EB MEDICINE

PEDIATRIC EMERGENCY MEDICINE PRACTICE

AN EVIDENCE-BASED APPROACH TO PEDIATRIC EMERGENCY MEDICINE ▲ EBMEDICINE.NET

Evidence-Based Emergency Management Of The Pediatric Airway

Abstract

Pediatric airway emergencies are rare, yet they are anxiety-provoking events that can occur in both pediatric and general emergency departments. Several novel concepts regarding preoxygenation during rapid sequence intubation, anticipation and prevention of intubation-related complications, the utility of premedication agents, and the selection of induction and paralytic agents have been highlighted in recent clinical trials and review articles. In this review, we analyze the data behind these concepts, highlight current pediatric literature related to these issues, and present reasonable conclusions based on the best available evidence. We begin with an analysis of the anatomic and physiologic differences commonly encountered in the pediatric patient during rapid sequence intubation, and we then review a systematic approach to the assessment of the pediatric patient in respiratory distress (ie, the pediatric assessment triangle) and conclude with a simple approach to pediatric rapid sequence intubation, starting with the preparatory phase and ending with postintubation management. We additionally highlight several alternative airway devices and discuss special situations, including rapid sequence intubation in the obese pediatric patient and in the difficult airway patient.

January 2013
Volume 10, Number 1

Authors

Amandeep Singh, MD
Alameda County Medical Center, Highland Hospital, Oakland, CA; Assistant Clinical Professor of Emergency Medicine, University of California San Francisco, San Francisco, CA

Oron Frenkel, MD
Alameda County Medical Center, Highland Hospital, Oakland, CA

Peer Reviewers

James Choi, MD
Associate Professor, Department of Anesthesia, University of Iowa Children's Hospital, Iowa City, IA

Ghazala Q. Sharieff, MD, FAAP, FACEP, FAAEM
Associate Clinical Professor, Children's Hospital and Health Center/University of California; Director of Pediatric Emergency Medicine, California Emergency Physicians, San Diego, CA

CME Objectives

Upon completion of this article, you should be able to:

1. Describe the anatomic and physiologic differences between pediatric and adult patients and how they relate to airway management
2. Describe new methods for preoxygenation.
3. Describe some medications used for rapid sequence intubation and their individual risks versus benefits
4. Describe special considerations in caring for obese patients and the uses of video laryngoscopy.

Prior to beginning this activity, see the back page for faculty disclosures and CME accreditation information.

Case Presentation

You are working a day shift that you traded with your colleague when your local EMS calls in about a 4-year-old boy who apparently went to sleep last night "fine" but is now febrile, significantly altered, and exhibiting a petechial rash. The paramedics report a respiratory rate of 40 breaths per minute, a heart rate of 180 beats per minutes, a blood pressure of 50/palp, and an oxygen saturation of 84% despite the use of high-flow oxygen via facemask. The child is weak, has increased work of breathing, and has a grayish skin color. As the child arrives in your resuscitation room, several questions come to mind: How am I going to preoxygenate this child prior to intubation? What if he begins to vomit and occlude his airway? What if I can't intubate or ventilate this child? What steps can I take to reduce the risk of him coding during the intubation? Why did I agree to work this shift?

Introduction

Managing the pediatric patient who requires an advanced airway is a fundamental skill for physicians who work in the emergency department (ED). Although there are many pathways that lead to respiratory failure, there are only a handful of final common pathways that result in placing an endotracheal tube in the trachea of a sick child. Fortunately, complete respiratory failure in the pediatric patient is an uncommon event. Emergency clinicians should be prepared for the unique challenges posed by the anatomy and physiology of the pediatric airway, be familiar with the rapid assessment of the pediatric patient who requires intubation, be equipped with the standard and alternative sizes of pediatric airway devices, and have an organized approach to prepare for and execute successful pediatric rapid sequence intubation (RSI). This issue of *Pediatric Emergency Medicine Practice* presents an updated and systematic analysis of key principles regarding the pediatric airway, including newly recognized tips regarding preoxygenation and prevention of desaturation during airway management, the latest on the use of pretreatment, induction, and paralytic agents in pediatric RSI, and highlights the potential pitfalls of tracheal intubation with direct and video laryngoscopy.

Critical Appraisal Of The Literature

Unfortunately, there are few well-done prospective randomized controlled trials comparing intubation devices and techniques or pretreatment, induction, and paralytic medications in emergency pediatric intubation. The majority of data regarding these issues come from retrospective archives and chart reviews that report what was done and show an association between a particular device, technique, or medication and the overall outcome of the patient. The nature of retrospective data limits the amount of information that can be abstracted from the medical record and ultimately cannot establish a cause-and-effect relationship between what is studied and the reported outcome. Prospective randomized trials that have been completed have had small sample sizes and may represent homogenous populations, thus limiting their external validity. Furthermore, the majority of data arise from the anesthesia literature, which pertains to elective pediatric intubations and not to the emergency or failing pediatric airway. Finally, there are areas within the airway literature where the best available evidence regarding pediatric techniques is extrapolated from the adult literature. These limitations should be kept in mind when reading this review.

Prehospital Care

Airway management with bag-valve mask and endotracheal intubation are fundamental skills in the out-of-hospital resuscitation of critically ill and injured patients. However, with reported failure rates ranging between 0% and 50%,[1-9] the overall efficacy and safety of prehospital endotracheal intubation in pediatric patients has been questioned. The wide variation in reported endotracheal intubation failure rates may be partially explained by experience and training of the prehospital personnel, availability and access to neuromuscular-blocking agents, and other patient setting characteristics such as cardiac arrest or trauma. Unfortunately, most investigations of prehospital airway management include heterogeneous samples of providers and patients, which obscures the true procedural success rates for these subgroups. Furthermore, many of the studies evaluating prehospital airway management are small in size, which is especially problematic when these relatively small differences in success rates may be clinically relevant. A recent systematic review of over 100 studies involving 57,132 prehospital patients found the overall success of ground paramedics for orotracheal intubation in pediatric patients to be 83.2% (95% confidence interval [CI], 55.2%-95.2%).[10] The wide CI that accompanies these data speaks to the significant variation in overall success rates between studies.

The effect of out-of-hospital endotracheal intubation on survival and neurologic outcome of pediatric patients was evaluated in a controlled clinical trial that encompassed the Los Angeles County and Orange County, California regions.[11] A total of 830 consecutive patients aged 12 years or younger or estimated to weigh < 40 kg who required airway management were assigned to receive either bag-valve mask ventilation or bag-valve mask ventilation followed by endotracheal intubation, with randomization based on day of the month. The authors found no significant difference in survival between the bag-valve mask group (123/404 [30%]) and the endotracheal intubation group (110/416 [26%]) (odds ratio [OR] 0.82; 95% CI, 0.61-1.11) or in the rate of achieving a good neurologic outcome (bag-valve mask, 92/404 [23%] vs endotracheal intubation, 85/416 [20%]) (OR 0.87; 95% CI, 0.62-1.22).[11] There was no significant difference in the complication rates between these procedures; however; there was a trend towards more patients experiencing gastric distension in the bag-valve mask group. In the endotracheal intubation group, 2% of patients had unrecognized esophageal intubation, 14% had unrecognized or recognized dislodgement of the endotracheal tube, 18% received a mainstem intubation, and 24% were intubated with a tube of the incorrect size.[11]

Several retrospective trauma registry reviews have reached the same conclusion.[12-15] In these trials, endotracheal intubation was associated with similar or worse outcomes compared to bag-valve mask ventilation in pediatric trauma patients. Due to the nature of retrospective reviews, these results may be partially or fully explained by differences in baseline patient conditions or therapies during resuscitation, but they do suggest an association between prehospital endotracheal intubation and overall worse outcome.

Despite the available evidence suggesting equivalence or better outcomes with bag-valve mask rather than endotracheal intubation in pediatric patients, a survey of EMS medical directors in California found that 22/25 (88%) of directors who responded to the survey continue to support the use of pediatric endotracheal intubation in their agencies. Over half of the survey respondents replied that "more evidence is needed" or "these results do not apply to my EMS system" as the top reasons to continue the practice of prehospital pediatric endotracheal intubation.[16]

Based on the best available evidence, it seems that prehospital use of bag-valve mask ventilation is comparable to endotracheal intubation in pediatric patients who are critically ill or injured and require respiratory support. Without dedicated and formal requirements regarding endotracheal intubation skills with pediatric patients, paramedic skill and knowledge degradation likely explains some of the failed intubations by these medical providers.[17] The use of bag-mask valve ventilation in pediatric patients is likely a safer and more effective option for these medical providers. Emergency clinicians with a higher skill set (eg, air transport medical providers or ambulance physicians who follow standardized guidelines) have higher success rates, fewer complications, and better outcomes.[18,19]

Practice Tip: When pediatric patients arrive in the ED already intubated, the first step should always be to confirm the endotracheal tube placement. Small tubes in small patients are easily dislodged during transport.

Anatomic And Physiologic Considerations

Anatomic Differences

Significant differences exist between the airway of the young child and the older child.[20-25] As children grow, their airways adopt a form more similar to adults and, in general, by 8 to 9 years of age, the airway is very similar to an adult airway. The following comments apply mainly to children < 8 years of age. **Table 1** lists a summary of the anatomic and physiologic differences in the airway of pediatric patients.

Occiput

Anatomically, infants and toddlers have a large, prominent occiput, which passively flexes the head and neck anteriorly when they are placed in a supine position. This can create a partial airway obstruction that may obstruct visualization of the airway structures during laryngoscopy. Proper positioning can be achieved by placing a small towel roll underneath the child at the level of the shoulders or by having a second person gently lift the child by the shoulders.

Table 1. Anatomical Differences In The Airway Of The Young Child (< 8 Years Of Age)

Feature of Anatomy/Physiology	Clinical Significance
Large occiput that may cause flexion of the airway in the supine position	The sniffing position is preferred. In small infants, a towel under the shoulders to elevate the torso relative to the head may be required.
Tongue occupies a relatively large portion of the oral cavity	May require oral or nasal airway to relieve obstruction
More cephalad larynx appearing more anteriorly, floppy epiglottis, and sharp angle between base of tongue and glottis opening	Direct laryngoscopy may be difficult
Small cricothyroid membrane	Needle cricothyrotomy is difficult. Surgical cricothyrotomy is impossible in infants and small children.
Shorter trachea	Risk of right mainstem intubation
Small airway diameter of supporting respiratory structures	Small amount of airway edema may cause disproportionately greater restriction to airflow in small children
Lower functional reserve capacity per weight, less glycogen and fat storage, and higher metabolic rate	Faster oxygen desaturation than adults

Care must be taken to avoid placing towels below the head, as is sometimes done in adult patients, which can lead to further mechanical and visual obstruction of the glottis.

Tongue

The tongue of the young pediatric patient occupies a relatively larger amount of space in the oral cavity compared to adults. When in the supine position, decreased muscle tone increases the likelihood of passive airway obstruction due to the tongue. Proper head positioning (as described previously) or the use of an oropharyngeal airway (or nasopharyngeal airway in older children) can alleviate obstruction from the tongue during ventilation with a bag-valve mask. Some practitioners prefer using a Macintosh blade for intubation (which is better designed to handle a large tongue) rather than the straight blade.

Neck

Several factors within the neck can make visualization of the vocal cords and proper placement and positioning of a definitive airway difficult in the pediatric patient. The combination of a more cephalad larynx, a long and floppy "omega-shaped" epiglottis, and abnormal angulation that makes the glottis opening appear slanted further away can make visualization of the vocal cords difficult during laryngoscopy. Additionally, narrowing of the pediatric airway is believed to occur at the glottis,[26-28] as in adults, as well as the cricoid ring, accounting for difficulty in passing the endotracheal tube into the trachea at these positions. Additional considerations include: (1) the smaller length of the trachea in pediatric patients (approximately 4 cm in a newborn compared to 12-15 cm in adults), which can lead to a higher risk of mainstem intubation; and (2) the narrowed cricothyroid space, which can make surgical cricothyrotomy difficult.

Airway Size

The diameter of the pediatric airway is much smaller than in the adult airway, making it far more vulnerable to obstruction by foreign objects, infection, edema, or secretions. The Hagen-Poiseuille law describes nonturbulent airflow resistance that is inversely proportional to the radius of the trachea to the fourth power. For example, decreasing the airway diameter from 4 mm to 2 mm (decrease of 50%) will result in a 75% decrease in the cross-sectional area and a 16-fold increase in the airflow resistance. The combination of smaller airways and increased airway resistance predisposes infants and young children to respiratory failure.

Mechanics Of Ventilation

Pediatric patients have smaller tidal volumes, greater chest wall compliance, and increased respiratory rates compared to adults. These features all impact the functional reserve capacity of children. Awake infants, for example, have 40% of the weight-normalized functional reserve capacity of adults.[23] In addition, during periods of apnea, a decrease in chest wall tone combined with greater chest wall compliance can reduce the functional reserve capacity even further.

Physiologic Response

Several anatomic and biochemical reasons explain why infants and children are at higher risk for respiratory fatigue than adults. Primarily, children have smaller lung volumes relative to their metabolic demand. From an anatomic perspective, infants and small children have a lower percentage of type I muscle fibers (as well as less glycogen and less fat storage) in their intercostal muscles and diaphragm.[25,29] Type I muscle fibers are less prone to fatigue, and the lack of a sustainable energy source can lead to early respiratory muscle weakness. In addition, as previously mentioned, a decreased functional reserve capacity results in less reserve oxygen for gas exchange. Infants and small children have a higher metabolic rate than adults and metabolize up to 6 mL of oxygen per minute, while adults only metabolize 3 mL of oxygen per minute.[23] All of these factors can cause infants and small children to desaturate much more quickly than adults during periods of apnea.

Emergency Department Evaluation

The Pediatric Assessment Triangle

Assessing a child for signs of respiratory distress or failure can be daunting. One approach to use is the pediatric assessment triangle (PAT), which assesses the overall appearance of the child, his/her work of breathing, and circulation to the skin.[30] The advantage of using the PAT is that it can be initiated in less than 30 seconds and can be done from across the room, prior to touching the child. Experienced practitioners already use this technique subconsciously when assessing respiratory distress. Once the PAT is completed, if immediate resuscitation is not required, a more complete assessment can be done.

Overall Appearance

The mnemonic "TICLS" summarizes a brief assessment of the overall appearance: Tone, Interactiveness, Consolability, Look/gaze, and Speech/cry.[31] **(See Table 2.)** The overall appearance assesses for adequacy of ventilation, oxygenation, brain perfusion, body homeostasis, and central nervous system function.

Work Of Breathing

The assessment of work of breathing should focus on audible airway sounds and visual clues to increased work of breathing. **(See Table 3 and Table 4.)**

Circulation To The Skin

The last component of the PAT is assessing circulation to the skin, looking for pallor, mottling, and cyanosis. **(See Table 5 and Table 6, page 6.)** Skin circulation reflects the adequacy of cardiac output, core perfusion, and perfusion of vital organs. Cold room temperatures may cause false skin signs (ie, the cold child may have normal core perfusion but abnormal skin circulation). Inspect the mucous membranes (lips, mouth) in dark- and light-skinned children as well as the nonmucosal skin (ie, face, chest, abdomen) for signs of poor skin perfusion.

Complete Assessment

The complete assessment of a child in respiratory distress takes into account a visual inspection of the child, assessment of respiratory rate and use of accessory muscles, oxygen saturation, and auscultation. Signs of respiratory distress in the child include tachypnea, use of accessory muscles, nasal flaring, tripod position, grunting respirations, and cyanosis. Signs of respiratory failure in the child include decreased level of consciousness, grunting respirations and increased work of breathing, poor air entry and decreased breath sounds, bradycardia, and apnea or bradypnea.

Emergency Department Treatment

RSI describes a sequential process of preparation, positioning, preoxygenation, sedation, paralysis, intubation, and postintubation confirmation to facilitate emergent tracheal intubation **(See Table 7, page 6.)** The success of the procedure depends on the following: (1) development of a simple, systematic approach regarding preparation and execution of the procedure; (2) anticipation of difficulties with intubation and/or ventilation, including having a rescue plan in case intubation does not go as planned; (3) prevention of oxygen desaturation, hypotension, acidosis, and vomiting during the procedure; (4) consideration of the pharmacologic agents needed for successful intubation; and (5) tube confirmation and postintubation management strategies.

Table 2. Tone, Interactiveness, Consolability, Look/Gaze, Speech/Cry (TICLS) Assessment

Characteristic	Features to Look For
Tone	Extremities should move spontaneously, with good muscle tone; should not be flaccid or move only to stimuli
Interactiveness	Should respond to environmental stimuli or presence of a stranger; should not be listless or lethargic
Consolability	Easily comforted or calmed by caretaker (ie, by speaking softly, holding child, or offering a pacifier)
Look/gaze	Should maintain eye contact with objects or people; should not have a "nobody home" or glassy-eyed stare
Speech/cry	Should be present, strong and spontaneous; should not be weak, muffled, or hoarse

Golden Rule: The child's general appearance is the most important thing to consider when determining how severe the illness or injury is, the need for treatment, and the response to therapy.

Preparation

There are a number of preparatory steps that should be completed prior to the initiation of RSI. If time allows, review the patient's past medical history to define any congenital conditions related to a potentially difficult airway. If the patient is cooperative, perform a complete airway assessment. Place the patient on a cardiac monitor with continuous pulse oximetry and automated blood pressure measurements. Establish at least 1, preferably 2, working intravenous (IV) lines, and draw up pretreatment, sedative, and paralytic agents in properly labeled syringes. Additionally, the person in charge of the intubation should make sure that the direct or video laryngoscope is working correctly and that an endotracheal tube of the proper size is prepared and tested for cuff integrity. **(See Table 8, page 6.)** Fallback plans, in the event of a failed intubation, should be formulated, and the proper "rescue" devices should be located and brought into the room. Throughout this phase, the patient should be receiving preoxygenation in the proper patient position.

Table 3. Airway Features

Characteristic	Features to Look For
Abnormal airway sounds	Gasping, hoarse speech, stridor, grunting, wheezing
Abnormal positioning	Sniffing position, tripoding, refusing to lie down
Retractions	Supraclavicular, intercostal, or substernal retractions of the chest wall; head-bobbing in infants
Flaring	Nasal flaring; seen in children of all ages with respiratory distress
Respiratory rate	Outside of normal range for age group **(see Table 4)**

Table 4. Normal Respiratory Rates

Age	Respiratory Rate, Breaths/min
< 1 y	30-40
1-2 y	25-35
2-5 y	25-30
5-12 y	20-25
> 12 y	15-20

Laryngoscopy Blade Choice

Choosing the correct size laryngoscope blade is critical to successful endotracheal intubation. Macintosh (curved) blades are used primarily in children > 2 years of age. The Macintosh blade is placed in the vallecula, lifting the base of the tongue and indirectly lifting the epiglottis. In infants and toddlers who have a large, floppy epiglottis, the curved blade often does not provide adequate exposure of the airway. In this age group, Miller (straight) blades are considered to be preferred, because they directly lift the epiglottis and improve visualization of the vocal cords. Miller 0 blades should be used only in premature infants and average-sized newborns. A Miller 1 blade is appropriate for most infants beyond the immediate newborn period. A Miller 1.5 blade can be used in children who are 1 to 3 years of age, and a Miller 2 blade is used for children older than 3 or 4 years of age. Another straight blade that can be useful in managing the pediatric airway is the Wis-Hipple blade. The Wis-Hipple straight blade has a widened and slightly curved distal tip that can be useful in controlling a large tongue, and it is well adapted to lifting the epiglottis.

Cuffed Versus Uncuffed Endotracheal Tubes

Conventional teaching has been that cuffed endotracheal tubes should not be used in children under the age of 8 years because of the risk of mucosal ischemia from a high-pressure tube cuff. Recent design changes in endotracheal tube cuffs now facilitate a low-pressure, high-volume tube cuff that produces an adequate tracheal seal without compromising mucosal circulation (second-generation endotracheal tubes).[32] Third-generation Microcuff® endotracheal tubes use an advanced microthin polyurethane material (10 microns thick) that permits tracheal sealing at even lower cuff pressures (compared to other cuffed tubes). The use of cuffed tubes in young children is increasing, especially in EDs and pediatric intensive care units.[33] Potential benefits of second- and third-generation cuffed endotracheal tubes are: (1) facilitating ventilation with higher airway pressures, (2) more consistent ventilation, (3) protection from gastric aspiration,[34] and (4) decreased need to exchange inappropriately sized endotracheal tubes. Meanwhile, the risks of uncuffed tubes becoming dislodged, allowing aspiration, and being inadequate for high airway pressures are quite substantial.

Practice Tip: Cuffed endotracheal tubes are safe and effective in children and should be your tube of choice in pediatric ED intubations in all children outside the neonatal period.

Endotracheal Tube Size

The internal diameter of the appropriate endotracheal tube for a child will roughly equal the size of that child's fifth finger, but this estimation may be difficult and unreliable.[35] Endotracheal tube size is more reliably based on the child's age and body length. For uncuffed endotracheal tubes (and for Microcuff® cuffed endotracheal tubes), use this formula: age (in years)/4 + 4. For traditional cuffed endotracheal tubes, 1 tube size smaller should be used. Alternatively, length-based resuscitation tapes can be used to guide equipment size. In premature

Table 5. Skin Circulation Characteristics

Characteristic	Features to Look For
Pallor	White or pale skin or mucous membrane coloration
Mottling	Patchy skin discoloration due to vasoconstriction
Cyanosis	Bluish discoloration of skin and mucous membranes

Table 6. Normal Heart Rates

Age	Heart Rate, Beats/min
< 1 y	110-160
1-2 y	100-150
2-5 y	95-140
5-12 y	80-120
> 12 y	60-100

Table 7. The 8 Ps of Rapid Sequence Intubation

1. Preparation
2. Preoxygenation
3. Prevention of complications
4. Pretreatment
5. Paralysis with induction
6. Protection and positioning
7. Placement with proof
8. Postintubation management

Table 8. Suggested Equipment For Successful Rapid Sequence Intubation

- Cardiac monitor with automated blood pressure measurements and continuous pulse oximetry
- Intravenous access
- Oxygen via nonrebreather mask
- Bag-valve mask with self-inflating bag
- Functional laryngoscope – direct, video-assisted, or optical stylet with various blade types and sizes
- Multiple endotracheal tubes with stylet and 10-cc syringe
- Intubation medications in properly labeled syringes
- Gum elastic bougie
- Functional suction device
- "Rescue" airway device
- End-tidal CO_2 detector
- Nasopharyngeal and oropharyngeal airway

infants, the gestational age, in weeks, divided by 10 roughly estimates the endotracheal tube size (eg, 25 weeks = 2.5-mm tube). Proper preparation requires having several endotracheal tubes available, including one that is 1 size larger than anticipated and one that is 1 size smaller than anticipated.

Video-Assisted And Optical Laryngoscopy

A recent innovation in airway management has been the introduction of video-assisted and optical laryngoscopy. The most common devices in the pediatric setting are the AIRTRAQ® Disposable Optical Laryngoscope (Prodol Meditec, Vizcaya, Spain),[36] the GlideScope® Video Laryngoscope (Verathon, Bothell, WA, USA),[37-43] the Storz DCI® Video Laryngoscope (Karl Storz, Tuttlingen, Germany),[44,45] and the Truview PCD™ Infant (Truphatek, Netanya, Israel).[46] A host of pediatric studies have emerged comparing these new technologies to traditional direct laryngoscopy, and the majority show these newer devices to be at least as good as direct laryngoscopy in endotracheal intubation in the patient with a normal airway and better than direct laryngoscopy in patients with difficult airways.[36-46] These devices are not foolproof, however, and complications have been reported.[47,48] As with any new technology, there is a learning curve associated with these devices, with many experienced practitioners noting that the time to intubation is longer with video-assisted or optical laryngoscopy compared to direct laryngoscopy. Additionally, many of these video-assisted devices require a specific stylet that is more rigid, has a sharper angulation, and may require additional manipulation to facilitate endotracheal tube placement compared to traditional devices.

Gum Elastic Bougie

In the ED, the gum elastic bougie is an invaluable tool that can facilitate difficult endotracheal intubation.[49-52] It can be used in situations when laryngoscopy views of the glottis are suboptimal or not possible and in the scenario when, despite adequate visualization of the glottis, the act of placement of an endotracheal tube obstructs the view of the glottis at the last moment. Bougie placement within the trachea can be confirmed by the unmistakable palpation of the tracheal rings as the bougie is passed and by resistance to advancement beyond the tracheal tree, both of which are absent with esophageal placement. An endotracheal tube is then passed over the gum elastic bougie while laryngoscopy is maintained to verify correct placement. Blindly inserting the endotracheal tube once the bougie is in the correct position is not advised, as unintended trauma to the laryngeal soft tissue may occur. Furthermore, a blind insertion may lead to unintentional trauma of the oropharynx. The pediatric bougie can accommodate a 4-0 or larger tubes.

Difficulties with bougie placement are mainly related to inability to insert the bougie past the hypopharynx and inability to pass the endotracheal tube over the bougie.[53] Three tricks may help facilitate passing of the endotracheal tube over the gum elastic bougie: (1) a counterclockwise rotation of the endotracheal tube as it approaches the larynx is advised, as it will decrease the chance of the tube catching on the laryngeal soft tissue; (2) although there is a tendency to remove the laryngoscope after the bougie is inserted, this should be avoided, as the hypopharyngeal soft tissue may push the bougie posteriorly and result in an inability to advance the endotracheal tube; and (3) if resistance is encountered as the endotracheal tube is passed through the laryngeal inlet, the tube should be withdrawn 2 cm, rotated counterclockwise 90°, and re-advanced.

Alternatively, the use of fiberoptic stylets can be used if it is available and if the provider is experienced with this technology. In manikin models with partially obstructed glottic views, the fiberoptic stylet was more effective than the gum elastic bougie in facilitating tracheal intubation.[54,55]

Preoxygenation

Preoxygenation is essential to provide a safety buffer during periods of hypoventilation and apnea.[56] It is thought to result in the formation of an oxygen reservoir within the lungs, blood, and body tissues. In both animal and human models, preoxygenation with 100% oxygen extends the duration of desaturation time from SpO_2 100% to SpO_2 90%, the so-called "safe apnea time."[56] There are a handful of small studies in the pediatric literature that support the use of preoxygenation;[63-69] however, the optimal patient position and duration of preoxygenation is not known.

Preoxygenation Position

The supine position may be a suboptimal position to achieve optimal preoxygenation.[56] As mentioned previously, the relatively larger occiput of the infant or toddler may cause unnecessary flexion upon the airway when the patient is in the supine position, limiting oxygen delivery to the lungs. A handful of adult studies have confirmed the benefits of preoxygenation in a half-sitting-up position compared to the traditional supine position. In separate trials, Ramkumar et al,[57] Lane et al,[58] and Baraka et al[59] examined the safe apnea time in the 20° to 45° sitting-up position compared to the supine position. In all 3 trials, the duration of safe apnea was extended by approximately 1.5 minutes. Dixon et al[60] and Altermatt et al[61] examined this issue in obese adult patients and found that preoxygenation in the half-sitting position extends the duration of safe apnea by nearly 1 minute when compared to the supine position. In patients where spinal immobilization prevents sitting up, the reverse Trendelenberg position is recommended for preoxygenation. Boyce et al[62] found that preoxygenation in the reverse Trendelenberg position resulted in nearly 1 minute of additional safe apnea, compared to the supine position, in obese adult patients. It seems reasonable that preoxygenation in a half-sitting position may improve the duration of safe apnea in pediatric patients requiring RSI.

Preoxygenation Duration

The optimal duration of preoxygenation varies for pediatric patients based upon age and size.[63,64] Infants and toddlers obtain maximal denitrogenation within 60 seconds of preoxygenation. For children aged 2 to 7 years, 2 to 3 minutes of 100% oxygen is thought to accomplish the nitrogen washout in the lungs and body tissue. When compared to 4 or 8 tidal capacity breaths, 3 minutes of 100% oxygen results in a higher degree of nitrogen washout.[67] Safe apnea times follow the same logic regarding age and size. For healthy children undergoing preoperative intubation using an anesthesia circuit capable of delivering 90% to 100% fraction of inspired oxygen (FiO_2), the duration of safe apnea following induction of RSI varies from 30 to 60 seconds in infants and toddlers to 60 to 120 seconds in children 2 to 7 years of age.[56] These guidelines regarding duration of preoxygenation prior to RSI should be kept in mind during pediatric RSI.

Preoxygenation Using A Nonrebreather Mask

Many EDs do not have access to standard anesthesia non-self-inflating bags, which allow virtually 100% FiO_2 with 6 L/min oxygen flow. Standard available nonrebreather masks at flow rates of 15 L/min deliver only 60% to 70% FiO_2, do not provide complete denitrogenation, and, accordingly, do not maximize the duration of safe apnea.[56] Increasing the flow rate by turning the oxygen regulation to its maximal setting beyond the maximum indicated value of 15 L/min is thought to improve the delivery of oxygen to $FiO_2 > 90\%$. Thus, a nonrebreather mask with the flow rate of oxygen set as high as possible is the recommended source of oxygen for preoxygenation prior to RSI in the ED.[56]

Preoxygenation Using Nasal And/Or Oral Airways

For critically ill children where the SpO_2 is < 95% despite adequate preoxygenation, the authors recommend the careful use of bilateral nasopharyngeal airways in the noncomatose patient (with the addition of an oral airway in the comatose child) to improve oxygen delivery and relieve mechanical obstruction from improper tongue or head position. If the oxygen level fails to improve with this strategy, the use of a bag-valve mask device with a practitioner dedicated to using both hands to achieve a good seal is the next appropriate step. Placement of a laryngeal-mask airway (LMA) to improve oxygenation may be needed in the comatose patient who fails to improve with good bag-valve mask technique and supplemental nasal and oral airways.

Preoxygenation Using Positive Pressure Ventilation

Alternatively, noninvasive positive pressure ventilation as a preoxygenation adjunct can be considered if a pediatric-sized mask is available and the patient tolerates the procedure. If the patient is making a respiratory effort but it is inadequate to maintain a reasonable saturation, an attempt should be made to assist rather than actively take over the ventilations. Although current indications for pediatric noninvasive ventilation have been recently reviewed, its use as a preoxygenation agent has not been described.[70,71] In the adult literature, application of noninvasive ventilation as a preoxygenation technique has been evaluated in a half-dozen studies, all of which noted an improvement in preoxygenation parameters.[72-77]

Practice Tip: Preoxygenation with the oxygen regulator set as high as possible, the use of a bag-valve mask with inflated oxygen reservoir, or the use of positive pressure ventilation can increase the amount of safe apnea time during RSI.

Prevention Of Complications

Several complications that are known to occur with RSI are: critical oxygen desaturation during the procedure, peri-intubation hypotension, profound bradycardia, worsening of acidosis, and vomiting resulting in aspiration. **(See Table 9.)** The prevention of these complications is critically important to consider when choosing pretreatment agents and oxygenation techniques during RSI.

Critical Oxygen Desaturation

Desaturation during RSI is a frequent and underreported complication. The use of an additional oxygen circuit applied via nasal cannula set at 15 L/min during the intubation (ie, apneic oxygenation) can prolong the duration of safe apnea and minimize the risks of critical oxygen desaturation. Using this technique, the pharynx remains filled with a high concentration of oxygen and acts as a reservoir from which the alveoli can draw oxygen during the placement of an endotracheal tube.[56] In 3 separate randomized controlled trials that took place in the operating room involving adult patients, the application of a nasal cannula set at 5 L/min of 100% FiO_2 resulted in a significantly longer period of safe apnea compared to control patients.[78-80] Several noncontrolled observational series using the same technique have come to the same conclusion.[81-87] Although pediatric data on this subject are lacking, it seems reasonable to apply a continuous nasal source of oxygen during the entire period of RSI.

Peri-intubation Hypotension

Peri-intubation hypotension occurs in up to 30% of emergent intubations.[88-93] Patients believed to be at significant risk for this outcome include those with hypotension or with tachycardia with normotension immediately before RSI and those with excess catecholaminergic states (eg, respiratory distress, severe pain, trauma) with rapid relaxation and high intrathoracic pressure after institution of positive pressure ventilation.[94]

Several options may attenuate a drop in blood pressure that may occur around the time of intubation. First, in order to avoid this complication, begin by choosing an induction agent with less depressant effect on the cardiovascular system (eg, etomidate) or an agent that can augment the blood pressure (eg ketamine). If an agent that can negatively affect the blood pressure is the only option, use smaller than normal doses until sedation is achieved.[94] Second, begin volume resuscitation with wide-open crystalloid fluids when hypovolemia is suspected prior to the intubation attempt.[94] Third, ensure that a pure vasoconstrictor is readily available.[94] Phenylephrine may be given at a dose of 1 mcg/kg IV every 15 to 20 minutes. It is a pure alpha agonist with no intrinsic inotropy and does not result in tachycardia. Fourth, commence positive pressure ventilation with the lowest possible positive end-expiratory pressure to produce acceptable oxygen saturation.[94]

Table 9. Prevention Strategies For Potential Complications

Complication	Prevention Strategy
Desaturation	• Preoxygenation with non-self-inflating bag and mask • Apneic oxygenation during RSI
Peri-intubation hypotension	• Choose etomidate or ketamine for sedation • Volume resuscitation prior to RSI • Phenylephrine 55-20 mcg/kg IV bolus • Low PEEP ventilator strategy
Bradycardia	• Pretreatment with atropine for infants < 1 year of age • For older children, atropine should be readily available
Severe acidosis	• Avoid hypotension • Match preintubation respiratory effort (unless asthma) • Obtain blood gas 10-15 minutes after intubation • Consider sodium bicarbonate
Vomiting/aspiration	• Cricoid pressure • Position patient in partial sitting position

Abbreviations: IV, intravenous; PEEP, positive end-expiratory pressure; RSI, rapid sequence intubation.

Bradycardia

Infants and children can develop profound bradycardia during intubation from medication effect, vagal effect from manipulation of the hypopharynx and epiglottis from the laryngoscopic blade, and from hypoxia.[95] Atropine blocks this reflex bradycardia and had been routinely recommended for pediatric intubation. The evidence from 2 pediatric trials suggest that the rate of profound bradycardia with RSI is much lower than previously reported and that the routine use of atropine does not reduce the incidence of bradycardia when given as a pretreatment agent.[96,97] Two quasi-systematic reviews of this topic arrived at the same conclusion.[98,99] Thus, the use of atropine as a routine agent in pediatric RSI is no longer mandatory, although its use is still recommended in infants < 1 year of age and can be considered in patients < 5 years of age. The dose of atropine pretreatment is 0.01 to 0.02 mg/kg (minimum dose, 0.1 mg; maximum dose, 0.5 mg). Should bradycardia occur during RSI, atropine and epinephrine must be readily available.

Severe Acidosis

Severe acidosis can result in profound hemodynamic complications, including cardiac arrest. This can occur when the patient is tachypneic as a response to an underlying metabolic acidosis and then, following intubation, the ventilator is set at an inappropriately low rate, causing respiratory acidosis in addition to the preexisting metabolic acidosis. Failure to maintain the same level of respiratory compensation for metabolic acidosis can cause a rapid decrease in pH, which promotes circulatory complications—most commonly bradycardia, asystole, or tachydysrhythmia.[94] To avoid acidosis-related complications with RSI, remember the following: First, take preventative measures to avoid hypotension during RSI.[94] Second, choose a ventilator respiratory rate that matches the patient's preintubation respiratory effort (so long as breath stacking does not occur).[94] In patients with asthma, this rule is violated, as breath stacking is common and patients require prolonged expiratory times. Third, obtain a blood gas within 10 to 15 minutes on the ventilator to evaluate the acid/base status.[94] Use of continuous end-tidal carbon dioxide ($ETCO_2$) monitoring is also helpful in this setting. Fourth, consider sodium bicarbonate[94] if the patient becomes unstable and other measures to address the acidosis have failed.

Vomiting/Aspiration

Aspiration of oral or gastric contents during laryngoscopy or intubation occurs in a small percentage of patients, but it can lead to significant morbidity.[100,101] Inadequate sedation, stimulation of the gag reflex by laryngoscopy, gastric distension from preoxygenation with positive pressure and preexisting conditions (such as bowel obstruction) can all lead to vomiting and aspiration. Cricoid pressure (which was once thought to help prevent passive regurgitation), if applied, should not be maintained during forceful vomiting due to the risk of esophageal rupture. Positioning the patient in a partial sitting position employs the benefit of gravity and positions the trachea at a higher angle compared to the supine position.

Pretreatment

A variety of pretreatment options exist in pediatric RSI. **(See Table 10.)** Traditional agents include lidocaine, opiates, atropine, and a defasciculating dose of a paralytic; however, use of these agents has been called into question recently. Newer agents to consider during the pretreatment phase include phenylephrine, sodium bicarbonate, and an antiemetic agent.

Lidocaine

Endotracheal intubation and laryngeal manipulation are known to transiently increase intracranial pressure. Lidocaine, at a dose of 1.5 mg/kg given several minutes before tracheal suctioning in intubated adult patients, has been shown to directly blunt the intracranial pressure rise that is expected to occur.[102-107] Whether this phenomenon occurs during pediatric RSI is unknown. There is also some evidence demonstrating that the administration of lidocaine in adults can result in a significant drop in the mean arterial pressure.[108] This is particularly concerning given that decreases in mean arterial pressure cause decreases in cerebral perfusion pressure. Furthermore, the intracranial pressure increase associated with intubation resolves in 3 to 5 minutes. Whether a mild and transient increase in intracranial pressure leads to clinically significant long-term neurologic outcomes is not known. Despite the lack of direct evidence for significant benefit, some authors continue to advocate for its use,[109,110] whereas others do not.[111,112] Given the lack of evidence regarding patient-oriented outcomes, the authors consider lidocaine an optional medication in the pretreatment of children with suspected increased intracranial pressure who require emergent intubation.

Table 10. Recommendations For Pretreatment Agents For Rapid Sequence Intubation

Pretreatment Agent	Recommendation
Lidocaine	No quality studies with patient oriented outcomes to support routine use. Optional use in children with suspected increased intracranial pressure.
Opiate	No quality studies with patient-oriented outcomes to support routine use. Not currently recommended in pediatric patients.
Atropine	Recommended for infants < 1 year of age. Optional use in children < 5 years of age.
Defasciculating dose of a paralytic	No quality studies with patient-oriented outcomes to support routine use. Not currently recommended in pediatric patients.
Phenylephrine	Limited evidence of patient-oriented outcomes to support use. Consider use in peri-intubation hypotension.
Bicarbonate	No current evidence to support routine use. Consider use in severe acidosis only if ventilation is adequate to remove the additional CO_2 produced.
Antiemetic	No current evidence to support routine use. Consider use to prevent vomiting/aspiration.

Opiates

Pretreatment with opiates is not generally recommended for children.[23,113] In adult patients, opiates (particularly fentanyl) are thought to attenuate the sympathetic response that sometimes occurs with endotracheal intubation. The usual recommended dose is 2 to 3 mcg/kg given 1 to 3 minutes prior to intubation; however, sympathetic blockade requires higher doses, 5 to 7 mcg/kg, a dose that may result in earlier than anticipated apnea and hypotension.[114]

Atropine

As mentioned previously, atropine prevents the bradycardia that may occur with manipulation of the hypopharynx and epiglottis with the laryngoscopic blade. Although prospective data are lacking, the routine use of atropine is recommended by some authorities as a premedication agent in all children < 1 year of age, children between 1 and 5 years of age who receive succinylcholine, adolescents who receive more than 1 dose of succinylcholine, and anyone with bradycardia immediately preceding the intubation. Proponents of the routine use of atropine argue that pretreatment outweighs any potential risk because young children can tolerate heart rates of 180 to 200 beats per minute with little effect. Opponents argue that eliminating steps that do not have clear evidentiary support streamlines pediatric resuscitation and limits chances for medication error. Several quasi-systematic reviews on the subject and a major airway textbook question this recommendation, concluding that there is insufficient evidence to currently recommend the routine use of atropine in pediatric RSI.[23,111,112]

Defasciculating Dose Of A Paralytic

The use of a defasciculating dose (ie, 1/10th the normal dose) of a nondepolarizing neuromuscular blocking agent prior to succinylcholine administration may result in decreased muscle fasciculations and diminished rise in intracranial pressure during endotracheal intubation. Although several animal studies[113-119] and 1 human study[120] demonstrated an increase in intracranial pressure when succinylcholine was administered, other studies[121-124] have shown minimal or no changes to intracranial pressure. A systematic review on this topic found limited data supporting this practice and concluded that the use of a defasciculating dose prior to paralytic administration in RSI has not been shown to affect neurologic outcome.[125] Furthermore, in pediatric patients, a defasciculating dose may completely paralyze the patient before unconsciousness is achieved.

Nontraditional Pretreatment Agents

As mentioned in the Prevention Of Complications section **(see page 8)**, there are several nontraditional agents that have some theoretical basis for use prior to RSI. These agents include phenylephrine to mitigate peri-intubation hypotension, sodium bicarbonate as a buffering agent for patients in severe acidosis, and metoclopramide and/or ondansetron to prevent vomiting during RSI. There are, however, limited data to support the use of these agents in RSI.

Phenylephrine is a pure alpha-adrenergic agonist that can transiently improve blood pressure and cardiac output. In patients who are hypotensive or who are at risk for becoming hypotensive during RSI, phenylephrine can be used to transiently improve the hemodynamics. Phenylephrine can be given in the pediatric patient at a dose of 1 mcg/kg as an IV bolus every 10 to 15 minutes as needed. In addition to phenylephrine,[126] other agents such as ephedrine[127,128] and ketamine[128] have been used successfully to mitigate the hypotension associated with induction prior to endotracheal intubation.

Sodium bicarbonate is sometimes considered as a potential buffering agent in patients with severe metabolic acidosis prior to RSI. The inevitable hypoventilation that occurs as these patients are intubated may worsen the overall acid-base status of the patient, leading to cardiac arrhythmias and hemodynamic compromise. Sodium bicarbonate given prior to RSI may provide a temporary buffer by stimulating the respiratory drive to exhale a larger proportion of CO_2 and may provide an intravascular buffer during the critical moments of RSI. There are no trials that have evaluated the use of sodium bicarbonate prior to RSI to prevent worsening acidosis. Routine use as a premedication is not recommended; however, there may be selected cases of severe acidosis where its use can be considered.

Antiemetic agents such as metoclopramide and/or ondansetron, when given prior to RSI, may decrease the incidence of vomiting and, therefore, aspiration. Theoretically, metoclopramide is a good choice in this setting as it is thought to both increase the lower esophageal sphincter pressure and enhance gastric emptying. There are no trials that have evaluated the use of an antiemetic agent prior to RSI to prevent vomiting or aspiration.

Paralysis With Induction

Induction

The ideal induction agent rapidly induces unconsciousness, provides some amount of temporary amnesia, has a short duration of action, and possesses minimal cardiovascular side effects. None of the current agents that emergency clinicians use possess all of these qualities. It is prudent to be familiar with the dosages, indications, and contraindications of several induction agents in case of medication unavailability and variability of the clinical scenario. **(See Table 11.)**

Etomidate

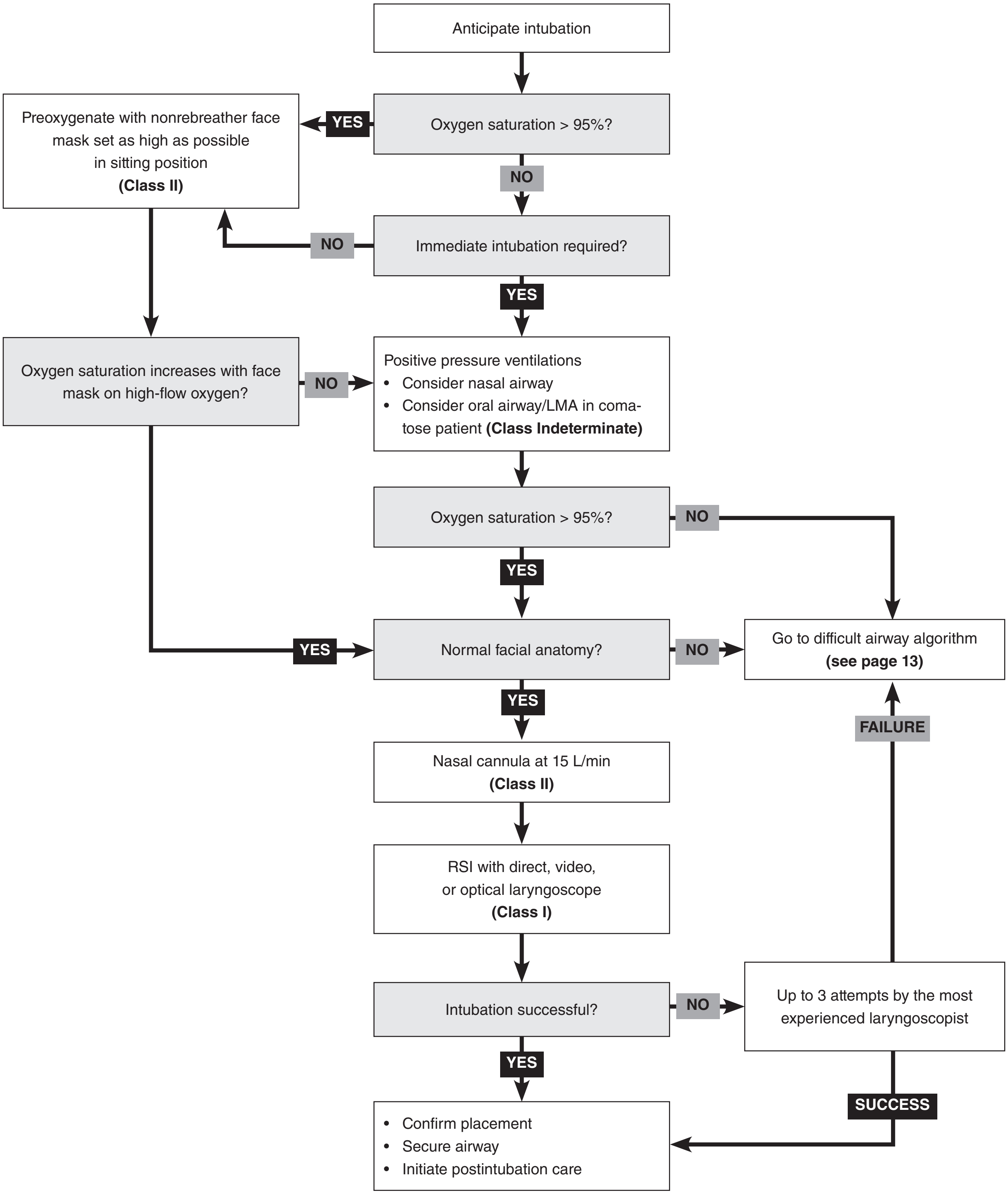
Etomidate (0.2-0.4 mg/kg IV) is an imidazole derivative sedative agent that produces rapid sedation (onset within 30-60 sec) and has a short duration of action (5-15 min). Etomidate's main advantage is that it exerts minimal cardiovascular and respiratory effects, making it a desirable agent in normotensive patients. Additionally, etomidate decreases cerebral metabolism and is considered safe in patients with elevated intracranial pressure.

Research studies have attempted to describe the quality of the sedation and intubating conditions that occur with etomidate, but due to the paralytic agent used, the lack of a standardized grading scale for this outcome, the inadequate use of independent observers recording the outcome during the procedure, and other factors, the quality of their results is limited.[129,130] There have been 3 pediatric studies that have evaluated etomidate for RSI in the ED.[130-132] In the first, a prospective series of children who received the combination of etomidate/rocuronium as part of RSI in a pediatric ED, intubating conditions were

Table 11. Preferred And Alternate Sedative Agents

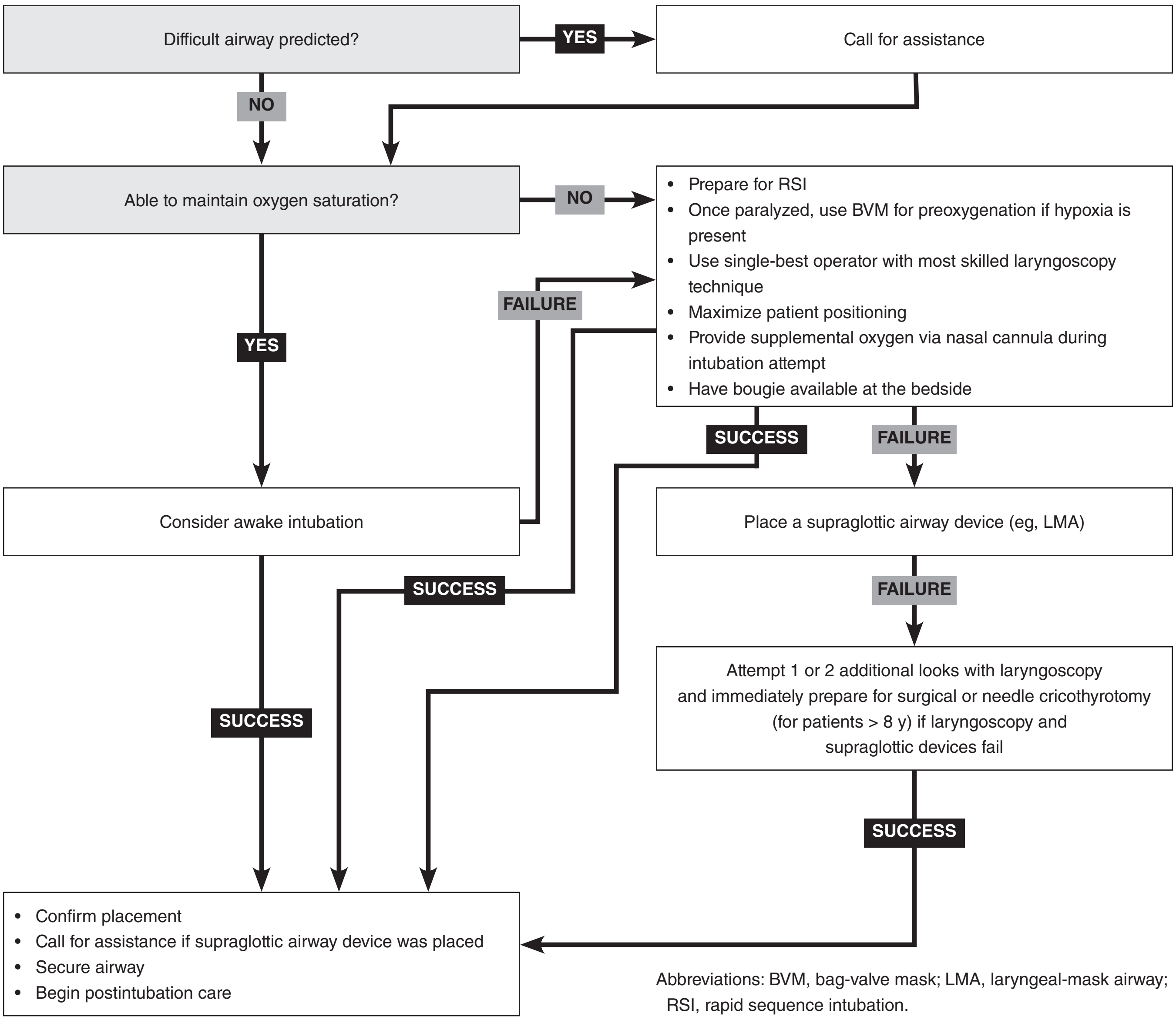
Clinical Situation	Preferred Sedative Agent	Alternative Sedative Agent
Hypotension	Ketamine	Etomidate
Increased intracranial pressure	Etomidate	Ketamine
Severe asthma	Ketamine	Etomidate
Status epilepticus	Benzodiazepine or propofol	Etomidate

Clinical Pathway For Managing The Pediatric Airway



Abbreviations: LMA, laryngeal mask airway; RSI, rapid sequence intubation.
For class of evidence definitions, see page 13.

Clinical Pathway For The Difficult Airway



Abbreviations: BVM, bag-valve mask; LMA, laryngeal-mask airway; RSI, rapid sequence intubation.

Class Of Evidence Definitions

Each action in the clinical pathways section of *Pediatric Emergency Medicine Practice* receives a score based on the following definitions.

Class I
- Always acceptable, safe
- Definitely useful
- Proven in both efficacy and effectiveness

Level of Evidence:
- One or more large prospective studies are present (with rare exceptions)
- High-quality meta-analyses
- Study results consistently positive and compelling

Class II
- Safe, acceptable
- Probably useful

Level of Evidence:
- Generally higher levels of evidence
- Non-randomized or retrospective studies: historic, cohort, or case control studies
- Less robust randomized controlled trials
- Results consistently positive

Class III
- May be acceptable
- Possibly useful
- Considered optional or alternative treatments

Level of Evidence:
- Generally lower or intermediate levels of evidence
- Case series, animal studies, consensus panels
- Occasionally positive results

Indeterminate
- Continuing area of research
- No recommendations until further research

Level of Evidence:
- Evidence not available
- Higher studies in progress
- Results inconsistent, contradictory
- Results not compelling

Significantly modified from: The Emergency Cardiovascular Care Committees of the American Heart Association and representatives from the resuscitation councils of ILCOR: How to Develop Evidence-Based Guidelines for Emergency Cardiac Care: Quality of Evidence and Classes of Recommendations; also: Anonymous. Guidelines for cardiopulmonary resuscitation and emergency cardiac care. Emergency Cardiac Care Committee and Subcommittees, American Heart Association. Part IX. Ensuring effectiveness of community-wide emergency cardiac care. *JAMA.* 1992;268(16):2289-2295.

This clinical pathway is intended to supplement, rather than substitute for, professional judgment and may be changed depending upon a patient's individual needs. Failure to comply with this pathway does not represent a breach of the standard of care.

noted to be "good" by the physician performing the intubation in 68 of 69 patients (98.6%) (95% CI, 92.2%-99.9%). Hypotension after induction with etomidate was uncommon, and when it did occur, it was either transient (5 patients) and did not require intervention or it was associated with a confounding diagnosis at the time of intubation (1 patient with traumatic hemorrhage and 1 patient with sepsis).[130] Two additional retrospective series confirm the efficacy and safety of etomidate in pediatric patients.[131,132] Reported problems with etomidate include myoclonus, vomiting, and temporary suppression of the adrenocortical axis. Although there are mixed and generally poor-quality data supporting the claim that a single dose of etomidate in patients with septic shock leads to a poor outcome, several major groups have come out against its use in this setting. An appropriate alternative in these patients is ketamine.[133]

Ketamine

Ketamine is a phencyclidine derivative that produces potent analgesia and amnesia at a dose of 1 to 4 mg/kg IV. Its onset of action is less than 2 minutes, and its duration of action is up to 30 minutes. Ketamine's advantages lie in the fact that it does not inhibit spontaneous respiration, making it an attractive agent for a sedative-only intubation, such as would occur in patients in whom difficult intubation and reoxygenation are expected due to anatomical abnormalities. Additionally, ketamine causes a catecholamine release, resulting in increases in blood pressure and heart rate via beta-1 adrenergic receptors and dilation of small airways through beta-2 adrenergic receptors. Ketamine is an especially useful agent in critically ill patients,[133] particularly severely asthmatic patients, when given at induction doses. Side effects that are seen with ketamine include tachycardia, hypertension, emergence phenomenon in older patients, laryngospasm, and excessive salivation. Additionally, in some critically ill patients whose endogenous catecholamines are depleted, ketamine can cause severe cardiac depression and resulting hypotension.[134] Previous concerns regarding caution in patients with increased intracranial pressure or increased intraocular pressure seem unwarranted.[135-141]

Propofol

Propofol (1-3 mg/kg IV) is a highly lipophilic, rapidly acting induction agent with an onset of action in 20 to 30 seconds and a duration of action of 10 to 15 minutes. Continuous sedation can be achieved with doses of 25 to 100 mcg/kg/min. Given its lipophilic nature, propofol can cross the blood-brain barrier and is believed to decrease cerebral metabolism. This neuroprotective effect, which must be balanced against the decrease in mean arterial pressure that occurs, may be useful in patients with head injury or increased intracranial pressure (eg, head trauma, meningoencephalitis).

Benzodiazepines (Diazepam, Lorazepam, Midazolam)

Diazepam (0.2-1.0 mg/kg IV), lorazepam (0.1-0.4 mg/kg IV), and midazolam (0.1-0.4 mg/kg IV) are effective, albeit slow-acting, sedative agents. Although useful in patients with status epilepticus or seizures from other causes, their negative effect on blood pressure and respiratory status limit their routine use in pediatric RSI in the ED.

Barbiturates (Methohexitol, Thiopental)

Thiopental (2-5 mg/kg IV) and methohexital (1-1.5 mg/kg IV) are short-acting barbiturates with a rapid onset (< 30 sec) and a short duration of action (5-10 min). Like propofol, these agents are lipid soluble, can easily cross the blood-brain barrier, and produce rapid central nervous system depression, decreased intracranial pressure, and decreased cerebral metabolic and oxygen demands. Indications for these agents include head-injured patients with normal blood pressure, patients with increased intracranial pressure secondary to meningoencephalitis, and patients with status epilepticus. Barbiturates can cause cardiac and respiratory depression and vasodilatation, producing hypotension. Additionally, up to 2% of patients have an allergic response to thiopental, causing laryngospasm and bronchospasm. Production of thiopental in the United States was discontinued in 2011.

Choice Of Induction Agent

There are no well-done prospective studies that have compared the use of contemporary induction agents for pediatric RSI. The largest retrospective series of adult and pediatric intubations had the unexpected finding that the choice of sedative agent was associated with the number of intubation attempts (P = 0.002).[142] Specifically, the use of thiopental, methohexital, and propofol was associated with a higher likelihood of intubation success compared to etomidate, ketamine, or a benzodiazepine.[142] Unfortunately, the retrospective nature of this trial and the lack of safety data points limit the conclusions; however, it may be that the intubating conditions produced by barbiturates and propofol may be superior to those by etomidate, ketamine, or a benzodiazepine at standard doses. It is also possible that the practitioners that chose to use these agents may have had a higher comfort level with using these medications and may have been more experienced in RSI.

Paralytics

Paralytic agents provide complete skeletal muscle relaxation, facilitating the success of endotracheal tube placement during RSI. There are 2 types of paralyzing agents: depolarizing (eg, succinylcholine) and nondepolarizing (eg, rocuronium), both of which are used extensively in RSI.

Practice Tip*:* Many experts believe that paralytics should not be included in the first intubation attempt in a patient with difficult anatomy, especially if rescue ventilation is expected to be difficult as well.

Succinylcholine

Succinylcholine is touted as the ideal paralytic agent for RSI,[143,144] principally because of its rapid onset of action (30-60 sec) and short duration of action (4-6 min) when given intravenously at a dose of 1 to 2 mg/kg. Nonetheless, several serious adverse effects of succinylcholine are known to occur, including hyperkalemia, malignant hyperthermia, masseter spasm, and cardiac dysrhythmias. As a result of these adverse effects, the use of succinylcholine is absolutely contraindicated under the following conditions: (1) preexisting hyperkalemia; (2) chronic myopathy or denervating neuromuscular disease; (3) 48 to 72 hours after burns, a crush injury, or an acute denervating event; and (4) in patients with a history of malignant hyperthermia. Relative contraindications for succinylcholine include: (1) unknown pseudocholinesterase deficiency (risk for prolonged duration of action), and (2) increased intracranial or increased intraocular pressure (although safe use in both conditions has been noted). The dose of succinylcholine for infants and young children is 2 mg/kg IV, which is higher than that recommended in adults. This is because succinylcholine is rapidly redistributed in extracellular water, and young children have a larger relative volume of extracellular fluid. For older children, 1.5 mg/kg IV is recommended.

Rocuronium

Rocuronium, when given at doses of 1.0 to 1.2 mg/kg IV, has a rapid onset of action (60-90 sec) but a longer duration of action (30-40 min) when compared to succinylcholine. None of the potentially life-threatening side effects that occur with succinylcholine are seen with rocuronium, making it the safer agent for RSI with respect to adverse effects. Intubating conditions between the 2 agents was evaluated in a meta-analysis that included 37 trials. Overall, succinylcholine was superior to rocuronium (relative risk, 0.86) (95% CI, 0.80-0.92) (n = 2690); however, in the subgroup where 1.2 mg/kg of rocuronium was evaluated, there was no statistical difference in intubation conditions.[145] A separate systematic review of 7 papers also arrived at the conclusion that there is no significant difference to time to intubate, intubating conditions, or intubating success rate when using 1.0 to 1.2 mg/kg rocuronium versus 1.0 to 1.5 mg/kg of succinylcholine during RSI in an ED setting.[146]

Rocuronium may provide a longer duration of safe apnea compared to succinylcholine. In a study of operative adult patients, the median time to desaturation to 95% was 358 seconds in patients receiving succinylcholine versus 378 seconds in the group given rocuronium ($P = 0.003$).[147] Similarly, in obese adult patients undergoing surgery, the succinylcholine group desaturated to 92% in an average of 283 seconds versus 329 seconds in the rocuronium group ($P = 0.01$).[148] If these data are replicated in further studies, this may provide a clear advantage for the use of rocuronium compared to succinylcholine. Because of its superior side-effect profile and equivalence in intubating conditions, time to intubate, and intubation success rate, the authors prefer to use rocuronium 1.0 to 1.2 mg/kg as the paralytic of choice in RSI.

Others Paralytics (Vecuronium, Pancuronium, Mivacuronium)

Other paralytics can be used in RSI; however, to achieve a rapid onset, higher-than-traditional doses must be used, which also lead to a prolonged duration of action. Additionally, there are no trials that support the use of vecuronium, pancuronium, or mivacuronium over the use of rocuronium or succinylcholine in pediatric RSI.

Protection And Positioning

Protection during RSI refers to protecting the airway by preventing vomiting and aspiration of gastric contents as well as protection of the cervical spine during endotracheal tube placement. Cricoid pressure is often used in pediatric intubation following administration of a sedative agent as part of RSI. In this technique, an assistant to the laryngoscopist places his fingers over the anterior neck at the cricoid cartilage and compresses the underlying structure with enough force to physically occlude the esophagus. This act is thought to prevent passive reflux as well as aspiration of the gastric contents. This was seen with Sellick's original report in 1961, in which he described 3 of 26 high-risk anesthesia cases where release of cricoid pressure led to the immediate reflux of gastric contents into the pharynx.[149] Since that time, few articles have been published in support of cricoid pressure.[150] Opposition to cricoid pressure is based mainly on the lack of proven benefit of cricoid pressure in preventing gastric aspiration and studies that have noted a negative effect on laryngeal view with cricoid pressure during RSI.[150-154] With these points in mind, cricoid pressure should be considered an optional step in pediatric RSI. It is unlikely to cause any harm when used appropriately, and it can be easily removed or converted to bimanual laryngoscopy when the laryngeal view is obstructed.

Prior to placement of the endotracheal tube, the patient should be positioned with the head in a midline sniffing position with the neck extended and chin lifted (the so-called "head elevated" laryngoscopy position). This can be accomplished with a head tilt and/or jaw thrust maneuver with the anatomic goal of aligning the eternal auditory meatus to the superior chest wall ("ear to sternal notch"). Proper positioning prior to laryngoscopy aligns the pharyngeal, tracheal, and oral axes and allows for improved laryngeal views. To align the pharyngeal and tracheal axes, the chin and head are moved anteriorly with respect to the shoulders, such that the external auditory canal is in line with the sternal notch. In infants and toddlers, because of a prominent occiput, a towel can be placed under the shoulders to achieve this position. To align the oral axis with the pharyngeal and tracheal axes, the head is extended on the neck, such that the nose and mouth are pointing toward the ceiling. This may be accomplished by gently rotating the head posteriorly, which also opens the patient's mouth, facilitating insertion of the laryngoscope.

Placement With Confirmation

Onset of paralysis generally occurs within 30 to 90 seconds following the administration of rocuronium or succinylcholine. Once the child has become apneic, muscle relaxation can be confirmed by testing the jaw for flaccidity. Once the lower jaw is confirmed to be completely relaxed, laryngoscopy can be performed, with careful attention to proper technique and avoidance of orotracheal (particularly dental) injury. The keys to successful intubation are following a standard procedure each time, achieving appropriate bed height, choosing correctly sized equipment, initially placing the laryngoscope blade into the right corner of the mouth (just to the base of the tongue) and lifting upward, and having an assistant pass the suction and the endotracheal tube to the laryngoscopist. With direct laryngoscopy, the greatest potential challenges involve laryngeal exposure and delivering the tube to the glottic opening without obstructing the line of sight.[155] Having an assistant provide traction to the right corner of the mouth can allow for more room to maneuver the endotracheal tube. Excessive cricoid pressure may result in airway collapse in infants and young children and should be avoided; however, judicious use of cricoid pressure can improve the visualization of the vocal cords. Bimanual laryngoscopy, using either the provider's right hand or an assistant's hand that is guided by the provider's right hand, is a useful maneuver to improve the laryngeal view.[154,156] A jaw-thrust maneuver during intubation may also aid in visualizing airway structures.

A good estimate for determining the endotracheal tube depth after intubation in patients > 44 weeks gestational age is 3 times the endotracheal tube size. For those < 44 weeks gestational age, endotracheal tube depth should be approximately 6 cm plus the patient's weight in kilograms. These determinations are only estimates, however, and secondary confirmation devices, imaging, and physical examination must verify all tube placements.

Proper endotracheal tube placement should always be confirmed by several methods. The clinical assessment begins with listening for breath sounds over the stomach and then proceeding to auscultation in the left and right axilla. In infants and small children, however, breath sounds can be transmitted easily. If breath sounds are heard in the stomach, the endotracheal tube should not be removed immediately. Decreased breath sounds over the left hemithorax may indicate a right mainstem intubation. In addition to clinical indicators, continuous pulse oximetry and continuous capnography (or $ETCO_2$ detector) should be used to confirm proper endotracheal tube placement. Whereas pediatric colorimetric CO_2 detectors can be used for children weighing < 15 kg, standard adult detectors can be used in children weighing > 15 kg. Colorimetric CO_2 detectors do not detect tracheal tube placement reliably in cases of low pulmonary blood flow, such as cardiac arrest and massive pulmonary embolism.[157,158]

Unsuccessful attempts at intubation will likely require reoxygenation of the patient prior to additional attempts at securing the airway. Use of dual nasopharyngeal airways, as well as an oropharyngeal airway, combined with a 2-person technique for bag-valve mask ventilation while attached to high-flow oxygen is the optimal technique for reoxygenation. Every bag-valve mask ventilation breath, however, potentially places the patient at risk for gastric distension and aspiration. Choosing a slow rate with low tidal volumes to reoxygenate the patient will minimize gastric insufflation while raising oxygen saturation to the desired level.[159] Patients who required noninvasive positive pressure ventilation for preoxygenation may benefit from reoxygenation with a mask hooked up to a standard mechanical ventilator.[159]

Postintubation Management

Following placement and confirmation, the endotracheal tube should be secured and its position verified by a chest radiograph. The ideal position for the endotracheal tube should be approximately 2 cm above the carina. A nasogastric or orogastric tube should be inserted to immediately evacuate the air and stomach contents, as substantial insufflation of the stomach can lead to impaired ventilation and, if untreated, can result in hypotension. Continuous analgesia and sedation should be provided and, in select cases, long-acting paralytics may be needed. A blood gas should be obtained after intubation, and ventilator settings should be adjusted based upon the results.

If an intubated patient develops problems with oxygenation or ventilation, a useful reminder of potential problems is the "DOPES" mnemonic: dislodgement, obstruction, pneumothorax, equipment failure, and stacking of breaths. The first step in assessing and managing these patients is to remove them from the ventilator and to bag-ventilate the patient by hand. This will rule out equipment failure as an etiology and give the practitioner a sense of the difficulty or ease of bagging the patient. Slowing of ventilations and allowing a longer expiratory time in patients with breath stacking (eg, severe asthma) should improve ventilation in these patients. A bolus of IV crystalloids should be given to patients with hypovolemia, as the combination of pharmacologic agents during RSI and positive pressure ventilation may decrease preload in susceptible patients. Next, evaluate for a dislodged tube. Dislodgement of the endotracheal tube may be more common in young children due to the relatively short length of their tracheas. Positioning the head in a neutral position and using a cervical collar is recommended by some prior to interfacility transport to limit movement of the head and the endotracheal tube. Obstruction of the tube may be due to a kink in the tube or from a mucous plug. Deep suctioning and mucolytics are indicated for suspected mucous obstruction. Be aware that breath sounds can be transmitted, thus the presence of a pneumothorax may be difficult to diagnose clinically. Poor perfusion may be the only sign of a tension pneumothorax in young children. A bedside ultrasound is a rapid, noninvasive, and reliable method of diagnosing pneumothorax in the ED. If there is no time for an ultrasound and the child is in extremis, a needle thoracostomy can be performed. If the patient is not in extremis and the cause of the problem is not obvious, a radiograph of the chest should be obtained to check for pneumothoraces or right mainstem intubation not appreciated on clinical examination.

Ventilator management is not within the scope of this discussion, but suffice it to say that it is critical to choose the correct parameters for the postintubation patient. A pediatric intensivist and/or anesthesiologist should be called for assistance, as needed, in the difficult-to-ventilate patient postintubation.

Alternative Airway Techniques

Supraglottic Airway Devices

Supraglottic airway devices deliver oxygen above the level of the vocal cords and are designed to be placed blindly. They can be especially useful when intubation problems occur in patients with a previously unrecognized difficult airway, especially in a "cannot intubate; cannot ventilate" scenario.

The most popular of these devices is the LMA, which consists of 2 parts: the tube and a distal elliptical-shaped mask with a cuff. When the cuff is inflated, the distal mask portion conforms to the anatomy in the lower airway, with the mask opening facing into the space between the vocal cords, allowing for oxygen delivery. The LMA can be a useful tool for preoxygenation or reoxygenation in patients where bag-mask ventilation is difficult or failing. These devices are relatively easy to insert, and their use has become more popular in prehospital and ED settings for adults and is expanding in the pediatric population.[162] The main disadvantage of the LMA is that the airway is not protected from regurgitated gastric contents with this device, and prolonged use can lead to local tissue ischemia and edema. Choosing the right size of LMA is critical to its success. **(See Table 12.)** Most LMAs now include information on the appropriate patient size on the packaging. Additionally, there are now intubating LMAs available where the endotracheal tube can be passed through the LMA itself.

Fiberoptic Intubation

Fiberoptic intubation can play an important part in the management of the anatomically difficult airway. In general, its use in the ED is limited by provider education regarding the device and appropriate technique and by patient factors such as secretions, blood, or vomitus in the crashing airway. The device consists of a long, flexible fiberoptic tube with a distal light source that can be manipulated in an anterior or posterior direction by a simple hand control. The proximal portion contains the hand control, a battery for the light source, and an optical piece that allows for visualization through the fiberoptic tube. There is some skill required in learning to use this device as well as with troubleshooting the device when the distal lens is fogged. The ease of use of video laryngoscopes that are based on similar technology (but have a shape and technique more familiar to the emergency physician) are likely to supplant the use of fiberoptic scopes at most institutions.

Table 12. Sample Of Recommended Laryngeal-Mask Airway Sizes Based On Size/Weight

Patient Weight, kg	LMA Size
< 5	1
5-10	1.5
> 10-20	2
> 20-30	2.5
> 30-50	3

Abbreviation: LMA, laryngeal-mask airway.

Digital Intubation

Digital intubation has a role in austere environments, in the setting of copious secretions or vomiting, or when other equipment has failed. It is contraindicated in very small children due to the technical difficulty of fitting 2 adult fingers in the child's mouth to accomplish the procedure. The index and long finger are inserted into the patient's mouth, past the base of the tongue until the epiglottis can be palpated. An endotracheal tube is then placed along the dorsal aspect of the fingers and slid past them into the trachea. The most concerning complication is the patient biting the practitioner, a situation easily avoidable with a bite block or oral airways. Tube placement should be confirmed immediately to recognize a possible esophageal intubation.

Cricothyrotomy

Surgical cricothyrotomy is reserved for patients > 8 years. In younger patients, surgical cricothyrotomy is nearly impossible, as the cricothyroid space is extremely narrow and the traditional landmarks are difficult to appreciate.

A variation on the traditional surgical technique involves using the gum elastic bougie and a standard endotracheal tube in place of a Shiley™ tracheal tube utilizing the Seldinger technique.[163] Using this technique, a single horizontal incision is made at the cricothyroid membrane. A finger is used to hold the place of the incision while the bougie introducer is placed into the trachea, enabling blind confirmation of tracheal placement, similar to orotracheal placement (clicking rings and bronchial tree resistance). The endotracheal tube is then advanced over the bougie just until the cuff balloon has entered the tracheal lumen. In a sheep model, emergency medicine residents and students were more successful, completed the procedure faster, and rated the procedure easier to perform compared to a traditional technique.[164] This technique has the added advantage of not requiring special equipment beyond a scalpel, bougie, and endotracheal tube, and it relies on similar praxis to the much less rare procedure of oral intubation.

Needle Cricothyrotomy

The equipment needed to perform this procedure should be easily reachable in case it is needed in the resuscitation area. In infants and young children, the procedure can be difficult due to short necks, small diameter of the trachea, and redundant skin and soft tissue. A regular IV catheter (no smaller than a 16-gauge) can be connected to the tube connector from a 3.0 endotracheal tube in the event that the specialized setup is not available. Connection to a jet ventilation system at 50 PSI of 100% oxygen or any oxygen source at 15 L/min can provide sufficient oxygenation for up to 30 minutes. This is considered a temporizing measure, not a definitive airway. Without appropriate ventilation, the patient will experience a progressive hypercarbic respiratory acidosis.

Risk Management Pearls For Pediatric Airway Management

1. Be absolutely sure that your endotracheal tube is in the central trachea and not in the esophagus. Use a combination of clinical signs and CO_2 detectors or capnography, pulse oximetry, and chest radiography to verify proper placement.
2. Be familiar with pediatric anatomy and physiology and anticipate that the critically ill child that requires intubation will likely desaturate quickly. Hypoxia must be avoided.
3. Do everything you can to ensure proper preoxygenation prior to intubation. This includes airway positioning, use of oro/nasotracheal airway devices, positive pressure ventilation, and may even include placing an LMA prior to RSI.
4. If you believe your patient is at high risk for vomiting and aspiration during RSI, consider decompressing the stomach with a nasogastric tube prior to intubation, positioning the patient in a sitting position during intubation, and pretreating with an antiemetic or prokinetic agent.
5. Consider placing the pediatric patient in a cervical collar prior to interfacility transport. Some experts believe that the restricted head movement while in a cervical collar will prevent inadvertent tube dislodgement.
6. Anticipate complications (desaturation, hypotension, bradycardia, vomiting, and acidosis) and take steps to avoid these complications prior to the administration of induction and paralytic agents.
7. Have a difficult airway plan for patients with abnormal craniofacial anatomy and consider expert consultation, if time permits, for intubation of these patients.
8. Do not paralyze a patient who has difficult airway anatomy and who you anticipate would be difficult to ventilate. Instead, consider an awake intubation in these patients.
9. Disclose any difficulties with intubation and complications to the family. Let them know how difficult the situation was, what happened, and what steps you took to address the situation.
10. Document any difficulties with intubation and complications in the medical record. Describe the situation, what happened, and the steps you took to address the situation.

Special Circumstances

The Obese Pediatric Patient

Pediatric obesity presents unique and significant challenges for airway management. Anatomic and physiologic changes in the pulmonary and gastrointestinal systems can lead to difficulties with preoxygenation, rapid desaturation times, and higher risks of vomiting and aspiration pneumonitis.[160] Three general strategies that can improve the duration of safe apnea are: (1) preoxygenation in the head-elevated laryngoscopic position,[60,61,161] (2) preoxygenation with continuous positive pressure ventilation,[72-75] and (3) providing a nasal cannula set at 15 L/min of high-flow oxygen[78,79] during RSI. Additionally, the patient must be placed in a head and torso ramped position that aligns the external auditory meatus to the sternal notch position for optimal success.

The Difficult Airway

For pediatric patients with anticipated difficult airways, the most important question to ask is whether you will be able to maintain adequate oxygenation and ventilation. In these cases, calling for assistance early is recommended, if anesthesiology is available. If you are able to maintain the oxygen saturation in these patients with supplemental oxygen, the experienced practitioner can consider doing an awake or sedative-only intubation without paralyzing the patient. If the situation is more urgent and hypoxia is present despite supplemental oxygen, the authors suggest preparing for immediate RSI.

Using the single best operator with the most-skilled laryngoscopy technique, maximize patient position by aligning the ear with the sternal notch, provide supplemental oxygen via nasal cannula during the intubation attempt (to improve time to critical oxygen desaturation), and have a gum-elastic bougie available at the bedside, if needed. A 2-handed bag-valve mask technique with dual nasal airways and a single oral airway can be used to improve the oxygen saturation prior to intubation. If direct or video laryngoscopy proves impossible, a supraglottic airway device can be rapidly inserted. When these devices are properly placed and no significant air leak is present, they allow adequate oxygenation and ventilation and can be left in place until an anesthesiologist or a more-skilled operator (who can intubate through this device) arrives. If the supraglottic device fails or is not available but adequate oxygen can be maintained, a maximum of 2 or 3 attempts with laryngoscopy can be made prior to moving to the surgical or needle cricothyrotomy option. If, at any time, reoxygenation attempts with the bag-valve mask and LMA fail, immediately prepare for surgical or needle cricothyrotomy.

Time- And Cost-Effective Strategies

- Pediatric intubation is not a common event in the ED. Make sure your ancillary staff is familiar with your algorithm and the equipment available.
- Always use a length-based resuscitation tape as one of the first steps in any pediatric resuscitation. This ensures your best chance at correct dosing of medications.
- Be familiar with your difficult airway equipment and where it is stationed in your ED. When time is critical is not the time to find out where your needle jet ventilation kit hides.
- The decision to intubate should not rely upon blood gas measurements. Waiting to get results only delays the delivery of definitive therapy. The decision to intubate is a clinical one.
- Be able to set up noninvasive ventilation yourself. Waiting for a respiratory therapist to come down and help you can be a waste of valuable time.

Disposition

Pediatric patients with respiratory failure should be transferred to and cared for in a hospital with a pediatric intensive care unit. Only children who have a rapidly reversible respiratory process who significantly improve on noninvasive ventilation can be considered for a lower level of care.

Summary

Successful management of the pediatric airway depends on careful preparation and adherence to a standard protocol regarding assessment and implementation of RSI. Knowledge of the differences between pediatric and adult airways will allow the emergency clinician to anticipate the anatomical and physiologic differences seen in children. Taking the time to properly preoxygenate the patient in the correct position; selecting the appropriate-sized equipment; anticipating and preventing RSI complications; and choosing appropriate premedication, induction, and paralytic agents will improve the chance for success. Once intubated, the emergency clinician must be meticulous in assessing the endotracheal tube position, as a single wrong move can lead to deadly consequences. Additionally, do not forget that successful postintubation management involves appropriate analgesia and sedation as well as ventilator management.

Case Conclusion

After 2 unsuccessful IV placement attempts were made, an intraosseous line was rapidly inserted in the septic 4-year-old. After antibiotics were given, you decided to place 2 nasal trumpets and sit the child at 25° to improve preoxygenation, keeping in the back of your mind the technique of positive pressure ventilation as a preoxygenation strategy in case this failed. The nasal cannula and airway positioning had the desired effect and raised the oxygen saturation to 98%. You decided that the child was hypovolemic and acidotic, and you began aggressive volume resuscitation in order to mitigate any peri-intubation hypotension that might occur. During this time, you drew up syringes of phenylephrine, atropine, ketamine, and rocuronium. After several minutes of preoxygenation and preparation for RSI, you administered the ketamine and rocuronium while placing a nasal cannula on the patient to permit apneic oxygenation. You had phenylephrine and atropine at the bedside in case hypotension or bradycardia developed. These maneuvers all had the desired effect of maintaining his blood pressure and oxygen saturation during this critical time. RSI was performed successfully, but in the back of your mind you knew that you had gum elastic bougie and LMA as backup devices in case direct laryngoscopy failed. The child was admitted quickly to the pediatric ICU, and as your adrenaline started to wear off you thought to yourself, "Yeah, this is why I went into emergency medicine!"

References

Evidence-based medicine requires a critical appraisal of the literature based upon study methodology and number of subjects. Not all references are equally robust. The findings of a large, prospective, randomized, and blinded trial should carry more weight than a case report.

To help the reader judge the strength of each reference, pertinent information about the study, such as the type of study and the number of patients in the study will be included in bold type following the references, where available.

1. Pointer JE. Clinical characteristics of paramedics' performance of pediatric endotracheal intubation. *Am J Emerg Med.* 1989;7(4):364-366. **(Retrospective cohort; 36 pediatric patients)**
2. Doran JV, Tortella BJ, Drivet WJ, et al. Factors influencing successful intubation in the prehospital setting. *Prehosp Disaster Med.* 1995;10(4):259-264. **(Prospective cohort; 236 patients)**
3. Aijian P, Tsai A, Knopp R, et al. Endotracheal intubation of pediatric patients by paramedics. *Ann Emerg Med.* 1989;18(5):489-494. **(Retrospective cohort; 42 pediatric patients)**
4. Losek JD, Hennes H, Glaeser P, et al. Prehospital care of the pulseless, nonbreathing pediatric patient. *Am J Emerg Med.* 1987;5(5):370-374. **(Retrospective cohort; 114 pediatric cardiac arrest patients)**
5. Losek JD, Bonadio WA, Walsh-Kelly C, et al. Prehospital pediatric endotracheal intubation performance review. *Pediatr Emerg Care.* 1989;5(1):1-4. **(Retrospective cohort; 63 pediatric patients)**
6. Nakayama DK, Gardner MJ, Rowe MI. Emergency endotracheal intubation in pediatric trauma. *Ann Surg.* 1990;211(2):218-223. **(Retrospective cohort; 6305 pediatric trauma patients)**
7. Kumar VR, Bachman DT, Kiskaddon RT. Children and adults in cardiopulmonary arrest: are advanced life support guidelines followed in the prehospital setting? *Ann Emerg Med.* 1997;29(6):743-747. **(Retrospective cross-sectional study; 47 pediatric cardiac arrest patients)**
8. Mogayzel C, Quan L, Graves JR, et al. Out-of-hospital ventricular fibrillation in children and adolescents: causes and outcomes. *Ann Emerg Med.* 1995; 25(4):484-491. **(Retrospective cohort; 157 pediatric cardiac arrest patients)**
9. Brownstein D, Shugerman R, Cummings P, et al. Prehospital endotracheal intubation of children by paramedics. *Ann Emerg Med.* 1996;28(1):34-39. **(Retrospective cohort; 355 pediatric patients)**
10. Hubble MW, Brown L, Wilfong DA, et al. A meta-analysis of prehospital airway control techniques part I: orotracheal and nasotracheal intubation success rate. *Prehosp Emerg Care.* 2010;14(3):377-401. **(Meta-analysis; 140 studies, 57,132 prehospital patients)**
11. Gausche M, Lewis RJ, Stratton SJ, et al. Effect of out-of-hospital pediatric endotracheal intubation on survival and neurologic outcome: a controlled clinical trial. *JAMA.* 2000;283(6):783-790. **(Prospective, quasi-randomized, clinical trial; 830 pediatric patients)**
12. Cooper A, DiScala C, Foltin G, et al. Prehospital endotracheal intubation for severe head trauma in children: a reappraisal. *Semin Pediatr Surg.* 2001;10(1):3-6. **(Retrospective trauma registry; 578 pediatric head trauma patients)**
13. Murry JA, Demetriades D, Berne TV, et al. Prehospital intubation in patients with severe head injury. *J Trauma.* 2000;49(6):1065-1070. **(Retrospective trauma registry; 852 head trauma patients)**
14. Stockinger ZT, McSwain Jr NE. Prehospital endotracheal intubation for trauma does not improve survival over bag-valve mask ventilation. *J Trauma.* 2004;56(3):531-536. **(Retrospective trauma registry; 533 trauma patients)**
15. DiRusso SM, Sullivan T, Risucci D, et al. Intubation of pediatric trauma patients in the field: predictor of negative outcome despite risk stratification. *J Trauma.* 2005;59(1):84-91. **(Retrospective trauma registry; 5460 pediatric trauma patients)**
16. Youngquist ST, Gausche-Hill M, Squire BT, et al. Barriers to adoption of evidence-based prehospital airway management practices in California. *Prehosp Emerg Care.* 2010; 14(4):505-509. **(Survey; 25 EMS medical directors)**
17. Youngquist ST, Henderson DP, Gausche-Hill M, et al. Paramedic self-efficacy and skill retention in pediatric airway management. *Acad Emerg Med.* 2008;15(12):1295-1303. **(Survey; 245 paramedics)**
18. Gerritse BM, Draaisma JM, Schalkwijk A, et al. Should EMS-paramedics perform paediatric tracheal intubation in the field? *Resus.* 2008;79(2):225-229. **(Prospective cohort; 155 pediatric patients)**
19. Martinon C, Duracher C, Blanot S, et al. Emergency tracheal intubation of severely head-injured children: changing daily practice after implementation of national guidelines. *Pediatr Crit Care Med.* 2011; 12(1):65-70. **(Prospective cohort with retrospective control; 296 patients)**
20. Santillanes G, Gausche-Hill M. Pediatric airway management. *Emerg Med Clin North Am.* 2008;2(4):961-975. **(Review article)**
21. Stewart C. Managing the pediatric airway in the ED. *Pediatric Emergency Medicine Practice.* 2006;3(1):1-24. **(Review article)**
22. Tucker JE, Coussa M. Pediatric rapid sequence intubation.

Pediatr Emerg Med Reports. 2009;14(1):1-12. **(Review article)**
23. Luten RC, McAllister JD. Approach to the pediatric airway. In: Walls RM, Murphy MF, editors. *Manual of Emergency Airway Management.* 3rd edition. Philadelphia: Lippincott, Williams & Wilkins; 2008:263–281. **(Book chapter)**
24. Sarnaik A, Heidemann SM. Respiratory pathophysiology and regulation. In: Kleigman RM, Rehrman RE, Jenson HB, eds. *Nelson Textbook of Pediatrics.* 18th edition. Philadelphia: Saunders; 2007:1719–1731. **(Book chapter)**
25. Moss IR. *Physiologic considerations.* In: McMillian JA, Feigin RD, DeAngelis CD, editors. Oski's Pediatrics. 4th edition. Philadelphia: Lippincott, Williams & Wilkins; 2006:300-305. **(Book chapter)**
26. Dalal PG, Murray D, Messner AH, et al. Pediatric laryngeal dimensions: an age-based analysis. *Anesth Analg.* 2009;108(5):1475-1479. **(Prospective cohort; 135 pediatric patients)**
27. Litman RS, Weissend EE, Shibata D, et al. Developmental changes of laryngeal dimensions in unparalyzed, sedated children. *Anesthesiology.* 2003;98(1):41-45. **(Prospective cohort; 99 pediatric patients)**
28. Motoyama EK. The shape of the pediatric larynx: cylindrical or funnel shaped? *Anesth Analg.* 2009:108(5):1379-1781. **(Editorial)**
29. Keens TG, Bryan AC, Levison H, et al. Developmental pattern of muscle fiber types in human ventilatory muscles. *J Appl Physiol.* 1978;44(6):909-913. **(Physiology study; 31 postmortum specimens)**
30. Dieckmann RA, Brownstein D, Gausche-Hill M. The pediatric assessment triangle: a novel approach for the rapid evaluation of children. *Pediatr Emerg Care.* 2010;26(4):312-315. **(Review article)**
31. American Academy of Pediatrics. *Pediatric Education for Prehospital Professionals: PEPP Textbook.* 2nd ed. Sudbury, MA: Jones & Bartlett Publishers; 2006. **(Book chapter)**
32. Fine GF, Borland LM. The future of the cuffed endotracheal tube. *Paediatr Anaesth.* 2004;14(1):38-42. **(Review article)**
33. Newth CJ, Rachman B, Patel N, et al. The use of cuffed versus uncuffed endotracheal tubes in pediatric intensive care. *J Pediatr.* 2004;144(3):333-337. **(Prospective cohort; 597 pediatric patients)**
34. Browning DH, Graves SA. Incidence of aspiration with endotracheal tubes in children. *J Pediatr.* 1983;102(4):582-584. **(Prospective; 27 pediatric patients)**
35. King BR, Baker MD, Braitman LE, et al. Endotracheal tube selection in children: a comparison of four methods. *Ann Emerg Med.* 1993;22(3):530-534. **(Prospective blinded; 237 pediatric patients)**
36. White MC, Marsh CJ, Beringer RM, et al. A randomized, controlled trial of the Airtraq optical laryngoscope with conventional laryngoscopy in infants and children. *Anaesth.* 2012;67(3):226-231. **(Prospective; 60 pediatric patients)**
37. Armstrong J, John J, Karsli C. A comparison between GlideScope Video Laryngoscope and direct laryngoscope in paediatric patients with difficult airways – a pilot study. *Anaesth.* 2010;65(4):353-357. **(Prospective pilot study; 18 pediatric patients)**
38. Kim HJ, Kim JT, Kim HS, et al. A comparison of GlideScope Videolaryngoscopy and direct laryngoscopy for nasotracheal intubation in children. *Paediatr Anaesth.* 2011;21(4):417-421. **(Prospective; 80 pediatric patients)**
39. Redel A, Karademir F, Schlitterlau A, et al. Validation of the GlideScope Video Laryngoscope in pediatric patients. *Paediatr Anaesth.* 2009;19(7)667-671. **(Prospective; 60 pediatric patients)**
40. Serocki G, Bein B, Scholz J, et al. Management of the predicted difficult airway: a comparison of blade laryngoscopy with video-assisted blade laryngoscopy and the GlideScope. *Eur J Anaesthesiol.* 2010;27(1);24-30. **(Prospective; 120 adult patients)**
41. Kim JT, Na HS, Bae JY, et al. GlideScope Video Laryngoscope: a randomized clinical trial in 203 paediatric patients. *Br J Anaesth.* 2008;101(4):531-534. **(Prospective; 203 pediatric patients)**
42. Trevisanuto D, Fornaro E, Verghese C. The GlideScope video laryngoscope: initial experience in five neonates. *Can J Anaesth.* 2006;53(4):423-424. **(Case series; 5 pediatric patients)**
43. Hirabayashi Y, Otsuka Y. Early clinical experience with GlideScope video laryngoscope in 20 infants. *Pediatr Anesth.* 2009;19(8):800-814. **(Case series; 20 pediatric patients)**
44. Vlatten A, Aucoin S, Litz S et al. A comparison of the STORZ video laryngoscope and standard direct laryngoscopy for intubation in the pediatric airway. *Pediatr Anesth.* 2009;19(11):1102-1107. **(Prospective randomized clinical trial; 56 pediatric patients)**
45. Hackell RS, Held LD, Stricker PA et al. Management of the difficult infant airway with the STORZ Video Laryngoscope: a case series. *Anesth Analg.* 2009;109(3):763-766. **(Case series; 7 pediatric patients)**
46. Singh R, Singh H, Vajifdar H. A comparison of Truview infant EVO2 laryngoscope with the Miller blade in neonates and infants. *Pediatr Anesth.* 2009;19(4):338-342. **(Prospective randomized clinical trial; 60 pediatric patients)**
47. Holm-Knudsen RJ, White J. The Airtraq may not be the solution for infants with difficult airways. *Pediatr Anesth.* 2010;20(4):374-375. **(Editorial)**
48. Cooper RM. Complications associated with the use of the GlideScope videolaryngoscope. *Can J Anaesth.* 2007;54(1):154-157. **(Case series; 2 patients)**
49. Sime J, Bailitz J, Moskoff J. The bougie: an inexpensive lifesaving airway device. *J Emerg Med.* 2012;43(6):e393-e395. **(Case series; 3 patients)**
50. Shah KH, Kwong BM, Hazan A, et al. Success of the gum elastic bougie as a rescue airway in the emergency department. *J Emerg Med.* 2011;40(1):1-6. **(Prospective; 26 patients)**
51. Arora MK, Karamchandani K, Trikha A. Use of a gum elastic bougie to facilitate blind nasotracheal intubation in children: a series of three cases. *Anaesth.* 2006;61(3):291-294. **(Case series; 3 pediatric patients)**
52. Lopez-Gil M, Brimacombe J, Barragan L, et al. Bougie-guided insertion of the ProSeal laryngeal mask airway has higher first attempt success rate than the digital technique in children. *Br J Anaesth.* 2006;96(2):238-241. **(Prospective randomized clinical trial; 120 patients)**
53. Shah KH, Kwong B, Hazan A, et al. Difficulties with gum elastic bougie intubation in an academic emergency department. *J Emerg Med.* 2011;41(4):429-434. **(Prospective; 88 patients)**
54. Kovacs G, Law JA, McCrossin C, et al. A comparison of fiberoptic stylet and a bougie as adjuncts to direct laryngoscopy in a manikin-simulated difficult airway. *Ann Emerg Med.* 2007;50(6):676-685. **(Prospective; 103 inexperienced laryngoscopist participants)**
55. Evans A, Morris S, Petterson J, et al. A comparison of the Seeing Optical Stylet and the gum elastic bougie in simulated difficult tracheal intubation: a manikin study. *Anaesth.* 2006;61(5):478-481. **(Prospective; 44 anesthetist participants)**
56. *Weingart SD, Levitan RM. Preoxygenation and prevention of desaturation during emergency airway management. *Ann Emerg Med.* 2012;5993):165-175. **(Review article)**
57. Ramkumar V, Umesh G, Philip FA. Preoxygenation with 20º head-up tilt provides longer duration of non-hypoxic apnea than conventional preoxygenation in non-obese healthy adults. *J Anesth.* 2011;25(2):189-194. **(Prospective trial; 45 adult patients)**
58. Lane S, Saunders D, Schofield A, et al. A prospective, randomised controlled trial comparing the efficacy of pre-oxygenation in the 20 degrees head-up vs supine position. *Anaesthesia.* 2005;60(11):1064-1067. (Prospective trial; 35 adult patients)

59. Baraka AS, Hanna MT, Jabbour SI, et al. Preoxygenation of pregnant and nonpregnant women in the head-up versus supine position. *Anesth Analg.* 1992;75(5):757-759. (Prospective trial; 20 adult patients)
60. Dixon BJ, Dixon JB, Carden JR, et al. Preoxygenation is more effective in the 25° head-up position than in the supine position in severely obese patients: a randomized controlled study. *Anesthesiology.* 2005;102(6):1110-1115. **(Prospective randomized clinical trial; 42 obese adult patients)**
61. Altermatt FR, Muñoz HR, Delfino AE, et al. Pre-oxygenation in the obese patient: effects of position on tolerance to apnoea. *Br J Anaesth.* 2005;95(5):706-709. **(Prospective randomized clinical trial; 40 obese adult patients)**
62. Boyce JR, Ness T, Castroman P, et al. A preliminary study of the optimal anesthesia positioning for the morbidly obese patient. *Obes Surg.* 2003;13(1):4-9. **(Prospective randomized trial; 26 obese adult patients)**
63. Videira RL, Neto PP, do Amaral RV, et al. Preoxygenation in children: for how long? *Acta Anaesthesiol Scand.* 1992;36(2):109-111. **(Randomized trial; 11 healthy children)**
64. Xue, FS, Tong SY, Wang XL, et al. Study of the optimal duration of preoxygenation in children. *J Clin Anesth.* 1995;7(2):93-96. **(Randomized trial; 40 healthy children)**
65. Dupeyrat A, Dubreuil M, Ecoffey C. Preoxygenation in children. *Anesth Analg.* 1994;79(5):1027. **(Editorial)**
66. Morrison JE, Collier E, Friesen RH, et al. Preoxygenation before laryngoscopy in children: how long is enough? *Pediatr Anaesth.* 1998;8(4):293-298. **(Prospective; 58 healthy children)**
67. Chiron B, Mas C, Ferrandiere M, et al. Standard preoxygenation vs two techniques in children. *Pediatric Anesthesia.* 2007;17(10):963-967. **(Prospective; 20 healthy children)**
68. Patel R, Lenczyk M, Hannallah R, et al. Age and the onset of desaturation in apnoeic children. *Can J Anesth.* 1994;41(9):771-774. **(Prospective; 50 healthy children)**
69. Xue FS, Luo LK, Tong SY, et al. Study of the safe threshold of apneic period in children during anesthesia induction. *J Clin Anesth.* 2006; 8(7):568-574. **(Prospective; 152 healthy children)**
70. Dels J, Estrada CM, Abramo T. Noninvasive ventilation techniques in the emergency department – applications in pediatric patients. *Pediatr Emerg Med Pract.* 2009;6(6);1-18. **(Review article)**
71. Calderini E, Chidini G, Pelosi P. What are the current indications for noninvasive ventilation in children? 2010. *Curr Opinion Anaesth.* 23(3);368-374. **(Review article)**
72. Delay JM, Sebbane M, Jung B, et al. The effectiveness of noninvasive positive pressure ventilation to enhance preoxygenation in morbidly obese patients: a randomized controlled study. *Anesth Analg.* 2008;107(5):1707-1713. **(Randomized controlled trial; 28 obese operative patients)**
73. Futier E, Constantin JM, Pelosi P, et al. Noninvasive ventilation and alveolar recruitment maneuver improve respiratory function during and after intubation of morbidly obese patients: a randomized controlled study. *Anesthesiology.* 2011;114(6):1354-1363. **(Randomized controlled trial; 66 obese operative patients)**
74. Cressey DM, Berthoud MC, Reilly CS. Effectiveness of continuous positive airway pressure to enhance pre-oxygenation in morbidly obese women. *Anaesthesia.* 2001;56(7):680-684. **(Randomized controlled trial; 20 obese operative patients)**
75. Gander S, Frascarolo P, Suter M, et al. Positive end-expiratory pressure during induction of general anesthesia increases duration of nonhypoxic apnea in morbidly obese patients. *Anesth Analg.* 2005;100(2):580-584. **(Randomized controlled trial; 30 obese operative patients)**
76. Herriger A, Frascarolo P, Spahn DR, et al. The effect of positive airway pressure during pre-oxygenation and induction of anaesthesia upon duration of non-hypoxic apnoea. *Anaesthesia.* 2004;59(3):243-247. **(Randomized controlled trial; 40 operative patients)**
77. Antonelli M, Conti G, Rocco M, et al. Noninvasive positive pressure ventilation versus conventional oxygen supplementation in hypoxemic patients undergoing diagnostic bronchoscopy. *Chest.* 2002;121(4):1149-1154. **(Randomized controlled trial; 26 intensive care unit patients)**
78. Baraka AS, Taha SK, Siddik-Sawwid SM, et al. Supplementation of pre-oxygenation in morbidly obese patients using nasopharyngeal oxygen insufflation. *Anaesth.* 2007;62(8):769-773. **(Randomized controlled trial; 34 obese operative patients)**
79. Ramachandran SK, Cosnowski A, Shanks A, et al. Apneic oxygenation during prolonged laryngoscopy in obese patients: a randomized, controlled trial of nasal oxygen administration. *J Clin Anesth.* 2010;22:164-168. **(Randomized controlled trial; 30 obese operative patients)**
80. Taha SK, Siddik-Sayyid SM, El-Khatib MF, et al. Nasopharyngeal oxygen insufflation following pre-oxygenation using the four deep breath technique. *Anaesthesia.* 2006;61(5):427-430. **(Randomized controlled trial; 30 patients)**
81. Comroe JH Jr, Dripps RD. Artificial respiration. *JAMA.* 1946;130:381-383. **(Case series; 2 patients)**
82. Enghoff H, Holmdahl MH, Risholm L. Oxygen uptake in human lungs without spontaneous or artificial pulmonary ventilation. *Acta Chir Scand.* 1952;103(4):293-301. **(Case series; 7 patients)**
83. Holmdahl MH. Pulmonary uptake of oxygen, acid-base metabolism, and circulation during prolonged apnoea. *Acta Chir Scand Suppl* 1956;212:1-128.
84. Frumin MJ, Epstein RM, Cohen G. Apneic oxygenation in man. *Anesthesiology* 1959;20:789-798. **(Observational; 8 patients)**
85. Babinski MF, Sierra OG, Smith RB, et al. Clinical application of continuous flow apneic ventilation. *Acta Anaesthesiol Scand.* 1985;29(7):750-752. **(Observational; 5 patients)**
86. Teller LE, Alexander CM, Frumin MJ, et al. Pharyngeal insufflation of oxygen prevents arterial desaturation during apnea. *Anesthesiology.* 1998;69(6):980-982. **(Randomized controlled trial; 12 patients)**
87. Baraka A, Salem MR, Joseph NJ. Critical hemoglobin desaturation can be delayed by apneic diffusion oxygenation. *Anesthesiology.* 1999;90(1):332-333. **(Commentary)**
88. Mort TC. Complications of emergency tracheal intubation: hemodynamic alterations. *J Intensive Care Med.* 2007;22(3):157-165. **(Review article)**
89. Franklin C, Jacob S, Hu T. Life-threatening hypotension associated with emergency intubation and the initiation of mechanical ventilation. *Am J Emerg Med.* 1994;12(4):425-428. **(Retrospective; 84 patients)**
90. Qadir S, Raju P, Smina M, et al. Life-threatening hypotension associated with emergency intubation and the initiation of mechanical ventilation. *Am J Respir Crit Care Med.* 2001;163:A128. **(Abstract)**
91. Stowe DF, Bosnjak ZK, Kampine JP. Comparison of etomidate, ketamine, midazolam, propofol, and thiopental on function and metabolism of isolated hearts. *Anesth Analg.* 1992;74(4):547-558. **(Animal study)**
92. Griesdale DEG, Bosma TL, Kurth T, et al. Complications of endotracheal intubation in the critically ill. *Intensive Care Med.* 2008;34(10):1835-1842. **(Prospective cohort; 136 patients)**
93. Mort TC. The incidence and risk factors for cardiac arrest during emergency tracheal intubation: a justification for incorporating the ASA guidelines in the remote location. *J Clin Anesth.* 2004;16(7):508-516. **(Retrospective chart review; 60 patients)**
94. *Manthous CA. Avoiding circulatory complications during endotracheal intubation and initiation of positive pressure ventilation. *J Emerg Med.* 2010;38(5):622-631. **(Review article)**
95. Jones P, Dauger S, Peters MJ. Bradycardia during critical care

intubation: mechanisms, significance, and atropine. *Arch Dis Child.* 2012;97(2):139-144. (Review article)
96. McAuliffe G. Bissonnette B. Boutin C. Should the routine use of atropine before succinylcholine in children be reconsidered? *Can J Anaesth.* 1995;42(8):724-729. **(Randomized controlled trial; 41 patients)**
97. Fastle RK. Roback MG. Pediatric rapid sequence intubation: incidence of reflex bradycardia and effects of pretreatment with atropine. *Pediatr Emerg Care.* 2004;20(10):651-655. **(Retrospective cohort; 163 patients)**
98. Bean A, Jones J. Atropine: re-evaluating its use during paediatric RSI. *EMJ.* 2007;24(5):361-362. **(Systematic review)**
99. *Fleming B, McCollough M, Henderson HO. Myth: atropine should be administered before succinylcholine for neonatal and pediatric intubation. *CJEM.* 2005;7(2):114-117. **(Systematic review)**
100. Tibodeau LG, Verdile VP, Bartfield JM. Incidence of aspiration after urgent intubation. *Am J Emerg Med.* 1997;15(6):562-565. **(Retrospective chart review; 87 patients)**
101. Sackles JC, Laurin EG, Rantapaa AA, et al. Airway management in the emergency department: a one-year study of 610 tracheal intubations. *Ann Emerg Med.* 1998;31(3):325-332. **(Prospective; 10 patients)**
102. Donegan MF. Intravenously administered lidocaine prevents intracranial hypertension during endotracheal suctioning. *Anesthesiology.* 1980;52(8):516-518. **(Prospective; 10 patients)**
103. White PF, Schlobohm RM, Pitts LH, et al. A randomized study of drugs for preventing increases in intracranial pressure during endotracheal suctioning. *Anesthesiology.* 1982;57(3):242-244. (Prospective; 15 patients)
104. Yano M, Nishiyama H, Yokota H, et al. Effect of lidocaine on ICP response to endotracheal suctioning. *Anesthesiology.* 1986;64(5):651-653. **(Prospective; 9 patients)**
105. Bedford RF, Winn HR, Tyson G. *Lidocaine prevents increased ICP after endotracheal intubation.* In: Shulman K, Mamorou, Miller JD, eds. Intracranial Pressure IV. Berlin, Germany: Springer; 1980:595-598. **(Book chapter)**
106. Hamill JF, Bedford RF, Weaver DC, et al Lidocaine before endotracheal intubation: intravenous or laryngotracheal? *Anesthesiology.* 1981;55(5):578-581. **(Prospective; 22 patients)**
107. Grover VK, Reddy GM, Kak VK, et al. Intracranial pressure changes with different doses of lignocaine under general anesthesia. *Neurol India.* 1999;47(2):118-121. (Prospective; 30 patients)
108. Asfar SN, Abdulla WY. The effect of various administration routes of lidocaine on hemodynamics and ECG rhythm during endotracheal intubation. *Acta Anaesthesiol Belg.* 1990;41(1):17-24. **(Prospective clinical trial)**
109. *Salhi B, Stettner E. In defense of the use of lidocaine in rapid sequence intubation. *Ann Emerg Med.* 2007;49(1):84-86. **(Editorial)**
110. Weingart S. Additional thoughts on the controversy of lidocaine administration before rapid sequence intubation in patients with traumatic brain injuries. *Ann Emerg Med.* 2007;50(3):353. **(Editorial)**
111. Robinson N, Clancy M. In patients with head injury undergoing rapid sequence intubation, does pretreatment with intravenous lignocaine/lidocaine lead to an improved neurological outcome? A review of the literature. *Emerg Med J.* 2001;18(8):453-457. **(Best evidence topic)**
112. *Villancourt C, Kapur AK. Opposition to the use of lidocaine in rapid sequence intubation. *Ann Emerg Med.* 2007;49(1):86-87. **(Editorial)**
113. Yamamato LG, *Emergency airway management – rapid sequence intubation.* In: Textbook of Pediatric Emergency Medicine, 5th edition. Fleisher GR, Ludwig S, Henretiq FM, eds. Lippincott Williams & Wilkins, Philadelphia 2006:81. **(Book chapter)**
114. Gerardi M, Sacchetti A, Cantor R, et al. Rapid sequence intubation of the pediatric patient. *Ann Emerg Med.* 1996;28(1):55-74. **(Review article)**
115. Bozeman WP, Idris AH. Intracranial pressure changes during rapid sequence intubation: a swine model. *J Trauma.* 2005;58(2):278-283. **(Animal study)**
116. Lanier WL, Iaizzo PA, Milde JH. Cerebral function and muscle afferent activity following intravenous succinylcholine in dogs anesthetized with halothane: the effects of pretreatment with a defasciculating dose of pancuronium. *Anesthesiology.* 1989;71(1):87-95. **(Animal study)**
117. Ducep JP, Deppe SA, Foley KT. A comparison of the effects of suxamethonium, atracurium, and vecuronium on intracranial haemodynamics in swine. *Anesth Intensive Care.* 1989;17(4):448-455. **(Animal study)**
118. Thiagarajah S, Sophie S, Lear E, et al. Effect of suxamethonium on the ICP of cats with and without thiopentone pretreatment. *Br J Anaesth.* 1988;60(2):157-160. **(Animal study)**
119. Cotterell JE, Hartung J, Giffin JP, et al. Intracranial and hemodynamic changes after succinylcholine administration in cats. *Anesth Analg.* 1983;62(11):1006–1009. **(Animal study)**
120. Stirt JA, Grosslight KR, Bedford RF, et al. "Defasciculation" with metocurine prevents succinylcholine-induced increases in intracranial pressure. *Anaesthesiology.* 1987;67(1):50-53. **(Prospective; 12 patients)**
121. Minton MD, Grosslight K, Stirt JA, et al. Increases in intracranial pressure from succinylcholine: prevention by prior non-depolarising blockade. *Anaesthesiology.* 1986;65(2):165-169. **(Prospective; 13 patients with increased intracranial pressure)**
122. Brown MM, Parr MJ, Manara AR. The effect of suxamethonium on intracranial pressure and cerebral perfusion pressure in patients with severe head injuries following blunt trauma. *Eur J Anaesthesiol.* 1996;13(5):474-477. **(Prospective; 11 head-injured patients)**
123. Kovarik WD, Mayberg TS, Lam AM, et al. Succinylcholine does not change intracranial pressure, cerebral blood flow velocity or the electroencephalogram in patients with neurologic injury. *Anesth Analg.* 1994;78(3):469-473.
124. McLesky CH, Cullen BF, Kennedy RD, et al. Control of cerebral perfusion pressure during induction of anaesthesia in high-risk neurosurgical patients. *Anesth Analg.* 1974;53(6):985-992.
125. *Clancy M, Halford S, Walls R, et al. In patients with head injuries who undergo rapid sequence intubation using succinylcholine, does pretreatment with a competitive neuromuscular blocking agent improve outcome? A literature review. *Emerg Med J.* 2001;18(5):373-375. **(Best evidence topic)**
126. Imran M, Khan FH, Khan MA. Attenuation of hypotension using phenylephrine during induction of anesthesia with propofol. *J Pak Med Assoc.* 2007;57(11):543. **(Prospective; 135 adult patients)**
127. Dhungana Y, Bhattarai BK, Bhadani UK, et al. Prevention of hypotension during propofol induction: a comparison of preloading with 3.5% polymers of degraded gelatin (Haemaccel) and intravenous ephedrine. *Nepal Med Coll J.* 2088;10(1):16-19. (Prospective randomized; 120 adult patients)
128. Ozkocak I, Altunkaya H, Ozer Y, et al. Comparison of ephedrine and ketamine in prevention of injection pain and hypotension due to propofol induction. *Eur J Anesthesiol.* 2005;22(1):44-48. (Prospective; 75 adult patients)
129. Zed PJ, Abu-Laban RB, Harrison DW. Intubating conditions and hemodynamic effects of etomidate for rapid sequence intubation in the emergency department: an observational cohort study. *Acad Emerg Med.* 2006;13(4):378-383. **(Prospective; 522 adult patients)**
130. Zuckerbraun NS, Pitetti RD, Herr SM, et al. Use of etomidate as an induction agent for rapid sequence intubation in a pediatric emergency department. *Acad Emerg Med.* 2006;13(6):602-609. **(Prospective; 77 pediatric patients)**
131. Sokolove PE, Price DD, Okada P. The safety of etomidate for emergency rapid sequence intubation of pediatric patients.

Pediatr Emerg Care. 2000;16(1):18-21. **(Retrospective; 100 pediatric patients)**
132. Guldner G, Schultz J, Sexton P, et al. Etomidate for rapid-sequence intubation in young children: hemodynamic effects and adverse events. *Acad Emerg Med.* 2003;10(2):134-139. **(Retrospective; 105 pediatric patients)**
133. *Jabre P, Cornbes X, Lapostolle F, et al. KETASED Collaborative Study Group. Etomidate versus ketamine for rapid sequence intubation in acutely ill patients: a multicentre randomised controlled trial. *Lancet*. 2009;374(9686):293-300. **(Prospective controlled trial; 655 patients)**
134. Dewhirst E, Frazier WJ, Leder M, et al. Cardiac arrest following ketamine administration for rapid sequence intubation. *J Intensive Care Med.* 2012 May 29. [Epub ahead of print]. **(Case report; 2 patients)**
135. Mayberg TS, Lam AM, Matta BF, et al. Ketamine does not increase cerebral blood flow velocity or intracranial pressure during isoflurane/nitrous oxide anesthesia in patients undergoing craniotomy. *Anesth Analg.* 1995;81(1):84-89. **(Prospective; 20 neurosurgical patients)**
136. Kolenda H, Gremmelt A, Rading S, et al. Ketamine for analgosedative therapy in intensive care treatment of head-injured patients. *Acta Neurochir.* (Wien) 1996;138(10):1193-1199. **(Prospective randomized trial; 35 patients with head injury)**
137. Bourgoin A, Albanèse J, Wereszczynski N, et al. Safety of sedation with ketamine in severe head injury patients: comparison with sufentanil. *Crit Care Med.* 2003;31(3):711-717. **(Prospective randomized trial; 25 patients with head injury)**
138. Bourgoin A, Albanese J, Leone M, et al. Effects of sufentanil or ketamine administered in target-controlled infusion on the cerebral hemodynamics of severely brain-injured patients. *Crit Care Med.* 2005;33(5):1109-1113. **(Prospective randomized; 30 patients with head injury)**
139. Schmittner MD, Vajkoczy SL, Horn P, et al. Effects of fentanyl and S(+)-ketamine on cerebral hemodynamics, gastrointestinal motility, and need of vasopressors in patients with intracranial pathologies: a pilot study. *J Neurosurg Anesthesiol.* 2007;19(4):257-262. **(Prospective randomized; 24 patients with head injury)**
140. *Filanovsky Y, Miller P, Kao J. Myth: ketamine should not be used as an induction agent for intubation in patients with head injury. *Can J Emerg Med.* 2010;12(2):154-157. **(Systematic review)**
141. Hughes S. Is ketamine a viable induction agent for the trauma patient with potential brain injury? *Emerg Med J.* 2011;28(11):1076-1077. **(Systematic review; 5 studies)**
142. Sivilotti ML, Filbin MR, Murray HE, et al. Does the sedative agent facilitate rapid sequence intubation? *Acad Emerg Med.* 2003;10(6):612-620. **(Retrospective registry of ED intubations; 2380 patients)**
143. Mallon WK, Keim SM, Shoenberger JM, et al. Rocuronium vs. succinylcholine in the emergency department: a critical appraisal. *J Emerg Med.* 2009;37(2):183-188. **(Systematic review)**
144. Seupaul RA, Jones JH. Does succinylcholine maximize intubating conditions better than rocuronium for rapid sequence intubation? *Ann Emerg Med.* 2011;57(3):301-302. **(Systematic review)**
145. Perry JJ, Lee JS, Sillberg VA, et al. Rocuronium versus succinylcholine for rapid sequence intubation. *Cochrane Database Syst Rev.* 2008 Apr 16(2):CD002788. **(Systematic review)**
146. Herbstritt A, Amarakone K. Is rocuronium as effective as succinylcholine at facilitating laryngoscopy during rapid sequence intubation? *Emerg Med J.* 2012;29(3):256-258. **(Best evidence topic)**
147. Taha SK, El-Khatib MF, Baraka AS, et al. Effect of suxamethonium vs rocuronium on onset of oxygen desaturation during apnoea following rapid sequence induction. *Anaesthesia.* 2010;65(4):358-361. **(Randomized; 60 adult patients)**
148. Tang L, Li S, Huang S, et al. Desaturation following rapid sequence induction using succinylcholine versus rocuronium in overweight patients. *Acta Anaesthesiol Scand.* 2011;55(2):203-208. **(Randomized; 60 obese adult patients)**
149. Sellick BA. Cricoid pressure to control regurgitation of stomach contents during induction of anesthesia. *Lancet.* 1961;2(7199):404-406. **(Observational study; 26 patients)**
150. *Ellis DY, Harris T, Zideman D. Cricoid pressure in emergency department rapid sequence intubations: a risk-benefit analysis. *Ann Emerg Med.* 2007;50(6):653-665. **(Systematic review)**
151. Butler J, Sen A. Cricoid pressure in emergency rapid sequence induction. *Emerg Med J.* 2005;22(11):815-816. **(Systematic review)**
152. Noguchi T, Koga K, Shiga Y, et al. The gum elastic bougie eases tracheal intubation while applying cricoid pressure compared to a stylet. *Can J Anaesth.* 2003;50(7):712-717. **(Prospective; 60 adult patients)**
153. Ho AM, Wong W, Ling E, et al. Airway difficulties caused by improperly applied cricoid pressure. *J Emerg Med.* 2001;20(1):29-31. **(Editorial)**
154. Levitan RM, Kinkle WC, Levin WJ, et al. Laryngeal view during laryngoscopy: a randomized trial comparing cricoid pressure, backward-upward-rightward pressure, and bimanual laryngoscopy. *Ann Emerg Med.* 2006;47(6):548-555. **(Prospective randomized; 1530 laryngoscopes by 104 participants)**
155. *Levitan RM, Heitz JW, Sweeny M, et al. The complexities of tracheal intubation with direct laryngoscopy and alternative intubation devices. *Ann Emerg Med.* 2011;57(3):240-247. **(Review article)**
156. Levitan RM, Mickler T, Hollander JE. Bimanual laryngoscopy: a videographic study of external laryngeal manipulation by novice intubators. *Ann Emerg Med.* 2002;40(1):30-37. **(Prospective; 9 novice intubators for 72 cases)**
157. Bhende MS, Thompson AE, Cook DR, et al. Validity of a disposable end-tidal CO_2 detector in verifying endotracheal tube placement in infants and children. *Ann Emerg Med.* 1992;21(2):142-145. **(Prospective; 173 pediatric patients)**
158. Li J. Capnography alone is imperfect for endotracheal tube placement confirmation during emergency intubation. *J Emerg Med.* 2001;20(3):223-229. **(Meta-analysis)**
159. *Weingart SD. Preoxygenation, reoxygenation, and delayed sequence intubation in the emergency department. *J Emerg Med.* 2011;40(6):661-667. **(Review article)**
160. *Dargin J, Medzon R. Emergency department management of the airway in obese adults. *Ann Emerg Med.* 2010;56(2):95-104. **(Review article)**
161. Levitan RM, Mechem CC, Ochroch EA, et al. Head-elevated laryngoscopy position: improving laryngoscopy by increasing head elevation. *Ann Emerg Med.* 2003;41(3):322-330. **(Human cadaver study)**
162. Barata I. The laryngeal mask airway: prehospital and emergency department use. *Emerg Med Clin North Am.* 2008;26(4):1069-1083. **(Review article)**
163. Reardon R, Joing S, Hill C. Bougie-guided cricothyrotomy technique. *Acad Emerg Med.* 2010;17 (2):225. **(Image/video clip)**
164. Hill C, Reardon R, Joing S, et al. Cricothyrotomy technique using gum elastic bougie is faster than standard technique: a study of emergency medicine residents and medical students in an animal lab. *Acad Emerg Med.* 2010;17(6):666-669. **(Randomized trial; 21 residents)**

CME Questions

Take This Test Online!

Current subscribers receive CME credit absolutely free by completing the following test. Each issue includes *4 AMA PRA Category 1 Credits*™, 4 ACEP Category I credits, 4 AAP Prescribed credits, and 4 AOA category 2A or 2B credits. Monthly online testing is now available for current and archived issues. To receive your free CME credits for this issue, scan the QR code below or visit www.ebmedicine.net/P0113.

1. **Which of the following is not a clinically significant difference in the physiology of the pediatric patient?**
   a. Children have a proportionally larger occiput.
   b. Children have fewer alveoli.
   c. Children utilize oxygen more quickly from their bloodstream.
   d. Children have a larger tongue proportional to their airway.
   e. Children naturally extend their necks when laid supine.

2. **Which method is least likely to improve pre-oxygenation?**
   a. High-flow nasal cannula underneath a face mask
   b. High-flow nasal cannula while a patient is apneic
   c. Utilizing continuous positive airway pressure
   d. Increasing the oxygen flow beyond 15 L/min on a face mask
   e. Humidified, blow-by oxygen delivered by a parent

3. **The most appropriate dosing for rocuronium for RSI is:**
   a. 0.4 mg/kg
   b. 0.8 mg/kg
   c. 1.0 mg/kg
   d. 1.5 mg/kg

4. **Succinylcholine would be contraindicated in:**
   a. A patient who had fallen from a horse with head trauma and is in cervical spine precautions
   b. A wheelchair-bound patient with muscular dystrophy
   c. A burn patient being brought from the scene to the ED
   d. A patient with a penetrating trauma to the abdomen
   e. A patient with severe rheumatologic disease

5. **One disadvantage of video laryngoscopy is:**
   a. In inexperienced hands, longer time to securing an endotracheal tube
   b. Worsened laryngoscopic view
   c. More difficult in the presence of blood or secretions
   d. Longer time to obtaining an adequate laryngeal view
   e. Contraindicated when a patient has cervical spine precautions

6. **The best available evidence shows that cricoid pressure:**
   a. May impede visualization of the glottic opening
   b. Reliably prevents aspiration
   c. Causes increased vagal tone and bradycardia
   d. Commonly results in tracheal injury
   e. Should be applied while preoxygenating a patient

7. **Which of the following is true concerning the intubation of obese patients?**
   a. Obese patients will desaturate at the same rate with appropriate preoxygenation.
   b. The ramped position achieves better laryngoscopic views than the supine "sniffing" position.
   c. Paralytics should be dosed according to ideal body weight.
   d. Obesity is a contraindication to etomidate use.
   e. Obese patients are more prone to hypotension after sedation.

Coming Soon In *Pediatric Emergency Medicine Practice*

The Febrile Young Infant: Rule Out Sepsis Workup Update

AUTHOR:

PAUL L. ARONSON, MD
Assistant Professor of Pediatrics, Department of Pediatrics, Section of Emergency Medicine, Yale School of Medicine, New Haven, CT

The febrile young infant is commonly encountered in the emergency department. The incidence of serious bacterial infection is high in these patients, and performance of a full sepsis workup is therefore recommended to rule out bacteremia, urinary tract infection, and bacterial meningitis. Parents and clinicians often question the necessity of this approach in the well-appearing febrile young infant, and it is important to understand and communicate the evidence that guides the approach to these patients. Additionally, recent research suggests that certain febrile young infants may not require the full sepsis workup; these studies will be reviewed in this issue of *Pediatric Emergency Medicine Practice*. The role of viral testing in the febrile young infant will also be discussed.

Pediatric Diabetic Ketoacidosis: An Outpatient Perspective On Evaluation And Management

AUTHOR:

WILLIAM BONADIO, MD
Attending Physician, Pediatric Emergency Medicine, Maimonides Medical Center, Brooklyn, NY

Diabetic ketoacidosis is a common, potentially-serious complication in children with diabetes mellitus. Diabetic ketoacidosis can accompany new-onset insulin-dependent diabetes mellitus, or it can occur with established insulin-dependent diabetes mellitus during the increased demands of an acute illness or with decreased insulin delivery due to omitted doses or insulin pump failure. Additionally, diabetic ketoacidosis episodes in children with type II diabetes mellitus are becoming more frequent. The initial management of children with diabetic ketoacidosis is frequently done in an emergency department. Although the diagnosis is usually straightforward in a known diabetic patient with expected findings, a fair proportion of new-onset diabetics present in diabetic ketoacidosis. Physicians must be cognizant that diabetic ketoacidosis is an important consideration in the differential diagnosis of pediatric metabolic acidosis. The purpose of this issue of *Pediatric Emergency Medicine Practice* is to acquaint emergency physicians with the pathophysiology, treatment, and potential complications of this disorder.

Physician CME Information

Date of Original Release: January 1, 2013. Date of most recent review: December 15, 2012. Termination date: January 1, 2016.

Accreditation: EB Medicine is accredited by the ACCME to provide continuing medical education for physicians.

Credit Designation: EB Medicine designates this enduring material for a maximum of *4 AMA PRA Category 1 Credits™*. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

ACEP Accreditation: *Pediatric Emergency Medicine Practice* is also approved by the American College of Emergency Physicians for 48 hours of ACEP Category I credit per annual subscription.

AAP Accreditation: This continuing medical education activity has been reviewed by the American Academy of Pediatrics and is acceptable for a maximum of 48 AAP credits per year. These credits can be applied toward the AAP CME/CPD Award available to Fellows and Candidate Fellows of the American Academy of Pediatrics.

AOA Accreditation: *Pediatric Emergency Medicine Practice* is eligible for up to 48 American Osteopathic Association Category 2A or 2B credit hours per year.

Needs Assessment: The need for this educational activity was determined by a survey of medical staff, including the editorial board of this publication; review of morbidity and mortality data from the CDC, AHA, NCHS, and ACEP; and evaluation of prior activities for emergency physicians.

Target Audience: This enduring material is designed for emergency medicine physicians, physician assistants, nurse practitioners, and residents.

Goals: Upon reading *Pediatric Emergency Medicine Practice,* you should be able to: (1) demonstrate medical decision-making based on the strongest clinical evidence; (2) cost-effectively diagnose and treat the most critical ED presentations; and (3) describe the most common medicolegal pitfalls for each topic covered.

Discussion of Investigational Information: As part of the newsletter, faculty may be presenting investigational information about pharmaceutical products that is outside Food and Drug Administration approved labeling. Information presented as part of this activity is intended solely as continuing medical education and is not intended to promote off-label use of any pharmaceutical product.

Faculty Disclosure: It is the policy of EB Medicine to ensure objectivity, balance, independence, transparency, and scientific rigor in all CME-sponsored educational activities. All faculty participating in the planning or implementation of a sponsored activity are expected to disclose to the audience any relevant financial relationships and to assist in resolving any conflict of interest that may arise from the relationship. Presenters must also make a meaningful disclosure to the audience of their discussions of unlabeled or unapproved drugs or devices. In compliance with all ACCME Essentials, Standards, and Guidelines, all faculty for this CME activity were asked to complete a full disclosure statement. The information received is as follows: Dr. Singh, Dr. Frenkel, Dr. Choi, Dr. Sharieff, Dr. Vella, and their related parties report no significant financial interest or other relationship with the manufacturer(s) of any commercial product(s) discussed in this educational presentation.

Method of Participation:

- **Print Semester Program:** Paid subscribers who read all CME articles during each *Pediatric Emergency Medicine Practice* 6-month testing period, complete the posttest and the CME Evaluation Form distributed with the June and December issues, and return it according to the published instructions are eligible for up to 4 hours of CME credit for each issue.
- **Online Single-Issue Program:** Current, paid subscribers who read this *Pediatric Emergency Medicine Practice* CME article and complete the online posttest and CME evaluation Form at ebmedicine.net/CME are eligible for up to 4 hours of Category 1 credit toward the AMA Physician's Recognition Award (PRA). Hints will be provided for each missed question, and participants must score 100% to receive credit.

Commercial Support: This issue of *Pediatric Emergency Medicine Practice* did not receive any commercial support.

Hardware/Software Requirements: You will need a Macintosh or PC with internet capabilities to access the website.

Additional Policies: For additional policies, including our statement of conflict of interest, source of funding, statement of informed consent, and statement of human and animal rights, visit http://www.ebmedicine.net/policies.

CEO & Publisher: Stephanie Williford **Marketing Manager:** Robin Williford
Managing Editor: Dorothy Whisenhunt **Director of Member Services**: Liz Alvarez

Direct all questions to:
EB Medicine
1-800-249-5770
Outside the U.S.: 1-678-366-7933
Fax: 1-770-500-1316
5550 Triangle Parkway, Suite 150
Norcross, GA 30092
E-mail: **ebm@ebmedicine.net**
Website: **EBMedicine.net**
To write a letter to the editor, email: JagodaMD@ebmedicine.net

Subscription Information:
1 year (12 issues) including evidence-based print issues;
48 *AMA PRA Category 1 Credits™*, 48 ACEP Category 1 Credits, 48 AAP Prescribed credits, and 48 AOA Category 2A or 2B credit; and full online access to searchable archives and additional free CME: $299
(Call 1-800-249-5770 or go to www.ebmedicine.net/subscribe to order)
Single issues with CME may be purchased at www.ebmedicine.net/PEMPissues

Pediatric Emergency Medicine Practice (ISSN Print: 1549-9650, ISSN Online: 1549-9669, ACID-FREE) is published monthly (12 times per year) by EB Medicine. 5550 Triangle Parkway, Suite 150, Norcross, GA 30092. Opinions expressed are not necessarily those of this publication. Mention of products or services does not constitute endorsement. This publication is intended as a general guide and is intended to supplement, rather than substitute, professional judgment. It covers a highly technical and complex subject and should not be used for making specific medical decisions. The materials contained herein are not intended to establish policy, procedure, or standard of care. Pediatric Emergency Medicine Practice is a trademark of EB Medicine.