Airway Management of Respiratory Failure

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KEYWORDS

- Airway management • Respiratory failure • Preoxygenation
- Rapid sequence intubation • Sedation • Difficult airway • Apneic oxygenation

KEY POINTS

- The decision to intubate a patient in respiratory distress is based on the physician's judgment as to whether the patient can maintain the airway, if ventilation and oxygenation are inadequate, and consideration of the expected clinical course.
- A careful evaluation of the patient's suitability to undergo the intubation process should occur before administration of sedative and neuromuscular blocking agents.
- Several distinct steps are followed in safely transitioning the awake, often unstable patient in need of an airway, to a sedated, stable patient with a secure airway.
- The key action in management of the airway is anticipation. Physicians should consider the barriers to airway control in advance, and be facile with the many techniques and technologies to rescue the airway should an unforeseen challenge arise.

Video showing Demonstration of the reduction in anatomic deadspace with high flow nasal oxygen accompanies this article at http://www.emed.theclinics.com/

INTRODUCTION

Diseases of the respiratory system are the reason for 1 in 10 emergency department visits, second only to injury and poisoning.[1] Further, nonrespiratory diagnoses, including overdose, cerebrovascular accident, shock, trauma, altered mental status, or upper airway compromise, may result in significant airway compromise or gas exchange derangements that require advanced airway management.[2–5] Although the proportion of these patients who require active airway management is unknown, this subset requires disproportionately more resources, skill, and expertise to correct a deteriorating course.

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THE DECISION TO INTUBATE

Patients in respiratory distress may describe heaviness, tightness, or squeezing sensation in the chest, or simply dyspnea at rest. Clinical signs of respiratory distress include tachypnea, accessory muscle use, intercostal retractions, paradoxic abdominal muscle use, wheezing, diaphoresis, tachy-dysrhythmias or brady-dysrhythmias, altered mental status, and hypoxia. Progression from respiratory distress to respiratory failure can evolve over minutes, and is characterized by the patient's inability to accomplish adequate gas exchange to maintain oxygenation and carbon dioxide elimination. That notwithstanding, there are likely no precise blood gas parameters that define the moment of intervention in respiratory failure. The decision to secure the airway in respiratory distress is rooted in 3 basic clinical questions[6]:

1. Is the patient able to maintain the airway?
2. Is ventilation or oxygenation inadequate?
3. What is the anticipated clinical course?

Is the Patient Able to Maintain the Airway?

What tools does the emergency physician have to evaluate the patient's ability to protect the airway? Several options exist, although none seem to provide clear answers as to when intervention is warranted. The Glasgow Coma Scale (GCS) is a time-honored, reproducible tool that does afford some guidance with extreme scores. The loss of the patient's gag reflex has been promoted as another indicator for the need to secure the airway. Despite the intellectual attractiveness of this notion, the presence or absence of the gag reflex has little to do with important outcomes, like aspiration pneumonia.

Since its introduction by Teasdale and Jennette in 1974,[7] the GCS has been widely used for prognostication in patients with altered mental status. It allows a quick assessment of altered patients and demonstrates good interrater reliability. Increasingly, it is widely used throughout a range of pathology to promote consistent communication across specialties, standardize observations, and suggest anticipated clinical course.[8,9] In the setting of trauma, a GCS of 8 or lower signifies coma. Eizadi-Mood et al[10] demonstrated aspiration pneumonitis was more likely in patients with low GCS (<6) in a population of poisoned patients undergoing gastric lavage. It is widely accepted that comatose patients are unable to maintain their airway and need definitive airway management.

But is a low GCS specifically reliable enough to guide the emergency physician in the decision to intubate? Rotheray and colleagues,[11] studied a Chinese population without predominance of intoxicants or trauma, and demonstrated a wide response of airway reflexes throughout a range of GCS scores, suggesting that patients with altered mental status *have significant risk of airway complications even with moderate or high GCS scores*.

In considering whether to intervene, should the emergency physician be reassured by an intact gag reflex? Maybe not. In 111 patients presenting with altered mental status, Moulton and colleagues[12] found absent gag reflexes at all GCS scores. The investigators emphasized that an absent gag reflex is a poor indicator of the need to intervene to prevent aspiration injury (ie, intubation), but should raise concern for "at-risk" airways.

In aggregate, the answer to the question, "Can this patient maintain the airway?" is not so straightforward. The emergency physician should be aware of the limitations of any single aspect of a patient's presentation. The ultimate answer to this first question will be informed by a careful evaluation of GCS, an assessment of the patient's gag reflex, and consideration of the entire clinical picture.

Is Ventilation or Oxygenation Inadequate?

The emergency physician is expected to recognize dangerous scenarios and intervene to reverse the downward spiral with strategies that often involve positive-pressure ventilation. For example, congestive heart failure worsens with pulmonary edema, anxiety, work of breathing, and hypoxia, and devolves into demand ischemia, catecholamine surge, hypertension, increased myocardial oxygen demand, and progressively poorer cardiac performance, ultimately resulting in circulatory arrest. Similarly, the dyspnea in bronchospasm (as in asthma) results in anxiety, increased work of breathing with concomitant worsening air trapping, ineffective alveolar ventilation, and hypercarbia with hypoxia, ultimately ending in fatigue and hypoventilatory cardiorespiratory arrest. In these scenarios, earlier intervention is favored while the patient can still tolerate hypoxia, acid-base disturbances, and hemodynamic instability, which often accompany the significant physiologic hurdle that is rapid sequence intubation (RSI).

What Is the Anticipated Clinical Course?

Emergency physicians may not be pressed to intubate a patient for airway protection or optimization of pulmonary function, but may consider intubation given what lies ahead. For example, a patient with altered mental status after a fall from height may have no trouble with airway protection, oxygenation, or ventilation. But this patient may not cooperate with c-spine protection, or have a need to travel away from the emergency department for long periods of time, or possibly require sedation for painful procedures. For any of these reasons, definitive airway management should strongly be considered. Similarly, specific disease entities that threaten the upper airway, such as trauma to the chest or neck (eg, expanding neck hematoma), infectious processes involving the oropharyngeal structures (eg, Ludwig angina), or late-developing airway compromise (eg, smoke inhalation), warrant contemplation of early airway intervention.

What Is the Role of Arterial Blood Gas Values in the Decision to Intubate?

Although the emergency provider may find it alluring to obtain arterial blood gas (ABG) measurements to inform the decision of whether or not to intubate, it is a temptation to be resisted. Oxygenation (S_aO_2) can often be reliably obtained with pulse oximetry (S_pO_2)[13] and even in hypoxic or shock states, oximetry remains clinically accurate.[14] Similarly, end-tidal carbon dioxide ($P_{ET}CO_2$) can be used as a noninvasive tool to evaluate arterial carbon dioxide (P_{aCO_2}) with good correlation.[15] Further, continuous capnography can produce waveform morphologies that can shine light on the underlying pathology (eg, bronchospasm), as well as trend impact of interventions (eg, noninvasive ventilation).[16]

If obtained, the emergency physician must be cautious regarding apparently reassuring ABG values. These values are simply a snapshot of the patient's physiologic condition, and cannot reflect dynamic improvement or deterioration like other bedside data. For example, poor air movement, fatigue, and worsening hypoxia mandate an escalation of efforts despite recent reassuring ABG values. Similarly, improved respiratory mechanics, less anxiety, and stabilizing S_pO_2 values indicate the success of interventions regardless of ABG values. In conclusion, despite the appeal of ABG values, the patient is better served by considering the entirety of the clinical picture in the decision to proceed with intubation.

IMPORTANCE OF FIRST-PASS SUCCESS

After the decision to intubate is made, the priority in adults is to optimize the chances to place a cuffed endotracheal tube through the vocal cords on the first attempt. That is, focus on first-pass success.

That first-pass success is associated with fewer adverse events is axiomatic. Adverse events in the peri-intubation period are defined in **Table 1**. An overall adverse event rate of 11% to 15% is reported,[3,17,18] meaning that the emergency physician should expect complications in the peri-intubation period once in every 8 patients. Sakles and colleagues[19] noted that the adverse event rate triples when more than one attempt is needed (1 attempt: 14.2% vs >1 attempt: 53.1%). A similar relationship was noted by Hasegawa and colleagues.[18] This should inform the mindset as preparations are made to intubate the emergency patient.

To ensure first-pass success, a careful evaluation must be undertaken to establish the patient's suitability for RSI. In some cases, RSI may not be the most appropriate technique to secure the airway. For example, if the physician anticipates a difficult airway and has both time and a cooperative patient, awake intubation may be pursued. On the other hand, in case of respiratory arrest, the patient may not need or tolerate RSI, and a crash airway is undertaken. But there is a broad expanse of patients between those extremes that require intervention to transition rapidly and

Table 1
Definitions of adverse events during intubation

Adverse Event	Definition
Oxygen desaturation[a]	Decrease in oxygen saturation ≥10% or <90%
Esophageal intubation	Improper placement of ETT in esophagus, reintubation required
Mainstem intubation	Radiographic identification of the tip of the ETT in a mainstem bronchus
Hypotension	Decrease in systolic blood pressure <90 mm Hg, unexplained by ongoing disease process or trauma
Aspiration	Presence of vomit at the glottis inlet visualized during intubation in a previously clear airway
Cardiac arrest	Pulseless dysrhythmia occurring during intubation
Cuff leak	Air leak around a cuffed ETT, controlled reintubation may be required
Accidental extubation	Accidental removal of endotracheal tube, immediate reintubation required
Laryngospasm	Adduction of the vocal cords preventing passage of the ETT through the glottis inlet
Dental trauma	Fracture or avulsion of a tooth during laryngoscopy
Dysrhythmia[b]	Bradycardia or any ventricular dysrhythmia
Pneumothorax	Radiographic identification of air in the pleural space, unexplained by ongoing disease process or trauma

In descending order of occurrence, based on frequency reported in Walls et al.[3]

Abbreviation: ETT, endotracheal tube.

[a] Various investigators define desaturation differently, and was not originally reported in Walls et al.[18,19,47]

[b] Tachycardia is not considered an adverse event.

Adapted from Sakles JC, Chiu S, Mosier J, et al. The importance of first pass success when performing orotracheal intubation in the emergency department. Acad Emerg Med 2013;20:73; with permission.

safely to a controlled airway. It is this patient population that benefits from an expeditious and competent march through the process culminating in a safely intubated patient. Careful preintubation evaluation and a well-conceived plan for securing the airway are the key elements in the management of patients who require intubation.

What Can Be Done to Improve Success When Securing the Airway?

Anticipation of the any difficulty ahead is the first priority. The typical patient requiring emergent airway intervention is physiologically marginalized. Once the physician administers sedative and paralytic agents, the risks to the patient increase. As protective airway reflexes are taken away, can the patient be readily intubated? When the patient's respiratory drive is suppressed, can the patient be ventilated using bag-mask ventilation (BMV)? If the patient cannot be intubated, can an extraglottic device (EGD) be placed to provide airway protection and oxygenation temporarily? If the patient cannot be intubated and cannot be oxygenated (ie, a "CICO" situation), can the physician provide a surgical airway to rescue the patient? It is wise then to evaluate the patient in light of these questions so as to anticipate difficulties before they arise?

Evaluation of Airway Difficulty

Some may consider evaluating the patient and simply assigning a Mallampati score for quick airway assessment before RSI, but this is likely not sufficient. An association between an increased Mallampati score and airway obstruction, limited mobility, or difficult intubation has not been established.[20] A systematic review of published literature found the sensitivity and specificity of the isolated Mallampati score to be inadequate for reliably predicting a difficult airway.[21]

The "LEMON" mnemonic emphasizes a systematic evaluation of patient characteristics that improve the physician's ability to predict difficult laryngoscopy and intubate with success. Elements of the prediction tool are illustrated in **Fig. 1** and include *Look* at the external features to form an impression of the difficulty; *evaluate* the anatomy of the airway using the 3-3-2 rule; assign a *Mallampati* score to the view of the posterior pharynx; identify airway *obstruction*, and degree of *neck* mobility.[22,23] Identifying at least one difficult airway criterion predicts adverse events in 1 of every 4 intubations.[19] Overall, utilization of tools, like the LEMON mnemonic, may encourage a more detailed presedation evaluation of the airway and identify barriers to successful airway management before problems arise.

Evaluation of Difficulty in Ventilating with Bag-Mask Ventilation

Evaluation of the patient appropriateness for bag-mask ventilation (BMV) is the next important consideration before undertaking RSI. Frequently, BMV is the rescue strategy after a failed intubation attempt. Not only is it critical for the emergency provider to master this skill, but also to ensure any assistants are skilled in the technique as well. Several patient characteristics can impede effective BMV and should be sought as part of a routine preparation for definitive airway management.[22,24] In an observational study of nearly half a million adult patients undergoing general anesthesia, Kheterpal and colleagues[25] demonstrated 13 patient characteristics that predict difficulty in BMV ventilation and direct laryngoscopy. "MOANS" is a simplified mnemonic that incorporates many predictive patient characteristics.[26] The MOANS tool has been promoted to help identify patients likely to be difficult ventilate via BMV techniques (**Table 2**).

L Look externally

Look at the patient externally for characteristics that are known to cause difficult laryngoscopy, intubation or ventilation.

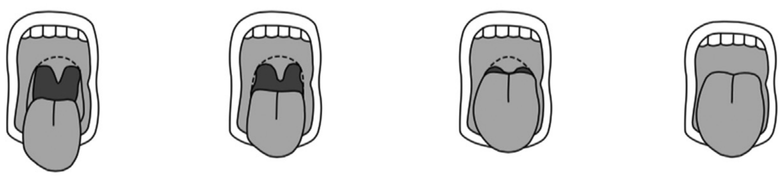
E Evaluate the 3-3-2 rule

In order to allow alignment of the pharyngeal, laryngeal and oral axes and therefore simple intubation, the following relationships should be observed. The distance between the patient's incisor teeth should be at least 3 finger breadths (3), the distance between the hyoid bone and the chin should be at least 3 finger breadths (3), and the distance between the thyroid notch and the floor of the mouth should be at least 2 finger breadths (2).

1 = Inter-incisor distance in fingers.
2 = Hyoid mental distance in fingers.
3 = Thyroid to floor of mouth in fingers.

M Mallampati

The hypopharynx should be visualized adequately. This has been done traditionally by assessing the Mallampati classification. The patient is sat upright, told to open the mouth fully and protrude the tongue as far as possible. The examiner then looks into the mouth with a light torch to assess the degree of hypopharynx visible. In the case of a supine patient, Mallampati score can be estimated by getting the patient to open the mouth fully and protrude the tongue and a laryngoscopy light can be shone into the hypopharynx from above.



Class I: soft palate, uvula, fauces, pillars visible | Class II: soft palate, uvula, fauces visible | Class III: soft palate, base of uvula visible | Class IV: hard palate only visible

O Obstruction?

Any condition that can cause obstruction of the airway will make laryngoscopy and ventilation difficult. Such conditions are epiglottis, peritonsillar abscesses and trauma.

N Neck mobility

This is a vital requirement for successful intubation. It can be assessed easily by getting the patient to place their chin down onto their chest and then to extend their neck so they are looking towards the ceiling. Patients in hard collar neck immobilization obviously have no neck movement are therefore harder to intubate.

Fig. 1. LEMON mnemonic for airway assessment. (*From* Reed MJ, Dunn MJ, McKeown DW. Can an airway assessment score predict difficulty at intubation in the emergency department? Emerg Med J 22(2):100; with permission.)

Technique of Bag-Mask Ventilation

Delivering slow, deliberate breaths to minimize insufflation of the stomach cannot be overemphasized.[27,28] Slow flow rates minimize gastric insufflation, reducing risk of vomiting. Often, in an effort to maximize ventilation, the well-intentioned assistant delivers BMV with rapid, staccatolike action. Given that the correct approach in adults emphasizes a slow positive-pressure breath delivered over 2 seconds, a single respiratory cycle can last 5 seconds or more, making the maximum respiratory rate 12 to 15 breaths per minute.

Table 2
The MOANS mnemonic to evaluate ease of BMV

MOANS Element	Description
Mask seal/Mallampati	Higher Mallampati (>2) should raise suspicion of difficulty in BMV[25] Facial hair can jeopardize the mask seal and can be overcome by applying water-soluble gel to the patient's beard.
Obesity	Defined as BMI >30 kg/m^2 and correlates with difficulty in BMV.[25,129]
Age[a]	With advanced age (>46 y old), the inferior pharyngeal sphincter muscles weaken and allow air to pass into the stomach during aggressive BMV attempts.[25,130]
No teeth	Adequate seal is difficult when the patient is edentulous. Dentures should remain in place to support the facial tissues and maintain the oropharyngeal geometry.
Snoring	Laxity and redundancy of upper airway tissues leads to snoring and can hamper attempts at BMV.[25] Elicit the history from patient or family before induction.

The MOANS mnemonic is described by Walls and Murphy[26] and incorporates many of the elements described by Kheterpal et al.[24]

Abbreviations: BMI, body mass index; BMV, bag mask ventilation.

[a] Walls et al report the age cutoff to be >49.[26]

Improvement in the effectiveness ventilation while bagging is typically accomplished through better positioning. Aligning the oral tracheal axis to effect a "sniffing position" is often achieved with a slight chin lift or a pad behind the shoulders. Consideration should be given to placement of an oral or nasopharyngeal airway to keep the posterior pharynx patent. The jaw thrust maneuver is a well-recognized technique to provide airway patency when a second person is trained in the technique.[29]

Evaluation of Suitability for Extraglottic Device

The spirit of anticipating airway management difficulties has generated a mnemonic for evaluating the suitability of extraglottic devices (EGDs) as alternative techniques for establishing an airway. Briefly "RODS" represents 4 factors that may influence ease of EGD use: *Restricted* mouth opening, preventing introduction of the EGD; *Obstruction* or *Obesity* may lead to inability to properly seat the device for an adequate seal (especially a laryngeal mask airway); *Disrupted* or *Distorted* airway, may prevent adequate seal, as in cases of epiglottitis, hematoma, or malignancy; and *Stiff*, refers to anatomy requiring inspiratory pressures that may exceed the seal pressure. It is important to remember that the RODS screening aid is based on expert opinion and the presence of one or more of the criteria would not necessarily prevent the use of an EGD.[26]

Evaluation of Difficulty in Performing Cricothyrotomy

Surgical cricothyrotomy is rare, with a frequency of 2 in 1000 airways requiring it as an initial method of airway management,[3] rising to 6 in 1000 airways when performed as a rescue alternative to RSI in civilian[30] and military populations.[31] This infrequent exposure to cricothyrotomy as a definitive technique can lead to unfamiliarity and indecision. Although this may be understandable given the rarity of task performance and prevalence of improved rescue airway adjuncts (eg, EGDs), hesitation and deliberation can be fatal.[32] For these reasons, emergency physicians must give some advance thought to surgical airway management before a patient deteriorates to the point of requiring one.

Experts have devised a systematic way to evaluate for anticipated difficulty in establishing a surgical airway. Consideration should be given to any recent *Surgery*, whereby the anatomy is distorted; presence of a *Mass*, such as a hematoma that may conceal landmarks; impaired *Access*, which may result from obesity, restricted movement, or external fixation; changes from previous *Radiation* may similarly distort landmarks; and airway *Tumors* may present challenges from identification of landmarks, to passage of the tube, to bleeding complications. Thus, the "SMART" mnemonic will remind practitioners of patient attributes that can complicate cricothyrotomy, and should be considered in advance of the need to act.[26]

THE PROCESS OF RAPID SEQUENCE INTUBATION

After assessment of the patient's need for an airway and evaluation of expected difficulties, the technique of RSI is most often used to provide ideal intubating conditions in most patients. In preparation for RSI, 7 distinct steps are recognized, from preparation through intubation and on to postintubation care, known as the "Seven Ps of RSI" (**Table 3**).[6]

Preparation

After the assessment of the patient's airway and suitability for RSI, prepare the patient, the equipment, and the team. Ensure the patient is monitored with pulse oximetry, 3-lead electrocardiogram rhythm, and blood pressure by using a noninvasive cuff cycling frequently. $P_{ET}CO_2$ should be monitored and should be readily available after the endotracheal tube (ETT) is placed. Intravenous access should be reliable with 2 peripheral intravenous (IV) lines. In all but a few select cases (congestive heart failure), a fluid bolus will support the patient through the hemodynamic changes associated with intubation.[33]

Equipment should be reviewed for availability and function. Video laryngoscopy picture and power source should be verified. Direct laryngoscope handles with an assortment of blade sizes and shapes (eg, Mac and Miller) should be *checked for function*.

Table 3
The 7 P's of rapid-sequence intubation

Time Course	Step	Details
−10 min	Preparation	Assemble team, equipment, medications, monitors
−8 min	Preoxygenation	Maximize oxygen saturation and stores to maximize apnea time
−3 min	Pretreatment	Administer medications to provide smooth transition through RSI
Time = 0	Paralysis with induction	Sedative and paralytic medications administered in rapid sequence to provide optimal intubating conditions
+15–30 s	Positioning	Ready patient for optimal laryngoscopy
+45 s	Pass the tube with verification	Intubate the airway and prove correct ETT placement with adjuncts
+90 s	Postintubation care	Prompt titration of sedation, close monitoring for arrhythmias and hypotension, chest radiography

Abbreviations: ETT, endotracheal tube; RSI, rapid-sequence intubation.

From Walls RM. Rapid sequence intubation. In: Walls RM, Murphy MF, editors. Manual of emergency airway management. 4th edition. Philadelphia: Lippincott Williams and Wilkins; 2012. p. 228; with permission.

And ETT should be tested for balloon integrity and fitted with a stylet, with an additional smaller ETT (eg, 0.5 mm smaller internal diameter) within reach if a difficult airway is anticipated. It is prudent to have airway rescue devices close at hand (eg, laryngeal mask airway, gum-elastic bougie, and esophageal tracheal tube). The physician should also confirm suction is nearby and functioning.

Team preparation includes assembling appropriate nurses, respiratory therapists, and a pharmacist, depending on local custom. Further discussion of the physician's assessment of the need for intubation, the initial plan for RSI, including medications, postintubation sedation plan, and alternate/rescue airway management strategies, should take place. Much of this preparation can occur while the patient is undergoing a period of preoxygenation.

Evolving emphasis on checklists to standardize the approach to routine health care procedures is gaining acceptance in the care of surgical[34] and intensive care unit (ICU) patients.[35,36] Development of a preintubation checklist for trauma patients intubated in the emergency department (ED) based on accepted safety elements undertaken by Smith and colleagues,[37] demonstrated substantial risk reduction in intubation-related complications. Clinicians may find checklists increasingly useful as a tool to organize the health care team's efforts in the preparation for intubation.

Preoxygenation

In preparation for intubation, the importance of preoxygenation cannot be overstated. Through the natural course of RSI, respiratory musculature is paralyzed and airway protective mechanisms are suppressed. The time to desaturation for a patient breathing room air can be shorter than the peak effect of RSI medications (ie, <90 seconds). Therefore, the physician should endeavor to extend the period of safe apnea in every intubation. These strategies include improved positioning, preoxygenation for a period of 3 to 5 minutes, nitrogen washout, and administration of high-flow nasal oxygen simultaneous with laryngoscopy.[38,39]

How is preoxygenation accomplished?

Preoxygenation and nitrogen washout can be accomplished in most cases with high fraction of oxygen (FiO_2) applied to the airway of the awake, spontaneously breathing patient over several minutes. Nasal cannulae alone at typical flow rates (2–6 lpm) are inadequate. Widely used "non-rebreather" (NRB) masks only supply up to 70% FiO_2 when supplied with traditional oxygen flow rates (ie, 15 lpm) and self-inflating bag-mask devices can supply only 80%+ FiO_2 if a tight seal is maintained and if equipped with a 1-way valve to limit entrainment of room air.[40] In most cases, FiO_2 approaching 90% can be achieved only with typical NRB masks if the flow delivers 30 lpm, or in some situations, set to "flush."

Various approaches are reported, including "3 minutes" of breathing high FiO_2.[6,41] In a review of preoxygenation strategies, Tanoubi and colleagues[39] describe the general superiority of 3 minutes of tidal breathing $FiO_2 = 1.0$ over either 4 or 8 rapid deep breaths of $FiO_2 = 1.0$. The investigators note that if time is limited, 4 or 8 maximal breaths over 30 to 60 seconds may be advantageous in emergent situations, but this approach requires a cooperative patient and high oxygen flow rates. In more difficult cases, consider a short period of noninvasive positive pressure ventilation (NIPPV) on FiO_2 of 100% to accomplish goals of nitrogen washout and optimization of preintubation oxygen saturations.[38,42]

How long is the time to desaturation?

Benumof and colleagues[43] produced a useful model to illustrate differences in time to desaturation across various patient populations (Fig. 2) based on earlier theoretic

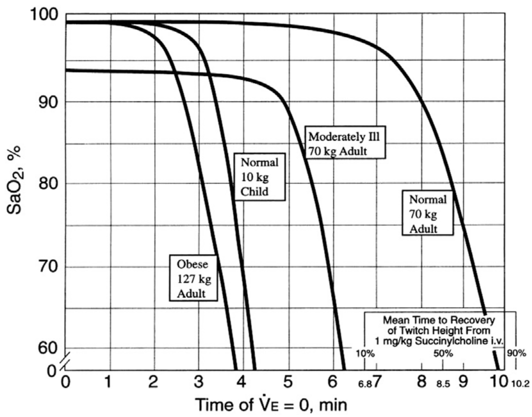


Fig. 2. Time to hemoglobin desaturation with initial FAO2 = 87%. S_aO_2 versus time of apnea for various types of patients. The mean times to recover from 1 mg/kg IV succinylcholine are depicted on the lower right-hand corner. (*From* Benumof JL, Dagg R, Benumof R. Critical hemoglobin desaturation will occur before return to an unparalyzed state following 1 mg/kg intravenous succinylcholine. Anesthesiology 1997;87(4):980; with permission.)

work on oxyhemoglobin desaturation by Farmery and Roe.[44] The message is clear: unless successful intervention to support oxygenation is accomplished, most patients will desaturate before recovery from short-acting paralytic agents occurs. Additionally, this model vividly demonstrates the heterogeneity of patient responses despite the apparently reassuring S_aO_2 at the onset of apnea. Over the past 2 decades, these concepts have been repeatedly supported by subsequent studies.

Maximizing preintubation oxygen saturation is of paramount importance. Davis and colleagues[45] demonstrated an accelerating desaturation curve for young, comatose trauma patients intubated by prehospital providers. Although a minority of patients (6%) with beginning S_pO_2 of 95% or higher desaturated during the intubation attempt, all patients with initial S_pO_2 of 93% or lower had critical desaturation.

Further complicating attempts at preoxygenation may be the predisposing pathology that initially indicated the need for intubation. Mort[46] observed that the critically ill, unstable patient does not preoxygenate adequately and desaturates rapidly. The complication of hypoxemia (simply to an S_pO_2 <90%) during emergent intubation causes a fourfold risk of cardiac arrest.[47]

Obese patients present a challenge for multiple reasons.[48] Given anatomic factors, like reduced functional residual capacity (FRC) and physiologic constraints, such as increased oxygen consumption rate (V_{O_2}),[39] hypoxemia develops rapidly in the apneic period.[49] Placing obese patients in reverse Trendelenburg position of 25 to 30°[50] and applying continuous oropharyngeal oxygen[41,51] prolongs the safe apnea period in obese patients considerably.

What is the physiologic basis for apneic oxygenation?

Frumin and colleagues,[52] provided an elegant discussion of the outstanding mechanism of apneic oxygenation in 1959. Assuming an apneic adult has a respiratory quotient of 1.0, and an FRC of 2000 mL filled with oxygen during the preoxygenation phase, and an average V_{O_2} of 300 mL/min, all of the oxygen would be consumed in 7 minutes. Holmdahl[53] demonstrated that carbon dioxide is partitioned in the buffering systems within the tissues and blood and only about 10% of evolved CO_2 crosses the alveolar interface to be exhaled. In this example, 300 mL O_2 is absorbed from the alveolar space and only 30 mL CO_2 replaces it each minute. If alveolar volume remains constant, pressure must decrease. In aggregate, there is net reduction in alveolar pressure compared with ambient pressure at the upper airways, resulting in a driving force down the respiratory tree. Frumin and colleagues[52] observed in 8 human subjects who remained sedated, intubated, and apneic on a closed-loop circuit with $FiO_2 = 1.0$, the S_aO_2 remained $\geq$98% for a duration of 18 to 55 minutes. They interpreted the gradual volume loss in the circuit's reservoir bag as "semi quantitative confirmation," of this process at work.

Such observations have led various investigators over the ensuing decades to recommend nasal cannula oxygen during apneic oxygenation at rates of 5 lpm[6,51] or 15 lpm just as induction medications are administered.[38] Aside from the mass transport of oxygen into the lungs described previously, recent work by Möller and colleagues[54] elegantly demonstrated the reduction in anatomic deadspace with high-flow nasal oxygen (15–45 lpm nasal flow). Interested readers are directed to the accompanying video 1.[55]

Pretreatment

Pretreatment agents in the critically ill patient Critically ill patients with status asthmaticus, acute coronary syndrome (ACS), or elevated intracranial pressure (ICP) can deteriorate while undergoing laryngoscopy. Repeated manipulation of the pharynx routinely causes a hyperdynamic response, which may worsen the blood pressure–heart rate product in patients with ACS, escalate ICP in the setting of impaired cerebral blood flow autoregulation, or precipitate catastrophic hemorrhage in vascular emergencies. Laryngeal stimulation can have profound respiratory effects (eg, laryngospasm, cough, and bronchospasm). Ideally, traditional agents like fentanyl or lidocaine (**Table 4**) used to mitigate injurious responses during intubation attempts would demonstrate a clear therapeutic benefit. However, unequivocal evidence

Table 4
Pretreatment medication summary

Agent	Dose	Onset	Duration of Action	Elimination	Drug Interactions	Indications
Lidocaine	1.5 mg/kg IV	45–90 s	10–20 min	Hepatic (90%); Renal excretion	Dofetilide (Dysrhythmia) Monoamine oxidase inhibitors (Hypotension) Amiodarone (Bradycardia)	Asthma Elevated ICP
Fentanyl	3 μg/kg IV	2–3 min	30–60 min	Hepatic (90%) and small intestine; Renal excretion	Cytochrome P-450 (CYP-3A4) inhibitors (macrolides, azoles, protease inhibitors) can prolong action.	To blunt hypertensive response, as in increased ICP, ACS, AAA or dissection.

Abbreviations: AAA, abdominal aortic aneurysm; ACS, acute coronary syndrome; ICP, intracranial pressure; IV, intravenous.

From Daro DA, Bush S. Pretreatment agents. In: Walls RM, Murphy MF, editors. Manual of emergency airway management. 4th edition. Philadelphia: Lippincott Williams and Wilkins; 2012. p. 235; with permission.

showing improved outcomes using pretreatment medications in the emergency patient population does not exist.[56] It had been proposed that lidocaine may have some impact on bronchospasm, but again this benefit is not supported by the literature.[57]

If pretreatment agents are deemed necessary, they should be given 3 to 5 minutes before initiation of RSI; however, rapid progression through the discrete steps leading to definitive airway management should not be delayed to incorporate pretreatment medications. Further, the real possibility of introducing unnecessary complexity or delay into the preintubation routine is a significant drawback. When weighed against the absent evidence of actual benefit, routine pretreatment with these agents during RSI in the emergent patient population cannot be uniformly recommended.

PARALYSIS WITH INDUCTION

The safe transition from an awake, spontaneously breathing patient in need of an airway to a sedated, stable patient with a secure airway is accomplished through a well-choreographed induction sequence. The pharmacologic agents facilitate this safe transition and need to rapidly meet several requirements, described in the following sections.

Provide Ideal Intubating Conditions

Rapid onset of both sedation and paralysis prevents aspiration, hypoxia, and hypercapnea. Within a narrow window, agents should facilitate excellent laryngoscopy with relaxation of laryngeal musculature, reduction in laryngospasm, and suppression of the gag reflex.

Prevent Hemodynamic Instability

Sedation with paralysis is often undertaken in unstable patients with poor cardiovascular reserve. Ideally, induction medications would have no impact on blood pressure, heart rate, cardiac contractility, and cerebral perfusion pressure.

Promote Analgesia and Amnesia

Reports of patient awareness during intubation and anesthesia do appear in the literature.[58,59] An induction regime should prevent pain, provide sedation, and facilitate amnesia to the event.

Although no single agent identified to date can meet all of the idealized characteristics, it is possible for the emergency physician to select agents that function in concert to accomplish the previously described goals. A decade ago, Sagarin and colleagues[30] reviewed frequencies of induction agents in a survey of 4513 intubations and found that etomidate was used in 69% of intubations, midazolam in 16%, fentanyl in 6%, and ketamine in 3%. It is unlikely that these proportions continue to represent physician practice today, as physician awareness of advantages of some agents (eg, ketamine or propofol) is rising while other medications fall out of favor (eg, fentanyl or midazolam). A summary of commonly used induction agents is provided in **Table 5**.

Etomidate

Etomidate is a commonly used induction agent in ED RSI. The typical dose is 0.3 mg/kg administered IV. It is generally considered to have minimal cardiovascular effects and may demonstrate neuroprotective qualities especially helpful in head-injured patients. Caution should be exercised in hypotensive patients, and the dosage should be reduced to 0.1 mg/kg IV.

Table 5
Common medications in rapid sequence intubation

	Medication	Dose	Indication	Modification in Shock States
Induction agents	Etomidate	0.3 mg/kg IV	RSI	0.1 mg/kg IV
	Propofol	0.5–1.5 mg/kg IV	May use for RSI in hemodynamically stable patients	Not indicated
	Ketamine	1–2 mg/kg IV	Hypotension Status asthmaticus	0.5 mg/kg IV
	Methohexital	1.5 mg/kg IV	Largely supplanted by etomidate, caution in hypotensive patients	0.5–0.75 mg/kg IV
	Midazolam	0.2–0.3 mg/kg IV	Considered too slow in onset for RSI	Not favored in hemodynamic instability
Paralytic agents	Succinylcholine	1.5–2.0 mg/kg	RSI in most cases Pregnancy Class C	None
	Rocuronium	1 mg/kg	RSI if succinylcholine contraindicated Pregnancy Class B	None
	Vecuronium	0.15 mg/kg	RSI if succinylcholine contraindicated Pregnancy Class C	None

Abbreviations: IV, intravenous; RSI, rapid sequence intubation.

Etomidate has been implicated in adrenal insufficiency occurring in critically ill septic patients.[60] The evidence of etomidate's role in demonstrable adrenal suppression exists, but no large studies have been completed to address clinically meaningful outcomes, such as impacts on length of stay, ventilator days, or mortality.[61] At this time, physicians deciding whether or not to use etomidate appear to have 3 choices: etomidate can be avoided entirely; etomidate can be considered for use in all but septic patients, or, given a review of the risks and benefits, etomidate can be considered for use, with the increased risk of adrenal insufficiency communicated to the inpatient team.

Propofol

Propofol is a popular induction agent for elective procedures when serial aliquots are administered to achieve the desired effect. But propofol is somewhat limited in its application in RSI of the emergency population given its tendency to cause myocardial depression and hypotension,[62] and concerns for awareness during induction.[63] Methodical titration is difficult in the setting of RSI, where the priority is rapid optimization of intubating conditions.

Ketamine

Ketamine is a dissociative anesthetic with some analgesic properties. It has centrally mediated sympathomimetic effects that can increase heart rate, support blood pressure, and improve cardiac output. Its role in induction and sedation has been reviewed recently.[64]

Reportedly, ketamine has drawbacks in head-injured patients as a cause of increased ICP. This concern is rooted in case reports[65] and small case series[66] from the early 1970s. Although no robust studies have investigated the impact of ketamine induction on ICP (the very scenario most relevant to the emergency physician), evidence is gradually accumulating to suggest that ketamine sedation has no discernible impact on cerebral perfusion pressure in traumatic brain injury (TBI). Further, with the recognition that even a single hypotensive event can increase mortality in TBI, ketamine may be a particularly attractive option for RSI in hypotensive patients.[63] Mayberg and colleagues[67] reported favorable effects of ketamine on intraoperative cerebral hemodynamics. Studies in the controlled environment of the ICU support a neuroprotective advantage of ketamine with a notable *decrease* in ICP during sedation when used in concert with other agents (propofol or benzodiazepines).[68] Thus, ketamine may have distinct advantages in head-injured populations.

Barbiturates

Methohexital is a barbiturate that has replaced the now-unavailable thiopental. It is an ultra–short-acting central nervous system depressant that promotes sedation without analgesia, and is more often used in procedural sedation rather than RSI. Dosage adjustments are warranted in unstable patients. Methohexital is known to have neuroprotective effects but lowers the seizure threshold.

Benzodiazepines

The benzodiazepine class of medications satisfies the requirements of sedation, amnesia, anxiolysis, and a degree of muscle relaxation. Midazolam is the representative agent for the purposes of RSI, with a faster onset of action than others in this class. However, significant disadvantages of midazolam as an induction agent for RSI include respiratory depression leading to apnea independent of neuromuscular blocker administration.[69] Additionally, midazolam may not reach peak effect of sedation as soon as typical neuromuscular blockers do (<2 minutes), raising the possibility of paralysis without adequate sedation. These disadvantages along with the wide range of sedation depth and dosing adjustment required in critically ill patients have rendered midazolam ill-suited as a single induction agent for RSI in the ED.[63]

PARALYTICS

Neuromuscular blockers (NMBs) are the medications that ultimately facilitate laryngoscopy, prevent laryngospasm, and enable passage of the ETT. This group of medications paralyzes skeletal muscles by 2 general mechanisms, and forms the basis of the classes of NMBs: depolarizing and nondepolarizing.

So-called depolarizing NMBs mimic the action of acetylcholine at the neuromuscular junction, resulting in an open conformation of nicotinic receptors and allowing a sodium influx to maintain a constant state of depolarization, thereby preventing muscle contraction (**Fig. 3**). Non-depolarizing NMBs competitively block acetylcholine at the nicotinic receptor, preventing a conformational change and inhibiting depolarization, and in this way block muscle contraction.

Depolarizing Neuromuscular Blockade

Succinylcholine (Sch) is the prototype depolarizing NMB used in the ED. It has rapid onset of action and provides neuromuscular blockade for 6 to 10 minutes. In adults, the typical dose is 1.5 mg/kg IV. However, some have advocated for increasing the initial dose to ensure rapid establishment of ideal intubating conditions without significant increase in recovery time.[62] Naguib and colleagues[70] demonstrated a stepwise improvement in intubating conditions with increasing doses of Sch, with the cohort

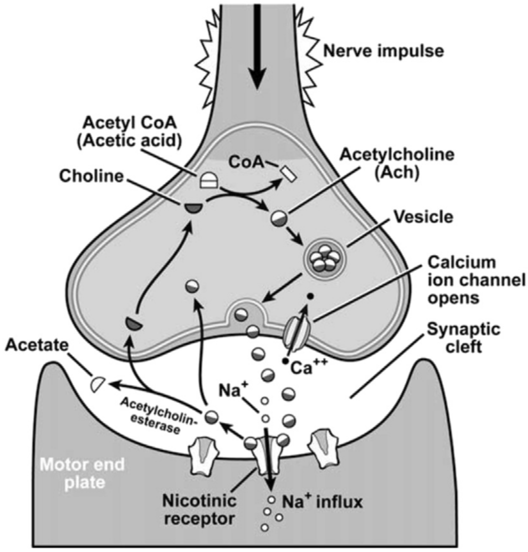


Fig. 3. Acetylcholine in the neuromuscular junction: synthesis, exocytosis, binding to the nicotinic receptor, release into synaptic space, and inactivation. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 2015. All Rights Reserved.)

receiving 2 mg/kg achieving excellent intubation conditions more than 85% of the time. An appreciation for the inaccuracy in estimating a correct weight for most emergency patients[71,72] combined with a broad range of hemodynamic stability should prompt the physician to choose a higher dose of Sch for RSI in the ED.

Despite the utility and widespread popularity of Sch in RSI, there are significant side effects and specific clinical situations in which it is to be avoided (**Table 6**). Clinicians should be aware of these significant side effects, and in specific populations, choose alternative agents for achieving neuromuscular blockade.

Nondepolarizing Neuromuscular Blockade

Rocuronium is the representative nondepolarizing NMB used in RSI in the ED (see **Table 4**). It has a rapid onset of action (60 seconds) but is known to provide paralysis for up to 60 minutes. Among NMBs, it is generally considered the safest in pregnancy (Pregnancy Category B). Rocuronium is typically the first NMB chosen when Sch is contraindicated.[73]

Vecuronium is an alternative to rocuronium when the latter is not available. Vecuronium requires an initial priming dose of 0.01 mg/kg followed 3 minutes later with an RSI dose of 0.15 mg/kg. This regimen provides peak intubating conditions in 90 seconds, but in some instances results in unpredictable neuromuscular blockade onset and can last 75 minutes.

Considering the entirety of the clinical presentation is important when choosing an NMB because specific paralytic agents may demonstrate obscure disadvantages. For example, when comparing rocuronium to succinylcholine, it has been shown that patients receive sedative medications later[74,75] and in lesser amounts[76] after undergoing RSI with rocuronium, possibly leading to a paralyzed, awake patient. Emergency physicians must have an awareness of the benefits *and* risks of a selected NMB.

Table 6
Adverse effects of succinylcholine

Side Effect		Population at Risk	Management Strategy
Hyperkalemia			
Receptor upregulation	Burns	Extrajunctional receptor sensitization occurs approximately 5–7 d after as little as 8% TBSA burn.	Safe in the acute period; beyond 5 d after burn, choose nondepolarizing agent.
	Denervation	Denervating events can sensitize patients as soon as 5 d after event (eg, spinal cord injury). Progressive neuromuscular disorders, such as botulism, GBS, MS, or ALS place the patient at perpetual risk.	Any individual denervating disorder should prompt use of nondepolarizing agent.
	Crush injury	Crush injuries can result in upregulation approximately 5 d after injury.	Recent history of crush injury (<6 mo) should prompt use of nondepolarizing agent.
	Severe infection	Intra-abdominal sepsis or other serious infection may precipitate receptor upregulation over d and may put patients at risk for mo. Often seen in ICU populations.	Caution in reintubation of ICU patients with severe infection. Consider use of nondepolarizing agent.
Myopathy		Contraindicated in muscular dystrophy, as upregulation and rhabdomyolysis can be catastrophic. Black box warning against use of Sch in elective pediatric intubations.	If myopathy suspected, choose nondepolarizing agent.
Preexisting hyperkalemia		No definitive contraindication in patients at risk for hyperkalemia (eg, dialysis patients).	Consider nondepolarizing agent in hyperkalemia manifesting with ECG changes.
Prolonged neuromuscular blockade		Deficiency of pChE prolongs the half-life of Sch. Liver disease, pregnancy, burns, or exposure to cocaine, metoclopramide, or esmolol may increase apnea time 3–9 min. Congenital deficiency can prolong duration of action by several hours.	Prompt placement of definitive airway. Aggressive sedation plan to prevent "paralyzed/awake" scenario.
Malignant hyperthermia		Personal or family history of MH is an absolute contraindication to Sch. Manifestations include muscle rigidity, autonomic instability, hypoxia, hypotension, lactic acidosis, hyperkalemia, myoglobinemia and DIC. Hyperpyrexia is a late finding.	Prompt treatment with dantrolene, and consider treatment for hyperkalemia.
Trismus/masseter muscle spasm		Characterized by jaw spasm with flaccidity of extremities. Strongly consider subsequent evaluation for MH.	Jaw spasm can be overcome with an immediate dose of a nondepolarizing agent.

Abbreviations: ALS, amyotrophic lateral sclerosis; DIC, disseminated intravascular coagulopathy; ECG, electrocardiogram; GBS, Guillain-Barre syndrome; ICU, intensive care unit; MH, malignant hyperthermia; MS, multiple sclerosis; pChE, plasma cholinesterase; Sch, succinylcholine; TBSA, total body surface area.

Adapted from Caro DA, Laurin EG. Neuromuscular blocking agents. In: Walls RM, Murphy MF, editors. Manual of emergency airway management. 4th edition. Philadelphia: Lippincott Williams and Wilkins; 2012. p. 254–9; with permission.

POSITIONING

The appropriate position of the head and neck during RSI should allow direct visualization of the larynx. This often includes extension of the next to the sniffing position absent the concerns for cervical spine immobilization. If free rotation of the head is permitted by the clinical situation, the sniffing position aligns the visual axis of the mouth, pharynx, and larynx. Investigators dispute the degree of extension of the head but agree that some degree of extension facilitates improved laryngoscopy over the neutral position.[77] The advent of video laryngoscopy may diminish the importance of precise positioning, but consideration should be given to position in advance of administration of RSI medications.

Patient positioning may impact regurgitation and aspiration. Theoretically, the head-up position could decrease the chance of passive regurgitation of stomach contents, as the lower esophageal sphincter tone decreases during RSI. Opponents of this position suggest that fluids often are actively transported up the esophagus due to vomiting. In this situation, vomiting can easily overcome the vertical distance to the pharynx and subsequently proceed passively down the bronchial tree to the carina. Proponents of keeping the patient flat, or head down, assert the relative safety of this orientation in the event of vomiting, as the carina is higher than the larynx in this position, preventing aspiration.[62]

What Role Does Cricoid Pressure Have in Rapid Sequence Intubation?

Cricoid pressure, or posterior pressure on the cricoid ring to prevent regurgitation of stomach contents during anesthetic induction, was originally described by Sellick.[78] The correct performance of the procedure involves an assistant identifying the cricoid cartilage (not the thyroid cartilage) and applying posterior pressure in the supine patient to compress the esophagus between the airway and the spine. Over the past half century, the Sellick *maneuver* has been exalted as crucial,[79] and criticized as dangerous[80,81] by various investigators, but has not been shown to actually succeed in preventing aspiration during RSI in controlled trials. Patients undergoing cricoid pressure observed with endoscopy are noted at times to have significant deformation of the cricoid cartilage and airway narrowing, potentially leading to a “can’t intubate, can’t oxygenate” scenario.[82,83] MRI in awake subjects subjected to cricoid pressure reveals significant lateral displacement of the still-patent esophagus.[84] If the Sellick maneuver is used, physicians should be aware that difficulties with ventilation and intubation can result without an established reduction in aspiration risk.[62]

Pass the Tube with Verification

The cuffed ETT maintains a patent airway, prevents aspiration, facilitates enhanced oxygenation, and allows selection of ventilation modalities that improve acid-base status. Correct placement requires skill and improves with experience.[19,30,85]

Cormack and Lehane[86] developed a grading scale for the appearance of the glottis on direct laryngoscopy in an effort to address difficult intubations and fatal complications. Their scale remains useful today (**Fig. 4**). It is important to recognize a Cormack and Lehane (CL) grade 3 or 4 when present, as it should prompt the physician to implement an alternate plan for securing the airway. In the original work, Cormack and Lehane[86] stated the frequency of a CL grade 3 airway view is approximately 1:2000 intubations. For emergency physicians who may intubate only a small cohort of patients each year, it is important to remember that this airway characteristic is unpredictable before the intubation attempt *until* RSI medications have been given and laryngoscopy is under way, but mandates activation of a difficult airway strategy.

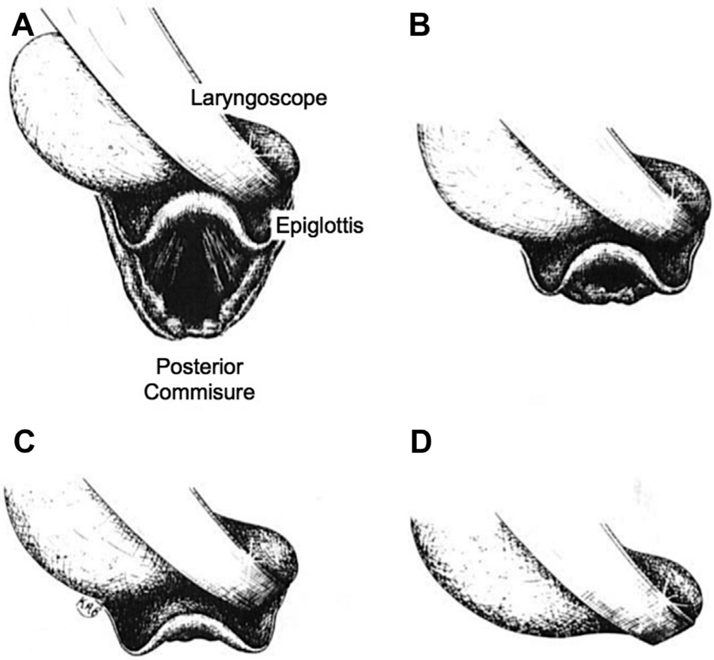


Fig. 4. CL scale evaluating the best views obtainable on direct laryngoscopy. (*A*) Most of the glottis is easily viewed, *termed* CL grade 1. (*B*) Only the posterior glottis is visible, although the arytenoids (and the cords) usually come into view with light pressure on the glottis, CL grade 2. Intubation is readily accomplished in most cases. (*C*) No part of the glottis is visible, although the epiglottis is visible, CL grade 3. Although rare, this view portends significant difficulty in intubation with direct laryngoscopy; other methods should be immediately considered. (*D*) Even the epiglottis is not seen. As it is a key landmark, slowly withdraw the laryngoscope and the epiglottis will usually fall into view. If not, this is termed a CL grade 4, and is very rare. Intubation with direct laryngoscopy is nearly impossible and other methods to secure the airway should be immediately pursued. (*From* Cormack RS, Lehane J. Difficult tracheal intubation in obstetrics. Anesthesia 1984;39:1106; with permission.)

Direct laryngoscopy (DL) enables the practitioner to pass the ETT through the cords to ensure correct placement; however, indirect methods have a role in securing the airway as well. Techniques such as fiberoptic bronchoscopy, placement of an intubating laryngeal mask airway, or using a gum-elastic bougie can all be considered indirect methods of intubation, as the ETT is not directly observed passing through the cords.[77]

Additional maneuvers can be helpful in improving laryngoscopy, including the BURP (Backward, Upward, Rightward Pressure) maneuver, in which the right hand of the intubator applies external pressure to the thyroid cartilage, and subsequently having an assistant maintain that position that allows optimal laryngoscopic view.[87] Others have redemonstrated improved laryngoscopic view with variations of this external thyroid manipulation.[88,89] It is important to remember that these manipulations are different from cricoid pressure in purpose and effect.[77]

With the advent of video laryngoscopy (VL), excellent indirect laryngoscopic views can be reliably attained in most cases, regardless of manufacturer.[90–92] VL may be especially useful in difficult glottis views (CL grade 3 or 4).[93,94] Although much of the work has been completed in elective cases (anesthesia) and controlled (ICU) settings, a growing body of work demonstrates the parallel utility of VL in the ED (**Table 7**).

Table 7
Selected studies comparing direct laryngoscopy to videolaryngoscopy

Author, Year	First-Pass Success, % DL	First-Pass Success, % VL	Overall Success, % DL	Overall Success, % VL	Time to Intubation, s DL	Time to Intubation, s VL	Cormack-Lehane Score I–II, % DL	Cormack-Lehane Score I–II, % VL	VL Used	Comment
Abdallah et al,[131] 2011	92	86	100	90	26	38	78	86	Pen (PENTAX Europe Gmbh, Hamburg, Germany)	105 morbidly obese patients requiring intubation for elective surgery.
Brown et al,[132] 2010	NR	NR	97	NR	NR	NR	80	93[a]	Sto (Karl Storz Gmbh & Co, KG, Tuttlingen, Germany)	Evaluated glottis view of 198 emergency patients requiring intubation.
Enomoto et al,[133] 2008	NR	NR	89	100[a]	51	54	89	100[a]	Pen	203 patients maintained in manual inline stabilization to simulate difficult airway while undergoing intubation for elective surgery.
Jungbauer et al,[134] 2009	NR	NR	92	99	60	40[a]	64	90[a]	Sto	200 elective surgery patients with expected difficult airway (Mallimpati ≥III).
Malik et al,[135] 2008	88	93	NR	NR	11.6[a]	18.9	83	100[a]	Pen Gli Tru (Truphatek International Ltd, Netanya, Israel)	120 elective surgery patients maintained in manual inline stabilization to simulate difficult airway. Intubated with DL or 1 of 3 VLs.
Malik et al,[136] 2009	68	88 (Gli) 72 (Pen)	84	96 (Gli) 100 (Pen)	13	17 (Gli) 15 (Pen)	68	100 (Gli)[a] 100 (Pen)	Gli Pen	75 elective surgery patients with difficult airways randomized to intubation with DL or VL (Glidescope or Pentax AWS).
Marrel et al,[137] 2007	80	95	100	100	93	59[a]	85	100[a]	X-Li (Teleflex Medical Europe Ltd, Dublin, Ireland)	80 morbidly obese patients undergoing intubation for elective surgery.
Mosier et al,[138] 2012	68	78[a]	NR	NR	NR	NR	NR	NR	Gli (Verathon Inc, Bothell, WA)	772 consecutive emergency patients requiring intubation.
Mosier et al,[91] 2013	61	79	91	98	NR	NR	62	86	Gli or C-MAC	290 medical ICU patients intubated with either DL or VL(either Glidescope or Storz C-MAC)
Platts-Mills et al,[98] 2009	84	81	NR	NR	30	42	NR	NR	Gli	280 emergency patients
Sakles et al,[139] 2012	73	79	84	97[a]	NR	NR	83	94	C-MAC (Karl Storz Gmbh & Co, KG, Tuttlingen, Germany)	750 consecutive emergency patients. VL ultimate success superior to DL with odds ratio 12.7.
Sakles et al,[140] 2014	71	81[a]	NR	NR	NR	NR	NR	NR	Gli C-MAC	2423 emergency department intubations in patients with predicted difficult airways.

Abbreviations: C-MAC, Karl Storz C-MAC videolaryngoscope; DL, direct laryngoscopy; Gli, Glidescope videolaryngoscope; NR, not reported by investigators; Pen, Pentax AWS laryngoscope; Sto, Karl Storz; Tru, Truview EVO2 videolaryngoscope; VL, Videolaryngoscope; X-Li, X-lite videolaryngoscope.
[a] Reported by investigators to be significant.

Several investigators have reviewed the existing literature and it is clear that use of VL can be an effective strategy for laryngoscopy in the ED, particularly in cases of suspected cervical spine injury or anticipated difficult airway.[92,95–99]

Verification of Endotracheal Tube Placement

Visualizing the direct cannulation of the trachea with the ETT is at times difficult, and additional methods are typically used to verify positioning. Physical examination findings (auscultation of the chest and abdomen, visualization of synchronous chest movement with inspiration, or fogging in the tube) are not collectively reliable. Rising pulse oximetry readings or chest radiography cannot dependably verify tube placement. Quantitative $P_{ET}CO_2$ detection is the most accurate technology to confirm correct ETT positioning.[16,100,101] Additionally, continuous $P_{ET}CO_2$ monitoring can provide information in real time as to the correct placement of the ETT should the patient's condition deteriorate.

A growing body of literature supports the role of point-of-care ultrasound in verifying ETT placement.[102] Two overall methods have been described: direct and indirect. The direct method of verification of proper ETT placement involves tracheal imaging to demonstrate anatomic changes that occur during passage of the ETT in real time. When the probe is placed in a transverse plane at the level of the cricoid cartilage, the provider can visualize the ETT passing between the vocal cords.[103–106] Indirect confirmation of correct ETT placement has also been described[107,108] and includes documenting the absence of the esophageal shadow on transverse view at the suprasternal notch or symmetric lung slide.[106,109,110] Both findings indirectly support a correctly placed ETT. Although verification of ETT placement with ultrasound appears to be effective in skilled hands, the role of ultrasound in RSI remains to be seen.

POSTINTUBATION MANAGEMENT

Physicians who intubate patients in the ED as part of their routine duties must consider the dangers posed in the postintubation period. Even though the focus is on the events leading up to passing, securing, and verifying placement of the ETT, the physician must give careful consideration to the complexities that lie ahead in the postintubation period.

What Are the Cardiovascular Responses to Intubation?

Understanding the expected hemodynamic changes during the peri-intubation period is an important step to successfully accomplish the goal of a stabilized, intubated patient. Laryngeal manipulation, prolonged apnea with its associated hypoxia or hypercapnea, induction agents, and the evolving intrathoracic physics during the conversion from negative to positive pressure ventilation can individually or collectively precipitate a maelstrom of cardiovascular instability. Added to these variables is the unstable nature of the patient whose deteriorating condition initially prompted the decision to intubate. In aggregate, the peri-intubation period is fraught with identifiable and dynamic risks that are variably present and threaten our intention to stabilize the patient. The circumspect physician has an understanding of these risks.

Hypotension

Hypotension is common in the postintubation period[33,111,112] and has been associated with cardiac arrest.[113] Factors leading to hypotension are manifold. Myocardial depression from induction agents, loss of vascular tone in the capacitance vessels of the lower extremities after neuromuscular blocking agents, or abrupt reversal of intrathoracic pressures with the institution of positive pressure ventilation can combine to significantly impact normotension.[114] Superimposed acid-base disorders, hemorrhage, myocardial dysfunction, or distributive shock (sepsis) can heighten the risk of hypotension.

Conventional vital signs are poor predictors of patients likely to develop hypotension after intubation. However, investigators have shown *Shock Index* (SI) may serve as a marker of limited cardiovascular reserve.[115] Shock Index is defined as[116]

$$\text{Shock Index} = \frac{\text{Heart Rate}}{\text{Systolic Blood Pressure}}$$

and can clarify the hemodynamic condition of the patient. Normal range of SI is 0.5 to 0.7, and an increased SI can signal shock before overt vital sign abnormalities manifest. Heffner and colleagues[115] demonstrated an SI of 0.9 predicted postintubation hypotension with 45% sensitivity and 89% specificity and suggested an SI cutoff of 0.8 would be effective to predict occurrence of hypotension immediately after intubation.

For these reasons, continued monitoring for hypotension is paramount. As invasive continuous monitoring is often not available in patients requiring emergent intubation, rapid cycling of a noninvasive blood pressure cuff should be set on the shortest cycle time to allow close observation of evolving changes in blood pressure. If time allows, aggregating 10 or 20 minutes of blood pressure readings during the RSI preparation phase will constitute a range of normal for the patient.

If hypotension is anticipated, the physician can adjust the common approach to RSI in several ways.[117] Although not supported by large trials, administering smaller doses of induction agents in sequence may allow a satisfactory level of sedation without the abrupt sympatholytic effect of routine full-dose sedation. Volume resuscitation can be instituted in advance of RSI in all except the most obviously volume-overloaded patients. Pure vasoconstrictors like phenylephrine should be drawn up and ready, and will provide valuable pressor support during induction and the immediate postintubation period.[118] Institution of positive pressure ventilation can complicate intrathoracic physics and threaten venous return in unstable patients. It is advised to start with low positive end-expiratory pressures (eg, 5 cm H_20 or less) and lower tidal volumes (eg, 6–8 mL/kg) and titrate upward if more support is required with careful attention to hemodynamics. Ventilator management strategies of the intubated patient in the ED are covered in detail elsewhere in this issue in an article by Dr Haney Mallemat.

Prolonged, repeated, or vigorous attempts at laryngoscopy can promote increases in parasympathetic tone, leading to bradycardia and decreased cardiac output, culminating in hypotension. Esophageal sphincter laxity may result from increased parasympathetic outflow, raising the risk of emesis and aspiration. Immediate laryngoscopy before RSI agents have reached peak effect can trigger vomiting via the patient's persistent intact gag reflex.

Hypertension

Alternatively, a hyperdynamic response to laryngeal manipulation can result, worsening myocardial strain, oxygen consumption, and exacerbate congestive heart failure. Abrupt hypertension in a patient vulnerable to the consequences of hemorrhage (eg, after trauma, cerebral bleed, or vascular catastrophe) can increase morbidity. At-risk populations for a hyperdynamic response include younger patients with neurologic insult, trauma, or sepsis.[33]

Tachycardia

Despite an appropriate and well-reasoned sedation plan, patients may still manifest tachycardia and hypertension that threatens their safety and mandates some intervention. Although much work has been devoted to anticipating and overcoming these dangerous sequelae, the physician must cautiously pursue specific remedies to avoid overcorrection. If the patient is considered adequately sedated, calcium channel blockers or β-adrenergic blockers may be used for pronounced tachycardia, with emphasis on short-acting agents.[33]

What Factors Influence Sedation in the Immediate Postintubation Period?

Adequate sedation in the postintubation period is often neglected in the ED.[119,120] Consequences of inadequate or absent sedation in the intubated patient are well described in the ICU, and include anxiety, agitation, accidental extubation, loss of venous access, suboptimal ventilatory support, increased oxygen requirements, barotrauma, and increased intracranial pressure.[121]

To meet the anticipated challenges of the intubated patient, the physician must have an explicit appreciation of the attributes of a successful sedation plan.

Much of the work to date on postintubation sedation focuses on intubated ICU patients. However, the same themes of anxiolysis and pain relief parallel the goals of the emergency practitioner.[122] Enacting a sedation plan for the intubated emergency patient requires knowledge of the risks, benefits, alternatives, and indications in pursuing a particular course of action. Characteristics of specific agents are summarized in **Table 8**. Pharmacists trained in the unique environment of the ED are an invaluable resource to the physician when tailoring the individual sedation plan to the clinical situation.[75,123,124]

Lighter levels of sedation to manage agitation are associated with decreased delirium and fewer ventilator days *in ICU populations*. Validated tools (eg, the Richmond Agitation-Sedation Scale) can be used to evaluate the depth of sedation. Additionally, in the management of the ICU population, an analgesia-first approach is favored. This means that administering opiate analgesics to control pain may obviate the need for benzodiazepine use.[122]

Although subjective, pain in the critically ill patient is a source of stress that can lead to arteriolar vasoconstriction and reduced tissue oxygen tension while simultaneously precipitating a hypermetabolic state. Vital sign changes do not correlate with pain experienced by intubated patients and are unreliable in determining the need for pain medication. Using validated tools for assessing pain in the sedated patient on a frequent basis allows prompt treatment of pain and leads to improved outcomes.

Table 8
Postintubation sedative medications

Class	Drug	Onset, IV	Duration of Action	Intermittent Dosing	Infusion Rate
Opiate analgesic	Fentanyl	1–2 min	30–60 min	0.35–0.5 μg/kg q 30–60 min	0.5–1.0 μg/kg/h
	Remifentanil	1–1.5 min	3–5 min	0.5–1.5 μg/kg	0.1 μg/kg/min
	Morphine	5–10 min	3–4 h	2–4 mg IV q 1–2 h	Not typical
	Hydromorphone	5–15 min	2–3 h	0.2–0.6 mg IV q 1–2 h	Not typical
Benzodiazepine	Midazolam	2–3 min	20–30 min	0.5–1 mg IV q 10–30 min	0.025 mg/kg/h
Other	Propofol	1.5 min	2–4 min	0.25 mg/kg	25–75 μg/kg/h
	Ketamine	1 min	5–10 min	0.2–0.8 mg/kg	0.5 mg/kg/h

Abbreviations: IV, intravenous; q, every.

Parenteral opiates, when titrated effectively, are all considered equivalent and the first-line drug class for treatment of pain in most situations.[122]

MANAGEMENT OF THE FAILED AIRWAY

Failed airway is the term applied to a patient requiring a definitive airway when any of the 3 following conditions exist[26]:

Failure to maintain acceptable oxygen saturation during or after one or more failed laryngoscopic attempts oxygenation, or

Three failed attempts at orotracheal intubation by an experienced intubator, even in the setting of acceptable oxygenation, or

A single best attempt at intubation fails and a “forced to act” situation arises (combative, hypoxic, or deteriorating patient).

When the intubating physician is pressed to make important decisions quickly in a failed airway scenario, many of the sequential steps toward securing the airway that should be considered are based on expert opinion. The critical act is the advance planning, anticipation, and preparation for the difficult or failed airway *before* it occurs. Although the management of a difficult and failed airway has been reviewed from anesthesia,[125] otolaryngology,[126] and emergency medicine[22] perspectives, providers may find consensus guidelines in the anesthesia literature useful.[127] Particularly suited to the emergency physician are the emergency airway algorithms and approach advocated by Walls and colleagues.[128]

SUMMARY

Patients in respiratory distress often require airway management, including endotracheal intubation. It takes a methodical approach to transition from an unstable patient in distress with an unsecured airway, to a stable, sedated patient with a definitive airway. Through a deliberate course of advanced preparation, the emergency physician can tailor the approach to the individual clinical situation and optimize the chance of first-pass success. Sedation of the intubated patient confers physiologic benefits and should be included in the plan for airway control.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found online at http://dx.doi.org/10.1016/j.emc.2015.08.007.

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