

Managing The Pediatric Airway In The ED

January 2006
Volume 3, Number 1

At 7:40 am, your local emergency medical services (EMS) calls about a 6-month-old girl found with cyanosis, respiratory difficulty, and an altered mental status after wheezing all night. The paramedics report a respiratory rate of 54 breaths per minute, a heart rate of 48 beats per minute, and a room air oxygen saturation of 78%. The child has intercostal retractions, supraclavicular retractions, grunting respirations, and nasal flare. The paramedics place her on high-flow oxygen, with only marginal improvement in her mental status and work of breathing. Her oxygen saturation rises to 85%. EMS has been unsuccessful in obtaining intravenous access. They begin to assist her respirations with a bag-valve mask, and tell you their ETA is 3 minutes.

As you and the nurses are scrambling to set up for the patient's arrival, several questions come to mind. What will I do if I am unable to intubate this girl? What will I do if her airway becomes completely occluded, and I can no longer even bag ventilate her? What are the common complications of intubation and mechanical ventilation in this age group? If this is how my shift is starting, what is the rest of the day going to look like?

THE agitated or unconscious child or infant with a compromised airway is a challenging, anxiety-provoking clinical problem that may be faced by everyone from basic life support (BLS) providers to emergency physicians. The management of the child's airway is arguably the most important life-saving skill any EMS provider possesses. A systematic approach, combined with adequate preplanning, serves to calm everyone down and offers the greatest likelihood of an optimal outcome. Over the years, many (if not most) emergency physicians have become experts in adult airway management. Unfortunately, adult intubation techniques, tools, and skills may not easily transfer to infants and young children. This does not mean that intubation of the pediatric airway is more difficult — just that different skills and tools are required to maximize the likelihood of success. Far fewer children than adults require prehospital or emergent intubation, even in designated "children's" EDs.¹ Fortunately, children account for only about 10% of all ambulance transports — and only 1% of critically ill ambulance transports.² Unfor-

Author

Charles Stewart, MD, FAAEM, FACEP
Emergency Physician—Colorado Springs, CO.

Peer Reviewers

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

Mike Witt, MD, MPH

Attending Physician, Division of Emergency Medicine, Children's Hospital Boston; Instructor of Pediatrics, Harvard Medical School—Boston, MA.

CME Objectives

Upon completing this article, you should be able to:

1. Describe the anatomical differences between the pediatric and adult airway;
2. List the steps required to perform rapid sequence intubation (RSI) in children; and
3. Compare and contrast the clinical effects of neuromuscular blocking agents used in the ED.

*Date of original release: January 30, 2006.
Date of most recent review: January 15, 2006.
See "Physician CME Information" on back page.*

Editor-in-Chief

Lance Brown, MD, MPH, FACEP, Chief, Division of Pediatric Emergency Medicine; Associate Professor of Emergency Medicine and Pediatrics; Loma Linda University Medical Center and Children's Hospital, Loma Linda, CA.

Associate Editor

Tommy Y Kim, MD, FAAP, Attending Physician, Pediatric Emergency Department; Assistant Professor of Emergency Medicine and Pediatrics, Loma Linda Medical Center and Children's Hospital, Loma Linda, CA.

Editorial Board

Jeffrey R. Avner, MD, FAAP, Professor of Clinical Pediatrics, Albert Einstein College of Medicine; Director,

Pediatric Emergency Service, Children's Hospital at Montefiore, Bronx, NY.

Beverly Bauman, MD, FAAP, FACEP, Assistant Chief, Pediatric Emergency Services, Oregon Health & Sciences University, Portland, OR.

T. Kent Denmark, MD, FAAP, FACEP, Residency Director, Pediatric Emergency Medicine; Assistant Professor, Departments of Emergency Medicine and Pediatrics; Loma Linda University Medical Center and Children's Hospital, Loma Linda, CA.

Michael J. Gerardi, MD, FAAP, FACEP, Clinical Assistant Professor, Medicine, University of Medicine and Dentistry of New Jersey; Director, Pediatric Emergency Medicine, Children's Medical Center, Atlantic Health System; Department of Emergency Medicine, Morristown Memorial Hospital.

Ran D. Goldman, MD, Associate Professor, Department of Pediatrics, University of Toronto; Division of Pediatric Emergency Medicine and Clinical Pharmacology and Toxicology, The Hospital for Sick Children, Toronto.

Martin I. Herman, MD, FAAP, FACEP, Professor of Pediatrics, Division of Critical Care and Emergency Services, UT Health Sciences, School of Medicine; Assistant Director Emergency Services, Lebonheur Children's Medical Center, Memphis TN.

Marilyn P. Hicks, MD, FACEP, Director, Pediatric Emergency Medicine Education, Department of Emergency Medicine, WakeMed, Raleigh, NC; Adjunct Assistant Professor, Department of Emergency Medicine, University of North Carolina, Chapel Hill, NC.

Mark A. Hostetler, MD, MPH, Assistant Professor, Department of Pediatrics; Chief, Section of Emergency Medicine; Medical Director, Pediatric Emergency Department, The University of Chicago, Pritzker School of Medicine, Chicago, IL.

Aison S. Inaba, MD, FAAP, PALS-NF, Pediatric Emergency Medicine Attending Physician, Kapiolani Medical Center for Women & Children; Associate Professor of Pediatrics, University of Hawaii John A. Burns School of Medicine, Honolulu, HI; Pediatric Advanced Life Support National Faculty Representative, American Heart Association, Hawaii & Pacific Island Region.

Andy Jagoda, MD, FACEP, Vice-Chair of Academic Affairs, Department of Emergency Medicine; Residency Program Director; Director, International Studies Program,

Mount Sinai School of Medicine, New York, NY.

Brent R. King, MD, FACEP, FAAP, FAAEM, Professor of Emergency Medicine and Pediatrics; Chairman, Department of Emergency Medicine, The University of Texas Houston Medical School, Houston, TX.

Robert Luten, MD, Professor, Pediatrics & Emergency Medicine, University of Florida, Jacksonville, Jacksonville, FL.

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

Gary R. Strange, MD, MA, FACEP, Professor and Head, Department of Emergency Medicine, University of Illinois, Chicago, IL.

tunately, this means that few practitioners have much experience intubating infants. Emergency physicians are not alone in this regard. Anesthesiologists who do not regularly perform pediatric intubations also lose the skills gained in training. Complicating matters is the fact that adult airway rescue techniques that may be appropriate for older children and adolescents may be very difficult or even dangerous for infants and younger children.

In this article, we will highlight the unique features of pediatric airway management and make recommendations on approaching the pediatric airway. There is an old adage about pediatric resuscitation — the 3 most important concepts to master are: 1. Airway, 2. Airway, and 3. Airway. This issue of *Pediatric Emergency Medicine PRACTICE* covers them all.

Abbreviations Used In This Article

ACLS — Advanced Cardiac Life Support
AIS — Abbreviated Injury Scale
AMPLE — Allergies, medications, past medical history, last meal, events leading to the need for intubation
BLS — Basic life support
BVM — Bag-valve-mask
CPAP — Continuous positive airway pressure
EDD — Esophageal detector device
EMS — Emergency Medical Services
ET — Endotracheal
ETI — Endotracheal intubation
ETT — Endotracheal tube
GCS — Glasgow Coma Scale
ICP — Intracranial pressure
ID — Inner diameter
LMA — Laryngeal mask airway
NG — Nasogastric
NPTR-3 — National Pediatric Trauma Registry phase 3
OD — Outer diameter
PALS — Pediatric Advanced Life Support
PEEP — Positive end-expiratory pressure
RCT — Randomized controlled trial
RSI — Rapid sequence intubation
TBI — Traumatic brain injury

Critical Appraisal Of The Literature

Few studies relevant to pediatric airway management have been conducted. In particular, the decision to train and allow paramedics to intubate the pediatric patient in the field has engendered considerable debate. The only prospective study there is — Gausche-Hill's 2000 review of 830 patients ≤ 12 years of age — has been praised, disparaged, and debated extensively.^{3,4}

Endotracheal intubation (ETI) of pediatric patients in this large study led to prolonged scene times, without better survival outcomes, neurological outcomes, or technical complication rates. The authors suggest that good bag-valve-mask (BVM) ventilation by less skilled professionals, until a higher level of skill and equipment is available, is not detrimental to the patient. Although the study by Gausche-Hill et al does not definitively settle the question,

it does provide evidence that prehospital pediatric intubation should not be performed by paramedics who lack substantial pediatric intubation training and practice.

There were significant flaws in the training of the nearly 2600 paramedics involved in this study. The paramedics had no training or access to rapid sequence intubation (RSI) techniques; they were trained, on manikins only, in a single, 6-hour session; as many as 33 months elapsed from the training until the close of the study; and no refresher training was given. Therefore, skill and knowledge degradation may have been considerable. One wonders if enough was done to train the paramedics for pediatric intubation, since the success rate for pediatric intubation in this study was only 57% (the *intention* to use ETI was considered for this number, rather than complications of ETI).

It is also not clear how evenly the paramedics were distributed between the 2 groups. Since nearly 2600 medics were involved, but only 830 children were intubated, clearly many medics did no intubations. It is possible that some may have gained significant practice or may have been substantially better with intubating children, but there was no discussion of this within the study. Since the results of the intervention clearly depend on the ability of the operator, a better study would randomize for each paramedic, so that their individual outcomes could be compared.

In another article, the same authors noted substantial decrements in airway skills after only 7 months.⁵ In this observation of 234 paramedics who received advanced training, one third did not retain BVM skills, and over 60% did not retain ETI skills, when these skills were retested at 6 months. Clearly, there is much room for improvement in training, practice, and skill retention in pediatric intubation for these medics.

Another large, retrospective study that used the National Pediatric Trauma Registry phase 3 (NPTR-3) abstracted the records of all patients with an Abbreviated Injury Scale (AIS) score ≥ 4 , if the patients had received either endotracheal intubation or bag-valve-mask ventilation.⁶ This data mining study netted a total of 578 cases; 479 children were intubated (83%), and bag-valve-mask ventilation was used in 99 (17%). The 2 cohorts did not differ in injury severity or mechanism, but those with endotracheal intubation were older; also, more children who were intubated received fluids (81% ETI vs 71% BVM) and intravenous medications (39% ETI vs 23% BVM) and were transported by helicopter (67% ETI vs 27% BVM). Death rates in both cohorts were similar. Functional outcome in patients >7 years old showed a nonsignificant trend in improved outcome in the patients who were intubated.⁶

Published in 1990, a small retrospective study conducted over the course of a year at a single medical center evaluated 16 prehospital attempts at advanced airway techniques in children and found that only 8 (50%) were successful (including both a successful and an unsuccessful cricothyrotomy). The authors actually attributed 4 deaths to major airway mishaps in the field.⁷

It is difficult to draw any conclusions from this tiny retrospective study about trauma patients, other than prehospital intubation of the traumatized pediatric patient may be quite difficult. The numbers are so small and the training so poorly documented that the results are essentially meaningless. Nonetheless, this study is often cited in support of the Gausche-Hill article in *JAMA*.

Another study that covered a substantially older age group was conducted in Los Angeles from 1995-1997.⁸ In this study, prehospital intubation of patients 11-20 years of age with a GCS ≤ 8 and an Abbreviated Injury Severity score ≥ 3 was studied. A total of 137 patients were examined, and 22 had successful intubations. The mortality of the 22 who were intubated was 19/22, versus 57 of 115 who were managed by BVM alone. The groups were not adjusted for comparative injuries. This study is also cited in support of the Gausche-Hill article, although the age group is not comparable.

It is clear that there is only one well-conducted, prospective outcome study that can be used to evaluate the role of prehospital care providers in intubating the pediatric patient. Unfortunately, this study has significant problems with training and skill retention in the paramedics selected for the study. As such, it may not reflect best practice.

Recognizing the paucity of real-world experience, the American Academy of Pediatrics and the American Heart Association have codeveloped the Pediatric Advanced Life Support (PALS) course.⁹ The emphasis in this course is recognition of the critically ill child prior to cardiorespiratory failure. By early identification of these children at risk, the physician can better prevent a poor outcome. It is possible that new pediatric Advanced Cardiac Life Support (ACLS) recommendations may emphasize bag-valve-mask ventilation of children and limit use of endotracheal intubation, at least in the prehospital area. The new AHA recommendations do advise caution with intubations.

Epidemiology, Etiology, And Pathophysiology

Anatomical Differences

The upper airway can be divided into 3 distinct segments: the oropharynx, the hypopharynx, and the larynx. The oropharynx includes the tongue and soft palate. The hypopharynx includes the epiglottis, the vallecula, aryepiglottic folds, and the retropharyngeal area. The larynx is the entrance to the airway and includes both the true and false vocal cords. The cricoid cartilage separates the larynx from the trachea and is completely composed of cartilage.

The airway of the younger child is very different from that of the older child or adult, and these pediatric features are usually present until about age 8 or 9. After this age, the airway becomes more adult-like in configuration, and the generalist emergency physician is on more familiar ground.

Occiput

The child's head and occiput are proportionately larger than an adult's. This will cause neck flexion and possible

airway obstruction when the child is supine. The sniffing position is the proper one for a child's airway. A roll may be placed under the back or shoulders, rather than under the neck, to better achieve this position.

Tongue

The tongue is large compared with an adult's, resulting in less oral space for intubation. Decreased muscle tone will increase the likelihood of passive airway obstruction by the tongue. Indeed, this is the most common cause of airway obstruction in children. Obstruction from tongue displacement can usually be helped with better head positioning or with the use of an airway adjunct, such as an oropharyngeal or nasopharyngeal airway.

Neck

The child's neck is much shorter, with a more anterior and cephalad larynx. Indeed, the larynx is so anterior that Sellick's maneuver is often required, not only to occlude the esophagus, but also to bring the vocal cords into view. Another helpful maneuver is getting lower than the patient and looking up at a 45 degree or greater angle when intubating. In very small children, it may be worthwhile to place the small finger of the left (laryngoscope) hand on the thyroid cartilage, to help with this posterior displacement. An assistant is more likely to be useful in intubating smaller children.

The larger mass of adenoidal tissues may make nasotracheal intubation more difficult. Nasopharyngeal airways are more difficult to pass in infants less than 1 year of age and are generally not recommended in this age group. As always, passage of an object into the nose can be associated with significant bleeding.

The epiglottis is flaccid, high, long, and narrow in the small child. It is also angled away from the long axis of the trachea. This makes direct laryngoscopy more difficult, as the angle between the base of the tongue and the glottic opening is more acute. The epiglottis in the infant and young child (up to about 8 years of age) is more easily picked up by a straight (Miller or similar) blade to facilitate intubation.

The risk of mainstem bronchus intubation is much higher in the small child, due to the shorter trachea and bronchus. The trachea is about 12-15 cm long in the adult, and only 4 cm long in the newborn. The endotracheal tube must protrude only 3 to 4 cm past the cords to avoid a right mainstem bronchus intubation.

The narrow tracheal diameter and the shortened distance between tracheal rings make tracheostomy technically more difficult. For this reason, The American Heart Association recommends a needle cricothyrotomy in children, rather than an open cricothyrotomy.

Airway Size

The diameter of the pediatric airway is much smaller than the adult airway, making it far more vulnerable to obstruction by either foreign objects or edema. Minor narrowing from respiratory infections or bronchospasm may result in

profound airway difficulties in the pediatric patient.

Airflow through a pipe like the bronchi is described by Poisson's equations. Airflow in the narrowed airway meets resistance that is described by an inverse proportion to the fourth power of the radius of the airway for laminar airflow, and to the fifth power for turbulent airflow¹⁰ — in other words, $R = 1/r^4$, where R is resistance, and r is the radius.

This means that just 1 mm of circumferential edema in an infant's airway will decrease the cross-sectional area by 75% and increase the airflow resistance 16-fold. With turbulent airflow, such as in a crying child, the work of breathing is increased 32-fold.

Mechanics of Ventilation

The child's chest wall is more compliant than an adult's, because it is more cartilage than bone. The diaphragm is higher, due to the relatively larger size of the abdominal contents and the smaller lung volumes of the child. Unfortunately, the child's lungs are also small in relation to the child's metabolic needs, so there is less margin than in the adult. The child's diaphragmatic muscles can be fatigued by increased work of respiration, and the mechanics of the child's inspiration can suffer. Likewise, a distended stomach can compress the diaphragm, even after intubation.

Physiologic Responses

The infant is a nose breather until approximately 3-6 months of age. Obligate nose breathing means that even minor nasal congestion can lead to some obstructive apnea.

High metabolic rates, small lung volumes, and a small functional residual capacity in relation to the infant's metabolic needs mean that the infant has significantly less reserve and apnea. Even with adequate preoxygenation, the child will rapidly desaturate, with subsequent cyanosis.

The infant and small child are at further risk of respiratory problems, because of their immature physiologic responses. The infant will become apneic and bradycardic in response to a hypoxic challenge, instead of increasing the respiratory effort and heart rate.

Behavioral immaturity can increase the risk of respiratory problems. The child is unable to talk and tell us that he or she is starting to wear out. The child is also prone to dangerous behavior without realizing the danger (eg, aspiration of foreign bodies).

Differential Diagnosis

Since this article will cover procedural skills for airway management, the differential diagnosis is that of the child with airway compromise from any cause. The causes of difficulty securing the airway in a child fall into 4 broad categories. The first consists of congenital abnormalities that lead to varying degrees of chronic airway obstruction — for example, glottic webs, hemangiomas, vascular rings, mandibular abnormalities, tracheal-esophageal fusions and fistulae, and laryngomalacia.¹¹ These conditions

have usually already been diagnosed by the time the child presents to an ED. The second category involves infections that affect the airway, such as epiglottitis, croup, retropharyngeal abscess, bacterial tracheitis, Ludwig's angina (in children with dental extractions), and diphtheria. These illnesses present with progressive airway obstruction over a relatively rapid course. The third category is comprised of those with trauma to the airway or aspiration of a foreign object. These children often have a sudden obstruction of the airway. The last group includes patients who do not have a known congenital or acquired abnormality and who are unexpectedly difficult to intubate. These children often have other illnesses that require intubation to protect the airway. The difficulties encountered in this group are often unpredictable.

Prehospital Care

The prehospital care of the pediatric patient with respiratory distress, a failing airway, or trauma involving the airway is the subject of much discussion, as noted in the critical appraisal of the literature. On one hand, there is clear evidence that hypoxemia leads to a poorer neurologic outcome in both adult and pediatric patients. On the other hand, there is evidence that hypoxemia may be more frequent in the prehospital setting for the pediatric patient, that successful prehospital intubation of the pediatric patient requires significant and specialized training, and that reported success rates are much lower than in adults.

In the largest prospective airway study to date, there was no benefit overall (or in any analyzed subgroup) from endotracheal intubation.³ While there are substantial flaws in training and skill maintenance attributed to this study, it is also clear that bag-valve-mask ventilation can maintain ventilation in these children. Until appropriate training and evaluation for paramedics is conducted, prehospital intubation of the child is problematic. The results may have been very different with more experienced paramedics.

ED Evaluation

Respiratory failure is the most common cause of cardiac arrest in the child. Respiratory failure can result from disease of the upper or lower airway, or it may be the end result of other disease processes. In most cases, the respiratory failure is preceded by a period of respiratory distress. The signs and symptoms of respiratory distress in children may be quite obvious or rather subtle. (Table 1 and Table 2)

History

Most commonly, a child in respiratory distress will have a history of "trouble breathing." The parents may note some coughing, rapid or noisy breathing, or some change in behavior. In neonates and young infants, tachypnea may alternate with bradypnea or apnea. Difficulty breathing, decreased activity and/or feeding, exhaustion, and color changes are often noted by parents. Small infants may

have difficulty drinking from a bottle, as they are unable to breathe through the nose, and the mouth is occluded while drinking. Parents of older children may note wheezing or a decrease in physical activity.

The past medical history is important, even in very small children, for determining the acute problem. The examiner should note, at a minimum, whether the child was premature, whether the birth was normal or abnormal, and whether the child went home with mother. The parents of the asthmatic child should be questioned about past hospitalizations, exacerbations, recent steroid use, recent physician visits, current use of medications, and intubations. A child with chronic cough or multiple episodes of pneumonia may be harboring a foreign body, or may have reactive airway disease or undiagnosed cystic fibrosis. In older children, the examiner should remember that tachypnea may be due to fever, hypovolemia, diabetic ketoacidosis, or sepsis.

Examination of the Child

Simply observing the patient is an important part of the physical examination. Is this child alert, cooperative, and playful, or listless and responding only to painful stimuli? An alert, awake, and playful child is simply unlikely to be in respiratory distress. The child with early respiratory distress is often irritable and anxious. They may not be able to assume a comfortable position, even in mother's arms. Early respiratory failure will be marked by agitation, and finally by lethargy, listlessness, and somnolence.

Most respiratory dysfunction originates in the airway and/or lungs; however, respiratory distress may be due to impaired diaphragmatic excursion (abdominal or gastric distension), or to infectious, metabolic, or CNS abnormalities.

Tachypnea

The child in respiratory difficulty who does not have a completely obstructed airway will almost always have tachypnea. Tachypnea is the most common response to an increased respiratory demand. Remember that tachypnea may also be noted as a response to metabolic acidosis, fever, sepsis, pain, or central nervous system disease or injury.

Since the normal respiratory rate varies with the age of the child, tachypnea must be assessed in the context of the patient's overall milieu. Newborns normally breathe

Table 1. Signs Of Respiratory Distress In The Child.

Tachypnea
Use of accessory muscles
Nasal flaring
Position of comfort
Tripod position
Grunting respirations
Cyanosis

40 to 50 times per minute. By 1 year of age, the respiratory rate is around 30 to 35, by 4 years it is 20 to 25, and by age 8 to 10 years, it is at the usual adult rate of 12 to 15 breaths per minute.

Use of Accessory Muscles

Inspection of the chest wall and neck may reveal retractions, as accessory muscles are recruited to help the child breathe. Retractions may be seen in the supraclavicular, infraclavicular, subcostal, and intercostal areas. If severe disease is present, the entire sternum may retract on inspiration. Retractions imply a significant amount of respiratory distress. They should never be ignored.

Patients who are struggling to breathe and who are not moving air or have limited air exchange are in imminent danger of respiratory arrest. These children should never be left alone, even for a moment.

Nasal Flare

When the child has increasing difficulty with the work of breathing, nasal flare may be noted. Nasal flaring, an outward and upward flaring of the nares on inspiration, is thought to be a primitive reflex seen in young infants, who are obligate nose breathers for the first 2 to 3 months of life — this is probably an attempt to decrease the airway resistance at the nares in the young infant. Again, this is a finding that must not be ignored.

Tripod Position

The first position that the child with respiratory distress will assume is a "position of comfort." This will usually be upright, leaning slightly forward, mouth open, and with head, neck, and jaw thrust forward to aggressively open the airway. This position is also referred to as the "sniffing position."

When they are in severe respiratory distress, patients may assume the "tripod position" — an upright posture, leaning forward and supporting the upper body with the arms placed either on the thighs or the bed. This position enhances the full use of the thoracoabdominal muscles for the work of breathing. It represents the final stage in recruitment of the accessory muscles of respiration. This patient is about to have a respiratory arrest.

Altered Respiratory Sounds

Listening to grossly audible breath sounds may help to localize the pathology or to confirm the patient's respiratory distress. Auscultation of the chest may reveal decreased

Table 2. Signs Of Respiratory Failure In The Child.

Decreased level of consciousness
Grunting respirations and increased work of breathing
Poor air entry and decreased breath sounds
Bradycardia
Apnea/slowed respirations

breath sounds, decreased air movement, and slowing respirations as the child progresses towards respiratory arrest.

Drooling

Drooling in a child may imply pooled secretions and at least a partially obstructed airway. Note that infants and younger children can drool without any airway obstruction, so observation of other parameters is important.

Grunting Respirations

Grunting is an ominous sign of impending respiratory failure. The sound is produced by partial closure of the glottis on the end of expiration. Grunting seems to provide an increased end-expiratory pressure and keep the terminal airways open.⁹ Grunting may be seen in primary lung disease or with systemic illnesses, such as sepsis. Observation of neonates who grunted led to the development of continuous positive airway pressure (CPAP) and positive end-expiratory pressure (PEEP) in the treatment of neonatal hyaline membrane disease. Grunting localizes the respiratory disease to the lower respiratory tract. That is, patients who grunt have pneumonia, asthma, or bronchiolitis, and not upper respiratory obstruction.

Stridor

Stridor is a harsh, high-pitched respiratory noise caused by turbulent airflow through a narrowed upper airway. Stridor may be heard on both inspiration and expiration. In the child, stridor implies at least a 50% narrowing of the upper airway. Stridor may indicate severe upper airway pathology, such as croup, epiglottitis, or foreign bodies in the airway. A less common cause is a congenital or iatrogenic narrowing of the glottic area.

Any examination of the upper airway should be done with extreme caution in the patient who has stridor. Anything that agitates the patient should be avoided, including separation from the parents, alteration of the patient's posture, rectal temperatures, blood draws, intravenous lines, and examination of the oral cavity.

Wheezes

Wheezes are characterized by a whistling sound associated with forced airflow through abnormally collapsed airways with residual trapping of air. The typical wheezing during expiration implies bronchiolar disease, either primary (due to structural change) or secondary (as in air trapping), both of which can be seen in asthma. The patient with asthma may wheeze during inspiration, as well. Grossly audible wheezing represents significant obstruction at the level of the lower airways. Although commonly associated with asthma, wheezes may also be due to other causes, including airway swelling, tumor, or obstructing foreign bodies.

Also, while the timing and apparent location of wheezing may be significant, even the most localized obstruction can produce diffuse bilateral sounds. At times, wheezing may not be heard initially, due to severe bron-

choconstriction and poor inhalation.

Rales

Rales are often described as sounding "like Rice Krispies[®] crackling." Development of rales requires a significant accumulation of alveolar fluid. Rales in a previously healthy child with cough and fever usually indicates pneumonia or reactive airway disease (asthma or bronchiolitis). In cardiac disease, nephrosis, and severe malnutrition, rales indicate significant pulmonary edema or congestive heart failure.

Poor Perfusion

Ominous signs of poor perfusion and oxygenation in the child or infant include pallor or cyanosis. Cyanosis is most easily noted circumorally in the child. The cyanosis will be central and will often be associated with somnolence.

Cyanosis, while certainly a clear and dramatic sign, has significant limitations as a diagnostic tool. It depends on the amount of hemoglobin in the blood and the status of the peripheral circulation. A child with severe anemia, for example, may have significant hypoxia without any visible cyanosis. Conversely, a very young infant whose hemoglobin has not yet fallen from the high levels found at birth may have peripheral cyanosis, despite a normal PO₂. Detection of cyanosis is quite difficult in poor light and in children with darker skin. Finally, even when present, cyanosis is a late development in respiratory diseases.

Treatment

Early Management of the Infant's Airway

The prominence of the occiput, the small neck, and the narrow thorax mean that positioning the child to avoid airway obstruction is different than for an adult. The child may need a pad or folded sheet under the small of the back, to lift the chest and compensate for the large occiput. This will allow the neck to assume a neutral position. Hyperextension of the neck may occlude the child's airway. The child's larger tongue may require a jaw thrust or chin lift in order to open the airway.

Oral airways in children can maintain a patent airway or eliminate pharyngeal obstruction by the tongue. This airway must be properly measured before use — one that is too large can cause pharyngeal and glottic trauma. An airway that is too small can push the tongue down and actually worsen the occlusion. Nasal trumpets are useful for older children and adolescents. They are not available for small children and infants. Insertion techniques, complications, and contraindications are no different from those in adults.

Bag-valve-mask ventilation is unchanged from that used in adults. In children, the size of the mask is critical. The mask must fit over the nose, cheeks, and chin. Using too small a bag will result in inadequate ventilation. Small-volume, self-inflating bags do not deliver an adequate tidal volume to the infant with poorly compliant lungs. Child-size and adult-size self-inflating bags may be used for the entire age range of infants and children without

fear of overinflation or barotrauma.¹² All bag-valve-mask systems require a reservoir to ensure that 100% oxygen is delivered.

Pediatric bag-valve-mask devices are usually fitted with pop-off valves set at about 30-35 cm H₂O pressure. This pressure cutoff was based on an experimental study involving newborn lungs and cannot be well extrapolated to the clinical picture. In the clinical model, increased airway resistance and decreased lung compliance may require ventilatory pressures well in excess of 30 cm H₂O.¹³ Activation of the pop-off valve may lead to inadequate delivery of needed volume, particularly in the presence of reduced lung compliance or increased airway resistance.¹⁴

When using the BVM to ventilate the patient, it is important to ensure that the child has a clear airway and that the chest rises while using the bag. Effective ventilation will move the child's chest about the same amount as when a child takes a deep breath. If there is no chest movement, there is no ventilation. If the ventilation is ineffective, both the airway and the ventilation efforts need to be promptly reassessed. The optimal position for the operator is usually behind the patient's head. Cricoid pressure should be used when the child is at risk for aspiration or vomiting.

Mouth-to-mask resuscitation is effective in children and infants and may be more effective than BVM. Inverting the Laerdal Pocket Mask™ may fit a child's airway better.

Steps for Pediatric Rapid Sequence Intubation

1. Assess the risks.
2. Get equipment ready.
3. Monitor the patient.
4. Preoxygenate the patient.
5. Sellick's maneuver.
6. Medicate the patient.*
7. Intubate the patient.
8. Verify placement.
9. Secure the tube.

*Airway obstruction, apnea, and circulatory arrest demand immediate endotracheal intubation, without any preparatory medications.

Although in-hospital intubation has a much lower incidence of complications than intubation of the pediatric patient in the field, about 25% of pediatric in-hospital endotracheal intubations do have complications, and about 30% of these are serious.¹⁵ These serious complications include the inability to intubate, mainstem intubation, aspiration, dislodgement of the tube, esophageal intubation, airway trauma, and barotrauma. These complications were markedly reduced with appropriate sedation in this and other studies.^{16,17}

Multiple clinical studies have demonstrated that RSI, for pediatric patients, can be performed safely and effectively in the field by properly trained providers.¹⁸ These reports encompass patients with a wide range of ages and clinical presentations. The key to success is proper training

Table 3. Contraindications To Rapid Sequence Intubation.

Spontaneous breathing with adequate ventilation
Operator concern that both intubation and mask ventilation may not be successful
Major laryngeal trauma
Upper airway obstruction
Distorted facial or airway anatomy

and skill retention.

Assess the Risks

Ensure that, at a minimum, the AMPLE (*a*llergies, *m*edications, *p*ast medical history, *l*ast meal, *e*vents leading to the need for intubation) history is available, if at all possible. The intubating clinician should personally examine the neck, face, head, nose, throat, and chest, even when a full-team approach is used for resuscitation. (See **Table 3** for contraindications to RSI).

Get Equipment Ready

In many EDs, equipment for pediatric emergency intubation is not always kept in the same working area where it will be needed. The operator should ensure that all necessary equipment is opened, laid out, and fully functional before any medications are given to the patient.

Generally, a straight blade is used for pediatric intubation, particularly for infants under a year old. The more anterior airway and the floppy epiglottis of the child and infant may make the straight blade more appropriate for the child from 12 months to 6 years of age. For a child older than 6-8 years of age, both Macintosh and straight blades are commonly used.

Minimum Equipment for Rapid Sequence Intubation

- Appropriately sized bag-valve mask with reservoir
- Suction (fully hooked up and functional)
- Oxygen (hooked up to a bag-valve mask)
- Laryngoscope, with appropriate sized blades and functioning lights
- Appropriately sized endotracheal tubes (get at least one size above and one below the predicted size)
- Stylet for the endotracheal tube
- All pharmaceutical agents to be used in the room where intubation is planned
- Alternative airway equipment in the location where intubation is planned

Equipment for an alternative airway should always be readily available in the proposed intubation room. For the field EMS provider, this means that the airway control kit can always rescue the airway. For the pediatric population, this should include both cricothyrotomy and jet ventilation equipment. Depending on the experience of the operator, an appropriately sized laryngeal mask airway could also be used.

Choosing a Pediatric Tube Size

There are many charts and tables to aid in tube size and selection, but these are rarely available when needed. An excellent and often readily available written aid to tube size and doses of resuscitation drugs is the Broselow® tape. This body tape converts body length into appropriate sizes for tubes, blades, length of tube to be inserted, size of laryngoscope blades to be used, and doses of drugs.

Remember in the child that you must not only select the proper size tube, you must put it into the larynx to the proper depth. Usually the depth of the tube in centimeters can be calculated as 3 times the size of the tube. A lighted endotracheal tube can be visualized in the child's neck, giving an appropriate depth. Alternatively, the Broselow® tape also gives the proper depth of insertion.

Cuffed vs Uncuffed Tubes

Most major emergency medicine, pediatric ICU, and pediatric anesthesia textbooks instruct that the tube should not have a cuff if the child is under 8 years of age. This dictum was promulgated prior to the development of low-pressure, high-volume cuffs in appropriate sizes for children and infants, and this is now open to question.

Uncuffed Tubes

In children, cuffed tubes are believed to add little to prevention of aspiration, and the smaller size of the cuffed tube will decrease the available airflow.¹⁹ There are 3 arguments against the use of cuffed endotracheal tubes:

1. The presence of a leak ensures that the tube is not compressing the tracheal mucosae against the child's nondistensible cricoid ring. Cuffed tubes increase the risk of mucosal injury in the airway. An uncuffed tube that is too large will also cause mucosal ulceration, tracheal swelling, and postextubation croup.
2. Adding a cuff necessitates using a smaller tube, which increases the airway resistance and work of breathing.¹⁹ Infants ventilated through small endotracheal tubes will have prolonged inspiration and expiration, leading to smaller delivered tidal volumes and a positive end-expiratory pressure during ventilatory support.¹⁹
3. Cuffs are not necessary, because the appropriately sized tube seals well at the cricoid ring. The narrowest part of the pediatric airway is in the subglottic area, rather than at the cords (as in adults).

An uncuffed tube should be large enough to fit the subglottic area and leak at about 25-30 mm Hg of inspiratory pressure. If the tube is so large that it does not leak at all, then the child should be reintubated with the next smaller size tube. A tube that is too small will allow aspiration and make positive pressure ventilation more difficult. A tube that leaks may invalidate tidal volume measurement accuracy in mechanically ventilated children with some mechanical ventilators.²⁰

Cuffed Tubes

The development of low-pressure, high-volume cuffs in appropriate sizes for children and infants means that a cuffed tube that allows complete protection against aspiration is now available. The modern low-pressure, high-volume cuff has much greater volume and requires a lower inflation pressure to produce a seal. Because the fit of the cuffed tube can be adjusted, the need for repeat intubation attempts to replace an ill-fitting tube is eliminated.

Since the inflated cuff must now go through the cords, inadvertent extubation with patient movement should be markedly decreased over the uncuffed tube. The seal of the cuff will improve the reliability of end-tidal gas monitoring and measurement of respiratory mechanics and markedly reduce the risk of aspiration.²⁰

Recent research from large studies has shown that these tubes are safe for long-term use in children.^{21,22} Current pediatric intubation recommendations may be outdated and certainly deserve further scrutiny, in view of these findings.

Monitor the Patient

Cardiorespiratory monitoring is essential for all patients who are ill enough to require intubation — children being no exception. Heart monitoring, pulse oximetry, and automated blood pressure monitoring should be readily available in every ED. These basic monitors should be used routinely in every patient for whom intubation is even contemplated.

Cardiac monitoring may alert the operator to bradycardia, tachycardia, or dysrhythmia in apneic patients. Pulse oximetry is the best means of demonstrating the development of hypoxia during an intubation attempt. Unsuspected hypotension may be revealed with automated blood pressure monitoring.

After intubation in an ED, the proper endotracheal tube position must be confirmed by physical examination, chest x-ray, and a nonauscultatory procedure.

Preoxygenate the Patient

Preoxygenation replaces the patient's functional residual capacity of the lung with oxygen. If the patient is placed on 100% oxygen as soon as intubation is considered, then they have already been preoxygenated.

In adults, preoxygenation will allow as much as 3-4 minutes of apnea before hypoxia develops. The child may not be able to tolerate apnea of this duration, due to smaller functional residual capacity and higher basal oxygen consumption. This translates to a quite limited measure of security while the pediatric patient is apneic during the RSI sequence.

A rise of the PaCO₂ in apnea is usually not of significant concern, unless the patient has a head injury or the airway is severely compromised prior to the intubation. PaCO₂ will rise at about 3 mm Hg/min, when the patient is apneic.

Ordinarily, a bag and mask should not be used to artificially ventilate the patient, when RSI is contemplated

and the patient is spontaneously breathing. The risk of gastric insufflation and subsequent regurgitation is reduced if bagging is not used. Ventilations may be assisted in synchrony with natural respirations while the patient is still breathing. If bagging is necessary, because of a failed intubation or respiratory compromise, then cricoid pressure (as described below) should be continued at all times.

Sellick's Maneuver

Sellick's maneuver (cricoid pressure) will decrease the chances of regurgitation by pressing the cricoid cartilage firmly against the esophagus.²³⁻²⁵ (The latter study shows the positive effects of Sellick's maneuver in children aged 2 weeks to 8 years.) When pressure is properly applied, the soft, yielding esophagus will be compressed between the cricoid cartilage and the vertebral column. (Figure 1)

Sellick's maneuver should always be used when the patient is ventilated with a bag-valve mask prior to intubation. The operator should not release cricoid cartilage pressure, until they are certain that the tube is in the trachea. Since Sellick's maneuver is not a guarantee against regurgitation, inflate the cuff of the tube as soon as possible for older children, and start positive pressure breathing for younger children and infants.

Medicate the Patient

The first medications given in RSI should reduce the physiologic responses of the patient to the forthcoming intubation. These responses include bradycardia, tachycardia, hypertension, hypoxia, increased intracranial pressure, increased intraocular pressure, and cough and gag reflexes.

Infants and young children can develop profound bradycardia during intubation from medication effects, vagal stimulation, and hypoxia. Vagal stimulation and subsequent bradycardia may occur from stimulation of the oropharynx by the laryngoscope blade.²⁶⁻²⁹ Succinylcholine

can also produce bradycardia in all age groups, although the mechanism of this is not clear.^{30,31} Hypoxia, of course, can lead rapidly to profound bradycardia.

Atropine blocks the reflex bradycardia that is associated with the use of succinylcholine and laryngoscopy. In children under the age of 5, this reflex is more pronounced. In the literature, pretreating these pediatric patients with atropine is often advocated, in order to minimize vagal effects.^{32,33} The appropriate dose is 0.02 mg/kg to a maximum of 0.5 mg in the child and 1 mg in the adolescent. A minimum dose of atropine should be 0.1 mg. For effect at the time of intubation, atropine should be administered at least 2 minutes prior to intubation.

Use of atropine in the pretreatment of pediatric patients prior to use of succinylcholine has been examined by Fleming et al in the *Canadian Journal of Emergency Medicine*.³⁴ These authors reviewed both prospective studies and surveys, and found that no pretreatment with atropine was needed.³⁵⁻³⁸ It should be noted that the authors of the 2 prospective studies also felt that atropine was unnecessary and should be reserved for children with persistent bradycardia.^{35,36} Many of the studies that have supported the use of atropine were conducted in the operating room and involved the use of multiple drugs, including anesthetic agents, which may have confounded any relationship between succinylcholine and bradycardia.³⁹ More than 80% of surveyed anesthesiologists believed that neonates, infants, and children should be premedicated with atropine, when repeated doses of succinylcholine were used.

Atropine prior to single-dose succinylcholine during pediatric intubation increases the likelihood of ventricular dysrhythmias and masks the bradycardia that can result from hypoxia. The use of atropine when more than 1 dose of succinylcholine is required may be appropriate, but the patient needs to be carefully evaluated for hypoxia before, during, and after the second dose of succinylcholine.

Lidocaine has been shown to attenuate the rise in intracranial pressure (ICP) associated with intubation, although the clinical importance of this rise is somewhat controversial.³³ It also decreases the cough reflex and may decrease the incidence of postlaryngoscopy hypertension and tachycardia.⁴⁰ Lidocaine may be ineffective in blunting the hypertension or tachycardia associated with intubation. The recommended dose of lidocaine is 1.5 to 3 mg/kg intravenously. As with atropine, when used, lidocaine must be given at least 2 minutes prior to intubation in order to be effective. Alternatively, lidocaine may be sprayed into the posterior pharynx and trachea. Again, this is somewhat controversial, as spraying lidocaine into the trachea may require almost as much manipulation as intubation itself.

Beta-blockers, such as esmolol 1.5 mg/kg over 30 seconds or labetalol 0.25 mg/kg, may also be used in the stable patient to blunt the rise in ICP associated with intubation.⁴¹ Use of beta-blocking agents is dangerous in the patient with cardiovascular instability or the asthmatic patient.

Figure 1. Sellick's Maneuver.

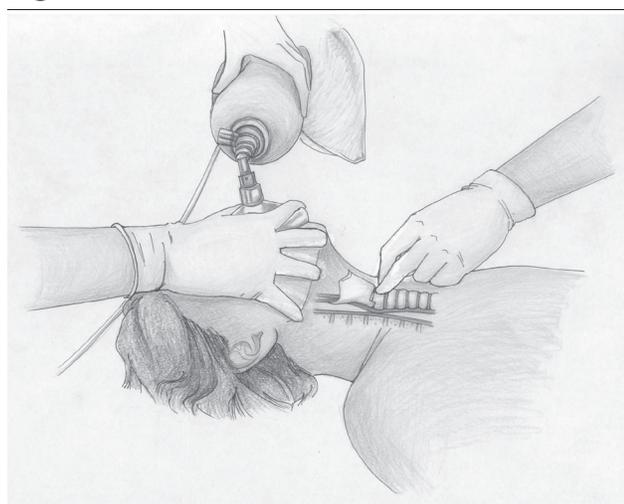


Illustration used with permission. Copyright © 2004 Kathy Mak. All rights reserved. Image available at: <http://www.aic.cuhk.edu.hk/web8/Intubation.htm>.

Attenuation of adverse cardiovascular and ICP responses is optional in moribund and desperate situations. In these cases, the intubator should proceed directly to paralytic and sedation agents.

Sedation/Paralysis

Multiple agents have been used for sedation during the process of intubation in children, among them barbiturates, benzodiazepines, opiates, nonbarbiturate sedatives, and dissociative agents. Each of these agents has their proponents and detractors, relative indications and contraindications. The ideal sedative should induce rapid unconsciousness in the child with a short duration and little or no cardiovascular side effects. Unfortunately, the ideal agent does not exist.

The sedative of choice should always be given prior to the paralytic agent. Although sedatives and paralytics can be given at the same time, paralysis is such a frightening event that sedation should be assured prior to the onset of paralysis.

Table 4 lists commonly used sedatives for RSI in both adults and children. Any of these sedating agents will produce acceptable results in RSI when used at the recommended dose. The choice of sedative is based on the clinical state of the patient and the effects and side effects of the medication.

“If the patient has a potential airway obstruction, it is generally safer to let them continue to breathe than to paralyze them.”

Opiates

Fentanyl is a rapid-acting and very potent opiate of relatively short duration. It produces analgesia within 90 seconds, with an effective duration of about 30 minutes. In addition to its profound sedative and analgesic effects, fentanyl may decrease the tachycardia and hypertension associated with intubation. It appears to be well tolerated hemodynamically, with little hypotension in most children. Fentanyl is indicated when hemodynamic control of the patient is critical. Fentanyl may be easily reversed with narcotic antagonists, such as naloxone.

The usual recommended dose of fentanyl is 2 to 3 $\mu\text{g}/\text{kg}$, given 1 to 3 minutes prior to intubation. A higher dose of 5 to 7 $\mu\text{g}/\text{kg}$ is indicated to block hypertension and tachycardia, and some authorities suggest as much as 15 $\mu\text{g}/\text{kg}$. Neonates appear to be more sensitive to fentanyl, and decreased doses should be used for them.

All opiates, fentanyl included, cause respiratory depression in a dose-dependent response. Fentanyl may also cause seizures, chest wall rigidity, and skeletal muscle movements. There are some reports of increased ICP associated with fentanyl, particularly in children. It should

be used with caution when ICP is a major factor.

An alternative narcotic agent with similar properties to fentanyl is **alfentanil**, 20-30 $\mu\text{g}/\text{kg}$. **Morphine** is not recommended for use in RSI in children.

Barbiturates and Other Hypnotic Agents

Thiopental (2-5 mg/kg IV) is a short-acting barbiturate with an onset of 10 to 20 seconds and duration of 5-10 minutes. There is abundant emergency and anesthesiology experience with thiopental for all ages. Although thiopental is a sedative, there is no analgesic effect. It causes a decrease in intracranial pressure, intracerebral blood flow, and cerebral oxygen consumption. It is most useful in patients with increased ICP (eg, head trauma, meningitis). Thiopental is not normally recommended for intubation sedation in children in other situations.

Thiopental may cause profound hypotension by vasodilation and myocardial depression. It should not be used in the hypotensive or hypovolemic patient of any age. Like all sedatives, thiopental causes respiratory depression. Thiopental should not be used for patients with asthma, as it may cause additional bronchospasm by release of histamine.

Methohexital (1-1.5 mg/kg IV) is a short-acting barbiturate with an onset of less than 1 minute and a duration of about 5-7 minutes. Methohexital is quite similar to thiopental in action and contraindications. It also causes respiratory depression and may cause seizures in high doses. It has no advantages over thiopental in children.

Etomidate (0.2 - 0.4 mg/kg IV) is an ultrashort-acting, nonbarbiturate hypnotic agent that has been used as an induction agent for anesthesia for years in both children and adults.⁴² Etomidate has minimal hemodynamic effects and may be the drug of choice in a hypotensive or trauma patient.⁴³ It causes less cardiovascular depression than either the barbiturates or propofol. Etomidate has also been shown to decrease intracranial pressure, cerebral blood flow, and cerebral oxygen metabolism.

Propofol (1-3 mg/kg IV) is a relatively new anesthetic induction and sedative agent. It has an extremely rapid onset, within 10 to 20 seconds, and a short duration of action of 10 to 15 minutes. Propofol should not be used in patients with known allergies to soy and eggs. Propofol decreases intracranial pressure and cerebral metabolism. It may cause significant hypotension, which limits usefulness in trauma patients. Lower doses can be used for patients with unstable blood pressure. Unlike other agents, propofol can be used as a drip for continued sedation after the intubation. The continued sedation dose is 0.075 to 0.15 mg/kg/minute.

Benzodiazepines

Diazepam (0.2-1.0 mg/kg IV) is a moderately long-acting benzodiazepine (30 to 90 minutes) with slow onset (2-4 minutes). It causes less cardiovascular and respiratory depression than the barbiturates. If alcohol is present, the respiratory depression of diazepam is augmented. Diazepam must be titrated, as the effective induction dose

is quite variable. It is more useful as a long-term sedative agent for the intubated patient after the procedure. Diazepam has significant amnestic effects.

Diazepam is irritating to veins and may cause localized thrombosis. This is a particularly important side effect in children who may have difficult venous access. Diazepam is not recommended for use in children for this reason alone. Do not use diazepam in patients with glaucoma.

Lorazepam (0.1-0.4 mg/kg) is a long-acting benzodiazepine, and it is most useful for long-term sedation of the intubated pediatric patient. It may be used as an anticonvulsant and sedative for the child with status epilepticus. It has no other place in RSI.

Midazolam (0.1-0.4 mg/kg IV) is a rapid-onset, short-acting benzodiazepine (30-60 minutes) with potent amnestic effects. It is slower in onset than the hypnotic agents and should be administered 2 full minutes before intubation is attempted. Midazolam may require 3 to 5 minutes for complete effect. The typical RSI dose is much higher than the dose used for sedation, and it still may not be reliably effective in a 0.3-mg/kg dose. Midazolam is faster in onset, shorter in action, and has a narrower dose range than either lorazepam or diazepam. Midazolam causes respiratory and cardiovascular depression. It does not increase ICP and may provide some small decrease in

cerebral blood flow.

The effects of the benzodiazepines are generally not as reliable for RSI as the hypnotic agents. Benzodiazepines are most useful as an adjunct, to provide retrograde amnesia of the procedure or as agents in the patient with ongoing seizures.

All of the benzodiazepines are reversible with flumazenil. There is a small but significant risk of seizures when using flumazenil. Benzodiazepines have little effect on the intracerebral pressure. All of the benzodiazepines are suitable for use in the patient with status epilepticus.⁴⁴

Neuroleptic Agents

The only neuroleptic agent that is useful for intubation is ketamine. Ketamine is often described as a dissociative anesthetic, where the patient may appear to be awake, but is amnestic and unresponsive to pain. In contrast to the other sedative agents, ketamine increases the cardiac output, pulse rate, blood pressure, myocardial oxygen consumption, cerebral blood flow, intracranial pressure, and intraocular pressure.⁴⁵ Although ketamine has direct negative inotropic properties, it causes a release of endogenous catecholamines, resulting in the positive overall effects. Ketamine also increases salivary and bronchial secretions.⁴⁶ Secretions can be decreased with atropine 0.01 mg/kg or glycopyrrolate 0.005 mg/kg. Ketamine causes

Table 4. RSI Sedation Agents.

Agent	Dose	Onset	Duration (minutes)	BP	Advantages	Disadvantages
Thiopental	2-5 mg/kg	15-20 seconds	5-10	May cause marked hypotension.	Lowers ICP, anticonvulsant.	Hypotension, histamine release, bronchospasm. Not normally recommended for children. Not recommended for trauma.
Methohexital	1-1.5 mg/kg	Less than 1 minute	5-7	May cause hypotension.	Rapid onset.	Respiratory depression. Can cause seizures.
Midazolam	0.1-0.4 mg/kg	1-2 minutes May require 3-5 minutes for complete effectiveness	30-60	+/-	Marked amnestic effect. Profound anticonvulsant. Little hemodynamic effect.	Dose required for sedation may vary markedly. Paradoxical excitation in some children.
Fentanyl	2-10 µcg/kg	60 seconds	About 30	May cause hypotension.	Reversible with naloxone.	Chest wall rigidity, +/- ICP, lowers seizure threshold.
Etomidate	0.2-0.4 mg/kg	15-30 seconds "ultrashort"	1-5	Fairly neutral.	Short duration, ICP, little hemodynamic effect.	Seizures ³²
Propofol	1-3 mg/kg	15-30 seconds "ultrashort"	10-15	Fairly neutral, but may cause hypotension.	Short onset/duration, anticonvulsant.	Hypotension
Ketamine	1-2 mg/kg	1 minute	5-10	Usually increases pressure.	Most useful in the asthmatic patient, due to bronchodilation.	+ICP/IOP, secretions, emergence, laryngospasm. Contraindicated in head injury. Increases secretions.

*Used with permission of the author. Stewart CE. *Emergency Airway Management*. ©2001; Brady Publishing Company. All rights reserved.

awakening hallucinations that many adults find unpleasant. These emergence reactions occur in up to 50% of adults, but are rare in children under 10 years of age.⁴⁷

Ketamine is particularly useful in the asthmatic patient, as it is a bronchodilator. It is the sedative of choice in the asthmatic child with respiratory failure.^{48,49}

Ketamine is contraindicated in head injury (due to both the increased oxygen consumption and increased intracranial pressure associated with ketamine). It should be used with extreme caution in hypertensive patients (because it increases blood pressure) and those with open eye injuries and glaucoma (due to increased intraocular pressure). However, ketamine may be the drug of choice in the hypotensive, unstable patient.

The dose of ketamine for RSI in children is 1-2 mg/kg. At this dose, anesthesia occurs within 1 minute and lasts about 5 to 10 minutes. Some authorities feel that children who are sedated with ketamine should also be treated with atropine to reduce secretions, but this opinion is not universal.

Neuromuscular Blocking Agents

The perfect paralytic agent for the child would have an extremely rapid onset and a duration that is proportional to the dose used — it would also have sedative, analgesic, and amnestic properties, be safe for use in all ages, from birth to over 100 years, have minimal side effects, and not require any special storage. This agent also does not yet exist. Current neuromuscular blocking agents may be either a depolarizing agent, such as succinylcholine, or a nondepolarizing agent, such as pancuronium or curare. None of these have sedative properties.

Use of neuromuscular blocking agents (Table 5) is controversial, with anesthesiologists fearing increased

morbidity and mortality when non-anesthesiologists use these agents. The largest study to date, in a community hospital with emergency physicians performing intubations with these agents, has not validated these concerns.⁵⁰ The only absolute contraindication to use of a neuromuscular blocking agent would be an inability to manage the airway after making the patient apneic.

Succinylcholine

Succinylcholine is considered an ideal paralytic agent, because of the rapid onset of action (within 45 seconds) and the short duration of the drug (4-5 minutes). The intravenous dose of succinylcholine is 2 mg/kg for infants and small children; for older children and adolescents, the dose is 1 mg/kg. Although approved for IM use in infants and children, the IM route is not recommended in the emergency patient. Unfortunately, succinylcholine has significant side effects, largely related to the depolarization of the muscle cell. These side effects limit the use of succinylcholine in children.

Hyperkalemia: Perhaps the most clinically significant complication of succinylcholine is hyperkalemia. Although the effect has been documented for over 30 years, the precise mechanism of hyperkalemia is not yet known. It is currently thought to be due to an increased number of acetylcholine receptors in these patients. The acetylcholine receptors are found within the muscle membrane, not just at the neuromuscular junction. The increase in acetylcholine receptor sites occurs within 5 to 20 days after the development of the disease or injury. Succinylcholine can cause lethal hyperkalemia in patients with burns, crush injuries, abdominal infections, tetanus, muscle disorders,

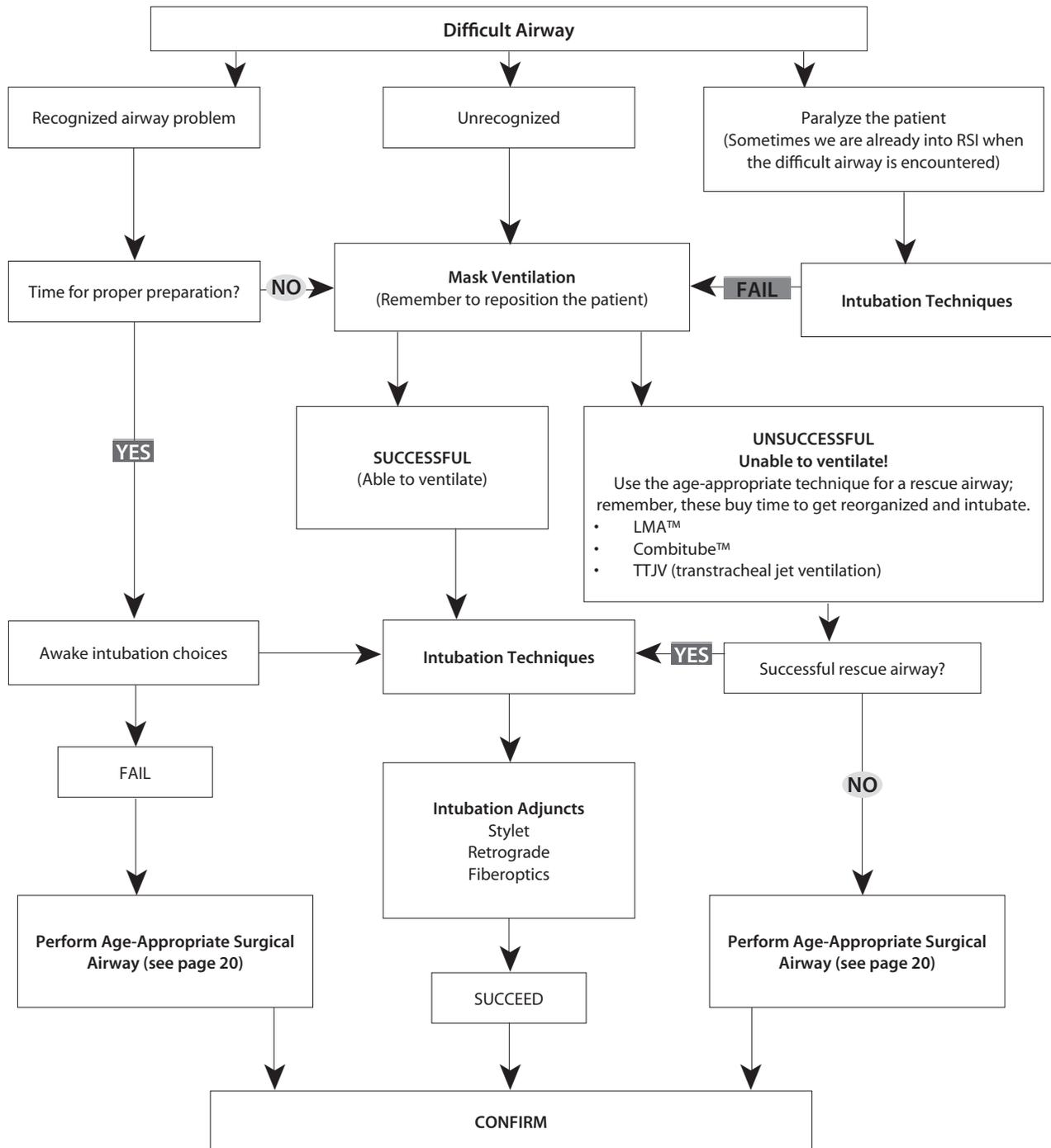
Continued on page 14

Table 5. Neuromuscular Blocking Agents.

Agent	Dose	Onset	Duration (minutes)	Special Properties
Nondepolarizing				
Vecuronium	0.1 mg/kg	Clinical effects in 30 seconds, paralysis in 1-4 minutes	30-60	Priming dose may shorten onset. Aminosteroid compound.
Pancuronium	0.1 mg/kg	90-120 seconds (may take longer)	45-90	Histamine release is common. Aminosteroid compound.
Mivacurium	0.15-0.3 mg/kg	30-60 seconds, intubation conditions within 75-120 seconds	15-20	Histamine release is common. Relatively rapid onset/offset. Benzylisoquinolinium compound.
Rocuronium	0.8-1.0 mg/kg	30 seconds or less in infants and children	30-45	Rapid onset, but dose required will increase duration of paralysis. Aminosteroid compound.
Depolarizing				
Succinylcholine	1-2 mg/kg IV 4-5 mg/kg IM	Within 45 seconds (rapid onset of action)	4-5 (shortest duration of all paralysis agents)	Significant potential side effects. Only medication that can be given IM for airway control.

*Used with permission of the author. Stewart CE. *Emergency Airway Management*. ©2001; Brady Publishing Company. All rights reserved.

Clinical Pathway: Management Of The Difficult Airway



The **evidence for recommendations** is graded using the following scale. For complete definitions, see back page. **Class I:** Definitely recommended. Definitive, excellent evidence provides support. **Class II:** Acceptable and useful. Good evidence provides support. **Class III:** May be acceptable, possibly useful. Fair-to-good evidence provides support. **Indeterminate:** Continuing area of research.

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.

Copyright ©2006 EB Practice, LLC. 1-800-249-5770. No part of this publication may be reproduced in any format without written consent of EB Practice, LLC.

and denervating disorders.⁵¹⁻⁵³ Succinylcholine can be used safely in massive trauma, burns, spinal cord injuries, etc, if used *within* this 5-day grace period. Obviously, patients with underlying hyperkalemia, such as patients with renal failure, should not be given succinylcholine.

Prolonged Paralysis: Succinylcholine can cause prolonged paralysis in those children who have a deficiency of pseudocholinesterase or an atypical pseudocholinesterase.⁵⁴ Several drugs have also been associated with prolonged paralysis, including magnesium, lithium, and quinidine.⁵⁵ Patients who are intoxicated with cocaine may have prolonged paralysis when given succinylcholine, because cocaine is competitively metabolized by cholinesterase. The net effect of any disturbance in metabolism of succinylcholine is to prolong paralysis from 5-10 minutes to several hours. Although known pseudocholinesterase deficiency is a contraindication, the only complication would be prolongation of the paralysis.

Malignant Hyperthermia: Malignant hyperthermia is thought to occur from excessive calcium influx through open channels.⁵⁶ It is associated with markedly increased temperatures, metabolic acidosis, rhabdomyolysis, and disseminated intravascular coagulopathy. Approximately 1 in every 15,000 patients given succinylcholine will develop malignant hyperthermia.⁵⁷ This problem has prompted the FDA to limit the use of succinylcholine in infants and children, except in emergency situations.⁵⁸

Increased Intraocular Pressure: Succinylcholine causes a transient rise in intraocular pressure. Theoretically, this increased intraocular pressure could cause expulsion of the vitreous in an open eye injury. There has never been a documented case of this complication, despite widespread use of succinylcholine in open eye surgery.⁵⁹ The prudent practitioner will use a nondepolarizing agent in penetrating eye injuries, if one is readily available.

Increased Intracranial Pressure: The significance of the rise in intracranial pressure that accompanies succinylcholine use is controversial. The drug has been used widely and successfully in this setting. The transient rise in pressure may be due to a direct effect of fasciculations, increased cerebral blood flow, or sympathetic stimulation. Pretreatment with a nondepolarizing agent will blunt this response,⁶⁰ though pretreatment may not be practical when intubation is urgent.

Muscle Fasciculations: Fasciculations are asynchronous contractions of every muscle fiber. These fasciculations occur until paralysis has been achieved. Diffuse muscle pain is a common complaint after the use of succinylcholine. During fasciculations, gastric pressure increases, enhancing the risk of aspiration.⁶¹ Fasciculations can be prevented by pretreatment with a small dose of a nondepolarizing agent, such as vecuronium, prior to the administration of succinylcholine.⁶⁰ Many physicians do not use a pretreatment dose.

If intubation is not successful during the initial paralysis, a second dose of succinylcholine can be used in adolescents; however, a repeated dose in infants and

small children may cause bradycardia and even asystole.⁶² Repeated doses of succinylcholine in children should not be used.

Nondepolarizing Agents

The nondepolarizing neuromuscular blocking agents bind in a competitive, nonstimulatory fashion to the α -subunit of the acetylcholine receptor. Because there is no muscle stimulation prior to paralysis, these agents do not produce fasciculations. There are 3 types of nondepolarizing drugs available: benzyloisoquinoliniums, aminosteroids, and quaternary amines. Of these, only the benzyloisoquinoliniums and aminosteroids are used in RSI.

Although usually not needed in the ED, nondepolarizing agents can be reversed by use of an anticholinesterase agent, such as edrophonium or neostigmine. Reversal may take several minutes and cannot be used as a "safety net" for a failed intubation.

The newer nondepolarizing agents (vecuronium, rocuronium, and mivacurium) can induce intubating paralysis in a time frame comparable with succinylcholine. Unfortunately, the shortest-duration nondepolarizing agent has a duration twice that of succinylcholine. Onset time of paralysis for nondepolarizing agents is inversely related to the potency of the agent.

Some patients have a significant release of histamine associated with use of the nondepolarizing muscle relaxants.⁶³ These symptoms can be avoided with slower infusion of the agent, but this may not be an option during emergency intubation. None of the nondepolarizing agents should be used in patients with myasthenia gravis.

Vecuronium: Vecuronium is an aminosteroid nondepolarizing agent. It has an intermediate duration of action of 30-60 minutes, with an initial dose of about 0.1 mg/kg. It produces clinical effects in 30 seconds and intubation paralysis in 1-4 minutes. A priming dose of 0.01 mg/kg given 2 minutes before intubation will shorten the onset of vecuronium to about 30 seconds. Concerns over arrhythmias in children associated with succinylcholine use have made high-dose vecuronium (0.28 mg/kg) a popular choice for emergent pediatric airways.⁶⁴

Vecuronium has been associated with a myopathy of critical illness in children who have concomitantly received high doses of steroids. The exact mechanism of the myopathy is not known. It is associated with use of other aminosteroid neuromuscular blocking agents. It is unlikely that single use of these agents will be associated with this myopathy, but caution should be used in children receiving high doses of steroids.

Rocuronium: Rocuronium is an aminosteroid nondepolarizing agent that is similar to vecuronium and has a very rapid onset of action. A dose of 0.8 mg/kg will produce paralysis in infants and children in 30 seconds or less. Recovery time from paralysis is between 30 and 45 minutes. This agent may be used quite successfully as a replacement for succinylcholine, if the extended recovery time is tolerable.

Mivacurium: Mivacurium is a short-acting nondepolarizing benzylisoquinolinium muscle relaxant. It has a short onset of action (30-60 seconds), with intubation conditions achieved within 75-120 seconds. It lasts only 15 to 20 minutes. The typical RSI dose is about 0.15 to 0.3 mg/kg. Mivacurium is metabolized by plasma cholinesterase, and children recover from blockade much quicker than adults do.⁶⁵ This effect may make mivacurium more useful in pediatric intubation.

Pancuronium: Pancuronium is another aminosteroid neuromuscular blocking agent that will provide acceptable conditions for intubation in 90-120 seconds, with paralysis that lasts from 45 to 90 minutes. It is classified as a long-acting agent with a slow onset. The slow onset limits its usefulness in the ED setting. Pancuronium is primarily excreted in the urine, so reduced renal function or urinary output will increase the duration of effect. Pancuronium can cause severe histamine reactions.

Intubate the Patient

Intubation is performed after the airway muscles are fully relaxed, which usually occurs about 45 seconds after the administration of succinylcholine. Cricoid pressure should be maintained until the cuff is inflated and the tube position verified.

The conventional wisdom is that the most experienced person present at an intubation should be the one doing the intubation, because the patient is paralyzed and sedated. This is an unacceptable policy for a training institution. If this caveat were always followed, newer physicians would remain untrained. Until a resident is completely comfortable, in the judgment of the attending, then the attending emergency physician should be *within reach* of the patient, until the patient is successfully intubated.

If intubation fails, cricoid pressure should be maintained, and the patient can be ventilated with a bag-valve mask. After the patient is reoxygenated, then either intubation should be reattempted, or an alternative airway technique employed.

Verify Placement

After intubation, the tube must be confirmed to be in the trachea. This verification is more important than the intubation itself. The bedside clinical assessment consists of visualizing the endotracheal tube as it passes through the vocal cords. This is followed by listening over the epigastrium for bowel sounds and listening over each lung field for the presence and equality of breath sounds. Looking for condensation on the endotracheal tube with exhalation and watching for the chest to rise and fall with inspiration completes the clinical assessment.

The process of verification of tube placement is controversial. Each and every one of the clinical indicators of proper tube placement has been known to fail. The sequence of events that precipitates intubation in the child is often accompanied by one or more conditions that can cause these failures of verification. Unrecognized esophageal

intubation is catastrophic for the patient. Further confirmation of tube placement can be by documentation of carbon dioxide from the lungs, documentation of stable or increasing oxygen saturation, and by x-ray of the chest for tube placement. The astute emergency physician will always verify the tube placement by using a combination of these and will always reverify tube placement in children when clinical conditions deteriorate or when the patient has been moved.

“An esophageal intubation is no sin, but there is great sin in not recognizing such a placement.”

Inspection

In the perfect intubation, the tube will be seen to pass through the child's cords. Unfortunately, in the stress of an emergency intubation — with vomitus or blood, difficult anatomy or cervical immobilization — visualization of the tube's passage through the cords is all too often merely a fond aspiration.⁶⁶

Likewise, it is difficult to even look for expansion of the chest without any gastric distention in the immobilized patient with potential chest trauma (and in many other clinical situations). While it is nice to see, it cannot be relied upon as the only sign of a good intubation.

Auscultation

Ideally, the breath sounds will be heard equally when the tube is in appropriate position in the trachea. Air meeting water (or fluid) causes bubbling, the sound of which implies that the tube is in the esophagus or stomach. In the small child, normal breath sounds may be heard when listening over the stomach. If breath sounds (but no bubbling) are heard over the stomach, do not pull the tube, but complete the rest of the assessment. Listen 2 breaths on the right third intercostal space in the midaxillary line and compare to 2 breaths on the left side in the third interspace.

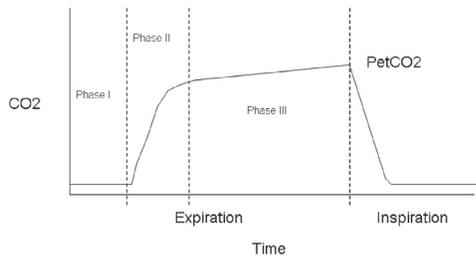
Pulse Oximetry

Pulse oximetry has long been a standard method of monitoring the patient with respiratory difficulties. If the oxygen saturation is rising, or stays at an acceptable level in a paralyzed patient, then the endotracheal tube is quite likely in the appropriate place (ie, there certainly is no esophageal intubation). Unfortunately, the pulse oximeter is not particularly useful in the patient with profound shock or cardiac arrest.

Carbon Dioxide Detectors

End-tidal carbon dioxide measurements or a disposable colorimetric device (CO₂ detector) can be used in children.^{67,68} These devices work by measurement (colorimetric or direct) of the carbon dioxide produced by the body and eliminated by the lungs.⁶⁹ If the ET tube is placed in

Figure 2. Normal Capnogram.



*Phase I: A near-zero baseline represents the exhalation of CO₂-free gas contained in dead space.

†Phase II: Rapid, sharp rise of the curve represents the exhalation of mixed dead space and alveolar gas.

‡Phase III: Alveolar plateau represents the exhalation of mostly alveolar gas.

§PETCO₂: End-tidal value that approximates the peak CO₂ concentration. This is normally at the end of exhalation.

||Inspiratory phase: The rapid, sharp downstroke represents inhalation of non-carbon dioxide-containing gas.

the esophagus, then there should be no carbon dioxide in the exhaled gas. The end-tidal CO₂ detector works so well in the operating room that its use there is considered standard of care by anesthesiologists.⁷⁰

A normal-looking waveform and a “digital read out” confirm that the endotracheal tube is in the trachea. (Figure 2) In low cardiac output states, such as shock, cardiac arrest, or inadequate chest compressions, ET CO₂ may not be detected. If a patient has consumed carbonated beverages or if mouth-to-mouth ventilation has been attempted, CO₂ may be detected after esophageal intubation (ie, a false positive).⁷¹ The ET CO₂ should rapidly decrease to zero (within 3-6 breaths) in this situation, and also the waveform will not be “normal-looking.” Vukmir et al reported a sensitivity and specificity of 100% for endotra-

Figure 3. Zoll Portable Monitor With End-Tidal CO₂ Detector.



Photograph courtesy of the author. Copyright © 2006 Charles Stewart. All rights reserved.

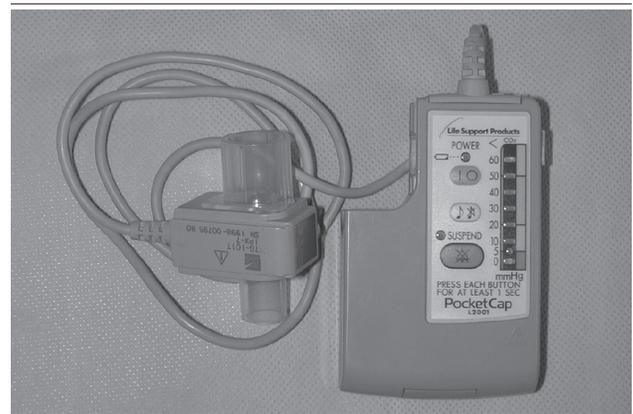
cheal tube localization by capnography.⁷²

The digital readout of ET CO₂ can be displayed in mm Hg (partial pressure of CO₂ in exhaled gas) or as a percentage of carbon dioxide in the exhaled gas. Most of the common devices use “infrared absorption of CO₂” as their principle of operation. (Figure 3 and Figure 4) Another similar CO₂ detection device is the MiniCAP III (MSA Catalyst Research, Owings Mills, Maryland). This device is a battery-operated capnometer that emits a flash and beep during each breath that contains CO₂. An alarm sounds for each breath that does not contain CO₂. It is small, relatively inexpensive, and reusable. Its reliability and sensitivity are comparable to the Easy Cap II.

In the colorimetric device (Figure 5), a pH-sensitive chemical indicator is enclosed in a plastic housing and is connected to the gas stream between the endotracheal tube and the bag-valve mask. This pH-sensitive indicator changes color when exposed to CO₂. The color varies between expiration and inspiration, as the CO₂ level increases or decreases. The color changes from purple (when exposed to room air or oxygen) to yellow (when exposed to about 4% CO₂). The response time of the device is sufficiently fast to detect changes of CO₂ breath-by-breath.

However, this device is not very sensitive when CO₂ output is low, as it is during CPR. All colorimetric CO₂ detectors have been shown to be falsely negative in the patient who has had a cardiac arrest and falsely positive in the patient who has recently consumed a carbonated beverage.⁷³ In one prospective study, the sensitivity of this device in detecting proper endotracheal placement in the cardiac arrest patient was only 85%.⁷⁴ This means that as many as 15% of properly placed endotracheal tubes (in cardiac arrest patients) would be inappropriately removed when this device is relied upon exclusively. These conditions occur far more frequently in emergency medicine practice than in the operating room. The waveform of a capnometer will not be normal in either of these conditions, and this should alert the operator to a potential problem.

Figure 4. Example Of A Digital CO₂ Detection Device.



Photograph courtesy of the author. Copyright © 2006 Charles Stewart. All rights reserved.

Esophageal Detector Devices

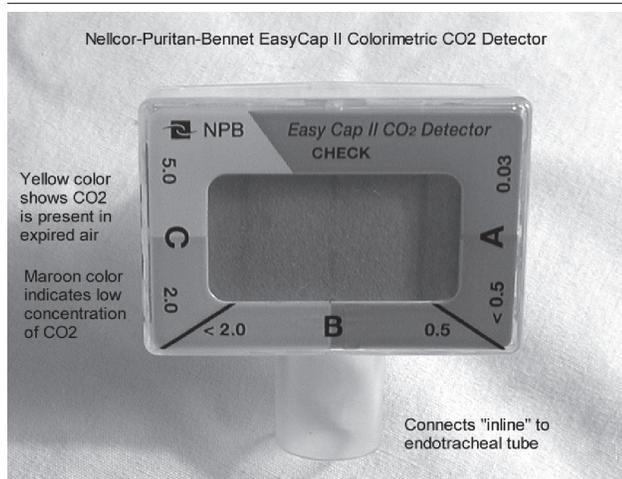
Syringe aspiration esophageal detector devices (EDDs) have recently been used to confirm tube placement.^{75,76} These devices use the rapid refill of a bulb syringe or equivalent through the endotracheal tube as “proof” that the tube is in the airway, rather than the esophagus. In adults, there is high assurance that the ETT is *not* in the esophagus, but the EDD may misidentify endobronchial or mainstem intubation as esophageal. Marley et al showed that the esophageal detection device correctly identified 100% of esophageal intubations (but only 35 of 40 ET intubations).⁷⁶ There is no study assuring that these devices will be effective in the deliberate air leak associated with uncuffed tubes used in a pediatric airway. EDDs are currently approved only for children older than 5 years or greater than 20 kg body weight.

Chest X-ray

Following confirmation by auscultation, inspection, esophageal detector devices, and/or CO₂ measurement, a chest x-ray should always be obtained. A chest x-ray can also help with depth and placement of the tube. Ideally, the tip of the endotracheal tube should be in the middle third of the trachea, just proximal to the carina. The provider must realize that, although a radiograph is viewed as a gold standard, the portable anteroposterior radiograph can miss an esophageal intubation, if the trachea and esophagus are aligned during the film.

Although it is impractical to get a radiograph confirming tube placement in every elective intubation in the operating room or in the field, this is not true in emergency medicine. Despite the fact that the radiograph will be the gold standard by which the legal field judges our performance, a radiograph takes several minutes to obtain and process, and the patient needs appropriate and adequate ventilation in the meantime. The clinician must confirm tube placement prior to obtaining a radiograph and ensure that the tube does not move during this radiograph.

Figure 5. Colorimetric CO₂ Detector.



Photograph courtesy of the author. Copyright ©2006 Charles Stewart. All rights reserved.

Secure the Tube

The risk of inadvertent dislodgement of the ETT or mainstem bronchus intubation is much higher in the small child, due to the shorter trachea and bronchus. The endotracheal tube must protrude only 3 to 4 cm past the cords, in order to avoid a right mainstem bronchus intubation. The tracheal length from larynx to carina is short (4-5 cm in a newborn and only 7-8 cm in an 18-month-old child), so dislodgement of the uncuffed endotracheal tube is a common complication. Since the child's neck is much more flexible than the adult's, and the tube most often does not have a cuff, motion of the neck can dislodge an ETT in a child.

Security of the tube includes sedation, ensuring that the child will not move and that the child's head does not move during radiographs and other procedures postintubation. Following each such procedure, the oxygen saturation should be carefully monitored. A falling saturation or change in clinical status should prompt the astute clinician to reassess the placement of the endotracheal tube.

“Do not let your patient suffer the consequences of a missed airway. ALWAYS HAVE A CONTINGENCY PLAN.”

Special Circumstances

Alternative Airways

Blind Nasal Intubation

Blind nasal intubation (BNI) should not be used on any pediatric patient who needs an airway rapidly. Despite claims to the contrary, BNI often requires minutes to complete, and as experienced physicians can readily attest, it is more difficult in the child than in the adult — the far anterior airway anatomy of the child makes BNI much more difficult. Also, in the child, the increased size of the adenoids makes nasal intubation fraught with hazards not seen with adult patients. The adenoids can make passage more difficult, they can bleed or even shear off and plug the endotracheal tube. BNI is a poor choice for the asthmatic patient in extremis and for children in respiratory failure.

If a nasal intubation is desired, a properly sized set of Magill forceps must be available. Vasoconstricting agents should be applied to both nostrils. After insertion into the child's nostril, the tube is observed with direct laryngoscopy. The Magill forceps are used to lift the tube into the proper position to be advanced straight into the glottis: they should not be used to push the endotracheal tube. Insertion of a nasal tube into the patient with a basilar skull fracture, a deviated nasal septum, a nasal fracture, enlarged adenoids, or a bleeding diathesis is ill advised.

Laryngeal Mask Airways in Children

The size 1 LMA™ has been used for neonatal resuscitation

with over a 94% success rate.⁷⁷ (Figure 6 and Figure 7) In the smaller-sized devices used in infants and small children, there will be leaks with positive pressure ventilation. This device has no route for suctioning or for delivering medications. It does not protect against aspiration and does have some associated gastric distention, from incomplete fit of the mask. Even with appropriate positioning of the cuff, if airway pressure is greater than 20 cm H₂O, then the child's stomach may be inflated.

Manual Intubation

Manual intubation, or more correctly digital/tactile intubation, has been used for centuries.⁷⁸ It fell into disfavor when Chevalier Jackson introduced laryngoscopy and direct vision of the vocal cords.⁷⁹ Manual intubation may have a limited place in the field, when equipment is not available or where equipment has broken during a procedure.^{80,81} It is not advised for use in very small children, due to the relatively large size of the adult's hand and the smaller size of the child's airway. Indications for manual intubation include: cramped quarters, copious oral secretions or vomitus, inability to visualize the vocal cords, suspected cervical spine trauma, and equipment failure or lack of laryngoscope.

Technique

The index and long fingers are inserted into the patient's mouth, past the base of the tongue, until the epiglottis is palpated. An endotracheal tube is passed between the fingers, over the epiglottis and into the trachea. If the patient is breathing, air movement may further guide placement. The patient's neck may remain in neutral position and the patient may remain in a cervical collar. The patient must be unresponsive, since the presence of a gag reflex will pose a danger to the operator.

Complications

The most feared complication of this procedure in pediatric patients is the same as in adults — being bitten by the patient. This can be prevented with the use of a bite block or oral airway inserted laterally along the molars. Digital intubation of conscious patients and seizing patients should be avoided.

As in all blind intubation techniques, esophageal

Figure 6. Laryngeal Mask Airway (LMA).

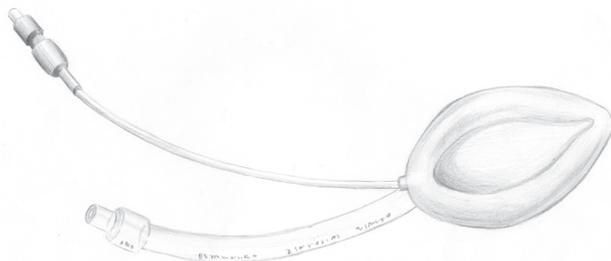


Illustration used with permission. Copyright © 2004 Esther Yip. All rights reserved. Image available at: <http://www.aic.cuhk.edu.hk/web8/Laryngeal%20mask.htm>.

intubation is a real possibility. This is an innocuous complication, if it is promptly recognized by the standard techniques for checking tube placement.

Stylet-guided Intubation

Lighted Stylet

Intubation with a lighted stylet depends upon transillumination of the soft tissue of the neck with a light placed in the larynx.⁸² It requires neither flexion nor extension of the neck in order to insert an endotracheal tube. It is suitable for the larger child. Equipment is not available for infants and smaller children.

Method

There is no lighted stylet that is designed specifically for children. Orotracheal intubation is performed with a standard endotracheal tube that has been shortened to 25 cm. This tube is placed over a lubricated surgical flex-light (Concept Corporation, Clearwater, Florida).⁸³ The light extends to the end of the shortened endotracheal tube.

Complications and Precautions

Inability to Visualize the Light

If the ambient lighting is extreme — as in direct sunlight — this method becomes difficult. In the original paper describing the technique, 2 of the 3 unsuccessful attempts were made in sunlight. In an ED, simply extinguishing the overhead lights for a few seconds may solve this problem. Blood, charcoal, and vomitus may further obscure the light at the end of the tube.

Esophageal Intubation

In very thin children, visualization of a midline glow may be found in esophageal intubation. Since this is a blind

Figure 7. LMA In Position.

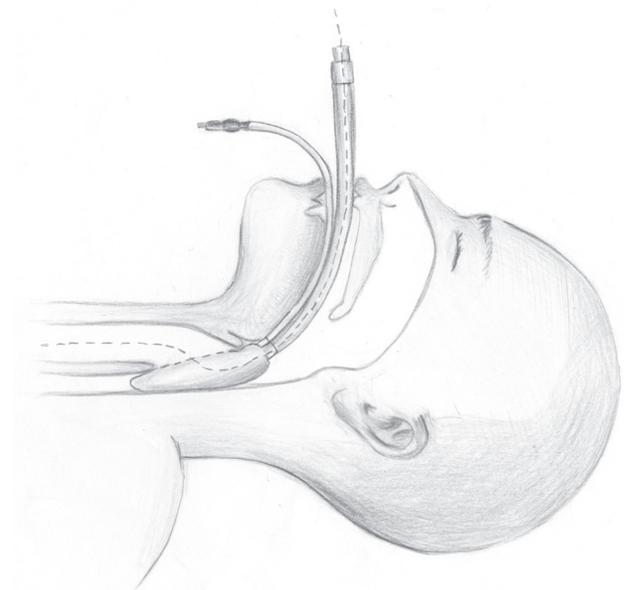


Illustration used with permission. Copyright © 2004 Esther Yip. All rights reserved. Image available at: <http://www.aic.cuhk.edu.hk/web8/Laryngeal%20mask.htm>.

technique, the operator must ensure that the tube placement is correct. Although this complication has not been reported in children, the smaller size, lesser neck mass, and smaller body weight of most children would make esophageal visualization more likely.

Loss of the Lightbulb

In 1 case in the original paper, the lightbulb at the end of the flexible stylet was dislodged. This required bronchoscopy for retrieval. Newer lights from the manufacturer have a shrink-fit plastic that improves strength and reduces this risk. A fiberoptic light source and stylet has been developed that eliminates the problem of bulb loss. The original lighted stylet is quite inexpensive and may be readily supplied to EMS field agencies, while the newer fiberoptic version is much more costly.

Nasogastric Tube/Suction Catheter as a Stylet

A helpful technique that is infrequently used is to employ a nasogastric (NG) or suction tube as a guide through the cords.⁸⁴ This is most helpful where the nasotracheal tube has been passed up to the cords, but cannot be passed through them. A NG tube or suction tube can then be slipped through the ET tube and passed through the cords. Using the smaller tube as a guide, the ET tube is then readvanced into the proper position.

The suction catheter could also be used to provide low-frequency, high-flow ventilation, in a manner similar to the more invasive jet ventilation techniques described below.⁸⁵ The suction or even just oxygen tubing may be

more easily passed than a larger-caliber endotracheal tube.

Fiberoptic-guided Intubation

The advantages of fiberoptic intubation in the child are the same as in the adult. Unfortunately, the fiberoptic scope is an expensive and relatively delicate instrument. Very small pediatric fiberoptic devices are correspondingly much more expensive and less likely to be readily available, except in specialty pediatric EDs.

The primary advantage of the flexible fiberoptic technique is in negotiation of difficult anatomy. The fiberoptic laryngoscopes allow the operator to orally or nasally intubate the patient without flexion of the neck and without the disadvantages of the blind techniques. A secondary advantage is in the ready diagnosis of the patient with an inhalation injury or with epiglottic disease.

Method

The intubating fiberscope can be introduced through either the nose or the mouth, but in children, the size of the nasal orifice may be a limiting factor. Nasal intubation is generally easier than oral intubation, because the back of the nasopharynx is aligned with the trachea.

Prepare the laryngoscope with a tube over it. There are 3.6-mm laryngoscopes (Olympus, Hamburg, Germany) that have recently been developed with both suction and oxygen delivery ports. This will fit snugly through a 4.5-mm ID endotracheal tube. A 2.2-mm OD fiberoptic scope is available, but this instrument is difficult to use with an endotracheal tube. With smaller adults

Key Points For Pediatric Airway Management

1. Pediatric anatomy is different from an adult's in more than just scale.
2. Pediatric airway techniques require preplanning and training.
3. Bag-valve-mask airway techniques should be mastered and used. They may be more successful in the field than attempting intubation.
4. When the airway is in jeopardy, the most experienced operator should be in control of the situation.
5. Atropine is not routinely needed for intubation, even in pediatric patients.

The cogent and prepared emergency practitioner should also remember a few basic rules. Be sure that you have both a half size larger and smaller than your predicted choice readily available when you use these rules.

Pediatric Intubation Rules To Memorize:

- If available, use a Broselow[®] tape for tube size and drug doses.

- For children, the formula is:

$$\frac{\text{Age (years)} + 4}{4} = \text{tube size}$$

Since the smallest, most easily available tube size is 3.0 mm, this is appropriate for the premature newborn, while

the newborn should get a 3.5-mm tube and the 1-year old should get about a 4.0-mm ID tube.

- If in doubt, use a tube that fits through the nose.
- Alternatively, use a tube about the size of the patient's little finger.
- A useful formula for oral tube length (tube insertion depth) is:

$$\frac{\text{Age (years)} + 12}{2} = \text{tube length}$$

Nasal tubes should be about 3 cm longer than the oral tube.

- Remember to use uncuffed tubes when intubating with a 5.0 or smaller ET tube. As noted in the section on choosing tubes, this may be open to some debate, but is still considered appropriate by most authorities.
- Remember that the most common pitfall in pediatric intubation is inserting the scope too far. This means that inability to see the cords may be due to the laryngoscope being past the cricoid membrane already!
- The tube should be inserted to a depth of about 3 times (in centimeters) the size of the tube (in millimeters). (Alternatively, the Broselow[®] will have insertion depths.) ▲

and children, use of a pediatric bronchoscope may allow placement of a smaller-diameter tube. This is a significant limiting factor in pediatric patients.

The basics of the technique are the same as for adults. The body of the scope includes the tip deflection unit, the working channel sleeve, and the focusing light. The scope is positioned by moving the entire scope in and out to control depth, and rotation of the scope and tip manipulations control the anterior/posterior and side motions. The tip of the fiberoptic can be moved up or down by moving the lever on the control body. The operator should remember that when the control lever is pushed up, the tip will move downwards. Side-to-side motion is achieved by rotating the instrument. To look right, the operator must twist the control body clockwise, which is replicated at the tip of the scope. After insertion into the oropharynx, the operator identifies the epiglottis and advances the scope past the epiglottis, through the cords, and into the laryngeal opening. The trachea is identified by the characteristic rings, after passage through the cords. The endotracheal tube is advanced over the scope, until the tip is seen through the scope's eyepiece. The scope is carefully withdrawn and the tube position verified (to ensure that it did not move during withdrawal of the scope) and then fixed in place.

Complications

By far the most serious complication from use of a fiberoptic laryngoscope in the pediatric patient is delay in oxygenation caused by an inexperienced operator. Skill with the fiberoptic laryngoscope should be gained during elective or semielective intubations, rather than during an emergency. Attempting to view landmarks from a new perspective with a new instrument, in a small child, while at the same time dodging bits of debris, secretions, and blood, is not going to be either quick or elegant.

Retrograde Intubation

A variant of the above technique is retrograde guided intubation, as described by Waters in 1963, for use in pa-

Eight Pitfalls To Avoid

1. Lack of preparation of equipment and drugs prior to starting the procedure.
2. Failure to preoxygenate the patient.
3. Using a bag-valve mask in the spontaneously ventilating patient.
4. Failing to use Sellick's maneuver.
5. Attempting intubation before paralysis is complete.
6. Failure to secure the airway after intubation.
7. Failure to continue sedation after intubation.
8. Failure to continue paralysis after intubation. ▲

tients with drastically altered anatomy.⁸⁶ It is particularly useful in the patient with facial trauma and a suspected neck injury, for whom a blind nasotracheal intubation is unfeasible. In this technique, a transtracheal needle or a needle passed through the cricothyroid membrane is used to thread a long wire stylet cephalad through the cords. The guide wire is retrieved in the oropharynx and a tube threaded over it. The tube is then passed into the trachea, past the vocal cords. Conceivably, the guide wire could be passed through a nostril and the entire process used to pass a nasotracheal tube. Successful pediatric use in a 14-month-old infant has been described.⁸⁷ This technique is no different in the child than in the adult.

The technique may be valuable where vomitus or bloody drainage obstructs the view or obscures the light in standard intubation. Retrograde guide wire intubation does take time to perform, but it is far more useful than repeated unsuccessful attempts at standard or blind nasal intubation in the difficult patient. Both Intracath® central venous pressure catheters and Seldinger guide wires have been used for this technique.

Complications appear to be related to the needle stick required and are usually minor. No significant contraindications are known.⁸⁸ Ensure that both ends of the guide wire are secured while trying to pass the tube, so that the guide wire will not be pulled free from the neck.

Surgical Airway in Children

If the child cannot be adequately ventilated by bag-valve mask, and endotracheal intubation is unsuccessful, then a surgical airway is indicated.

Cricothyrotomy

Surgical cricothyrotomy should be reserved for the child over 8 years old. This is a somewhat arbitrary age that necessitates a judgment call, as some children at 8 may be large enough for performance of the procedure, and some 12-year olds may be too small. Although it is possible to perform a cricothyrotomy in the smaller child, the landmarks are correspondingly smaller (in particular, the cricoid membrane is much smaller), and the assurance of success is proportionally smaller, with a higher potential for complications. The risk of bleeding complications is the reason that the PALS course states for recommending that needle cricothyrotomy be performed in young children.⁹

Needle Cricothyrotomy

The equipment needed for this procedure in a child should be readily available in the resuscitation area. In infants and young children, this procedure may be quite difficult, because of the short neck, floppy and redundant soft tissues, and the small diameter of the trachea. Nevertheless, it may be the only available surgical airway in the field.

A 15-mm endotracheal tube connector (fitting all resuscitation equipment) from a 3-mm endotracheal tube will fit into the large-bore (12-14-16 gauge) intravenous catheter hub used for needle tracheostomy. The airway resistance will be great, because of the resistance to flow

in the small piping. With a 100% oxygen source, adequate oxygen saturation can be maintained, even with slower rates of ventilation. Unfortunately, hypercapnia will result in almost all of these patients. Transtracheal (needle cricothyrotomy) should be considered as a temporizing airway only.

Use of a Cook® Critical Care “Melker Emergency Cricothyrotomy Catheter Set” may provide a wider-bore tube with less airway resistance. This device may be used as a needle tracheostomy in larger children.

Disposition

The child who is intubated must be admitted. After the intubation the child will require meticulous attention to tube placement and securing of the tube to prevent movement. With the smaller tubes used in infants and children, fastidious maintenance of tube patency and security is essential.

Summary

Management of the pediatric airway is no more complex than management of the adult airway. It does involve anatomy of a different size, and it does require different tools, different techniques, and perhaps a different mindset. If these differences are not appreciated, the pediatric intubation becomes several orders of magnitude more difficult. Managing the pediatric airway successfully requires preplanning, careful attention to detail, and a serious focus on each step as it is performed. ▲

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 reference, where available. In addition, the most informative references cited in the paper, as determined by the authors, will be noted by an asterisk (*) next to the number of the reference.

1. Nakayama DK, Waggoner T, Venkataraman ST, et al. The use of drugs in emergency airway management in pediatric trauma. *Ann Surg* 1992;216:205-211. **(Review)**
2. American Academy of Pediatrics. *Emergency Medical Services for Children: The Role of the Primary Care Provider*. 1st ed. Elk Grove Village, IL: American Academy of Pediatrics; 1992. **(Textbook)**
- 3.* Gausche-Hill M, Lewis RJ, Stratton SJ, et al. Effect of out-of-hospital pediatric endotracheal intubation on survival and neurological outcome: A controlled clinical trial. *JAMA* 2000;283:783-790. **(Semi-randomized controlled clinical trial; 830 patients)**
4. Gausche-Hill M, Lewis RJ, Gunter CS, et al. Design and implementation of a controlled trial of pediatric endotracheal intubation in the out-of-hospital setting. *Ann Emerg Med* 2000;36:356-365. **(Study design for reference 3)**
- 5.* Henderson DP, Gausche M, Goodrich PD, et al. Education of paramedics in pediatric airway management: effects of different retraining on self-efficacy and skill retention. *Acad Emerg Med* 1998;4:29. **(Abstract; preliminary results of reference 3)**
6. Cooper A, DiScala C, Foltin G, et al. Prehospital endotracheal intubation of severe head injury in children. A reappraisal. *Semin Pediatr Surg* 2001;10:3-6. **(Retrospective data mining study of trauma database)**
7. Nakayama DK, Gardner MJ, Rowe MI. Emergency endotracheal intubation in pediatric trauma. *Ann Surg* 1990;211:218-223.
8. Murray JA, Demetriades D, Berne TV, et al. Prehospital intubation in patients with severe head injury. *J Trauma* 2000;49:1065-1070. **(Retrospective data mining study; trauma database of 13 hospitals)**
9. Chameides L, Hazinski MF, eds. *Textbook of Pediatric Advanced Life Support*. Dallas, TX: American Heart Association; 1994. **(Textbook)**
10. Dickison AE. The normal and abnormal pediatric upper airway. Recognition and management of obstruction. *Clin Chest Med* 1987;8:583-596. **(Review)**
11. Infosino A. Pediatric upper airway and congenital anomalies. *Anesthesiol Clin North Am* 2002;20:747-766. **(Review)**
12. Todres ID. Pediatric airway control and ventilation. *Ann Emerg Med* 1993;22:440-444. **(Review)**
13. Rosen M, Laurence KM. Expansion pressures and rupture pressures in the newborn lung. *Lancet* 1965;2:721-722.
14. Hirschman AM, Kravath RE. Venting vs ventilating: a danger of manual resuscitation bags. *Chest* 1982;82:369-370. **(Case reports)**
- 15.* Rivera R, Tibballs J. Complications of endotracheal intubation and mechanical ventilation in infants and children. *Crit Care Med* 1992;20:193-199. **(Prospective, serial observation; 869 ICU patients)**
- 16.* Gnauck K, Lungo JB, Scalzo A, et al. Emergency intubation of the pediatric medical patient: Use of anesthetic agents in the emergency department. *Ann Emerg Med* 1994;23:1242-1247. **(Prospective study; 60 consecutive patients)**
17. Easley RB, Segeleon JE, Haun SE, et al. Prospective study of airway management of children requiring endotracheal intubation before admission to a pediatric intensive care unit. *Crit Care Med* 2000;28:2058-2063. **(Prospective study; 250 consecutive patients)**
18. Sing RF, Reilly PM, Rotondo MF, et al. Out of hospital rapid sequence induction for intubation of the pediatric patient. *Acad Emerg Med* 1996;3:41-45. **(Retrospective review; 40 patients)**
19. Okhuysen RS, Bristow F, Burkhead S, et al. Evaluation of a new thin-walled endotracheal tube for use in children. *Chest* 1996;109:1335-1338. **(Animal study/product description)**
20. Al-Majed SI, Thompson JE, Watson KF, et al. Effect of lung compliance and endotracheal tube leakage on measurement of tidal volume. *Crit Care* 2004;8:R398-R402. **(“Test lung” study; nonclinical, but involving respirator measurements and respirators used in children)**
21. Newth CJ, Rachman B, Patel N, et al. The use of cuffed versus uncuffed endotracheal tubes in pediatric intensive care. *J Pediatr* 2004;144:333-337. **(Prospective, consecutive study; 860 children)**
- 22.* Deakers TW, Reynolds G, Stretton M, et al. Cuffed endotracheal tubes in pediatric intensive care. *J Pediatr* 1994;125:57-62. **(Prospective, consecutive study; 243 patients)**
- 23.* Sellick BA. Cricoid pressure to control regurgitation of stomach contents during induction of anesthesia. *Lancet* 1961;2:404-406. **(Procedure description, classic literature article)**
24. Salem MR, Sellick BA, Elam JO. The historical background of cricoid pressure in anesthesia and resuscitation. *Anesth Analg* 1974;53:230-232. **(Historical article)**
25. Moynihan RJ, Brock-Utne JG, Archer JH, et al. The effect of cricoid pressure on preventing gastric insufflation in infants and children. *Anesthesiology* 1993;78:652-656. **(Clinical study; 59 patients)**
26. Leigh MD, McCoy DD, Belton MK, et al. Bradycardia following intravenous administration of succinylcholine chloride to infants and children. *Anesthesiology* 1957;18:698-702. **(Case report; 4 patients)**
27. Cordero L Jr, Hon EH. Neonatal bradycardia following nasopharyngeal stimulation. *J Pediatr* 1971;78:441-447. **(Case report)**
28. Reid LC, Brace DE. Irritation of the respiratory tract and its reflex effect upon the heart. *Surg Gynecol Obstet* 1940;70:157-162. **(Historical, theoretical basis of bradycardia during intubation)**
29. Brady JP, Tooley WH. Cardiovascular and respiratory reflexes in the newborn. *Pediatr Clin North Am* 1966;13:801-821. **(Historical review article, theoretical basis of bradycardia during intubation)**
30. McLeskey CH, McLeod DS, Hough TL, et al. Prolonged asystole after succinylcholine administration. *Anesthesiology* 1978;49:208-210. **(Case report)**
31. Mathias JA, Evans-Prosser CD, Churchill-Davidson HC. The role of the non-depolarizing drugs in the prevention of suxamethonium bradycardia. *Br J Anaesth* 1970;42:609-613. **(Review)**
32. Yamamoto LG. Rapid sequence anesthesia induction and advanced airway management in pediatric patients. *Emerg Med Clin North Am* 1991;9:611-638. **(Review)**
33. Yamamoto LG, Yim GK, Britten AG. Rapid sequence anesthesia induction for emergency intubation. *Pediatr Emerg Care* 1990;6:200-213. **(Case report/review; 19 patients)**
34. Fleming B, McCollough M, Henderson SO. Myth: Atropine should be administered before succinylcholine for neonatal and pediatric intubation. *Can J Emerg Med* 2005;7(2):114-117. **(Literature review)**
- 35.* McAuliffe G, Bissonnette B, Boutin C. Should the routine use of atropine before succinylcholine in children be reconsidered? *Can J Anaesth* 1995;42(8):724-9. **(Randomized controlled trial; 41 children)**
36. Mirakhur RK, Clarke RS, Elliott J, et al. Atropine and glycopyrronium premedication. A comparison of the effects on cardiac rate and rhythm during induction of anaesthesia. *Anaesthesia* 1978;33(10):906-912. **(Randomized controlled trial; 3 groups of 20 children)**
37. Whyte S, Birrell G, Wyllie J. Premedication before intubation in UK neonatal units. *Arch Dis Child* 2000;82(1):38-41. **(Survey of providers in UK NICU)**

38. Parnis SJ, Van der Walt JH. A national survey of atropine use by Australian anaesthetists. *Anaesth Intensive Care* 1994;22(1):61-65. (Survey of providers in Australian anaesthesia)
39. Annala P, Viitanen H, Reinikainen P, et al. Induction characteristics of thiopentone/suxamethonium, propofol/alfentanil or halothane alone in children aged 1-3 years. *Eur J Anaesthesiol* 1999;16(6):359-366. (Randomized controlled trial; 90 children)
40. Morris I. Pharmacologic aids to intubation and the rapid sequence induction. *Emerg Med Clin North Am* 1988;6:753-768. (Review)
41. Levitt AM, Dresden GM. The Efficacy of Esmolol versus Lidocaine to Attenuate the Hemodynamic Response to Intubation in Isolated Head Trauma Patients. *Acad Emerg Med* 2001;8(1):19-24. (Randomized controlled trial; 30 patients)
42. Giese JL, Stanley TH. Etomidate. A new intravenous anesthetic induction agent. *Pharmacotherapy* 1983;3:251-258. (Review)
43. Plewa MC, King R, Johnson D, et al. Etomidate used during emergency intubation of trauma patients. *Am J Emerg Med* 1997;15:98-100. (Letter)
44. McDuffee AT, Tobias JD. Seizure after flumazenil administration in a pediatric patient. *Pediatr Emerg Care* 1995;11(3):186-187. (Case report)
45. Green LM, Nakamura R, Johnson NE. Ketamine sedation for pediatric procedures: Parts I and II. *Ann Emerg Med* 1990;19:1024-1046. (Review)
46. Epstein FB. Ketamine dissociative sedation in pediatric emergency medical practice. *Am J Emerg Med* 1993;11:180-182. (Review)
47. Jankiewicz AM, Nowakowski P. Ketamine and succinylcholine for emergency intubation of pediatric patients. *DICP* 1991;25:475-476. (Case report)
48. Tobias JD. Airway management for pediatric emergencies. *Pediatr Ann* 1996;25:317-328. (Review)
49. Nichols DG. Emergency management of status asthmaticus in children. *Pediatr Ann* 1996;25:394-403. (Review)
50. Dufour DG, Larose DL, Clement SC. Rapid sequence intubation in the emergency department. *J Emerg Med* 1995;13:705-710. (Review)
51. Zink BJ, Snyder HS, Raccio-Robak N. Lack of a hyperkalemic response in emergency department patients receiving succinylcholine. *Acad Emerg Med* 1995;2:974-978. (Prospective study; 100 consecutive patients)
52. Smith RB, Grenvik A. Cardiac arrest following succinylcholine use in patients with central nervous system injuries. *Anesthesiology* 1970;33:558-560. (Case reports)
53. Tolmie JD, Joyce TH, Mitchell GD. Succinylcholine danger in the burned patient. *Anesthesiology* 1967;28:467-70. (Case reports)
54. McStravog LJ. Dangers of succinylcholine in anesthesia. *Laryngoscope* 1974;84:929-932. (Review article)
55. Morris IR. Pharmacologic aids to intubation and the rapid sequence induction. *Emerg Med Clin North Am* 1988;6:753-768. (Review)
56. Gronert GA, Antognini JF. Malignant hyperthermia. In: Miller RD, ed. *Anesthesia*. 4th ed. New York, NY: Churchill Livingstone; 1994:1075-1093. (Textbook chapter)
57. Ording H. Incidence of malignant hyperthermia in Denmark. *Anesth Analg* 1985;64:700-704. (Retrospective review/questionnaire; 154 identified patients)
58. *Physicians' Desk Reference* 1996. 50th ed. Montvale, NJ: Medical Economics; 1996:1073-1075. (Reference book)
59. Libonati MM, Leahy JJ, Ellison N. The use of succinylcholine in open eye surgery. *Anesthesiology* 1985;62:637-640. (Review)
60. Saverese JJ, Miller RD, Lien CA, et al. Pharmacology of muscle relaxants and their antagonists. In: Miller RD, ed. *Anesthesia*. 4th ed. New York, NY: Churchill Livingstone; 1994:417-487. (Textbook chapter)
61. Kharasch M, Graff J. Emergency management of the airway. *Crit Care Clin* 1995;11:53-66. (Review)
62. Rosenburg H, Gronert GA. Intractable cardiac arrest in children given succinylcholine. *Anesthesiology* 1992;77:1054. (Letter)
63. Sarner JB, Brandom BW, Woelfel SK, et al. Clinical pharmacology of mivacurium chloride (BW B1090U) in children during nitrous oxide-halothane and nitrous oxide-narcotic anesthesia. *Anesth Analg* 1989;68:116-121. (Dose response study; 36 patients)
64. Wright JL, Patterson MD. Resuscitating the pediatric patient. *Emerg Med Clin North Am* 1996;14:219-231. (Review)
65. Goudsouzian NG, Denman W, Schwartz A, et al. Pharmacodynamic and hemodynamic effects of mivacurium in infants anesthetized with halothane and nitrous oxide. *Anesthesiology* 1993;79:919-925. (Dose response study; 90 patients)
66. White SJ, Slovis CM. Inadvertent esophageal intubation in the field: Reliance on a fool's "gold standard." *Acad Emerg Med* 97;4:89-91. (Editorial)
- 67.* Macleod, BA, Heller MB, Gerard J, et al. Verification of endotracheal tube placement with colorimetric end-tidal CO2 detection. *Ann Emerg Med* 1991;20:267-270. (Prospective study; 250 consecutive intubations)
68. Bhende MS. End-tidal carbon dioxide monitoring in pediatrics - clinical applications. *J Postgrad Med* 2001;47:215-218. (Review)
69. Cardos MM, Banner MJ, Melker RJ, et al. Portable devices used to detect endotracheal intubation during emergency situations: A review. *Crit Care Med* 1998;26(5):957-964. (Review)
70. Ginsburg WH. When does a guideline become a standard? The new American Society of Anesthesiologists guidelines give us a clue. *Acad Emerg Med* 1993;21:1891-1896. (Editorial)
71. Garnett AR, Germin CA, Germin AS. Capnographic waveforms in esophageal intubations: effect of carbonated beverages. *Ann Emerg Med* 1989;18:387-390. (Animal study)
72. Vukmir RB, Heller MB, Stein KL. Confirmation of endotracheal tube placement: a miniaturized infrared qualitative CO2 detector. *Ann Emerg Med* 1991;20:726-729. (Prospective study; 88 consecutive adult patients requiring 100 emergency intubations)
73. Garza M. End tidal CO2 detector questions arise. *JEMS* 1991;16:22-23. (Editorial)
74. Bhende MS, Thompson AE. Evaluation of an end-tidal carbon dioxide detector during pediatric cardiopulmonary resuscitation. *Pediatrics* 1995;95:395-399. (Prospective consecutive study; 40 children)
75. Zaleski L, Abello D, Gold MI. The esophageal detector device, does it work. *Anesthesiology* 1993;79:244-247. (Prospective study, 300 patients)
76. Marley CD Jr, Eitel DR, Anderson TE, et al. Evaluation of a prototype esophageal detection device. *Acad Emerg Med* 1995;2:503-507. (Prospective randomized study; 51 patients)
- 77.* Mizushima A, Wardall GJ, Simpson DL. The laryngeal mask airway in infants. *Anesthesia* 1992;47:849-851. (Prospective study; 50 consecutive patients)
78. Stewart RD. Tactile orotracheal intubation. *Ann Emerg Med* 1984;13:175-178. (Case report)
79. Collins VJ. *Principles and Practice of Anesthesiology*. Philadelphia, PA: Lea & Febiger; 1952:288. (Textbook reference, historical)
80. Hudon F. Intubation without laryngoscopy. *Anesthesiology* 1945;6:476-482. (Historical review article)
81. Hardwick WC, Bluhm D. Digital intubation. *J Emerg Med* 1984;1:317-320. (Prospective study; 66 consecutive patients)
82. Vollmer TP, Stewart RD, Paris, PM, et al. Use of a lighted stylet for guided orotracheal intubation in the prehospital setting. *Ann Emerg Med* 1985;14:324-328. (Prospective study; 24 consecutive patients)
83. Ellis DG, Stewart RD, Kaplan RM, et al. Success rates of blind orotracheal intubation using a transillumination technique with a lighted stylet. *Ann Emerg Med* 1986;15:138-142. (Prospective, consecutive study; 50 patients)
84. Dryden GE. Use of a suction catheter to assist blind nasal intubation. *Anesthesiology* 1976;45:260. (Letter)
85. Down MP. Emergency transtracheal ventilation. *Anesthesia* 1997;52:91-92. (Letter)
86. Waters DJ. Guided blind endotracheal intubation. *Anesthesia* 1963;18:158-62. (Case report)
87. McNamara RM. Retrograde intubation of the trachea. *Ann Emerg Med* 1987;16:680-682. (Review)
88. Akinyemi OO. Complications of guided blind endotracheal intubation. *Anesthesia* 1979;34:590-592. (Case reports; 12 patients)

Physician CME Questions

- During a blind nasal intubation in an adolescent, what is the most common complication?
 - Epiglottal tears
 - Esophageal insertion
 - Cranial insertion
 - Submucosal dissection
 - Turbinate laceration
- Why would digital intubation not be appropriate for an infant?
 - Operator injury
 - Laryngospasm
 - Epiglottis trauma
 - Inability of the operator to intubate
 - Esophageal intubation
- In which of the following clinical conditions would a surgical cricothyrotomy *not* be indicated?
 - Obstructive lesions of the upper airway in a 10-year-old child
 - High suspicion of cervical spine trauma in a 5-year-old child
 - Laryngeal stenosis in a 13-year-old child
 - Structural deformity of the upper airway in a 17-year-old adolescent
 - All of the above

4. **Which of the following conditions should preclude use of a fiberoptic laryngoscope?**
 - a. Inexperienced operator
 - b. Copious secretions
 - c. Large amounts of blood in the posterior oropharynx
 - d. Retropharyngeal edema
 - e. All of the above

5. **Which of the following are not anatomical differences associated with pediatric patients?**
 - a. Shorter and more anterior larynx
 - b. Long and narrow epiglottis
 - c. More acute angle between base of the tongue and glottic opening
 - d. Relatively longer trachea and bronchus
 - e. The head and occiput are proportionally larger.

6. **Which of the following statements about the use of cuffed endotracheal tubes in children is *not* correct?**
 - a. Cuffed tubes limit the flow of air into the child's respiratory tract.
 - b. Cuffed tubes increase the resistance to airflow in the child's airway.
 - c. Cuffed tubes can be used in children over the age of 4.
 - d. Cuffed tubes will help prevent aspiration, but are not used for other reasons.
 - e. The narrowest part of the airway is the subglottic area.

7. **What statement about the use of succinylcholine is *not* correct?**
 - a. Succinylcholine should not be used for routine intubation of children during anesthesia in the operating room.
 - b. Succinylcholine should not be used in a patient with a 6-day-old crush injury to the leg.
 - c. Succinylcholine can cause malignant hyperthermia.
 - d. A second dose of succinylcholine during intubation may cause tachycardia in young children.
 - e. Succinylcholine can cause increased intraocular pressure.

8. **Which of the following agents is most useful in intubating the young patient with profound respiratory distress from asthma?**
 - a. Ketamine
 - b. Fentanyl
 - c. Etomidate
 - d. Midazolam
 - e. Thiopental

9. **When intubating the small child or infant, it is recommended that the rescuer use:**
 - a. a curved laryngoscope blade.
 - b. an uncuffed endotracheal tube.
 - c. a cuffed endotracheal tube.
 - d. a straight laryngoscope blade.

10. **Which of the following agents will provide the quickest paralysis for RSI?**
 - a. Succinylcholine
 - b. Rocuronium
 - c. Vecuronium
 - d. Pancuronium
 - e. Propofol

11. **The smallest catheter that the physician should use for percutaneous transtracheal ventilation in a child is:**
 - a. 12-gauge
 - b. 14-gauge
 - c. 16-gauge
 - d. 22-gauge
 - e. 30-gauge

12. **The use of a laryngoscope and the subsequent passage of an endotracheal tube may cause the child's heart rate to drop precipitously. This is due to vagal stimulation.**
 - a. True
 - b. False

13. **When you insert an endotracheal tube too far, the end will most likely be in the:**
 - a. vallecula
 - b. carina
 - c. right mainstem bronchus
 - d. left mainstem bronchus
 - e. esophagus

14. **Which of the following conditions can cause upper airway obstruction in the child?**
 - a. Epiglottitis
 - b. Anaphylaxis
 - c. Aspirated hot dog
 - d. Red rubber ball
 - e. All of the above

15. **Which of the following can cause a false-positive end-tidal CO₂ reading?**
 - a. Ingestion of iodine-containing seafood
 - b. Ingestion of red meat
 - c. Ingestion of carbonated beverages
 - d. Esophageal intubation
 - e. Ingestion of a large amount of acetaminophen

Physician CME questions conclude on back page

16. Which of the following is the most common cause of cardiac arrest in children without a known preexisting medical condition?

- a. Unrecognized congenital cardiac disorders
- b. Respiratory arrest
- c. Lightning strikes
- d. Sustained high fever
- e. Emotional neglect

Erratum: Volume 2, Numbers 11 & 12

We regret that the full, current titles were not listed for 3 of the coauthors of The Things Kids Bring Home From Abroad: Evaluating The Returning Child Traveler With Fever. The correct titles are as follows:

Tamara L Thomas, MD, Professor, Department of Emergency Medicine; Director, International Emergency Medicine, Loma Linda University School of Medicine—Loma Linda, CA.

Tae E Kim, MD, Assistant Professor, Department of Emergency Medicine, Loma Linda University School of Medicine—Loma Linda, CA.

Deborah Washke, MD, Fellow, International Emergency Medicine, Department of Emergency Medicine, Loma Linda University School of Medicine—Loma Linda, CA.

Coming in Future Issues:

Sinusitis • DKA • Pain Control And Sedation

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 RCTs
- 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.

Physician CME Information

This CME enduring material is provided by Mount Sinai School of Medicine and has been planned and implemented in accordance with the Essentials and Standards of the Accreditation Council for Continuing Medical Education. Credit may be obtained by reading each issue and completing the printed post-tests administered in December and June or online single-issue post-tests administered at EBMedicine.net.

Target Audience: This enduring material is designed for emergency medicine physicians.

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.

Date of Original Release: This issue of *Pediatric Emergency Medicine Practice* was published January 30, 2006. **This activity is eligible for CME credit through January 1, 2009.** The latest review of this material was January 15, 2006.

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. *Disclosure of Off-Label Usage:* The ACCME mandates that all off-label uses of pharmaceutical agents be described. This issue of *Pediatric Emergency Medicine Practice* discusses no off-label use of any pharmaceutical product.

Faculty Disclosure: 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. Stewart, Dr. Sharieff, and Dr. Witt report no significant financial interest or other relationship with the manufacturer(s) of any commercial product(s) discussed in this educational presentation.

Accreditation: Mount Sinai School of Medicine is accredited by the Accreditation Council for Continuing Medical Education to sponsor continuing medical education for physicians.

Credit Designation: Mount Sinai School of Medicine designates this educational activity for up to 4 hours of Category 1 credit toward the AMA Physician's Recognition Award. Each physician should claim only those hours of credit actually spent in the educational activity. *Pediatric Emergency Medicine Practice* is approved by the American College of Emergency Physicians for 48 hours of ACEP Category 1 credit (per annual subscription). This continuing medical education activity has been reviewed by the American Academy of Pediatrics and is acceptable for up to 48 AAP Credits. These credits can be applied toward the AAP CME/CPD Award available to Fellows and Candidate Fellows of the American Academy of Pediatrics.

Earning Credit: Two Convenient Methods

- **Print Subscription Semester Program:** Paid subscribers with current and valid licenses in the United States who read all CME articles during each *Pediatric Emergency Medicine Practice* six-month testing period, complete the post-test and the CME Evaluation Form distributed with the December and June issues, and return it according to the published instructions are eligible for up to 4 hours of Category 1 credit toward the AMA Physician's Recognition Award (PRA) for each issue. You must complete both the post-test and CME Evaluation Form to receive credit. Results will be kept confidential. CME certificates will be delivered to each participant scoring higher than 70%.
- **Online Single-Issue Program:** Paid subscribers with current and valid licenses in the United States who read this *Pediatric Emergency Medicine Practice* CME article and complete the online post-test and CME Evaluation Form at EBMedicine.net are eligible for up to 4 hours of Category 1 credit toward the AMA Physician's Recognition Award (PRA). You must complete both the post-test and CME Evaluation Form to receive credit. Results will be kept confidential. CME certificates may be printed directly from the Web site to each participant scoring higher than 70%.

***Pediatric Emergency Medicine Practice* is not affiliated with any pharmaceutical firm or medical device manufacturer.**

CEO: Robert Williford. **President & General Manager:** Stephanie Williford. **Publisher:** Cheryl Strauss. **Director of Member Services:** Charlotte Pratt.

Direct all editorial or subscription-related questions to EB Practice, LLC: **1-800-249-5770** • Fax: 1-770-500-1316 • Non-U.S. subscribers, call: 1-678-366-7933

EB Practice, LLC • 305 Windlake Court • Alpharetta, GA 30022

E-mail: emp@empractice.net • Web Site: <http://EBMedicine.net>

Pediatric Emergency Medicine Practice (ISSN Print: 1549-9650, ISSN Online: 1549-9669) is published monthly (12 times per year) by EB Practice, LLC, 305 Windlake Court, Alpharetta, GA 30022. 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 Practice, LLC. Copyright ©2006 EB Practice, LLC. All rights reserved. No part of this publication may be reproduced in any format without written consent of EB Practice, LLC. Subscription price: \$299, U.S. funds. (Call for international shipping prices.)