient safety and optimal surgical outcomes. Effective airway management reduces postoperative pulmonary complications and accelerates recovery. This expert consensus aims to update the earlier consensus based on the latest research and emphasize aspects that were previously overlooked.

Methods: A comprehensive search up to June 2024 was performed. Earlier consensus documents were reviewed to ensure thorough coverage. A modified Delphi method involved 62 domestic experts from various surgical and anesthetic specialties who discussed and voted on preliminary recommendations in face-to-face meetings, requiring ≥70% agreement. Drafts were then reviewed by 18 international experts via email to incorporate diverse insights.

Results: Through the modified Delphi method, consensus was achieved with ≥70% agreement among the 62 domestic experts, ensuring that the preliminary recommendations were robust and widely supported.

Additionally, feedback from the 18 international experts provided diverse insights that further refined and validated the recommendations. Recommendations were established for preoperative airway preparation, anesthesia management, surgical approach, postoperative airway management, and managing coexisting respiratory diseases. These recommendations update the perspectives of earlier consensus documents based on the latest research and emphasize non-intubated surgery, inhalation therapy, and individualized treatment for patients with coexisting pulmonary diseases.

Conclusions: This expert consensus provides a valuable reference for clinical practice. Further technological optimization and clinical research are needed to improve perioperative airway management.

Keywords: Perioperative airway management; non-intubated surgery; anesthesia; inhalation therapy; coexisting pulmonary disease

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Introduction

Perioperative airway management is critical for ensuring patient safety and optimizing surgical outcomes. Enhanced Recovery After Surgery (ERAS) protocols are now widely applied in clinical practice, with perioperative airway management being a crucial component of ERAS (1). Its clinical application can effectively reduce postoperative pulmonary complications, accelerate patient recovery, shorten the hospital length of stay (LOS), lower readmission and mortality rates, and reduce hospitalization costs. Previous consensus guidelines have strengthened surgeons' understanding of airway management, lung function protection, and the reduction of pulmonary complications (2-4). This has facilitated a more effective and integrated approach to perioperative airway management and ERAS.

In recent years, new evidence in airway management has highlighted the need to update the multidisciplinary international expert consensus on perioperative airway management. This update integrates clinical practice experience with the latest research findings from both domestic and international studies to ensure more rational and standardized application of airway management in clinical practice.

Highlight box

Key findings

- We recommend implementing non-intubated airway management for suitable patients to enhance airway status and expedite recovery, utilizing inhalation therapy tailored to perioperative airway conditions to improve patient outcomes, and providing personalized airway management for patients with coexisting pulmonary diseases to improve surgical safety and reduce complications.

What was recommended and what is new?

- Earlier expert consensus on perioperative airway management emphasized topics such as preoperative pulmonary function assessment, preoperative smoking cessation, and postoperative pulmonary rehabilitation.
- This consensus updates previously highly focused areas and places emphasis on non-intubated approaches, inhalation therapy, and the management of comorbid pulmonary diseases during the perioperative period.

What is the implication, and what should change now?

- This expert consensus implicates the continual advancements in surgical techniques, anesthesia methods, and pharmacological developments, recommending their integration into perioperative airway management to enhance patient outcomes. It emphasizes the necessity of individualized airway management tailored to unique disease profiles. Future clinical studies focusing on perioperative airway management in specific patient populations are essential to provide robust clinical evidence, thereby facilitating personalized perioperative care.

Methods

A comprehensive search was conducted on PubMed. Original articles published in English before June 2024 were included. Combinations of the following terms were searched online: "airway management", "multidiscipline", "perioperative", "preoperative", "postoperative", "lung function", "rehabilitation", "anesthesia", "tubeless", "surgery", "asthma", "obstructive sleep apnea syndrome", "pulmonary fibrosis", and "chronic obstructive pulmonary disease". Furthermore, previous consensuses about airway

management have also been scanned to avoid missing any qualified study.

To develop this consensus recommendation, we employed a modified Delphi method involving the following steps. A panel consisting of 62 domestic experts with relevant expertise in thoracic surgery, otolaryngology, general surgery, cardiac surgery, anesthesiology, and nursing fields were assembled to discuss and vote on preliminary recommendations. During an initial face-to-face meeting, all domestic experts engaged in discussions followed by a voting process to establish consensus on each recommendation. A minimum threshold of 70% agreement among participants was set to define consensus. Following the initial consensus-building phase, the draft recommendations were circulated to 18 international experts via email for their feedback and suggestions. This step ensured that the recommendations were informed by diverse perspectives and expertise. The titles of all discussed topics along with the rate of agreement for each are listed in *Table 1*. Personal points of view of different experts is included in the Appendix 1.

Consensus 1: preoperative airway preparation

(I) In which cases do you recommend that pulmonary ventilation and diffusion tests be routinely indicated? Preoperative pulmonary ventilation and diffusion function tests are recommended for elderly patients and those with pulmonary comorbidities. For patients undergoing pulmonary surgery, these tests are routinely required as they can not only predict the risk of perioperative complications and long-term quality of life, but also provide an objective basis for surgical decision-making (agreement rate 90%).

(II) For which patients are preoperative exercise tests necessary? Preoperative exercise tests are recommended for elderly patients and those with cardiopulmonary diseases. Exercise tests are recommended for pulmonary surgery when either the predicted postoperative forced expiratory volume in the first second (ppoFEV1) or the predicted postoperative diffusion capacity of carbon monoxide (ppoDLco) is below 60% (agreement rate 85%).

(III) Under what circumstances is arterial blood gas analysis advised? Arterial blood gas analysis is recommended for patients with symptoms of respiratory failure, severe respiratory comorbidities, or when pulmonary function tests are difficult to perform (agreement rate 97.5%).

(IV) How should a patient be managed if airway hyperresponsiveness (AHR), unstable asthma or chronic obstructive pulmonary disease (COPD) surgery be delayed in favor of using inhaled corticosteroids (ICS) with bronchodilators? If a patient is found to have AHR, unstable asthma or COPD during preoperative evaluation, the use of ICS in combination with bronchodilators, such as ICS + long-acting beta-agonists (LABA) or ICS + LABA + long-acting muscarinic antagonists (LAMA), is recommended and surgery should be temporarily delayed until a new evaluation is obtained, if possible (agreement rate 75%).

(V) Who should receive preoperative breathing and aerobic training? Preoperative breathing and aerobic training are recommended, especially for patients at high risk of postoperative complications, as they benefit more from prehabilitation (agreement rate 85%).

(VI) How should smoking cessation be managed prior to surgery? Smoking cessation at least 2 weeks before surgery is recommended. Patients should still be encouraged to quit smoking for as long as possible if they cannot follow a 2-week smoking cessation plan (agreement rate 75%).

(VII) For which patients is preoperative weight management and obstructive sleep apnea syndrome (OSAS) screening advised? Preoperative weight management is recommended for patients who are malnourished or obese before elective surgery. High-risk obese patients should also undergo screening for OSAS (agreement rate 75%).

(VIII) What should be done if airway obstruction is found on preoperative computed tomography (CT)? Bronchoscopy is advised for patients with airway stenosis seen on chest CT scan (agreement rate 100%).

Preoperative pulmonary function assessment plays a critical role in predicting surgical outcomes and postoperative complications, as well as guiding the selection of surgical type and scope. Pulmonary ventilation and diffusion function tests are routine preoperative examinations in pulmonary surgery. For non-thoracic surgery patients, these tests are recommended for elderly patients and those with heart or lung diseases. Due to significant individual differences, relying solely on the absolute value of forced expiratory

Table 1 List of consensus and agreement rate

Recommendation	Agreement rate (%)
Consensus 1: preoperative airway preparation	
Preoperative pulmonary ventilation and diffusion function tests are recommended for elderly patients and those with pulmonary comorbidities. For patients undergoing pulmonary surgery, these tests are routinely required as they can not only predict the risk of perioperative complications and long-term quality of life, but also provide an objective basis for surgical decision-making	90
Preoperative exercise tests are recommended for elderly patients and those with cardiopulmonary diseases. Exercise tests are recommended for pulmonary surgery when either the ppoFEV1 or the ppoDLco is below 60%	85
Arterial blood gas analysis is recommended for patients with symptoms of respiratory failure, severe respiratory comorbidities, or when pulmonary function tests are difficult to perform	97.5
If a patient is found to have AHR, unstable asthma or COPD during preoperative evaluation, the use of ICS in combination with bronchodilators, such as ICS + LABA or ICS + LABA + LAMA, is recommended and surgery should be temporarily delayed until a new evaluation is obtained, if possible	75
Preoperative breathing and aerobic training are recommended, especially for patients at high risk of postoperative complications, as they benefit more from prehabilitation	85
Smoking cessation at least 2 weeks before surgery is recommended. Patients should still be encouraged to quit smoking for as long as possible if they cannot follow a 2-week smoking cessation plan	75
Preoperative weight management is recommended for patients who are malnourished or obese before elective surgery. High-risk obese patients should also undergo screening for OSAS	75
Bronchoscopy is advised for patients with airway stenosis seen on chest CT scan	100
Consensus 2: anesthesia management	
Using a laryngeal mask airway for airway management can be applied in various types of surgical procedures to reduce airway epithelial damage caused by endotracheal intubation. For thoracic surgery, patients who are suitable for non-intubated spontaneous breathing anesthesia (tubeless VATS technique) should be taken to consideration	95
When performing endotracheal intubation, select the appropriate tube size and use a video laryngoscope for guidance. During ventilation, follow lung-protective ventilation principles	100
Intravenous propofol, combined with volatile anesthesia, is recommended as the primary maintenance drug. Short-acting anesthetics should be used to facilitate faster postoperative extubation	100
The use of a steroid muscular relaxant is recommended because the antagonist sugammadex can rapidly and completely reversed it, facilitating faster extubation	90
Intraoperative bronchospasm should be relieved with bronchodilators and intravenous corticosteroids or aminophylline	100
Fluid management during anesthesia is crucial to prevent postoperative pulmonary edema or sputum retention caused by airway dryness	100
Consensus 3: surgical approach	
Preoperative surgical path planning is essential to shorten the operation time and preserve normal structures that do not need to be damaged	100
For pulmonary surgery, it is recommended to preserve as much lung tissue as possible while ensuring radical tumor resection. Sleeve resection is recommended even in case of patient with good functional status and after neoadjuvant therapy	90
For laryngotracheal surgery, it is essential to prevent foreign objects from entering the airway and to protect the airway from damage by surgical instruments. Airway management should be crucial even during tracheal resection by cross-field intubation	100

Table 1 (*continued*)

Table 1 (*continued*)

Recommendation	Agreement rate (%)
Consensus 4: postoperative airway management	
Postoperative ICS + LABA + LAMA can help alleviate persistent cough after pulmonary resection	80
Patients who are able to walk should begin early mobilization. For those who cannot mobilize, healthcare personnel should assist with frequent repositioning to prevent hypostatic pneumonia	100
Preventing postoperative sputum retention is crucial. Effective early postoperative cough, combined with mechanical sputum clearance and the use of intravenous ambroxol or oral acetylcysteine to reduce sputum viscosity, are recommended	100
Postoperative individualized rehabilitation exercise is recommended for thoracic surgery, even though it is controversial if it reduces postoperative complications or shortens LOS. However, it can improve activity levels and quality of life after surgery	100
CPAP or NIV can be considered for acute respiratory failure but are not used routinely	85
Postoperative pain can limit adequate sputum clearance, especially after chest and abdominal surgeries. Effective postoperative pain relief facilitates sputum clearance and reduces pulmonary complications. We recommend a multimodal analgesia regimen based on NSAIDs, while minimizing the use of opioid analgesics	95
If there is no lung air leak, the postoperative chest drainage tube should be removed promptly. Be vigilant for pleural effusion following major upper abdominal surgery	95
Consensus 5: management of coexisting respiratory diseases	
It is recommended that patients with asthma control their symptoms as much as possible before surgery. Perioperative bronchospasm should be closely monitored	95
ICS + LABA + LAMA perioperatively is recommended for patients with COPD. Be vigilant for postoperative respiratory failure and provide respiratory support promptly if needed	90
Monitor for perioperative hypoxemia in patients with OSAS. Tracheal intubation is recommended for surgery, and postoperative care should avoid the supine position to prevent airway obstruction	85
For patients with pulmonary fibrosis, there are higher postoperative complications and long-term mortality rates. A sub-lobar resection may help reduce acute exacerbation of postoperative pulmonary fibrosis	95
A multidisciplinary consultation is recommended for patients with multiple respiratory diseases or complex respiratory conditions to evaluate surgical risk	100

AHR, airway hyperresponsiveness; COPD, chronic obstructive pulmonary disease; CPAP, continuous positive airway pressure; CT, computed tomography; ICS, inhaled corticosteroids; LABA, long-acting beta-agonists; LAMA, long-acting muscarinic antagonists; LOS, length of stay; NIV, non-invasive ventilation; NSAIDs, nonsteroidal anti-inflammatory drugs; OSAS, obstructive sleep apnea syndrome; ppoDLco, predicted postoperative diffusion capacity of carbon monoxide; ppoFEV1, predicted postoperative forced expiratory volume in the first second; VATS, video-assisted thoracoscopic surgery.

volume in the first second (FEV1) for screening may be biased. By considering factors such as gender, height, weight, and age, the use of ppoFEV1 as a percentage of the expected value better addresses individual variability (5). The diffusion function is primarily measured through the diffusion capacity of carbon monoxide (DLco) (6). Both FEV1 and DLco are independent factors in predicting postoperative complications and mortality following pulmonary resection. When both ppoFEV1 and ppoDLco are greater than 60%, surgery is considered low risk (7). Puente-Maestú *et al.* (8) show that postoperative complications significantly increase when ppoFEV1 or ppoDLco is as low as 30% to 40%. Ferguson *et al.* (9) show that when ppoFEV1 or ppoDLco is <30%, the all-cause mortality rate rises significantly. When both ppoDLco and ppoFEV1 are greater than or equal to 40% but either or both are less than 60%, a low-technology cardiopulmonary exercise test (CPET) like a stair-climbing test (SCT) or a shuttle walk test (SWT) is required. If either ppoFEV1 or ppoDLco is less than 40%, a comprehensive CPET is necessary, and a multidisciplinary consultation

with anesthesiology and pulmonology is recommended to assess surgical risk (10). Preoperative pulmonary function tests can also help detect undiagnosed chronic respiratory diseases, such as COPD (11). If preoperative pulmonary function show airflow limitation, such as FEV1/FVC <0.7, bronchodilator test is advised and a respiratory consultation should be requested to determine whether there is COPD or asthma (12,13).

Preoperative exercise tests, including CPET and low technology exercise tests, help assess cardiopulmonary capacity. For non-pulmonary surgery, exercise tests are recommended for elderly patients and those with underlying cardiopulmonary diseases. Preoperative exercise tests are recommended for patients whose ppoFEV1 or ppoDLco is less than 60% for pulmonary surgery. SCT or SWT can be considered when ppoFEV1 and ppoDLco are both greater than or equal to 40% but either is less than 60% (14,15). A meta-analysis from Boujibar *et al.* (16) demonstrated that an SCT distance of less than 10 meters was associated with a high risk for surgery, with a relative risk (RR) of 2.34 [95% confidence interval (CI): 1.59–3.43]. Win *et al.* (17) suggested SWT <400 meters indicates high surgical risk. CPET is recommended when either ppoFEV1% or ppoDLco% is less than 40% or SCT or SWT indicates high risk. A meta-analysis from Arbee-Kalidas *et al.* (18), including 37 studies with 6,450 patients, suggested that a higher maximum oxygen consumption (VO_2max) was significantly associated with a lower risk of mortality [mean difference (MD) =3.66; 95% CI: 0.88–6.43] and fewer complications (MD =2.06; 95% CI: 1.12–3.00). Patients with a VO_2max greater than 20 mL/(kg·min) are considered relatively safe for surgery (19). When VO_2max is between 10–20 mL/(kg·min), the extent of surgical resection should be calculated based on the patient's specific condition. VO_2max less than 10 mL/(kg·min) is associated with high postoperative mortality and complication rates (15,20). For patients with exercise tests, previous history of coronary disease, as well as active symptoms indicating high risk, further cardiology assessment with cardiac coronary CT or coronary angiography is necessary to evaluate coronary artery status. Additionally, a multidisciplinary consultation involving cardiology, pulmonology, and anesthesiology is recommended to assess the surgical risk thoroughly (21).

Arterial blood gas analysis can be performed on patients with symptoms of respiratory failure, severe respiratory diseases, or when pulmonary function tests cannot be obtained. This test can reveal conditions such as hypoxemia or hypercapnia (22). Routine blood gas analysis is unnecessary for younger patients in good physical condition, as arterial blood gas sampling is painful and offers limited clinical benefit.

Patients with AHR are at an increased risk of experiencing bronchospasm during and after surgery. If the preoperative evaluation reveals that a patient has AHR, unstable asthma or COPD, pre-treatment with ICS combined with bronchodilators, such as ICS + LABA or ICS + LABA + LAMA, is recommended. This pre-treatment strategy helps to stabilize the airway, reduce inflammation, and minimize the risk of perioperative respiratory complications.

Preoperative exercises like breathing exercises and aerobic training are beneficial. A meta-analysis from Xu *et al.* (23) found that preoperative interventions significantly reduced the risk of postoperative pulmonary complications [odds ratio (OR) =0.32; 95% CI: 0.22–0.47] and shortened the LOS [weighted mean difference (WMD) =−1.68 days; 95% CI: −2.23 to −1.13]. A meta-analysis from Gravier *et al.* (24), including 14 studies with involvement of 791 participants, reported that preoperative exercise could reduce postoperative complications (RR =0.58; 95% CI: 0.45–0.75) and recommended prehabilitation programs of no less than 2 weeks to improve preoperative criteria and reduce postoperative complications effectively. We also support the effectiveness of such short-term exercise programs, as they are unlikely to delay surgery and show good patient compliance. It is important to note that a previous study suggested that the benefits of preoperative exercise may be insignificant for low-risk patients (25). However, high-risk patients, particularly those with poor preoperative lung function or concomitant lung diseases, are more likely to benefit from preoperative exercise (26).

Several studies have shown that active smoking increases the risk of postoperative complications. A meta-analysis from Mills *et al.* (27), including 6 randomized controlled trials (RCTs) and 15 observational studies, indicated that smoking abstinence for at least 4 weeks or longer may be associated with reduced perioperative respiratory complications. However, the included RCTs did not specifically study the impact of smoking cessation on lung surgery. Fukui *et al.* (28) suggested that smoking cessation at any time before surgery benefits postoperative outcomes for lung resection. Kadomatsu *et al.* (29) did not find a definitive relationship between the duration of smoking cessation and the incidence of postoperative complications, suggesting that it is unnecessary to delay surgery for the sake of smoking cessation duration. Considering that the

previously recommended 4-week cessation period might delay surgery, we recommend at least 2 weeks of smoking cessation before surgery (27). If the patients are unable or do not have the time to follow a 2-week smoking cessation plan, such as those with large central tumor, they should still be encouraged to quit smoking for whatever duration possible. The smoking cessation of 2 weeks should not be treated as an "all or none" rule.

Studies have reported more significant morbidity and longer LOS in underweight patients compared to obese or overweight patients (30-32). Obesity itself is not a contraindication for lung resection, but it may be associated with increased difficulties with intubation and longer surgery times (32). The previous study also indicates that obese patients may have increased airway inflammation and a higher risk for OSAS (31). Therefore, it is recommended that underweight patients improve their nutritional status. Obese patients, especially those undergoing neoadjuvant therapy or elective surgeries, should aim for weight reduction. Additionally, they should undergo OSAS screening using tools like the Nutritional Risk Score (NRS), the Malnutrition Universal Screening Tool (MUST), and the Subjective Global Assessment.

Second-time thoracic surgery brings its own technical challenges. Second-time surgery on the same side is associated with significant intrapleural adhesions, longer operative duration and a greater likelihood of needing to perform surgery via thoracotomy. Second-time surgery performed on the opposite side to the first operation means that single lung ventilation is a particular challenge, as the ventilated lung may only consist of a single lobe. For patients undergoing a second-time lung surgery, blood flow and ventilation redistribution can result in disproportionate lobe function. Pulmonary imaging with ventilation-perfusion is recommended to assess the function of each lobe (33,34). This helps determine the ventilation and perfusion status of each lobe, guiding the surgical plan and avoiding severe pulmonary function impairment. Bronchoscopy is advised for patients with airway obstruction seen on a chest CT scan as this may add specific information about the airway involvement, the need for preoperative rigid endoscopy to recover the bronchial canalization and accurately evaluate the base implant of the tumor.

Consensus 2: anesthesia management

(I) For which procedures is a laryngeal mask airway recommended to reduce airway epithelial damage? Using a laryngeal mask airway for airway management can be applied in various types of surgical procedures to reduce airway epithelial damage caused by endotracheal intubation. For thoracic surgery, patients who are suitable for non-intubated spontaneous breathing anesthesia [tubeless video-assisted thoracoscopic surgery (VATS) technique] should be taken to consideration (agreement rate 95%).

(II) How should endotracheal intubation be performed to follow lung-protective principles? When performing endotracheal intubation, select the appropriate tube size and use a video laryngoscope for guidance. During ventilation, follow lung-protective ventilation principles (agreement rate 100%).

(III) Which anesthesia maintenance strategy is recommended for faster postoperative extubation? Intravenous propofol, combined with volatile anesthesia, is recommended as the primary maintenance drug. Short-acting anesthetics should be used to facilitate faster postoperative extubation (agreement rate 100%).

(IV) How should a muscle relaxant be selected? The use of a steroid muscular relaxant is recommended because the antagonist sugammadex can rapidly and completely reversed it, facilitating faster extubation (agreement rate 90%).

(V) How should intraoperative bronchospasm be managed? Intraoperative bronchospasm should be relieved with bronchodilators and intravenous corticosteroids or aminophylline (agreement rate 100%).

(VI) What should be considered in fluid management during anesthesia? Fluid management during anesthesia is crucial to prevent postoperative pulmonary edema or sputum retention caused by airway dryness (agreement rate 100%).

The primary goals of intraoperative anesthesia management include minimizing pulmonary and systemic inflammatory responses and facilitating early extubation. A laryngeal mask is a supraglottic airway device that does not require insertion into the trachea, theoretically reducing damage to the airway epithelium. It can be easily and safely used for laryngotracheal surgery, in particular for the airway management during laryngotracheal and cervical trachea resection and reconstruction (35). Many disciplines have conducted RCTs to verify the feasibility of laryngeal mask airway management (36-39). For selected patients, the tubeless VATS technique is the optimal choice for ERAS in experienced centers. Compared to the tracheal intubation method, the tubeless VATS technique uses a laryngeal

mask, which avoids damage to the airway mucosa and vocal cords caused by intubation, thereby reducing the incidence of postoperative coughing (40,41). The tubeless VATS technique minimizes the use of muscle relaxants, enhancing postoperative tracheal ciliary movement and sputum clearance. Additionally, it can shorten the LOS and benefit postoperative cognitive function (41,42). The tubeless VATS technique uses a laryngeal mask to assist in airway management, maintaining low tidal volume ventilation to ensure adequate oxygenation (43,44). Reasons for converting from tubeless VATS technique to intubation include persistent hypoxemia (PaO_2 <60 mmHg or SpO_2 <90%), severe hypoxemia (PaO_2 <55 mmHg or SpO_2 <85%), severe hypercapnia ($PaCO_2$ >70–80 mmHg), and acidosis (pH <7.1) (45,46). For safety reasons, a single-lumen endotracheal tube should always be prepared for emergencies, and a bronchoscope should be available to ensure safe access to the bronchial system (47). Anesthesiologists should be skilled in intubating patients in the lateral decubitus position. Tubeless VATS is not yet fully implemented worldwide, but it is being actively promoted globally. In China, its adoption is progressing very rapidly. Further research is needed to better highlight its clinical utility and support its broader application in clinical practice.

If tubeless VATS surgery is not possible or safety conditions are not met, double lumen tube placement continues to be the preferred option in most thoracic surgery centers.

The selection of an appropriately sized endotracheal tube is paramount to minimizing airway damage during endotracheal intubation. Applying lidocaine or beclomethasone spray during intubation can increase patient comfort with the tube and effectively reduce postoperative coughing (48,49). Using a video laryngoscope for intubation guidance helps the speed and success of positioning and reduces mal-positioning rates (50,51). In thoracic surgery, a double-lumen tube (DLT) is preferred for single-lung ventilation. A tidal volume of 6–8 mL/kg ideal body weight should be used during double-lung ventilation, along with appropriate positive end-expiratory pressure (PEEP) and lung recruitment maneuvers. Before one-lung ventilation, preoxygenation with pure oxygen can accelerate the collapse of the surgical side lung (1). During one-lung ventilation, a tidal volume of ≤6 mL/kg ideal body weight should be set, along with PEEP of 5–10 cmH_2O, and the lowest fraction of inspired oxygen (FiO_2) necessary to maintain satisfactory arterial oxygen saturation (52). Peak airway pressure should not exceed 35 cmH_2O, and plateau pressure should not exceed 25 cmH_2O, $PaCO_2$ is usually maintained at 35–45 mmHg (53). Both volume-controlled and pressure-controlled ventilation modes can be used, but pressure-controlled ventilation is recommended first if there are high-risk factors for lung injury (53).

Intravenous anesthesia with propofol and remifentanil, combined with inhalational anesthesia using sevoflurane or desflurane, can be used to maintain anesthesia in thoracic surgery (54). Using short-acting anesthetics as much as possible can shorten postoperative extubation time and reduce complications (1). Volatile anesthesia can reduce systemic and local inflammatory responses, but only subgroup analyses suggest that patients with severe surgical injuries benefit from the anti-inflammatory effects of volatile anesthetics (55). This anti-inflammatory effect does not show clinical significance in less severe cases. Tubeless VATS technique using vagal nerve blockade, intercostal nerve blockade, and pleural surface local anesthetic spraying to anesthetize specific nerves or regions, can lead to lower amounts of anesthetics used (56-58).

We recommend using steroid muscular relaxants, such as rocuronium (59,60). As non-steroid muscular relaxants cannot be completely reversed, whereas steroid muscular relaxants can be fully antagonized by sugammadex (61). Sugammadex is significantly faster than neostigmine in reversing neuromuscular blockade, with 2 mg/kg of sugammadex reversing moderate blockade 10.22 minutes (6.6 times) quicker than neostigmine 0.05 mg/kg, and 4 mg/kg reversing deep blockade 45.78 minutes (16.8 times) faster than neostigmine 0.07 mg/kg (62). In addition, sugammadex appears to have a better safety profile than neostigmine, with 40% fewer adverse events (62).

In the event of intraoperative bronchospasm, it should be promptly managed to ensure airway patency. Continuous oxygen inhalation should be maintained to provide adequate ventilation. The first choice for inhaled bronchodilators is terbutaline spray, administered repeatedly through the mouth or endotracheal tube, in combination with intravenous corticosteroids or aminophylline to relieve bronchospasm (63). These measures can quickly alleviate bronchospasm and ensure the smooth progression of the surgery.

Controlling the speed and volume of fluid administration during anesthesia is essential. Excessive or rapid infusion can lead to pulmonary edema and diffusion impairment (64). Insufficient fluid administration or excessive diuresis can cause dehydration, airway dryness, weakened mucociliary clearance, sputum retention, and even atelectasis.

Additionally, if the anesthesia duration is prolonged or if there are excessive airway secretions, intermittent bronchoscopic suctioning should be performed promptly to maintain airway patency.

Consensus 3: surgical approach

(I) How important is preoperative surgical path planning for improving surgical outcomes? Preoperative surgical path planning is essential to shorten the operation time and preserve normal structures that do not need to be damaged (agreement rate 100%).

(II) How should lung tissue be handled during pulmonary surgery to ensure both tumor resection and preservation? For pulmonary surgery, it is recommended to preserve as much lung tissue as possible while ensuring radical tumor resection. Sleeve resection is recommended even in case of patient with good functional status and after neoadjuvant therapy (agreement rate 90%).

(III) What precautions should be taken during laryngotracheal surgery to protect the airway? For laryngotracheal surgery, it is essential to prevent foreign objects from entering the airway and to protect the airway from damage by surgical instruments. Airway management should be crucial even during tracheal resection by cross-field intubation (agreement rate 100%).

Preoperative surgical planning is crucial. Shortening surgery time can reduce anesthesia duration and airway intubation time, thereby lowering the risk of postoperative airway complications. Ideally, surgical techniques should employ minimally invasive methods and instrumention to minimize injury of tissue. If conditions permit, it is advisable to perform preoperative three-dimensional reconstruction to clarify the surgical approach (65). Preserving typical structures in the surgical area as much as possible, such as branches of the vagal nerve and bronchial arteries during lung surgery, can reduce intraoperative and postoperative airway injury and inflammatory responses, helping to minimize postoperative cough (66,67).

For pulmonary surgery it is recommended that as much lung tissue is preserved as possible while meeting the oncological requirement (68). Minimizing lung tissue loss and avoiding excessive lymph node dissection are crucial to reducing postoperative respiratory complications. The JCOG0802 multi-center study (69) found that anatomical segmentectomy improved overall survival compared to lobectomy for peripheral stage IA non-small cell lung cancer (NSCLC), although it nearly doubled the local recurrence rate. Similarly, the CALGB 140503 study (70) showed no significant differences in overall survival or disease-free survival between sublobar resection and lobectomy for node-negative, peripheral stage IA NSCLC. These large, rigorous studies suggest that sublobar resection may be non-inferior in survival for patients with small, peripheral tumors. Moreover, less extensive resection implies less surgical trauma, which helps reduce airway complications caused by inflammation (41). Sleeve resection (bronchial and/or vascular) can avoid pneumonectomy in many cases of centrally-located lung cancer. It is recommended even in case of patient with good functional status and after neoadjuvant therapy (71). In case of laryngotracheal resection and reconstruction a laryngeal mask can be safely and easily used, moreover is recommended the use of cross-field ventilation of the distal tracheal stump after tracheal resection, and during the end-to-end reconstruction phase (35).

For otolaryngology surgeries, particularly those involving the use of a suspension laryngoscope within the airway, it is essential to ensure that the endotracheal tube cuff fully seals the airway to prevent blood, secretions, or foreign objects from entering the trachea during the procedure. Additionally, precautions must be taken in order to avoiding the ignition of flammable gases by laser or other thermal devices, which could damage the airway. Care should also be taken to prevent excessive airway pressure caused by surgical instruments' compression of the endotracheal tube by surgical instruments, as this can lead to CO_2 retention.

Consensus 4: postoperative airway management

(I) How can persistent cough after pulmonary resection be managed? Postoperative ICS + LABA + LAMA can help alleviate persistent cough after pulmonary resection (agreement rate 80%).

(II) When should early mobilization be initiated post-surgery, and what measures should be taken for patients who cannot mobilize? Patients who are able to walk should begin early mobilization. For those who cannot mobilize, healthcare personnel should assist with frequent repositioning to prevent hypostatic pneumonia (agreement rate 100%).

(III) What strategies are recommended to prevent postoperative sputum retention? Preventing postoperative sputum retention is crucial. Effective early postoperative cough, combined with mechanical

sputum clearance and the use of intravenous ambroxol or oral acetylcysteine to reduce sputum viscosity, are recommended (agreement rate 100%).

(IV) Should postoperative rehabilitation exercise be implemented after thoracic surgery? Postoperative individualized rehabilitation exercise is recommended for thoracic surgery, even though it is controversial if it reduces postoperative complications or shortens LOS. However, it can improve activity levels and quality of life after surgery (agreement rate 100%).

(V) When can continuous positive airway pressure (CPAP) or non-invasive ventilation (NIV) be considered post-surgery? CPAP or NIV can be considered for acute respiratory failure but are not used routinely (agreement rate 85%).

(VI) What is the impact of postoperative pain and how can it be controlled? Postoperative pain can limit adequate sputum clearance, especially after chest and abdominal surgeries. Effective postoperative pain relief facilitates sputum clearance and reduces pulmonary complications. We recommend a multimodal analgesia regimen based on nonsteroidal anti-inflammatory drugs (NSAIDs), while minimizing the use of opioid analgesics (agreement rate 95%).

(VII) When should a postoperative chest drainage tube be removed? If there is no lung air leak, the postoperative chest drainage tube should be removed promptly. Be vigilant for pleural effusion following major upper abdominal surgery (agreement rate 95%).

The incidence of postoperative persistent coughing is relatively high and significantly impacts quality of life. Sawada *et al.* (72) reported that ICS and bronchodilators can alleviate postoperative coughing. A recent RCT that was presented at the American Association of Thoracic Surgery demonstrated that postoperative use of the ICS + LABA + LAMA significantly reduced the incidence of persistent postoperative cough (13.73% *vs.* 40.38%, P<0.05) (73). This may be explained by the fact that surgical trauma can induce airway inflammatory responses, leading to AHR and bronchospasm (74). The combination of ICS and bronchodilators reduces inflammation and airway spasms, thereby decreasing the occurrence of postoperative cough.

Patients who are able to walk should begin early mobilization as soon as possible. Early mobilization is beneficial because it helps improve circulation, reduces the risk of blood clots, and promotes faster recovery (75). Additionally, it can enhance muscle strength and prevent muscle atrophy, thereby improving overall physical function. For patients who are intubated or unable to ambulate, healthcare personnel should assist with frequent repositioning. Repositioning is crucial in preventing hypostatic pneumonia, which can occur when patients remain in one position for too long (76). By regularly changing positions, the lungs are encouraged to fully expand, which helps in clearing secretions and maintaining respiratory function. Additionally, repositioning helps prevent pressure ulcers and other complications associated with prolonged immobility, contributing to a quicker recovery process.

Promoting clearance of airway secretions is critical to postoperative airway management, as poor secretion clearance can lead to inadequate lung re-expansion and an increased risk of pulmonary infection (77). Mechanical airway clearance can effectively promote secretion removal (78). Intravenous ambroxol or oral acetylcysteine can encourage the clearance of sputum (79,80). Effective active coughing postoperatively also aids in secretion removal (81).

Wang *et al.* (82) suggested that postoperative exercise training could significantly improve the quality of life of patients undergoing pulmonary surgery, as measured using short form 36 healthy survey (SF-36) physical and mental domain scores. Additionally, postoperative exercise may improve physical activity and cough symptoms after pulmonary resection (83,84). However, a meta-analysis from Xu *et al.* (23) suggested interventions delivered during the immediate postoperative period did not have any significant effects on either postoperative pulmonary complication (OR =0.85; 95% CI: 0.56 to 1.29) or LOS (WMD =–0.23 days; 95% CI: –1.08 to 0.63). Taken together, based on current evidence, postoperative exercise may or may not reduce the occurrence of postoperative complications or shorten LOS, but it probably improves the quality of life, postoperative activity level and cough symptoms.

A multicenter RCT conducted by Abrard *et al.* (85) where the most patients underwent cardiac and pulmonary surgeries demonstrated that prophylactic NIV does not reduce the incidence of acute respiratory failure. Lorut *et al.* (86) suggested prophylactic postoperative NIV did not reduce the rate of adverse events in COPD patients undergoing lung resection surgery and did not influence other postoperative complications rates, mortality rates, and duration of intensive care unit (ICU) and hospital stay. A meta-analysis by Lockstone *et al.* (87), which included 17 studies, confirmed that prophylactic postoperative CPAP or NIV did not reduce postoperative pulmonary complications.

Although these patients would seem to be the ones most likely to benefit with postoperative non-invasive ventilatory support, yet well-designed RCTs have confirmed its ineffectiveness. Thus, the routine use of CPAP or NIV to prevent postoperative complications has yet to be proven effective to date. However, for patients with postoperative acute respiratory failure, CPAP and NIV are still valuable as they help reduce the reintubation rate and improve perioperative outcomes (88,89). High-flow nasal cannula (HFNC) offers several advantages, including improved oxygenation, better patient comfort, and reduced airway resistance compared to traditional oxygen therapy methods. Post hoc analysis of an RCT (90) showed HFNC is not inferior to NIV in terms of treatment failure rates (13.3% *vs.* 15.4%, respectively, P=0.62), ICU mortality (2.2% *vs.* 5.9%, P=0.22), length of ICU stay (median 5.0 *vs.* 4.0 days, P=0.63), or length of hospital stay (median 10.0 *vs.* 11.1 days, P=0.71). However, skin breakdown at 24 hours was significantly more common with NIV than with HFNC (9.2% *vs.* 1.6%, respectively, P=0.01). Furthermore, when acute respiratory failure does occur, HFNC can be an effective treatment modality either on its own or in conjunction with CPAP or NIV (91).

Postoperative pain can limit effective coughing, leading to inadequate clearance of sputum and airway secretions. This increases the risk of atelectasis and pulmonary infections. Therefore, individualized pain management should be emphasized, and preventive and multimodal analgesia should be advocated. Using NSAIDs as the foundation of a multimodal pain management approach can reduce the need for opioids (92). This can be combined with various methods to enhance pain control, such as patient-controlled analgesia (PCA) pumps, local wound infiltration, intercostal nerve blocks, and paravertebral blocks (93-95).

For thoracic surgery, the drainage tube should be removed as soon as possible if there is no pulmonary air leak. A meta-analysis conducted by Zhang *et al.* (96) suggests that it is generally safe to remove the drainage tube when the 24-hour drainage volume is less than 300 mL, provided that bleeding and chylothorax are excluded. Additionally, other prospective studies have demonstrated that the removal of the drainage tube is safe when the volume is less than 450–500 mL (97,98).

Consensus 5: management of coexisting respiratory diseases

(I) What should be considered during the perioperative period for patients with asthma? It is recommended that patients with asthma control their symptoms as much as possible before surgery. Perioperative bronchospasm should be closely monitored (agreement rate 95%).

(II) What should be considered during the perioperative period for patients with COPD? ICS + LABA + LAMA perioperatively is recommended for patients with COPD. Be vigilant for postoperative respiratory failure and provide respiratory support promptly if needed (agreement rate 90%).

(III) What should be considered during the perioperative period for patients with OSAS? Monitor for perioperative hypoxemia in patients with OSAS. Tracheal intubation is recommended for surgery, and postoperative care should avoid the supine position to prevent airway obstruction (agreement rate 85%).

(IV) What should be considered during the perioperative period for patients with pulmonary fibrosis? For patients with pulmonary fibrosis, there are higher postoperative complications and long-term mortality rates. A sub-lobar resection may help reduce acute exacerbation of postoperative pulmonary fibrosis (agreement rate 95%).

(V) When should a multidisciplinary consultation be considered for patients with complex respiratory conditions? A multidisciplinary consultation is recommended for patients with multiple respiratory diseases or complex respiratory conditions to evaluate surgical risk (agreement rate 100%).

Patients with a recent history of acute exacerbation of asthma or who have experienced acute exacerbations have a higher likelihood of bronchospasm during and after surgery (99). Therefore, it is crucial to assess asthma control preoperatively. Patients with well-controlled asthma should maintain their current medication regimen before surgery. Patients with poorly controlled asthma should upgrade their regimens to ICS + LABA, ICS + LABA + LAMA, or even add systemic corticosteroids. Ideally, surgery should be performed after achieving complete asthma control. If asthma cannot be controlled in the short term or if the patient has a history of acute exacerbation within the past 6 months, a reevaluation of surgical and anesthetic risk is required. Preoperative use of short-term systemic corticosteroids for 3–5 days may reduce the likelihood of intraoperative bronchospasm (100). During intubation, gentle technique is essential as it can trigger bronchospasm. Postoperative NIV or CPAP may benefit patients with

persistent airway spasms after extubation.

The perioperative administration of ICS + LABA + LAMA can effectively improve airflow limitation in COPD, suppress inflammatory responses, reduce airway spasms, and alleviate lung hyperinflation and respiratory symptoms. Mucolytics should be used preoperatively for patients with excessive airway secretions (101). Protective ventilation strategies during surgery are recommended. It is essential to monitor closely for signs of respiratory distress after extubation. If such symptoms arise, prompt use of CPAP or NIV is necessary to ensure perioperative safety. Perioperative combined use of ICS and bronchodilators can effectively improve patients' respiratory function (102). Using ICS + LABA + LAMA is better than LABA + LAMA in improving lung function and postoperative outcomes in patients with lung cancer combined with COPD (103).

Patients with OSAS are prone to airway obstruction and hypoxemia during the perioperative period. If hypoxemia is present preoperatively, NIV or CPAP is recommended. During anesthesia, tracheal intubation is preferred for airway management. It is advisable to perform the extubation when the patient is awake and in a lateral or semi-upright position to prevent airway obstruction. Maintaining a semi-upright position is essential to post-extubation, and continuing to use of NIV or CPAP, if used preoperatively is crucial. Continuous monitoring of blood oxygen saturation is crucial.

Patients with pulmonary fibrosis who undergo pulmonary surgery have higher rates of complications and long-term mortality (104-106). Preoperative ventilatory function is usually normal, so the evaluation of diffusion capacity is crucial. Nintedanib, an antifibrotic agent, is used in the treatment of pulmonary fibrosis; however, its perioperative use to mitigate acute exacerbations remains controversial due to concerns regarding its potential to delay wound healing while it has been shown to slow the progression of fibrosis (107). A smaller resection extent may reduce postoperative complications, and the tubeless VATS technique might be suitable for these patients (108,109).

A multidisciplinary consultation with departments such as pulmonology, cardiology, radiology, and anesthesiology is recommended for patients with multiple respiratory diseases or complex respiratory conditions. A comprehensive assessment by the multidisciplinary team can provide a better understanding of surgical risks and potential complications, helping to develop a safer and more personalized anesthetic and surgical plan. This approach maximizes surgical success and improves postoperative recovery outcomes.

Discussion

This consensus updates some previously established practices and introduces several new vital aspects. We want to emphasize the importance of perioperative medication management and minimizing unnecessary intubations.

For patients with preoperative uncontrollable asthma, AHR, and COPD, ICS + LABA + LAMA can be used perioperatively. ICS + LABA + LAMA is a helpful treatment option for the maintenance treatment of COPD (110). Its components help reduce airway inflammation, thereby alleviating AHR and bronchospasm. Postoperative early decline in lung function, persistent cough, and shortness of breath may be associated with AHR and bronchospasm (74). ICS + LABA + LAMA has been shown to reduce persistent postoperative cough in single-center study (73). Further multicenter clinical trials are needed to validate its efficacy in postoperative airway management.

With the continuous improvement of laryngeal mask devices, clinical research across various disciplines has indicated that the ventilation provided by laryngeal masks can meet the requirements of many types of surgical procedures (36,37,39,111). For example, in thoracic surgery, the tubeless VATS technique reduces airway damage caused by intubation and requires fewer opioids and muscle relaxants. Additionally, it results in shorter operation times, earlier mobilization, and a reduced postoperative LOS (112). Currently, this technique can be safely applied to minor procedures like wedge resections and complex thoracic surgeries such as tracheal operations and extensive mediastinal tumor resections (43,113). Despite the potential advantages of tubeless VATS technology, its adoption has been limited to only a few high specialized centers. This may be attributed to the need for close cooperation between surgeons and anesthesiologists. To maximize patient benefits, anesthesiologists and surgeons must learn and master this technique actively.

Conclusions

In conclusion, this consensus highlights the critical importance of airway management, emphasizing the need for advanced techniques and early interventions. Moving forward, it is crucial to place even greater emphasis on optimizing airway management to improve patient outcomes.

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Footnote

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