AIRWAY MANAGEMENT

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Airway Management Outside the Operating Room Environment

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Emergency airway management outside the operating room setting is a challenge for anesthesiologists. This review discusses the increased risks and problems that anesthesia providers may face when managing these patients, and provides guidance on how to prepare for their management.

Results of the American Society of Anesthesiologists (ASA) Closed Claims Project database and the 4th National Audit Project (NAP4) from the United Kingdom have demonstrated an increased incidence of airway-related complications associated with airway management outside the operating room and in the emergent setting.[1,2] The NAP4 report found that 61% of airway events in the ICU setting resulted in brain damage or death (Table 1).[1] The ASA Closed Claims Project database analysis of adverse events outside the operating room found that respiratory-related events were twice as common in remote locations as in the operating room (44% vs 20%) and most often caused by inadequate oxygenation or ventilation.[2]

Challenges of Emergent Airway Management

Most patients who require emergent airway management are critically ill, often with significant comorbidities

that can affect hemodynamic stability and pulmonary reserve. Outside the operating room setting, available equipment and personnel can be quite variable, and the space in which to provide airway management also can be limited. These factors should be considered when preparing for and providing airway management for these patients.

The incidence of difficulty in airway management is significantly higher outside the operating room setting, and complications such as hypoxemia, aspiration, and cardiac arrest are much more common.[3,4]

The Importance of Oxygenation

Maintaining oxygenation and ventilation in a critically ill patient who requires intubation can be challenging, especially in patients who already require supplemental oxygen, continuous positive airway pressure (CPAP), or bi-level positive airway pressure (BiPAP) (Figure 1). Reduced oxygen reserve may be due to a variety of factors: anemia, low cardiac output, ventilation/perfusion mismatch, cardiopulmonary pathology, obesity, or reduced respiratory effort.[5,6] A study by Mort demonstrated that critically ill patients do not tolerate interruptions in supplemental oxygen delivery and therefore are at high risk for hypoxemia during airway interventions.[7] Mort found that preoxygenation in this patient population for 4 to 8 minutes did not result in a significant increase in arterial oxygen concentration or prevent hypoxemia during airway management. Patients who cannot achieve oxygen saturation above 95% with preoxygenation have a high likelihood of desaturation during the period of apnea and intubation.[8]

Techniques for Oxygenation

A variety of methods exist for preoxygenation before airway management (Figure 1). Routine methods in a spontaneously breathing patient include

Table 1. NAP4 Results[1]

Prospective study of airway-related adverse events over a 1-year period of 300 hospitals in the United Kingdom.
61% of airway events in the ICU resulted in death or brain damage.
Common Themes:
Almost 50% of cases in obese patients
Large number of events occurred during off-hours
Lack of capnography, lack of needed equipment
Lack of experienced personnel, inadequate training
Delayed recognition of high-risk patients
Lack of backup plans for management

NAP4, Fourth National Audit Project

Table 2. Methods of Oxygen Delivery And Approximate FiO_2 Delivered

Delivery Method	Oxygen Flow, L/min	Approximate FiO_2 Delivered
Nasal cannula	1-6	0.24-0.44
Face mask	6-12	0.35-0.65
Face mask with reservoir	6-15	0.60-0.80+
Face tent	8-12	0.28-1.00

FiO_2, fraction of inspired oxygen

Figure 1. Methods of oxygen delivery.

Left to right: nasal cannula, face mask, face mask with a reservoir bag, face tent, BiPAP/CPAP (Flow-Safe CPAP device, courtesy of Mercury Medical).

BiPAP, bi-level positive airway pressure; **CPAP,** continuous positive airway pressure

oxygen delivery via a nasal cannula or face mask with or without a reservoir bag ("non-rebreather"). The inspired oxygen delivered to the patient depends on the method employed (Table 2). Positive airway pressure can be added either continuously (CPAP) or intermittently during inspiration (BiPAP) to relieve partial airway obstruction and increase the inspired oxygen, a technique often employed for patients with obstructive sleep apnea. Preoxygenation in the head-elevated position is recommended whenever possible.[9] The addition of passive nasal oxygenation via a high-flow nasal cannula also has been reported to extend the period of safe apnea and prevent desaturation during intubation attempts.[9,10]

Nonbreathing patients will require bag-valve-mask ventilation by the airway provider. If ventilation is difficult, adjuncts that can assist include nasal airways, oral airways, jaw thrust, or two-person mask ventilation (Figure 2). If these maneuvers fail, placement of a supraglottic airway device (SAD) can be lifesaving.[11]

Novel Oxygenation Techniques

Some novel methods for oxygenation have been introduced to the market (Figure 3). The Optiflow device (Fisher & Paykel Healthcare) delivers humidified high-flow nasal oxygen at a rate up to 30 L per minute, and can be applied to both the awake and sedated/apneic patient to deliver supplemental oxygen.[12,13] The Super-NO_2VA device (Revolutionary Medical Devices) delivers nasal positive-pressure and high-flow oxygen via a mask that fits over the nose. Both of these new devices can deliver nasal oxygen during airway management, unlike the traditional CPAP or BiPAP mask, and may potentially prolong apnea times in high-risk patients. The recently revised Difficult Airway Society guidelines for difficult airway management recommend the use of apneic oxygenation techniques for high-risk patients.[14]

Important Questions to Ask

When called to provide airway management in the emergent setting or outside the operating room, after obtaining as much history about the patient as possible, there are several important questions to ask to assist in creating a safe plan for airway management:

- First, how stable is the patient, and how much time is there to prepare for the intubation? This can affect the ability to obtain additional equipment and personnel support.
- Next, might mask ventilation, SAD placement, or intubation be difficult? These questions can help guide the creation of backup plans.
- Finally, what resources are necessary to manage the patient? Are they readily available? Who can be called to assist? How much time is needed to assemble additional personnel and/or equipment? If the patient is stable and personnel and/or equipment on-site are inadequate, it is reasonable to consider relocation to the operating room, if that option exists.

Figure 2. Jaw thrust maneuver (top) and two-person mask ventilation maneuver (bottom).

Figure 3. The SuperNO_2VA nasal CPAP device (left) and the Optiflow device (right).

Courtesy of Revolutionary Medical Devices, Inc, and Fisher & Paykel Healthcare Limited.

CPAP, continuous positive airway pressure

Planning and Backup Plans: Assessment, Equipment, and Personnel

Assessing for Difficulty

When planning for airway management in the emergent setting, in addition to asking the previously discussed questions, it can be helpful to attempt to *predict difficulty*. Many studies have examined the reliability of descriptive preoperative airway assessments, but no single diagnostic test has been demonstrated to be highly specific or sensitive.[15,16] Some of the challenges of accurate prediction are lack of consensus for the definition of "difficult intubation" and the relatively low incidence of difficulty, even in high-risk populations. Research has found that the risk of preparing for a difficult intubation that turns out to be straightforward is low, but the risk of being unprepared for an unanticipated difficult intubation is high, so it is preferable to err on the side of caution.[15-17] Tables 3 and 4 list several patient characteristics that have been associated with difficult airway management.[15-19]

It is important to assess for potential difficulty not only with intubation but also with ventilation, as hypoxemia is a common complication in these patients. The MACOCHA score (**M**allampati, **A**pnea syndrome, **C**ervical spine limitation, **O**pening mouth less than 3 cm,

Table 3. Risk Factors for Difficult Mask Ventilation

Increased body mass index
History of snoring/obstructive sleep apnea
Presence of a beard
Lack of teeth
Age >55 y
Mallampati score III or IV
Limited mandibular protrusion test
Male gender
Airway masses/tumors/radiation

Table 4. Risk Factors for Difficult Laryngoscopy

History of difficult laryngoscopy
Difficult mask ventilation
Obesity/obstructive sleep apnea
Limited mouth opening
Mallampati score III or IV
Decreased thyromental distance
Decreased sternomental distance
Limited head and neck extension
Increased neck circumference

Table 5. The MACOCHA Score for Identifying Difficult Intubation In the ICU Setting

Factor	Points
Patient Related:	
Mallampati score III or IV	5
Obstructive sleep apnea	2
Reduced cervical spine mobility	1
Limited mouth opening (<3 cm)	1
Pathology Related:	
Coma	1
Hypoxia (SaO_2 <80%)	1
Operator Related:	
Nonanesthesiologist	1
Total	**12**

MACOCHA, Mallampati, **A**pnea syndrome, **C**ervical spine limitation, **O**pening mouth less than 3 cm, **C**oma, **H**ypoxia, **A**nesthesiologist untrained; **SaO_2,** oxygen saturation

Table 6. Recommended Equipment For an Airway Cart

Supraglottic airway devices
Video laryngoscope
Flexible bronchoscope
Endotracheal tubes of various sizes
Endotracheal tube guides/bougies
End-tidal carbon dioxide detectors
Equipment/supplies to perform a surgical airway

Coma, **H**ypoxia, **A**nesthesiologist untrained) has been described to predict difficult intubation in the ICU with 7 clinical factors (Table 5).[20] Scores above 3 were associated with an increased incidence of difficult intubation, and this score has been used by nonanesthesiologists to predict difficulty in the ICU setting.[20,21]

In the emergent setting, time may be limited to perform a thorough airway assessment, so a patient's intubation history also can be useful, especially if previous difficulty was encountered. The importance of airway planning, the creation of airway plans, and the gathering of needed personnel and equipment cannot be stressed highly enough. Both the ASA difficult airway guidelines and the NAP4 report stress the importance of obtaining adequate personnel and equipment.[1,11]

Equipment

Once the patient has been assessed and airway management plans have been created, it is very important to have the necessary equipment at the bedside, in working condition and ready for use. This should include devices for both oxygenation and intubation. Both the ASA Closed Claims Project database and NAP4 report recommend the use of airway carts to ensure that equipment for airway management is available in all locations when and where they may be needed.[11,22] Table 6 lists some of the airway equipment recommended to be included in these carts, similar to the devices and supplies that would be available inside the operating room.[22] In addition, a portable airway bag or smaller cart that could be brought to remote locations can be useful, especially when the available space is too small to accommodate a large cart (Figures 4 and 5). Standardization of airway equipment (and personnel) has been demonstrated to reduce airway-related adverse events.[23]

If a full complement of airway devices equivalent to what is available in the operating room is not possible due to limited resources, then SADs and a video laryngoscope, at a minimum, should be available when possible. SADs are recommended for rescue ventilation when intubation fails and play an important role in maintaining oxygenation.[11] Several studies have demonstrated increased first-pass success at intubation with a video laryngoscope in both the ICU and emergency department settings, as well as in the hands of less experienced airway managers.[24-26]

Creation of Backup Plans

A variety of published algorithms exist for the management of the difficult airway. The majority of these algorithms stress the importance of creating backup plans for airway management, including alternate methods for oxygenation, ventilation, and intubation (Figures 6 and 7).[11,14]

It has been argued that in an emergency situation, these algorithms may be too complex or not readily accessible for use during emergent, stressful situations.[27,28] The Vortex Approach is a "high-acuity implementation tool" created for anesthesia providers during emergent airway management, recommended by the Australian and New Zealand College

Figure 4. A portable airway management bag.

Courtesy of the University of Florida College of Medicine.

Figure 5. An airway cart.

Courtesy of the University of Florida College of Medicine.

American Society of Anesthesiologists®

DIFFICULT AIRWAY ALGORITHM

1. **Assess the likelihood and clinical impact of basic management problems:**
   - **Difficulty with patient cooperation or consent**
   - **Difficult mask ventilation**
   - **Difficult supraglottic airway placement**
   - **Difficult laryngoscopy**
   - **Difficult intubation**
   - **Difficult surgical airway access**
2. **Actively pursue opportunities to deliver supplemental oxygen throughout the process of difficult airway management.**
3. **Consider the relative merits and feasibility of basic management choices:**
   - **Awake intubation *vs.* intubation after induction of general anesthesia**
   - **Non-invasive technique *vs.* invasive techniques for the initial approach to intubation**
   - **Video-assisted laryngoscopy as an initial approach to intubation**
   - **Preservation *vs.* ablation of spontaneous ventilation**
4. **Develop primary and alternative strategies:**

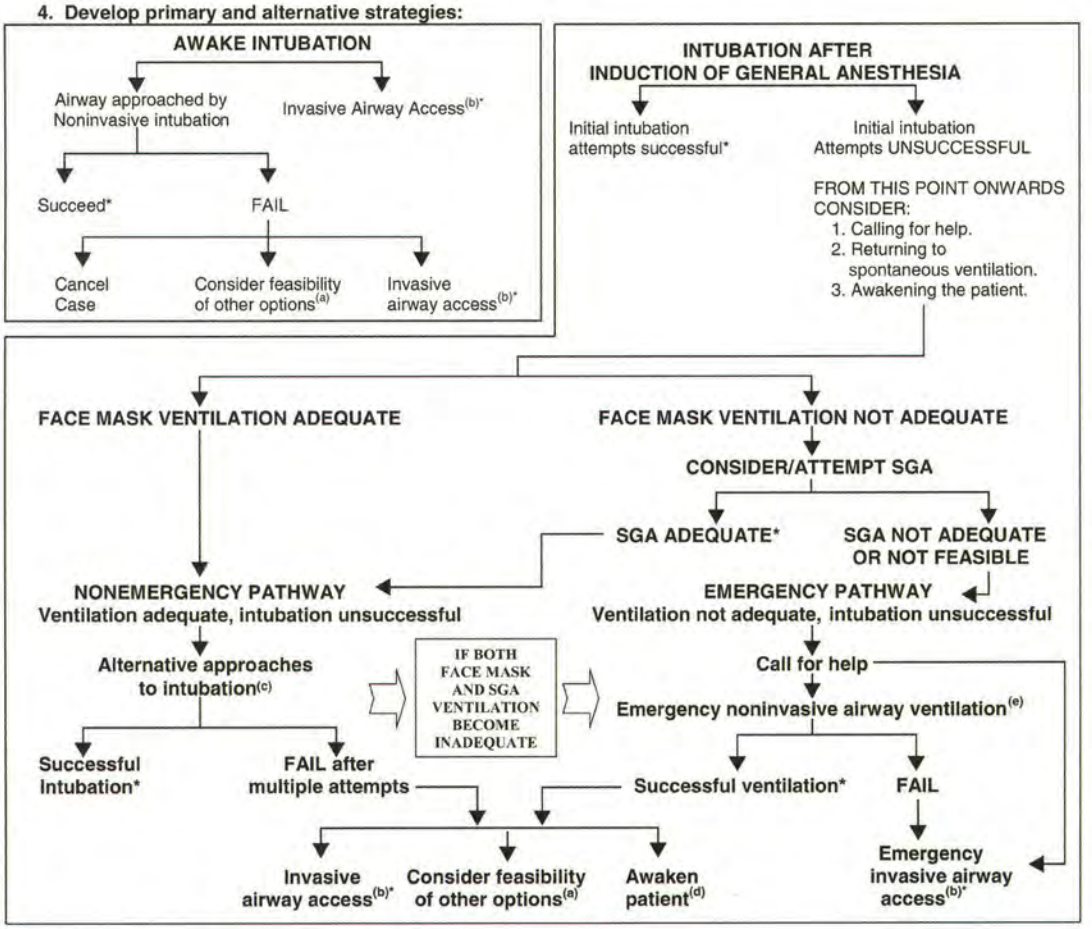


Figure 6. The 2013 ASA Difficult Airway Algorithm

*Confirm ventilation, tracheal intubation, or supraglottic airway (SGA) placement with exhaled CO_2.

a. Other options include (but are not limited to): surgery utilizing face mask or SGA anesthesia (e.g., LMA, ILMA, laryngeal tube), local anesthesia infiltration or regional nerve blockade. Pursuit of these options usually implies that mask ventilation will not be problematic. Therefore, these options may be of limited value if this step in the algorithm has been reached via the Emergency Pathway.

b. Invasive airway access includes surgical or percutaneous airway, jet ventilation, and retrograde intubation.

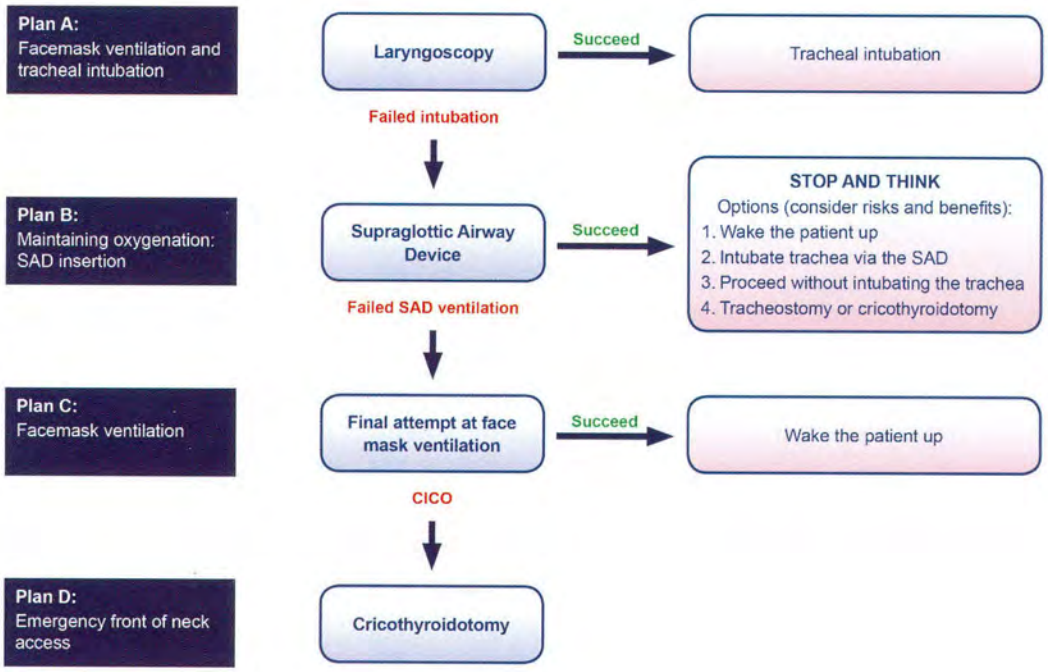
c. Alternative difficult intubation approaches include (but are not limited to): video-assisted laryngoscopy, alternative laryngoscope blades, SGA (e.g., LMA or ILMA) as an intubation conduit (with or without fiberoptic guidance), fiberoptic intubation, intubating stylet or tube changer, light wand, and blind oral or nasal intubation.

d. Consider re-preparation of the patient for awake intubation or canceling surgery.

e. Emergency non-invasive airway ventilation consists of a SGA.

Reprinted with permission, from Apfelbaum JL, Hagberg CA, Caplan RA, et al. Practice guidelines for management of the difficult airway: an updated report by the American Society of Anesthesiologists Task Force on Management of the Difficult Airway. *Anesthesiology*. 2013;118(2):251-270.[11]

Editor's note: Elsewhere SGA referred to as SAD (supraglottic airway device).



This flowchart forms part of the DAS Guidelines for unanticipated difficult intubation in adults 2015 and should be used in conjunction with the text.

Figure 7. The Difficult Airway Society 2015 Difficult Intubation Guidelines.

CICO, Cannot Intubate, Cannot Oxygenate; **SAD,** Supraglottic Airway Device
Reprinted with permission from the Difficult Airway Society (DAS).[14]

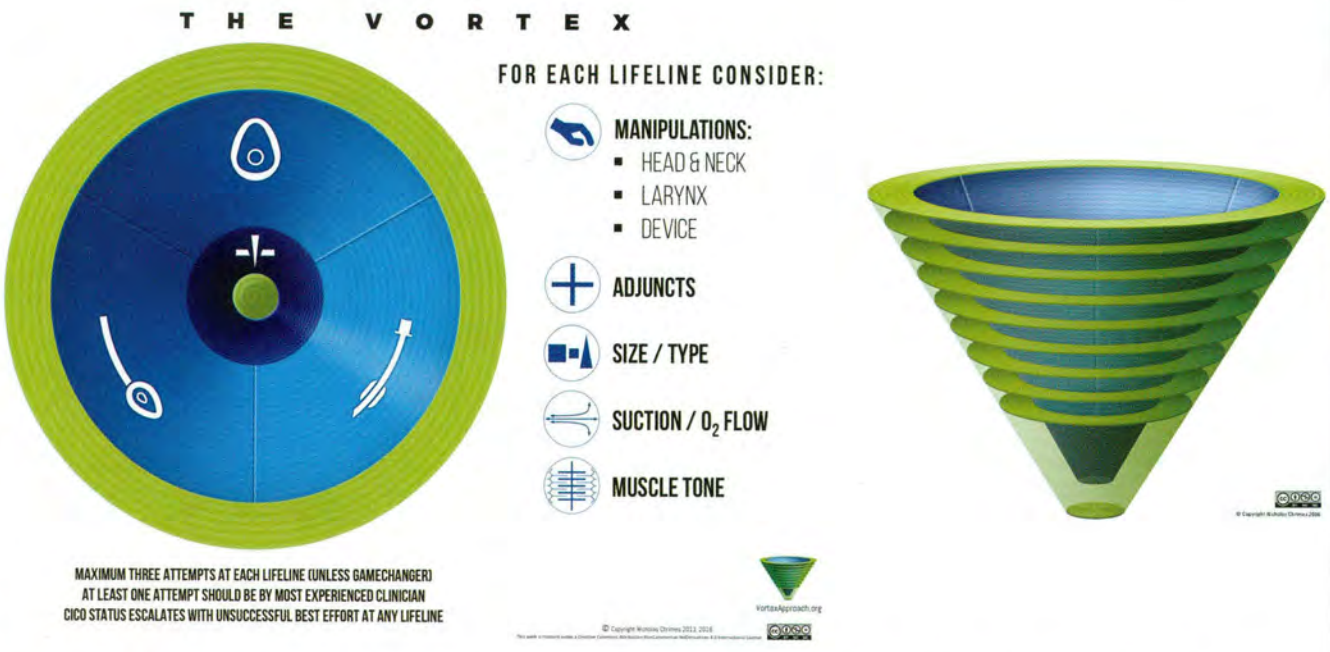


Figure 8. The Vortex Approach, view from above (left) and side view (right).

Reprinted with permission from Nicholas Chrimes, MBBS (Hons), FANZCA, creator of the Vortex Approach.[27]

of Anaesthetists.[27,28] Unlike more comprehensive algorithms, the Vortex Approach is a graphic model that advises up to 3 best attempts at 3 nonsurgical techniques: face mask ventilation, SAD placement, or endotracheal intubation. If these attempts fail, the Vortex model recommends a surgical airway, or "front of neck access" (Figure 8).

Personnel: Role of Multidisciplinary Teams

Additional personnel are important aspects of emergency airway management. They can assist with difficult ventilation and the implementation of backup plans. The inclusion of personnel from other specialties—such as surgery, otolaryngology, or emergency medicine—provides additional expertise as well as the ability to implement multiple backup plans, especially if a surgical airway is anticipated or necessary. Also, the collaboration and communication of a multidisciplinary airway team have been demonstrated to improve outcomes and reduce adverse airway events.[29,30]

What Is the Optimal Location for Airway Management?

In the majority of cases, airway management will occur in situ where the patient is located. However, if the patient is considered stable for transfer and the airway management team has concerns about the safety of managing the airway in the ICU or on the wards, transportation to the operating room, if available, may be considered. The operating room environment has several advantages: increased workspace, personnel familiarity with difficult airway management, and often a broader selection of airway equipment.

Case Examples

Angioedema

Angioedema is most often caused by medications, such as angiotensin inhibitors, but also can be caused by diseases including spontaneous urticaria or C1-inhibitor deficiency. Patients usually present to the emergency department with facial and tongue swelling, which can progress to the larynx, causing dyspnea or stridor. Airway management in these patients, both SAD placement and intubation, may be challenging. Therefore, it is preferable to secure the airway early before significant symptoms develop.[31] In some situations, close observation and corticosteroids may be appropriate if symptoms are mild. Nasal endoscopy or ultrasound can be useful adjuncts to assess the degree of laryngeal edema and guide management plans.[32,33] Awake fiber-optic intubation is a safe, conservative approach to airway management of these patients, ideally with a multidisciplinary approach. Significant laryngeal edema may require a smaller endotracheal tube. The majority of these patients are monitored in an ICU setting, with delayed extubation until resolution of the laryngeal edema.

Trauma Patients

Trauma patients provide a variety of challenges. These patients usually present to the emergency department with minimal history and unknown injuries that may cause hemodynamic compromise. In addition, approximately 2% to 5% of trauma patients present with a cervical spine injury.[34] Most trauma patients arrive in a cervical collar until an injury is ruled out; therefore, cervical spine precautions during airway management are usually required.

An airway assessment should be performed if time permits. The airway management plan will vary depending on the type of injury. Many trauma patients arrive intoxicated or combative, and airway management may be indicated in order to perform additional testing, such as CT or MRI. Administration of medications for intubation should be selected carefully, as they may worsen or cause hemodynamic instability. All trauma patients should be considered a "full stomach" and at risk for aspiration, so rapid sequence intubation is the most common method of intubation.

Cervical Spine Injury

Cervical spine precautions should be taken for any trauma patient with a suspected or known cervical spine injury. High cervical spine injuries (C3 or higher) may result in impaired or absent respiration, requiring emergent intubation.[35] If the patient is stable, moving the patient to the operating room for airway management can be considered, but these patients may require intubation while in the emergency department. Stabilization of the neck should be maintained during airway management, either via the cervical collar or via manual in-line stabilization (MILS) to minimize cervical spine movement during intubation. Visualization of the glottis may be more difficult in the presence of a cervical collar or MILS, increasing the risk for failed intubation.[36] MILS has been demonstrated to cause less cervical spine movement compared with the presence of a cervical collar.[36] Awake flexible scope intubation causes the least amount of cervical spine movement, but requires a cooperative, stable patient. Alternate airway devices,

Table 7. Airway-Related Changes During Pregnancy

Capillary engorgement of airway mucosa, leading to airway edema, nasal hyperemia, and increased tissue friability
Increased oxygen consumption and decreased functional residual capacity, leading to increased risk for desaturation during apnea
Gravid uterus, leading to increased risk for aspiration
Engorged breast tissue, leading to increased difficulty of laryngoscope placement

such as a video laryngoscope, should be immediately available in case difficulty is encountered.

Head Injury

Patients with a closed head injury may present with a range of symptoms: headache and dizziness, nausea and vomiting, seizures, speech or motor impairment, or altered or loss of consciousness. The Brain Trauma Foundation recommends securing the airway for any head injury patient with a Glasgow Coma Score less than 9.[37] Hypercarbia should be avoided and hyperventilation initiated after intubation if suspected intracranial hypertension exists.[38] Elevating the head of the bed during airway management and treatment of systemic hypertension also can prevent elevations of intracranial pressure. If a rapid sequence intubation is chosen—due to aspiration risk—theoretical concern exists over the use of succinylcholine causing increases in intracranial pressure, but use of a longer-acting muscle relaxant such as rocuronium will prolong apnea time as well as delay the ability to obtain a neurologic exam after airway management.[39,40]

Pregnant Patients

Airway management of pregnant patients can be challenging due to the physiologic changes that occur during pregnancy (Table 7). For this reason, airway-related events are one of the top 10 causes of maternal mortality, and the incidence of difficult intubation is higher in this patient population.[41,42]

Airway management is most often required during cesarean delivery, but pregnant patients also may present for airway management for other emergent scenarios, such as trauma or emergency surgery. If intubation for airway protection is not required, regional anesthesia is usually preferred if not contraindicated or insufficient for the procedure. If difficulty with intubation is suspected and the patient is stable, securing the airway while the patient is awake may be the safest option. Nasal flexible scope intubation, if selected, should be performed with caution due to the increased risk for epistaxis. Rapid sequence intubation is the most common method chosen for intubation after administration of general anesthesia due to the increased risk for aspiration. Hypoxia due to the inability to intubate or oxygenate will affect not only the mother but also the fetus. For this reason, SADs should be available for rescue ventilation and supersede the risk for aspiration in the presence of hypoxemia. Alternate airway devices, such as video laryngoscopes and flexible intubation scopes, also should be available due to the increased incidence of difficulty.

Airway Management During Cardiopulmonary Resuscitation

The most recently updated cardiopulmonary resuscitation (CPR) guidelines from the American Heart Association stress early initiation of chest compressions with minimal interruptions.[43] In addition, several studies have demonstrated no difference in survival when comparing CPR alone with CPR plus positive-pressure ventilation.[44,45] Current recommendations suggest that either an endotracheal tube or other advanced airway device, such as a SAD, should be placed with minimal interruptions in chest compressions. Continuous quantitative capnography is useful for both confirmation of endotracheal tube placement as well as detection of return of spontaneous circulation. Intubation may be difficult if attempted during chest compressions, so it is reasonable to maintain adequate mask ventilation and delay intubation attempts until chest compressions are paused. SADs that do not require visualization of the larynx may be easier to place during CPR. Hyperventilation should be avoided during CPR, as it has been associated with decreased survival rates.[46]

Conclusion

Airway management outside the operating room environment is more challenging and associated with higher complication rates. Patients requiring urgent/emergent airway management often are hemodynamically unstable and may have reduced pulmonary reserves, putting them at increased risk for hypoxia during intubation. Optimal attempts at preoxygenation, mobilization of additional resources and personnel, and availability of airway equipment are vital to ensure safe airway management in these patients. Newer and novel methods of oxygenation can be employed to maximize oxygen delivery during airway maneuvers. If available, a multidisciplinary approach is preferred. The creation of backup airway plans and use of algorithms and cognitive aids also are important steps. It is important to anticipate and prepare for difficulty to increase the chances of success and avoid complications.

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