

# Preventive strategies in airway management; a narrative review of epidemiological insights from anesthesia and ENT practice



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## Abstract

Airway management remains a cornerstone of safe clinical practice in both anesthesia and otolaryngology, where failure to anticipate complications can lead to significant morbidity and mortality. Preventive strategies are increasingly emphasized through epidemiological insights that highlight risk factors such as anatomical variations, comorbidities, and procedural complexities. In anesthesia, structured preoperative assessment, use of advanced airway devices, and simulation-based training have demonstrated measurable reductions in adverse events. Similarly, ear, nose, and throat (ENT) practice contributes preventive approaches through early identification of obstructive pathologies, minimally invasive interventions, and multidisciplinary collaboration in complex airway cases. Epidemiological data underscore the importance of integrating risk stratification tools, continuous monitoring, and evidence-based guidelines to mitigate complications across diverse patient populations. This narrative review synthesizes current preventive strategies from anesthesia and ENT perspectives, offering a comprehensive framework for optimizing airway safety and improving patient outcomes.

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## Introduction

Airway management is a cornerstone of both anesthetic and otolaryngologic practice, representing a domain where technical expertise, interdisciplinary collaboration, and patient safety converge. Despite revolutionary advances in airway devices, monitoring, and education, airway-related complications remain a significant source of morbidity and mortality across perioperative, emergency, and critical care settings (1). The concept of a “shared airway”, where anesthesiologists and surgeons operate within the same anatomical space, underscores the unique challenges and risks inherent to ear, nose, and throat (ENT) procedures, necessitating meticulous planning and communication. The increasing complexity of patient populations, including those with comorbidities and prior airway interventions, further amplifies the need for robust preventive strategies (2). While most airway management is routine and uneventful, the rare occurrence of catastrophic events such as “cannot intubate, cannot oxygenate” (CICO) scenarios, aspiration, or airway trauma can have

devastating consequences for patients and clinicians alike (3). This narrative review synthesizes epidemiological data, risk factors, common complications, and preventive strategies in airway management, drawing from both anesthesia and ENT clinical perspectives. By integrating evidence from large-scale audits, closed claims analyses, and recent guideline updates, the review aims to provide a comprehensive framework for understanding and mitigating airway-related adverse events. Special attention is given to the unique epidemiology of airway complications in ENT practice, the interplay of patient- and situation-related risk factors, and the evolution of preventive approaches, including technological innovations, team training, and quality improvement initiatives. The review also addresses pediatric considerations, physiologically difficult airways, and the legal and ethical dimensions of airway management. Ultimately, the goal is to inform clinical practice and guide future research toward safer, more effective airway management across anesthesia and ENT domains.

**Key point**

Airway management in anesthesia and ENT (ear, nose, and throat) practice remains a high-risk domain where rare complications can be catastrophic. Clinical practice demands vigilance, with apneic oxygenation applied universally in vulnerable groups such as obese, pregnant, pediatric, and critically ill patients, especially during rapid sequence induction. Extubation planning, risk stratification, and optimized preoxygenation strategies are as vital as intubation itself. Research should clarify pediatric oxygen delivery techniques, refine flow parameters, and support the development of durable, cost-effective airway devices. Ultimately, safe airway care requires a multidisciplinary, patient-centered approach that integrates technology, clinical judgment, and continuous quality improvement.

**Search strategy**

A comprehensive literature search was conducted using the valid databases, including PubMed, Web of Science, Scopus, and Google Scholar search engine, to identify relevant studies on preventive strategies in airway management within anesthesia and ENT practice. The search included articles published in English up to November 2025, employing combinations of Medical Subject Headings (MeSH) and free-text terms such as ‘airway management’, ‘anesthesia’, ‘otolaryngology’, ‘patient safety’, ‘perioperative care’, and ‘preventive strategies’. Boolean operators (AND, OR) were applied to refine results, and filters were set for human studies, clinical trials, reviews, and observational studies. Reference lists of retrieved articles were also screened to capture additional relevant publications. Studies focusing on pediatric and adult populations, as well as those addressing perioperative and emergency airway management, were included, while case reports and non-peer-reviewed sources were excluded to ensure methodological rigor.

**Epidemiology of airway-related adverse events**

Complications associated with airway management persist despite notable advancements in technology, monitoring, and the dissemination of guidelines. The Fourth National Audit Project (NAP4), conducted by the Royal College of Anaesthetists in collaboration with the Difficult Airway Society in the United Kingdom (UK), reported that 1 in 22,000 cases of tracheal intubation in the operating room was associated with severe adverse events, such as death, brain damage, emergency surgical airway, or unplanned intensive care unit (ICU) admission (1). In a 2005 study of one million American Society of Anesthesiologists (ASA) physical status 1–2 patients, the risk of death or other serious complications from anesthesia was about 10 per million anesthetics, with 40% of events related to airway problems. The ASA closed claims program found that 17% of claims were due to respiratory events associated with airway management, with 6% being direct airway injury. In a 29-country prospective study of ICU intubations, 45.2% of patients experienced at least one major adverse event within 30 minutes of tracheal intubation (3). In the ICU, airway complications resulted in death or significant

neurological injury in 61% of cases, a rate much higher than during anesthesia (14%) or in the emergency department (31%) (4). The NAP4 audit reported an incidence of airway-related death or brain injury of 7 per million anesthetics in the UK, while the ASA Closed Claims Program later noted rising complications in nonoperating room settings with increased mortality. NAP4 further demonstrated that airway events in ICUs and emergency departments carried substantially higher risks, with about 60% resulting in death or severe neurological damage. Nearly half of the cases were linked to ENT surgery, which showed a threefold higher incidence, and ENT surgeons were responsible for two-thirds of the procedures (3). Data from Togo revealed a 2.6% mortality within 24 hours of surgery, with 93% deemed avoidable; anesthesia accounted for 50% of these deaths, including 30% related to respiratory care. In comparison, findings from the UK’s NAP7 highlighted that airway and respiratory issues were responsible for 13% of perioperative cardiac arrests and 9% of deaths (5). Respiratory complications account for 37% of anesthesia-related injuries in the operating room and 38% in non-operating room settings; a recent UK investigation using comparable methodology reported similar rates, with a greater frequency of events among patients identified as having a difficult airway (2). Airway events associated with mortality or brain damage occurred at rates 35-fold higher in the emergency department and 55-fold higher in the ICU relative to those observed during anesthesia (3).

**Epidemiology in ENT practice specifically**

The ENT procedures present unique epidemiological challenges due to the “shared airway” between anesthesiologist and surgeon, altered anatomy from pathology or previous treatment, and the need for unobstructed surgical access (2). Approximately half of the major airway events in NAP4 occurred during ENT surgery, with an almost threefold higher incidence compared to other surgical specialties; patients undergoing ENT operations faced a 26-fold higher frequency of emergency airway surgery compared with other surgical populations, highlighting the necessity of clear, systematic airway management strategies (3).

The ENT surgeons carried out about two-thirds of procedures linked to major airway complications, of which over one-third were associated with head, neck, or tracheal pathology, and 70% of these cases presented with airway obstruction (3). The ENT practice is further complicated by the prevalence of airway tumors, foreign bodies, and contractures from prior radiotherapy, all of which increase the risk of difficult intubation and perioperative airway compromise (2).

Airway management in ENT surgery has progressively evolved through the pursuit of enhanced surgical access, innovations in minimally invasive and robotic techniques, and the introduction of high-flow nasal oxygen and

tubeless field approaches (2). Tubeless anesthesia, facilitated by high-flow nasal oxygenation (HFNO), has demonstrated feasibility and safety in providing an uninterrupted surgical field during laryngeal surgeries, though it remains uncommon and requires careful patient selection and backup planning (6).

### Epidemiology of airway-related adverse events in ENT practice

The NAP4 examined significant complications related to airway management across the UK, emphasizing that the majority were associated with head, neck, or tracheal pathology and frequently manifested as airway obstruction (7). Compromised airways are more common in patients undergoing ENT surgeries (8). A difficult airway was encountered in 15 patients (7.5%), intraoperative tracheostomy was performed in 136 cases (68%), and indirect laryngoscopy was pre-emptively utilized in 32.8% overall and 45.4% of revision surgeries (9). Microlaryngeal surgeries require special considerations for airway management to facilitate patient safety while allowing for complete surgical exposure. There are a variety of airway management techniques available, such as jet ventilation, transnasal humidified rapid insufflation ventilatory exchange, Tritube, and conventional endotracheal tubes (ETTs), among which ETTs continue to be widely used (10). Among patients undergoing surgery for ear, nose, or throat malignancies, the incidence of difficult endotracheal intubation can approach 16% (11), representing approximately a sixfold increase compared with the general surgical population (11-15).

The growing complexity of patient cohorts, particularly those with multiple comorbid conditions, has driven the need for more advanced strategies in airway management, while laryngospasm remains a frequent occurrence following ENT interventions due to airway instrumentation and the presence of blood (8). Analysis of demographic characteristics in patients with difficult airways revealed that 53.3% reported alcohol use, 66.6% were active smokers, 94% had an ASA physical status of 2-3, and 60% presented with tumor stage T2-T3 (9). The primary concern regarding the use of 5.0 ETTs for patients undergoing microlaryngeal procedures is whether they provide adequate oxygenation and ventilation. Specific considerations include risk of oxygen desaturation and need for excessively elevated peak inspiratory pressures, which may lead to pulmonary barotrauma (10). While comprehensive airway assessment before surgery is critical, routine anesthesia screening methods overlook factors such as aspiration risk, lower airway complications, and lesions involving the tongue base (16). Aspiration of a blood clot after airway surgery may precipitate acute airway compromise and sudden cardiac arrest (8). Tracheostomy can result in complications, including bleeding, infection, delayed wound healing, pneumothorax, tracheostoma misplacement, tracheal

perforation, stenosis, or tracheomalacia, several of which may pose life-threatening risks (9). Surgeons and anesthesiologists may be hesitant to choose such a small-diameter ETT and have limited data available to support their utility and safety (10). Neck alterations following radiation therapy and limited mandibular advancement represent key predictors of impossible mask ventilation, challenging mask ventilation, and difficult intubation in susceptible patients (17, 18).

The progression of airway management in ENT procedures has been shaped by the pursuit of better surgical access, innovations in minimally invasive and robotic techniques, expanding knowledge of apneic oxygenation, and the advent of high-flow nasal oxygen systems (16). Post-operative nausea and vomiting are frequent following ENT procedures, necessitating routine prophylactic measures to reduce their occurrence (8). Patients who underwent intraoperative tracheostomy experienced markedly prolonged durations of mechanical ventilation and overall hospitalization compared with those who did not (9). Minimal data describes the utility of conventional (non-laser) 5.0 ETTs for use in different types of microlaryngeal surgeries (10).

### Risk factors for airway complications

#### *Patient-related risk factors*

Risk factors for airway complications can be broadly categorized as patient-related or situation-related. Obese and morbidly obese patients are over-represented in all areas of airway complications, with obesity being a significant predictor of airway difficulty due to both anatomical and physiological factors (3). Obese patients are twice as likely to have a severe airway complication as those who are not obese, and patients with a body-mass index (BMI) higher than 40 are four times as likely to have a severe complication (1). Obesity, affecting over 40% of the United States population, represents a major global health concern and is strongly associated with obstructive sleep apnea (OSA), as excess adipose deposition around the pharyngeal airway narrows the lumen and heightens the risk of collapse during sleep, thereby compounding airway vulnerability (19). Central obesity, independent of BMI, is a predictor of OSA severity, and a one-unit increase in BMI is associated with a fourfold increase in risk for sleep apnea. Other patient-related risk factors include anatomical abnormalities (e.g., limited neck mobility, craniofacial anomalies), OSA, history of difficult intubation, and comorbidities such as diabetes mellitus (20). Patients with OSA are at even higher risk of increased airway difficulty and airway obstruction, leading to rapid hypoxia. The prevalence of OSA in men has been reported to be 38% overall and 17% for moderate or severe OSA, with prevalence increasing with age and adiposity (3). Male sex, older age, postmenopausal status in women, and hereditary factors also contribute to increased OSA risk and, by extension, airway management challenges

(20). In pediatric patients, congenital malformations (e.g., Pierre Robin, Apert, Crouzon, Goldenhar syndromes), dysmorphic facial features, respiratory conditions, tumors, trauma, and recent upper respiratory infections increase the risk of airway complications (21). A history of bronchopulmonary dysplasia in former premature infants, a full stomach, and respiratory distress (stridor or dyspnea) are additional risk factors in children (22).

### **Situation-related risk factors**

Situation-related risk factors include emergency airway management, non-operating room settings, off-hours procedures (evenings and weekends), incomplete airway assessment, and lack of backup airway plans. Timing of events is critical, with 69% occurring at induction of anesthesia, 12% during maintenance, and 14% after surgery. The ICU patients often present additional challenges, such as obtundation, agitation, or physiologic derangements (e.g., severe hypoxemia, acidosis, right ventricular failure), making standard airway management more hazardous. Complications are higher during off-hours and are associated with incomplete airway assessment and failure to plan for failure (3).

In the ICU, displaced airways, particularly tracheostomies, represent the leading source of major morbidity and mortality, whereas in the emergency department, most adverse events arise from rapid sequence induction; increasingly, the notion of a “physiologically difficult airway” underscores that even with normal anatomy, critical illness can render intubation hazardous due to rapid desaturation or cardiovascular collapse (3). Shared airway procedures, particularly in ENT, are commonly encountered in pediatric surgery, otolaryngology, oral and maxillofacial surgery, and dentistry under general anesthesia, all of which increase the risk of airway compromise due to the proximity of surgical and anesthetic interventions (2).

### **Common complications of airway management**

Hypoxia is the most common and feared complication, occurring during difficult or failed intubation due to inadequate oxygenation or ventilation, and can result in hypercapnia, acidosis, arrhythmias, neurological injury, cardiac arrest, and death (23, 24). A study found that 45.2% of ICU intubations were associated with at least one major adverse event, most commonly cardiovascular instability (42.6%), severe hypoxemia (9.3%), or cardiac arrest (3.1%) (24). Tracheal intubation difficulty accounted for 23% of airway complications, failed mask ventilation for 3%, aspiration for 1.8%, and laryngospasm for 7%. Sore throat is common after placement and removal of an ETT or supraglottic airway, with an incidence between 14% and 60% (3). Hoarseness has been reported in up to 50% of intubated patients and in approximately 15% of laryngeal mask airway (LMA) patients; traumatic injuries to soft tissues of the oropharynx and dentition are frequent, with

dental injuries being a leading cause of legal complaints (25). Unrecognized esophageal intubation remains a significant cause of morbidity and mortality, accounting for 6% of airway-related complications in NAP4. Longer-term intubation is associated with vocal cord granulomas, paralysis, and subglottic stenosis (3).

Emergence and recovery events accounted for 25% of complications and were associated with blood in the airway, airway obstruction, and post-obstructive pulmonary edema. Aspiration is a serious complication, particularly in patients with a full stomach, and can lead to pneumonia, acute lung injury, or death (3). Laryngospasm is a life-threatening event, particularly in pediatric patients, with an incidence ranging from 1.6% to 12.5% in adenotonsillectomy (25). In children, hypoxemia, laryngospasm, and airway trauma are the most common complications, with severe events such as aspiration, emergent surgical airway, and unrecognized esophageal intubation occurring in 3% of cases (22).

### **Preventive strategies in anesthesia for mitigating the risk of airway complications**

#### **Assessment and planning**

Effective prevention of airway complications depends on thorough pre-assessment, deliberate planning for potential difficulties, and anticipation of failures. Before anesthetic induction or airway manipulation, the designated provider should evaluate risk factors across patient, clinical, surgical, environmental, and anesthetic domains (26).

Assessment of patient demographics and personal factors relevant to difficult airway includes prior intubation challenges, abnormal airway anatomy, snoring, OSA, diabetes, and diagnostic findings. Physical examination should additionally evaluate features such as mouth opening, cervical mobility, Mallampati classification, thyromental distance, and neck circumference that may signal increased airway difficulty (26). Neglecting airway evaluation or disregarding its findings is associated with adverse outcomes. The latest ASA guidelines on difficult airway management emphasize the importance of structured assessment and planning, incorporating updated infographics to assist clinicians in risk prediction and in determining whether airway management should be performed awake or under anesthesia (3). A preformulated strategy for management of the anticipated difficult airway should be developed, considering the anticipated surgery, patient condition, cooperation, age, and the skills and preferences of the anesthesiologist. Strategies should be identified for awake intubation, the patient who can be ventilated but is difficult to intubate, the patient who cannot be ventilated or intubated, and difficulty with emergency invasive airway rescue (26). A thorough airway assessment and creation of a patient-specific management strategy, feasible with current personnel and resources and shared with all team members, are essential. In situations where laryngoscopy, mask ventilation, supraglottic airway

use, or surgical airway may be difficult, or when aspiration or rapid oxygen desaturation is likely, awake intubation is advisable (3).

### **Devices and techniques**

To reduce hypoxic risk in airway management, patient-specific preoxygenation should be performed, aiming for an exhaled oxygen concentration greater than 90% before the onset of apnea (27). Preoxygenation can be performed using noninvasive positive pressure ventilation, oxygen by face mask, or HFNO, with HFNO being particularly effective in challenging airways (28). Continuous administration of oxygen during apnea (apneic oxygenation) enhances peripheral capillary oxygen saturation (SpO<sub>2</sub>), reduces the incidence of hypoxemia, extends the safe apnea period, and increases the success rate of first-pass intubation (27). Meta-analyses have shown that video laryngoscopy significantly increases the number of successful intubations on the first attempt, improves glottic visualization, and reduces the incidence of esophageal intubations compared to direct laryngoscopy (29). Noninvasive devices for airway management include rigid laryngoscopic blades of alternative design and size, adjuncts (introducers, bougies, stylets), videolaryngoscopes, flexible intubation scopes, supraglottic airway devices, and lighted or optical stylets (26). Advances in technology, such as innovative oxygenation techniques, routine use of capnography, second-generation supraglottic devices, and videolaryngoscopy, have enhanced the safety of airway management. The practice of peri-oxygenation, involving continuous oxygen supplementation beginning before anesthetic induction, helps prolong oxygen reserves and delay desaturation during apnea (3). Apneic oxygenation techniques have demonstrated significant efficacy in delaying desaturation before tracheal intubation in obese patients, with HFNO reducing the incidence of hypoxemia, increasing the lowest SpO<sub>2</sub>, and decreasing the need for additional respiratory support (27). The LMA is an excellent alternative to mask ventilation during shared airway procedures, as it eliminates tongue obstruction, decreases the number of oxygen desaturations, and does not require administration of a paralytic. Standardization of airway equipment and personnel, as well as familiarity and use of airway guidelines, algorithms, and cognitive aids, have been demonstrated to reduce complications (25). Combination techniques, such as direct or video laryngoscopy combined with optical/video stylet or flexible intubation scope, and supraglottic airway combined with optical/video stylet, have shown high success rates in anticipated difficult airway patients (26).

### **Peri-procedural management**

Careful monitoring of hemodynamic status with appropriate fluid and pressor support may help reduce complications, although the effectiveness of these

measures remains uncertain. Equally critical is the planning of tracheal extubation in high-risk airways, where airway exchange catheters or supraglottic devices can serve as transitional aids. Sedative agents such as etomidate or ketamine are advantageous due to their minimal impact on blood pressure and cardiac function, while neuromuscular blockade can improve conditions for mask ventilation and intubation in difficult scenarios. Simulation training, including the use of airway mannequins and virtual reality platforms, provides a safe environment to rehearse complex airway management, reinforce algorithms, and practice emergency techniques such as surgical airway access (3).

### **Preventive strategies in ENT practice for mitigating the risk of airway complications**

#### **Shared airway techniques**

The ENT surgeries frequently necessitate “tubeless” techniques, in which the ETT is absent from the operative field to ensure clear visualization and access to the pharynx, larynx, or upper airway. The HFNO has become a pivotal method for such anesthesia, delivering warmed, humidified oxygen at flows up to 70 L/min and supporting extended apneic oxygenation (6). HFNO offers opportunities for a tubeless oxygenation system that is easy to handle and not limited to the surgery of the endolarynx. Jet ventilation systems, both low-frequency and high-frequency, are also used to provide oxygenation during ENT procedures, though they carry risks of hypercapnia, soiling, and barotrauma; specialized ETTs, such as nerve integrity monitor electromyography tubes, microlaryngoscopy tubes, laser-resistant tubes, and preformed RAE tubes, have been developed to address specific surgical challenges in ENT procedures (30). The choice of airway device and technique should be tailored to the procedure, patient characteristics, and anticipated risks; comprehensive planning for tubeless field techniques must include re-intubation and surgical airway planning if adequate oxygenation is not achieved or if the airway becomes obstructed (2). A secure approach to tubeless anesthesia involves contingency planning, such as endotracheal intubation or jet ventilation, and relies on effective collaboration between surgical and anesthesia teams (6).

#### **Surgical airway and emergency access**

Tracheostomy with local anesthesia is rarely considered but is encouraged as a primary or backup technique in difficult airway scenarios (3). Awake tracheostomy is typically performed in emergent settings in patients with inherently difficult airways and requires close communication between an anesthesiologist and otolaryngologist (31). The emergent surgical airway of choice in adults is cricothyroidotomy, while in children, needle cricothyroidotomy with percutaneous transtracheal ventilation is preferred due to anatomical

limitations. Awake tracheal intubation is the gold standard where expertise is available, and some guidelines specify that awake surgical tracheostomy can be performed under local anesthetic (2). During CICO scenarios, transition to emergency front-of-neck airway is often delayed and may fail if not practiced and planned for. Anaesthetists should be skilled and practiced in surgical (scalpel) cricothyroidotomy, and simulation training is recommended (3).

### Conclusion

Airway management continues to represent a high-stakes challenge in both anesthesia and ENT practice, where rare but catastrophic complications highlight the need for vigilance and innovation. Despite progress in technology, guidelines, and training, preventable adverse events persist, emphasizing the importance of ongoing research and quality improvement. Universal adoption of apneic oxygenation is critical, particularly in vulnerable populations such as obese patients, pregnant women, children, the critically ill, and during rapid sequence induction, yet uncertainties remain regarding optimal techniques for pediatric intubation and ideal oxygen delivery parameters. Future investigations should prioritize refining risk stratification tools, enhancing preoxygenation and apneic oxygenation strategies, and designing cost-effective, durable airway devices adaptable to diverse clinical settings. Addressing the unique challenges of resource-limited environments requires tailored training, equipment innovation, and collaborative knowledge-sharing networks to strengthen global airway safety. Sustainable capacity building, empowerment of local healthcare providers, and rigorous evidence generation are essential to establish context-specific best practices. Ultimately, advancing airway management will depend on a multidisciplinary, patient-centered approach that integrates technological innovation, human factors, and continuous quality improvement to ensure safer outcomes across anesthesia and ENT care.

### Authors' contribution

**Conceptualization:** Farzin Davoodi and Malihe Abniki

**Data curation:** Malihe Abniki and Zahra Abbasi.

**Investigation:** Farzin Davoodi and Zahra Abbasi.

**Supervision:** All authors.

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**Writing—original draft:** All authors.

**Writing—review and editing:** All authors.

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The authors declare that they have no competing interests.

### Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors utilized Grammarly and Copilot to refine grammar points and language style in writing. Subsequently, the authors thoroughly reviewed and edited the content as necessary, assuming full responsibility for the accuracy

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