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AIRWAY MANAGEMENT (LC BERKOW, SECTION EDITOR)

Complications of Airway Management

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Abstract

Purpose of Review Despite notable advancements in technology and monitoring, coupled with the dissemination of guidelines, complications associated with airway management persist. This comprehensive review delves into the most prevalent complications, exploring their incidence rates, identifying associated risk factors, and proposing reduction strategies. Drawing insights from recent closed claims analyses, comprehensive reviews, and established guidelines, this review aims to provide a contemporary understanding of the challenges in airway management.

Recent Findings Notwithstanding the progress in technology and adherence to guidelines, serious complications persist, particularly in emergent situations and non-operating room settings. The evolving landscape of medical practice has witnessed a substantial rise in anesthetic procedures conducted outside the traditional operating room environment. Concurrently, the patient demographic for these procedures has shifted towards individuals with heightened medical complexities, amplifying the susceptibility to complications.

Summary The key to mitigating the risk of complications lies in conducting a thorough airway assessment, meticulously planning for potential difficulties and failures, and proactively anticipating complications. Notably, the surge in non-operating room procedures and emergency settings necessitates an equivalent level of preparation and patient assessment as observed in the traditional operating room. This includes the deployment of identical equipment and support. The integration of Airway Leads assumes significance in this scenario, contributing significantly to the standardization of equipment and procedures across the hospital. Their role also extends to education initiatives aimed at enhancing airway safety and reducing complications hospital-wide.

Keywords Intubation · Extubation · Hypoxia · Aspiration · Bronchospasm · Laryngospasm

Introduction

Despite notable advancements in technology and monitoring, coupled with the dissemination of guidelines, complications associated with airway management persist. Complications can occur with any type of airway intervention, including mask ventilation, intubation, and extubation, and can be immediate or delayed. Mechanical or traumatic complications can occur as a result of the placement or removal of an airway device, but hemodynamic and physiological complications can also occur. The consequences of these complications can be minor, such as sore throat or soft tissue injury, but can also be more serious, even resulting in brain damage or death.

Incidence and Risk Factors

Minor complications related to airway management are common, while major complications are rarer. The American Society of Anesthesiologists (ASA) Closed Claims Program publishes airway related complications reported to their database. The closed claims analysis published in 2011 reported that 17% of claims were due to respiratory events associated with airway management, of which 6% were direct airway injury [1]. A more recent publication from this program in 2019 reported an increase in airway-related complications in nonoperating room locations and a higher incidence of death associated with airway-related claims [2]. Of note, two-thirds of complications occurred during intubation and one-third at extubation or in recovery. The authors

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also reported that despite the publication of guidelines, a common factor in reported claims was inadequate airway assessment or failures in judgement, such as delaying placement of a supraglottic airway or invasive emergency airway access [2].

The 4th National Audit Project (NAP4), published in 2011, was an impressive collection by the Difficult Airway Society and the Royal College of Anaesthetists of airway-related complications over a one-year period in the UK [3••]. The results of this project had an enormous impact, and launched the publication of new guidelines, as well as the Airway Leads Network [4]. Major complications, such as death or brain damage, were found in 1 out of 21,598 reported cases, with higher incidences outside the operating room setting. A more recent study in the UK using similar methods found similar complication rates and a higher incidence of complications in patients predicted to have a difficult airway [5]. The recently published 7th National Audit Project (NAP7) of the UK studied perioperative cardiac arrest events and found that airway- and respiratory-related complications were the causative factors for 13% of cardiac arrests and 9% of deaths [6].

Both the ASA Closed Claims Database and the NAP4 project found several risk factors/themes associated with complications, such as obesity, and a higher rate of complications both outside the operating room setting and for emergency airway management. Complications in the NAP4 project were also higher during off hours (such as evenings and weekends) and associated with incomplete airway assessment, as well as failure to create back-up airway plans and to "plan for failure" [7]. In general, risk factors can be patient related or situation related (see Table 1) [1, 2, 4].

Physiological Complications

The administration of medications to facilitate airway management as well as the procedures of laryngoscopy and intubation can cause a variety of physiological complications. Inadequate ventilation or oxygenation or hemodynamic changes can result in hypoxia, arrhythmias, hemodynamic instability, and even cardiovascular collapse or death [7–9].

Hypoxia

Hypoxia can occur during difficult or failed intubation due to inadequate oxygenation or ventilation, as the patient is usually (but not always) rendered apneic during airway management. Hypoxia can also occur due to intrinsic causes, such as bronchospasm, laryngospasm, aspiration, or airway obstruction. Unrecognized esophageal intubation can also result in hypoxia. Hypoxia can result in hypercapnia and acidosis, which can trigger arrhythmias and neurological injury. If untreated, hypoxia can ultimately lead to other complications such as hypotension, brain damage, cardiac arrest, and death [7]. Mort et al. found that over 70% of patients requiring airway management in the intensive care unit (ICU) setting experienced hypoxia, and 1 in 50 experienced cardiac arrest [8]. Patients with increased oxygen demand or reduced oxygen delivery may not tolerate even a short period of apnea and are at higher risk of developing hypoxia during airway management; this type of patient is termed a "physiologically difficult airway" [10•].

Several strategies can be employed to reduce the risk of hypoxia during airway management. "Peri-oxygenation," or the application of supplemental oxygen throughout airway management starting prior to induction of anesthesia or administration of sedating medication, can delay desaturation during periods of apnea [11]. This strategy has been recommended by several guidelines and societies, including the ASA, the Difficult Airway Society, and the Society for Airway Management, especially for patients at higher risk [12••, 13•, 14•]. Peri-oxygenation can be delivered via low-flow or high-flow nasal cannula, nasal continuous positive airway pressure, or high-flow humidified oxygen systems via the nose, allowing for continuous oxygen delivery (apneic oxygenation) during laryngoscopy and intubation [15, 16]. Several studies show that hypoxia events are lower with the use of video laryngoscopy compared to direct laryngoscopy [17–19].

Table 1 Risk factors for airway-related complications

Patient-related factors	Situation-related factors
Obesity	Emergency airway management
Airway exam characteristics associated with difficulty	Multiple intubation attempts
Physiological difficulty	Airway management outside the operating room
Increased oxygen demands	Poor planning for airway management
Decreased oxygen delivery	Re-intubation after failed/unplanned extubation
Respiratory insufficiency	Human factors
Coagulopathy	Lack of situational/time awareness
	Task fixation

Hemodynamic Changes

Hemodynamic changes can occur due to medications given to facilitate intubation, the patient's underlying physiological condition, or failure to secure the airway and the hypoxia that then ensues. Hypotension is common as the majority of medications used to facilitate intubation cause vasodilation, and critically ill patients who require intubation may already be hypovolemic or hypotensive at the time of airway management or have preexisting reduced cardiac function [13•]. The causes of hypotension are multifactorial and can also be caused by the transition from spontaneous to controlled ventilation which can result in decreased venous return. Hypotension has been reported in over 50% of critically ill patients during airway management, and, if untreated, it can progress to cardiac arrest [8, 20]. Two recent studies—the International Observational Study to Understand the Impact and Best Practices of Airway Management in Critically Ill Patients (INTUBE) and Preoperative Exercise to Decrease Postoperative Complication Rates and Disability Scores (PREPARE) trials—investigated the use of fluid boluses as well as vasopressors to reduce hemodynamic changes such as hypotension during airway management [21, 22]. Unfortunately, neither study found that either strategy was effective in reducing cardiovascular instability during airway management in critically ill patients. Medications such as etomidate or ketamine may be considered for sedation as they are less likely to cause hypotension or depressed cardiac function [23•].

Manipulation of the airway during laryngoscopy and intubation can also trigger sympathetic and parasympathetic stimulation, resulting in tachycardia, hypertension, or arrhythmias, especially in a critically ill patient who may not tolerate deep sedation for the procedure [10•, 20]. These hemodynamic responses can potentially lead to myocardial ischemia or a cerebrovascular accident if severe and not treated. Adequate sedation prior to laryngoscopy can mitigate these responses but should be titrated carefully in the critically ill patient to avoid hypotension. Several studies show that the use of video laryngoscopy or a supraglottic airway may trigger less of a hyperdynamic response compared to direct laryngoscopy [17, 19, 24].

Bradycardia during airway manipulation is more common in neonates and children, due to increased vagal tone, but can occur in adults as well. However, the most common cause of bradycardia in both children and adults is hypoxia [25]. For this reason, the first treatment of bradycardia should be the correction of hypoxia. Once that is ruled out, other causes can be investigated and treated. Succinylcholine can also be a cause of bradycardia in children as well as adults if they receive repeated doses [25].

More severe arrhythmias, such as supraventricular tachycardia, ventricular tachycardia, ventricular fibrillation, and cardiac arrest are less common but can occur with prolonged hypotension or hypoxia [20, 21]. Critically ill patients are at higher risk for these more severe arrhythmias, and cardiac arrest was reported in over 50% of these patients in the NAP4 report and in 43% of patients in the INTUBE study [4, 21]. Providers should be prepared to initiate advanced cardiovascular life support protocols to manage these arrhythmias, especially in the emergent setting or for the critically ill patient.

Most physiological complications can be mitigated or prevented by maintaining oxygenation throughout airway management, as well as careful selection of medications for sedation. Close attention to the patient's hemodynamic status and fluid and pressor resuscitation may also prevent hemodynamic complications, although the evidence is unclear as to the success of these strategies [21, 22].

Mechanical/Traumatic Complications

Sore Throat

Sore throat commonly occurs after placement and removal of an endotracheal tube or supraglottic airway, with an incidence between 14 and 60% in the literature [26–28]. Symptoms vary widely; most are minor and resolve within 24 to 48 h and can include pain, soreness, cough, hoarseness, or dysphagia [28]. Sore throat may be caused by trauma during laryngoscopy or due to irritation or injury to the mucosa from the airway device itself or during suctioning. Several risk factors have been linked to sore throat after airway management, such as the use of a larger endotracheal tube, higher cuff pressures, coughing during emergence, use of a double lumen tube, or intubation without the use of neuromuscular blockade [27, 29]. The use of a cuff manometer to measure cuff pressures has been linked to a lower incidence of sore throat, and some supraglottic airway devices are now marketed with a built-in manometer device to measure cuff pressures [30, 31]. Other pharmacological strategies to reduce sore throat have been described, such as lidocaine applied either topically to the endotracheal tube or sprayed onto the vocal cords, lozenges, steroids, and topical benzydamine [32, 33]. Currently, the evidence to support any of these pharmacological strategies to prevent sore throat is varied and unclear [32–34].

Soft Tissue/Dental Injury

Traumatic injuries to soft tissues of the oropharynx and dentition can occur during airway management. Dental injuries are one of the most common causes of legal complaints [35, 36]. Teeth, especially if they are loose or decayed, can be further loosened, cracked, or dislodged during intubation or extubation or as the result of a bite block placed during a

procedure [35]. A dislodged tooth is at risk of becoming aspirated into the trachea, so it should be located and removed to avoid this complication. Dislodged teeth should be placed in saline, and a dental consult as well as discussion with the patient should be done postoperatively [35, 36]. It is good practice to discuss potential risks preoperatively with patients who demonstrate poor dentition or loose teeth [37]. The use of a mouthguard has been suggested to prevent dental injury, but their effectiveness is still controversial [35, 36].

Other injuries to the soft palate, tongue, tonsils, and uvula have also been reported and if severe can potentially cause airway edema or even obstruction [1]. Injuries to the palate and tonsils have been reported during endotracheal tube placement during video laryngoscopy [38]. The vocal cords and arytenoids can also be injured during placement of an airway device and can result in hoarseness or dysphonia [39]. Longer-term intubation has been associated with the development of vocal cord granulomas, vocal cord paralysis, and subglottic stenosis, all of which may require further treatment or repair [39]. Nasal intubation can be complicated by bleeding, nasal trauma, or infection [40].

Rarer Traumatic Injuries

Rarer traumatic injuries have been reported in association with airway management, such as temporomandibular joint dislocation, cervical spine injury, and barotrauma or pneumothorax due to high positive pressures [40, 41]. Barotrauma in intubated patients suffering from the COVID-19 virus has been recently reported as a potential complication [42]. A recent case report described a cervical spine injury in a patient with ankylosing spondylitis during a challenging intubation using video laryngoscopy [43].

Aspiration

Aspiration during airway management can occur in the setting of a full stomach due to the loss of airway reflexes and relaxation of the lower esophageal sphincter allowing gastric contents to potentially enter the trachea and lungs. Rapid sequence intubation has been routinely performed to reduce this risk [23•]. The use of cricoid pressure to reduce aspiration risk continues to be controversial as a strategy with weak evidence to support its use, and many providers have abandoned its routine use [44, 45]. The recent widespread use of glucagon-like peptide-1 (GLP-1) agonists for weight loss has resulted in higher concerns over the presence of a full stomach and increased aspiration risk in fasted patients on these medications presenting for surgery [46]. The ASA recently published a consensus statement recommending that patients hold these medications for 1 week prior to surgery, and if a patient exhibits symptoms suggestive of a full stomach (nausea, vomiting, bloating, abdominal pain), the physician should consider postponing the procedure or performing gastric ultrasound to assess for gastric contents [46]. The use of gastric ultrasound preoperatively for any patient at risk of aspiration can be performed to determine the need for a rapid sequence intubation, and this practice has been increasing with the wider availability of point-of-care ultrasound devices [47].

Bronchospasm and Laryngospasm

Bronchospasm can be triggered during instrumentation of the airway and is more common in patients with reactive airway diseases such as asthma, chronic obstructive pulmonary disease, and acute respiratory illnesses/infections [48, 49]. Patients who chronically smoke or vape are also at higher risk. Anaphylaxis can also present as bronchospasm, which can present as wheezing, decreased oxygen saturations, high peak airway pressures, and a drop or loss of end tidal carbon dioxide. The newer reversal agent sugammadex has been associated with bronchospasm [50]. Treatment as well as prevention of bronchospasm include insuring an adequate depth of anesthesia and bronchodilators [48, 49].

Bronchospasm as well as laryngospasm are quite common in children undergoing airway management [48]. Laryngospasm can occur during airway management and after extubation due to laryngeal stimulation or secretions. It usually resolves with positive pressure ventilation but may require administration of a muscle relaxant or reintubation of the airway after extubation if severe. A recent meta-analysis reported the effectiveness of dexmedetomidine in reducing laryngospasm as well as agitation in children undergoing anesthesia [51]. The recently published NAP7 examined perioperative complications and found laryngospasm to be the most common reported airway complication (37%) [6].

Esophageal Intubation

Despite advances in monitoring and technology, unrecognized esophageal intubation still occurs and can result in hypoxia, hypercarbia, brain damage, and even death [1, 2, 3••]. The NAP4 found that 6% of airway-related complications were due to unrecognized esophageal intubation [3••]. The Project for the Universal Management of Airways, an international society of airway experts from several airway societies, recently published guidelines for the prevention of unrecognized esophageal intubation [52••]. These guidelines recommend the use of universal waveform capnography to confirm endotracheal intubation and state that the lack of a sustained waveform pattern for at least seven breadths ("no trace = wrong place") should prompt an immediate evaluation to assess if the endotracheal tube is in the trachea or in the esophagus [52••, 53]. These guidelines also recommend the use of video laryngoscopy, which has

been demonstrated to reduce the incidence of unrecognized esophageal intubation. Severe bronchospasm or cardiac arrest can also result in the lack of exhaled carbon dioxide and can be confounding complications that need to be recognized early and managed once esophageal intubation has been ruled out with confirmation of correct tube placement.

Unplanned Extubation

Unplanned extubation can occur in the operating room, ICU, or emergency department (ED) setting. It can occur as a result of external forces on the endotracheal tube, as can occur during movement of the patient that results in dislodgement of the tube, or a self-extubation where the patient removes the tube prematurely [54]. Unplanned extubation can result in hypoxia, hypercarbia, hemodynamic instability, arrythmias, and even brain damage or death, especially if reintubation is challenging or delayed [55]. Signs of accidental extubation may include hypoxia and oxygen desaturation, decrease or loss of capnography, or a sudden loss of tidal volume or presence of a leak around the tube. Risk factors for unplanned extubation include lack of adequate securement of the endotracheal tube, transport or change in position of an intubated patient, and lack of adequate sedation or restraints, as well as inadequate staffing in the ICU or ED, especially during changes in patient position. Several strategies have been recommended to reduce the risk of unplanned extubation, such as protocols for turning of patients, protocols for adequate sedation, the use of continuous capnography for all intubated patients, and protocols for weaning and extubation in the ICU setting [56].

Strategies for the Prevention of Complications

Many airway-related complications can be prevented with a thorough airway assessment, anticipation of airway difficulty, and the creation of back-up plans and planning for failure. The most recent version of the ASA Practice Guidelines for Management of the Difficult Airway places a larger emphasis on airway assessment and planning and includes several new infographics to guide airway managers in the prediction of risk and stratification to either awake or asleep airway management [12••]. These guidelines also highlight several strategies to improve airway management (Table 2). One of the new infographics from these guidelines also recommends that if difficulty is suspected with laryngoscopy, mask ventilation, supraglottic airway placement, or surgical airway, or if there is an increased risk of aspiration or rapid desaturation, an awake intubation should be considered.

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 [57, 58•, 59•]. Simulation can be a valuable tool to practice difficult airway management, review algorithms, and ensure familiarity with airway equipment without any risk of patient harm [60–63]. Airway mannequins, including those designed to practice surgical airway techniques, can be used to practice emergency airway procedures that may not be commonly performed clinically to allow for familiarity and potentially reduce complications when they are performed on an actual patient during an emergency [58•]. Several virtual reality simulators now exist for training on flexible bronchoscopic intubation, direct laryngoscopy, and surgical cricothyrotomy [61, 62]. These simulators are portable, so they do not require a dedicated simulation space or scheduled session, allowing for easy and repeated access by many providers in multiple locations with minimal interruptions to clinical workflow and no risk of patient harm. With the increased emphasis on shift work and compliance with duty hours, as well as the increasing reliance on video laryngoscopy, there is concern that trainees are not performing as many advanced airway management techniques as may be required during an airway emergency [64]. Simulation and virtual reality may be a solution to bridge this gap.

In the USA, many hospitals have developed airway response teams to manage both planned and unplanned difficult airways, addressing standardization of both equipment and personnel, with significant impacts on patient safety and a reduction in complications [58•, 59•, 65, 66]. The Difficult Airway Society developed the concept of an "Airway Lead Network" consisting of a designated provider who coordinates and leads standardization of airway equipment and educational programs related to airway management and identifies and addresses gaps in knowledge and equipment to improve practice [67]. This concept has been widely implemented in the UK, with Airway Leads established in 97% of hospitals. The Society for Airway Management has established a special project dedicated to the creation of a similar Airway Leads Network in the USA [68]. The goal of the Airway Leads Network is to ensure that every airway provider has the tools and skills they need to manage an airway successfully, no matter how difficult [69].

Table 2 Recommendations from the ASA difficult airway guidelines

Optimize oxygenation and deliver oxygen throughout airway management
Limit attempts and consider calling for help
Be aware of the passage of time
Stay time, attempt, and SPO_2 aware
Avoid task fixation
Consider awake intubation if:
Suspected difficulty with: mask ventilation, supraglottic airway placement, laryngoscopy, or surgical airway
Increased risk of rapid desaturation or aspiration

Conclusions

Despite recent advances in airway technology and the publication of numerous guidelines, complications related to airway management continue to occur. A thorough airway assessment, planning for difficulty and failure, and anticipation of complications can potentially mitigate the risks of adverse events. Hypoxia is an underlying cause of many complications, and newer guidelines emphasize the value of providing oxygenation throughout airway management to mitigate this risk.

The increasing trend toward procedures requiring anesthetic and airway management outside of the operating room, often on sicker patients, has resulted in increased rates of airway-related complications during these procedures. Preparation and patient assessment for anesthetic and airway management outside the operating room and for emergency procedures should be the same as in the operating room, including the same equipment and support. Providers should maintain and practice airway skills with a variety of airway management techniques, and simulation can be a valuable tool for practice. Airway Leads and the use of simulation can play an important role in education and standardization of equipment and procedures throughout the hospital to improve airway safety and decrease complications.

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Compliance with Ethical Standards

Competing interests Dr Berkow currently serves as the Section Editor for the Airway Management Section of Current Anesthesiology Reports.

Dr Berkow serves on the Teleflex Medical Advisory Board and the Masimo Scientific Advisory Board.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by the author.

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- • Of importance
- •• Of major importance

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