

Procedural Sedation Curriculum Nationwide Children's Hospital Columbus, Ohio

Module 1: Airway Management

Introduction

The most immediate concern in the management of pediatric resuscitations and medical emergencies is an assessment of the airway and respiratory function. Regardless of the etiology of respiratory failure, further attempts at resuscitation or treatment of the underlying condition will fail if airway control with restoration of ventilation/oxygenation is delayed or ineffective. Emergency airway management may be fraught with difficulties as there may be limited time to prepare for the problem thereby emphasizing the need for prior preparation and appropriate training of all essential personnel.¹

An added concern with airway management in the trauma setting is the protection of the cervical spine. Until proven otherwise, it is assumed that all pediatric trauma patients have a cervical spine injury. Although a thorough physical examination and radiologic investigation can be used to exclude an injury; in the emergent setting, there is frequently inadequate time to embark on such investigations. Therefore, the airway is managed with the assumption that there is an injury and techniques are used to control the airway and intubate the trachea (see below) which will not be harmful if an injury is found during the subsequent evaluation. The issues of airway management in the trauma setting, the radiologic evaluation of the cervical spine, and the techniques used to prevent cervical spine injury during airway management are reviewed in greater depth in reference 2.²

Airway management

The goals of airway management are: 1) to relieve anatomic obstruction, 2) to prevent the aspiration of gastric contents, and 3) to promote adequate gas exchange. All patients should receive 100% oxygen (delivered by a non-rebreathing system) until the initial assessment of respiratory function is made even if the oxygen saturation is adequate. The administration of 100% oxygen provides an alveolar oxygen tension of 600-700 mmHg so that there is a significant reservoir of oxygen in the lungs to provide an adequate supply of oxygen during periods of respiratory compromise. With an alveolar oxygen tension of 600-700 mmHg, a patient with a normal functional

residual capacity (FRC) can tolerate periods of apnea of 5 to 10 minutes without a significant drop in the hemoglobin oxygen saturation. It must be remembered that in the pediatric population, a lower FRC and higher oxygen consumption results in a more rapid drop in oxygen saturation and therefore a lesser margin of safety than in the adult population. Additionally, patients with alveolar space disease or chronic lung diseases will also have a lower reserve and therefore be more likely to desaturate during periods of apnea.

Airway management may be as simple as relieving soft tissue obstruction of the airway by proper positioning of the head. Several factors predispose the pediatric trauma patient to airway obstruction. Airway obstruction most commonly occurs because the tongue and/or pharyngeal soft tissues collapse into the airway. Alterations in the level of consciousness, related to closed head injury or cardiovascular compromise with inadequate cerebral perfusion, can lead to relaxation of pharyngeal musculature with soft tissue obstruction of the airway. The proportionately larger head of the child, when compared to the rest of the body, promotes neck flexion. The oral cavity is relatively small and the tongue is relatively large. All of these factors make upper airway obstruction a likely occurrence in children.

Simple measures to relieve airway obstruction include proper positioning of the head with avoidance of neck flexion (head tilt), anterior displacement of the mandible (jaw thrust), lifting the anterior portion of the mandible (chin lift), or placement of an oral airway. These three maneuvers (head tilt, jaw thrust, and chin lift) are collectively referred to as the triple airway maneuver. An additional option is placement of an oral or nasal airway to provide anterior movement of the tongue. Use of a nasal airway is preferred over an oral airway in combative or semiconscious patients as an oral airway may lead to stimulation of the gag reflex and vomiting. The head tilt is avoided in the trauma setting because of the possibility of aggravating a cervical spine injury.

Decisions regarding endotracheal intubation include the route (oral versus nasal) and awake versus anesthetized. These decisions are based on the assessment as to the normalcy of the airway and the ability to successfully perform endotracheal intubation (see below for management of the

abnormal airway). In most cases, the preferred route for endotracheal intubation is oral. Attempts at nasal intubation can result in bleeding which can obstruct visualization and make further attempts at endotracheal intubation impossible. Awake nasal intubation can lead to significant increases in intracranial pressure (ICP) and is absolutely contraindicated in patients with closed head injuries. Nasal intubation is also contraindicated in patients with evidence of facial trauma, cerebrospinal fluid leaks, or physical findings suggestive of basilar skull fracture (i.e. Battle's sign, raccoon eyes, hemotympanum). Any of the above are suggestive of disruption of the cribriform plate and the usual barrier between the nasopharynx and the intracranial vault.

Prior preparation is an absolute requirement to ensure that endotracheal intubation is accomplished in an expedient manner. The available equipment should include a resuscitation bag and oxygen source (it is important to double-check that the oxygen flow is turned on), appropriate sized masks, laryngoscopes, endotracheal tubes, stylets, suction, and drugs. Various sizes and shapes of laryngoscopes are available, but they can most simply be classified as either straight (Miller) or curved blades (Macintosh). During laryngoscopy, the straight blade is placed on the laryngeal side of the epiglottis while the curved blade is placed on the pharyngeal side of the epiglottis in the vallecula. The author's preference is to use straight blades for children who weigh less than 6-10 kgs and curved blades for older patients. Suggested sizes and types of laryngoscopes are listed in table 1. The appropriate sized endotracheal tube (ETT) is based on the patient's age. A 3.0 mm or 3.5 mm ETT should be used in a term neonate while a 4.0 mm ETT is appropriate for an infant that is 2 to 6 months of age. Beyond 6 months of age, the appropriate sized tube (mm) can be estimated using the rule: **(AGE + 16)/4**

Another method of estimating endotracheal tube size is to use an ETT whose outside diameter approximates that of the patient's little finger. The formulas used to estimate ETT size are only starting guidelines; the real test is during laryngoscopy and passage of the ETT through the glottis. Excessive force must be avoided. The ETT should pass through the cords easily without undue force. Following placement, there should be a minimal air leak heard around the ETT with

inflating pressures of 20-30 cmH₂O. The latter number is chosen since pressures above this exceed the perfusion pressure of the tracheal mucosa and may result in tissue necrosis, edema, scarring, and post-extubation problems. While cuffed ETT's are not routinely recommended for patients less than 6 to 8 years of age, it is important to note that it is the pressure from cuff inflation and not the cuff itself that causes the damage. In specific circumstances it may be appropriate to use a cuffed ETT in younger patients. With severe pulmonary parenchymal disease, high peak inflating pressures may be needed to provide adequate oxygenation and ventilation. Without a sealed airway with a cuffed ETT, it may not be feasible to deliver these high pressures. As the formulas are only starting guidelines, it is possible that the chosen uncuffed ETT will be too small with the need to change the ETT because of the excessive air leak. In the emergency setting, repeated laryngoscopies and changes of the ETT are not desirable and it may be appropriate to use a cuffed ETT the first time and inflate the cuff if necessary. If a cuffed ETT is used, a half size smaller tube should be chosen and the cuff inflated with the least amount of air necessary to prevent an excessive air leak.

An additional issue with emergency patients is the risk for aspiration during intubation. Unlike endotracheal intubation performed for elective surgical cases in the operating room, patients that present with acute medical emergencies are frequently not NPO. During sedation and paralysis for endotracheal intubation, passive or active regurgitation of stomach contents may occur. Trauma, pain, and anxiety all delay gastric emptying, therefore regardless of when the patient last ate, they are still considered to have a "full stomach". Therefore, techniques to minimize the risks of regurgitation of stomach contents are necessary.^{3,4}

The risks of pulmonary damage following acid aspiration are related to both the volume and pH of the fluid. The risks are greatest with volumes in excess of 0.4 mL/kg and a pH less than 2.5. With emergency airway management, there is not adequate time for pharmacologic management of either the volume or the pH of the fluid. The techniques used to prevent acid aspiration include cricoid pressure and rapid neuromuscular blockade/anesthesia (rapid sequence induction and intubation). Attempts at emptying the stomach with an orogastric tube are not recommended since

it does not effectively empty the stomach and may also induce vomiting.

The goals of a rapid sequence intubation are to secure the airway and protect the lungs from acid aspiration. Cricoid pressure (Sellick's maneuver) is a technique that prevents the passive regurgitation of stomach acid. The upper esophagus is compressed against the cervical vertebral column by applying anteroposterior pressure on the cricoid cartilage. The cricoid cartilage is the only complete ring of the trachea and can be used to compress the esophagus without interfering with the ability to pass an endotracheal tube. Cricoid pressure should be maintained from the time consciousness is lost until proper placement of the endotracheal tube is confirmed or until the patient reawakens if intubation is unsuccessful.

The second key to a successful endotracheal intubation is the appropriate use of rapidly acting neuromuscular blocking agents and anesthetic agents. With rapid neuromuscular blockade and anesthesia, the possibility of vomiting at the time of intubation is reduced. Rapid sequence intubation should always be preceded by the administration of 100% oxygen via a tight-fitting face mask. With full denitrogenation, the typical adult, without pulmonary parenchymal disease and/or abnormalities of functional residual capacity, can sustain approximately 5-10 minutes of apnea without developing hypoxemia. The period of apnea to the development of hypoxemia may be significantly less in infants and children due to their increased metabolic rate for oxygen and decreased functional residual capacity. The use of a pulse oximeter during endotracheal intubation provides an added margin of safety and alerts the physician performing the intubation when the attempt should be aborted and bag-mask ventilation started. Gentle assisted ventilation with cricoid pressure can be applied following the administration of anesthetic agents and neuromuscular blocking agents to maintain oxygenation and ventilation until the onset of full neuromuscular blockade adequate for endotracheal intubation. The latter technique may also be used to provide hyperventilation prior to intubation in patients with altered intracranial compliance who are at risk for increases in intracranial pressure.

THE NORMAL AIRWAY: Sedative and neuromuscular blocking agents are contraindicated if the airway is judged to be abnormal and there is a question of the ability to successfully complete endotracheal intubation. In this situation, other techniques to secure the airway are needed (see below). If the airway is assessed as normal, one can proceed with neuromuscular blocking agents and sedative/analgesic agents for endotracheal intubation (table 2). The neuromuscular blocking agent used may be either a depolarizing agent such as succinylcholine or a non-depolarizing agent (pancuronium, vecuronium, rocuronium). The advantages of succinylcholine include a rapid onset of action (30 to 45 seconds) as well as a short duration of action (4 to 5 minutes). The latter may be particularly important in patients with head trauma or suspected cervical spine injury so that immediate reassessment of their clinical status is possible. The short duration also provides a margin of safety should the clinician be faced with the "cannot intubate" scenario. If successful bag/mask ventilation can be provided, it may be most appropriate to allow the effects of the succinylcholine and the sedative agent to dissipate and attempt endotracheal intubation using another approach (see below). Extensive burns, crush injuries, and various neurologic and neuromuscular diseases remain contraindications to succinylcholine as an exaggerated hyperkalemic response may be seen (table 3). Succinylcholine is also contraindicated in patients with open globe injuries since the contraction of the extraocular muscles may lead to expulsion of the intraocular contents and permanent loss of vision.

Succinylcholine has been demonstrated to cause a modest increase (5-10 mmHg) in ICP.⁵ However, with its rapid onset of neuromuscular blockade, endotracheal intubation can be accomplished sooner with the restoration of adequate oxygenation and ventilation. The latter are the primary determinants of cerebral blood flow and ICP. Because of the effect of succinylcholine on ICP, its use in patients with altered intracranial compliance remains controversial. In the emergency setting, regardless of the age of the patient, a small dose of an anticholinergic agent such as atropine (5 to 10 mcg/kg up to 0.4 mg) is suggested prior to the administration of succinylcholine to prevent bradycardia.

Non-depolarizing muscle relaxants should be used in situations or with underlying conditions that contraindicate succinylcholine. Several different non-depolarizing agents are available (table 4). Their primary differences include onset and duration of action, metabolic fate, and cardiovascular effects. Significant histamine release can occur with several of the agents including curare, atracurium, and mivacurium thereby limiting their use in the emergency setting. Pancuronium (0.15 mg/kg) will provide acceptable conditions for intubation in 90 to 120 seconds with paralysis lasting from 45 to 90 minutes. Mild histamine release and an increase in heart rate related to its vagolytic effects may be seen. Pancuronium is primarily (70 to 80%) dependent on renal excretion with a significantly prolonged effect in patients with renal insufficiency/failure. A more rapid onset of paralysis can be achieved with either vecuronium or rocuronium. As vecuronium is devoid of cardiovascular effects, increased doses can be used to speed the onset of neuromuscular blockade. Doses of 0.3 mg/kg will provide acceptable conditions for endotracheal intubation in 60 to 90 seconds with a duration of blockade of 60 to 90 minutes. Priming may also be used to speed the onset of vecuronium. For this, 0.01 mg/kg is administered followed in 2 to 3 minutes by the remainder of the intubating dose of 0.15 mg/kg. In the emergency setting, a priming dose is generally not recommended since it may induce significant amounts of neuromuscular blockade. It is also generally recommended that the intubating dose be given 2 to 3 minutes after the priming dose. This delay may not be practical during emergency airway management. Due to these problems, this practice is not recommended for emergent airway management.

The problem of the delayed onset with non-depolarizing muscle relaxants has been somewhat alleviated with the introduction of rocuronium.⁶ Acceptable intubating conditions are achieved within 60 seconds in the majority of patients, making it the most rapidly acting of the non-depolarizing neuromuscular blocking agents. Like vecuronium, it is relatively devoid of cardiovascular effects causing only mild tachycardia. The duration of action following an intubating dose of 0.6 to 1.2 mg/kg is 30 to 60 minutes.

The second decision pertains to the drugs used to provide amnesia/analgesia during rapid

sequence induction (table 2). The drugs chosen are based on two factors: the patient's hemodynamic status and the presence/absence of increased ICP (table 5). In the hemodynamically stable patient (with or without a closed head injury), standard induction doses of thiopental (4 to 6 mg/kg) or propofol (2 to 3 mg/kg) can be used. In addition to providing anesthesia for the procedure of endotracheal intubation, both agents will also provide CNS protection. Both propofol and thiopental decrease the cerebral metabolic rate for oxygen leading to reflex cerebral vasoconstriction and a lowering of ICP.^{7,8} Lidocaine (1.5 mg/kg), 1-2 minutes prior to endotracheal intubation, can also be used to blunt the increase in ICP which can occur during laryngoscopy.

In the hemodynamically unstable patient without closed head injury, etomidate (0.2 to 0.3 mg/kg) or ketamine (0.5 to 1 mg/kg) may be used to provide amnesia/analgesia.^{9,10} Neither agent will significantly affect cardiovascular function. Although ketamine has direct negative inotropic properties, it causes a release of endogenous catecholamine which generally overshadow its direct negative inotropic effects on myocardial contractility. The end result is generally an increase in heart rate and mean arterial pressure. Ketamine is the drug of choice during the endotracheal intubation of patients with increased airway reactivity. The release of endogenous catecholamines may be beneficial in patients with bronchospastic disorders.

Ketamine has a variable effect on ICP with some studies suggesting an actual increase of the ICP. As such, it is generally contraindicated in patients with altered intracranial compliance. In the hemodynamically unstable patient with a closed head injury, etomidate can be used to provide amnesia and lower ICP without deleterious effects on cardiac output and systemic vascular resistance. Etomidate, like propofol and thiopental, decreases ICP by decreasing the cerebral metabolic rate for oxygen and cerebral blood flow. Etomidate does depress adrenal cortical function for up to 24 hours following a single dose although negative effects on clinical outcome have not been demonstrated. However, the role of etomidate remains somewhat controversial.

Once endotracheal intubation is accomplished, correct endotracheal tube placement can be confirmed by one of several means including direct visualization of the tube passing through the

vocal cords, auscultation of breath sounds, mist in the ETT, carbon dioxide in the exhaled gases, fiberoptic documentation of tracheal rings or subsequent chest x-ray. Capnography or documentation of end-tidal CO₂ (ETCO₂) serves as a useful adjunct to endotracheal tube placement and should be considered routine in any setting in which endotracheal intubation occurs. Many of the newer ETCO₂ devices are compact and portable allowing for their easy transport to any locale in which endotracheal intubation is necessary. Alternatively, disposable, one time use, devices are available to document the presence of CO₂ in exhaled gases. These devices rely on a chemical reaction between the substrate in the paper and the CO₂ resulting in a color change demonstrating the presence of CO₂. Once correct endotracheal tube placement is identified, the tube is taped securely in position, bilateral breath sounds are auscultated again (after taping the ETT) and a chest x-ray is obtained. Once the ETT is secured, the stomach is decompressed with an orogastric or nasogastric tube.

FAILED ENDOTRACHEAL INTUBATION: If the trachea cannot be intubated after paralysis and sedative agents have been given, an immediate decision must be made as to how to handle the failed intubation. A second attempt at intubation may be tried after changing the patient's head position, the laryngoscope blade, or adding pressure on the larynx to help visualize the glottis. If these maneuvers fail, 100% oxygen should be administered through a tight-fitting face mask and assisted ventilation initiated. Cricoid pressure should be maintained until the patient awakens. At this point, the alternatives to be considered should follow the algorithm provided by American Society of Anesthesiologists for failed intubation. If bag-mask ventilation is successful, there is time to consider alternative routes of securing the airway such as fiberoptic intubation, performance of a tracheostomy using local anesthesia, or retrograde intubation techniques. Such techniques should only be performed by physicians skilled in pediatric airway management. If the trachea cannot be intubated, but bag/mask ventilation is adequate, the most prudent maneuver is to allow the effects of the neuromuscular blocking/sedative agents to dissipate and for the patient to resume spontaneous

ventilation.

If bag/mask ventilation cannot be accomplished, one must move quickly along the ASA algorithm to prevent hypoxemia, hypoxia, and CNS sequelae. The options at this point include placement of a laryngeal mask airway (LMA), use of the Combitube, or needle cricothyrotomy. The use of any of these devices without proper training is not recommended. Of the three, the LMA is the easiest to become facile with, has the highest incidence of success, and the lowest incidence of adverse sequelae. Placement and use of the LMA is a skill that anyone who may be involved in airway management may want to take the time to learn.¹¹ Training with the LMA has recently been incorporated in some advanced pediatric life support courses. Reference 12 provides a more thorough review of the use of the LMA in the emergency setting.¹²

The LMA is available in 7 sizes to accommodate all sizes of patients from infancy through large adults (table 6). It consists of a silicone rubber tube connected to a bowl-shaped mask with an inflatable rubber cuff. The LMA is designed to sit in the hypopharynx directly over the glottis. It is passed without direct visualization into the oropharynx until resistance is felt. Placement can be accomplished with the neck in a neutral position making it suitable for use in the trauma patient. Following placement, the cuff is inflated and the 15 mm adaptor is connected to an Ambu bag or the anesthesia circuit allowing for either spontaneous or positive pressure ventilation. Placement of the LMA is the initial maneuver following failed intubation recommended in the "cannot intubate/cannot ventilate" algorithm.

The LMA can also be used as a guide for endotracheal intubation using one of several techniques.¹³⁻¹⁵ As the distal opening of the correctly positioned LMA sits superior to the glottic opening, blind passage of an ETT through the LMA and into the trachea is possible. During insertion and passage through the LMA, the ETT is rotated 90° so that the tip of the ETT will pass through the bars at the distal opening of the LMA. Due to the similar lengths of the LMA and the ETT, there will be a limited amount of the ETT that protrudes beyond the end of the LMA following correct positioning in the trachea. It is therefore recommended that the LMA and ETT be left in

place since removal of the LMA may dislodge the ETT. Success rates of up to 90% have been reported with blind passage of an ETT through the LMA.

Although cricoid pressure is recommended to prevent aspiration during airway management in the pediatric trauma patient, it has been demonstrated that the application of cricoid pressure may interfere with successful LMA placement and/or blind intubation through the LMA. Cricoid pressure increases the angle between the shaft of the LMA and the trachea. Therefore, cricoid pressure should be temporarily released during LMA placement or blind intubation through the LMA.

Alternatively, a gum elastic bougie (GEB) or intubating stylet can be passed through the LMA and into the trachea.¹⁶ These are narrow cylindrical device, 3 to 4 mm in diameter and 50 to 70 cm in length. As the GEB is passed into the trachea, a characteristic click is felt as the tracheal rings are engaged. After the GEB is passed into the trachea, the LMA is removed, and an ET tube passed over the GEB into the trachea. Rotation of the ET tube 90° in either direction may facilitate passage of the ET tube into the trachea. Success rates of up to 80% have been reported with this technique.

The LMA can also be used as a guide during oral fiberoptic bronchoscopic guided endotracheal intubation. Following LMA placement, the fiberoptic bronchoscope can be passed through the LMA past its distal opening and directly into the trachea. An ETT that has been previously placed over the FOB can then be guided into the trachea.

The LMA does not seal the airway and therefore the patient is still at risk for aspiration. It is used as a temporizing measure to reestablish ventilation and oxygenation or as an adjunct to guide endotracheal intubation. Despite these limitations, it may be life-saving in the "cannot intubate/cannot ventilate" scenario.

Needle cricothyrotomy is accomplished by inserting a 14 or 16 gauge intravenous catheter through the cricothyroid membrane into the trachea. The catheter is advanced through the skin into the trachea with a syringe that is filled with air or air/saline. Constant pressure is maintained on the

plunger as the syringe is advanced and air bubbles can be seen in the saline when the trachea is entered. The plastic catheter is then advanced over the needle into the trachea. The plastic catheter should advance without resistance off the needle and into the trachea. Once the catheter is positioned in the trachea, the syringe is attached again and the aspiration repeated to ensure the correct placement of the catheter. An alternative means includes the use of a syringe and needle as previously described, but with the passage of a guidewire into the trachea followed by a dilator and a catheter. The latter may ensure that the catheter is not advanced off the needle into a false tract. A more recently described technique for ensuring the intratracheal location of the catheter includes the attachment of an ETCO₂ detector to the syringe or needle.¹⁷ As the trachea is entered, CO₂ will be detected.

Identification of the trachea and correct catheter placement may be quite difficult in younger patients or patients with distorted anatomy. The importance of ensuring that the catheter is in the trachea prior to instituting jet ventilation cannot be overemphasized. Jet ventilation through a catheter that is not in the trachea is disastrous as subcutaneous emphysema and distortion of the anatomy may preclude further airway maneuvers resulting in significant morbidity and mortality.

Once the catheter is placed in the trachea, oxygenation is maintained by intermittent jets from a high pressure system. An oxygen line and toggle valve originating at a 50 psi oxygen source can be attached directly to the intravenous catheter. If this is not readily available, the small end of the 15 mm adapter from a 3.0 mm endotracheal tube will fit into the intravenous catheter. Alternatively, the small end of the 15 mm adaptor from a 7.0 mm endotracheal tube can be inserted into the barrel of a 3 mL syringe and the luer lock end attached to the catheter. The 15 mm adapter allows connection to the oxygen supply such as a standard resuscitation bag. Any of the above mentioned techniques can be used to provide oxygenation although their efficacy in providing ventilation and CO₂ removal is somewhat limited. The latter is not a problem as most patients tolerate hypercarbia without significant adverse physiologic effects.

THE ABNORMAL AIRWAY: Occasionally, the airway of a patient is such due to an underlying condition (i.e., Pierre-Robin sequence) to suggest that endotracheal intubation may be difficult. Other clues, noted on physical examination, that suggest direct laryngoscopy and endotracheal intubation may be difficult are listed in table 7. In these situations, alternatives to standard rapid sequence intubation with muscle paralysis/anesthesia are required to ensure patient safety. An attempt at blind nasal intubation may be indicated in patients without facial trauma, signs of basilar skull fracture, and normal ICP.

Awake intubations are generally difficult in younger patients due to their age, level of understanding, and inability to cooperative. Awake intubation (of any route) is contraindicated in patients with increased intracranial pressure, penetrating neck wounds, and open globe injuries. However, in the cooperative patient with a suspected difficult airway, there is generally nothing to lose by attempting a careful awake intubation. Awake intubation may be made easier by the combination of small doses of intravenous sedation (midazolam 0.03 to 0.5 mg/kg) and topical anesthesia of the airway with a local anesthetic solution. This may be accomplished by aerosolizing a local anesthetic, topical application of local anesthetic to the mucosa of the oropharynx or the direct blockade of the innervation of the airway. The latter techniques of direct blockade of airway innervation should only be attempted by those trained in these techniques. A review of these techniques is provided in references 2 and 18. Consultation with a pediatric anesthesiology or other subspecialists trained in difficult airway management is suggested when confronted with such patients.

The structures of the oropharynx can be quickly anesthetized by topical spray (4% lidocaine or benzocaine). A second option is the use of a nebulizer (same as that used for nebulizing beta adrenergic agonists) for the administration of 3 to 5 mL of 2% or 4% lidocaine depending on the size of the patient. The total dose of lidocaine should not exceed 5 to 7 mg/kg (0.25 to 0.35 mL/kg of a 2% solution). Either of the above mentioned choices will provide adequate anesthesia of the airway above the level of the vocal cords. More distal anesthesia may be obtained with the aerosolized

administration of lidocaine.

Following the achievement of topical anesthesia of the airway, several options exist for airway management. The first is direct laryngoscopy with oral endotracheal intubation. Despite the anticipation of difficult oral endotracheal intubation, this technique is frequently successful. The technique can be safely performed in patients with documented or suspected cervical spine injuries. Meschino et al noted no exacerbation of neurologic injury in their series of 165 trauma patients who underwent awake, oral endotracheal intubation.¹⁹

In addition to direct laryngoscopy with oral endotracheal, the options for oral endotracheal intubation in the awake patient include the Bullard laryngoscope, the light wand, fiberoptic guided endotracheal intubation, and wire-guided retrograde intubation.²⁰ The majority of experience with any of these techniques has been in the adult population and their use in the awake state, as with awake oral endotracheal intubation, requires an alert, cooperative patient.

The Bullard laryngoscope (Circon ACMI, Stamford CT) is an anatomically shaped laryngoscope that uses fiberoptic technology to view the larynx.^{21,22} As such, direct visualization is not required and the need for lining up the oropharynx and larynx is eliminated. The blade is in the shape of a curved L. Once the blade has been rotated around the base of the tongue, force is applied superiorly (in a plane perpendicular to the axis of the patient) to visualize the larynx. While visualization of the larynx is usually excellent, passage of the endotracheal tube into the glottis may be difficult. The current design has an intubating style that is incorporated into the laryngoscope and lies along the right, posterolateral aspect of the blade in an attempt to correctly align the ETT and the airway. The Bullard laryngoscope can be used in the awake patient or following the induction of general anesthesia with spontaneous ventilation or following the provision of neuromuscular blockade. As there is limited movement of the cervical spine with both placement and subsequent use, it has been recommended as a useful tool for managing the airway in patients with suspected or confirmed cervical spine injury. Further refinements in indirect videolaryngoscopy has led to the introduction of other tools including the Glidescope and the Storz video laryngoscope which may

also have a role in airway management in the difficult situation or patient population.

The light wand is a malleable illuminating stylet that can be used for blind oral intubation. The illuminating stylets can be inserted into an ETT of 5.0 mm or greater. As such, the technique can be used in patients as young as 5 to 6 years of age. The distal end of the stylet and ETT are bent 90° to facilitate entry into the trachea. The preparation of the patient for awake oral intubation using the lightwand is the same as for other awake techniques and can include topical anesthesia or direct nerve blockade. Alternatively, the device can be used after the induction of general anesthesia with either spontaneous or controlled ventilation. If awake, the patient is instructed to protrude the tongue and the stylet with ETT are inserted blindly into the oropharynx. As the device passes around the posterior aspect of the tongue and into the larynx, the light can be visualized in the anterior aspect of the neck at the level of the thyroid cartilage. Observation of the light may be facilitated by turning down the room lights. The light can be followed into the suprasternal notch if entry into the trachea occurs while the light disappears if the tube passes into the esophagus. Once the ETT enters the trachea, the usual procedure is followed to confirm correct positioning. Successful use of the technique has been described in patients with normal and abnormal airways, in children, and in the trauma setting.^{22,23} Since neck movement is not required for successful placement, it can be used in patients with cervical spine injuries and has also been suggested as a back-up or alternative means of intubating the trachea when direct laryngoscopy fails.

Recent advances in technology have significantly improved the quality of fiberoptic devices as well as decreasing their size making them suitable adjuncts to airway management in children. Fiberoptic guided endotracheal intubation may be used via the oral or nasal route to aid in endotracheal intubation of the difficult airway. However, certain problems exist surrounding their use in the emergency setting. Most importantly, significant practice and experience may be required to become facile with these techniques especially in smaller children. Once learned, ongoing practice is required to maintain the skills. Blood or secretions in the airway can significantly interfere with airway visualization. As important, fiberoptic techniques can be time consuming or

impossible in the uncooperative patient.

Respiratory function following endotracheal intubation

Following successful endotracheal intubation, confirmation of correct ET tube placement is mandatory and should begin with the auscultation of bilateral breath sounds. No method of confirming the intratracheal location of an ETT is 100% sensitive except for the direct observation of tracheal rings when a bronchoscope is passed through the ETT. End-tidal CO₂ is suggested whenever airway management is performed as an additional means of confirming correct ET tube placement. The end-tidal CO₂ monitor may also be useful during transport to identify inadvertent endotracheal extubation should it occur and to ensure that the desired arterial CO₂ range is maintained.²⁴ The latter may be particularly important if hyperventilation is instituted as a means of controlling ICP.

Once endotracheal intubation is performed and confirmed, one's attention should focus on providing oxygenation and ventilation. Initial tidal volumes of 8 to 12 mL/kg are suggested with respiratory rates adjusted according to the patient's age and the desired arterial CO₂. Once the initial tidal volume is set, the peak inflating pressure (PIP) should be noted. PIPs greater than 35-40 cmH₂O suggest altered compliance with the need for appropriate investigation (see below). The initial F_iO₂ should be 1.0. Moderate periods of time even up to 10 to 12 hours of the high F_iO₂ will not be detrimental to pulmonary function. An F_iO₂ of 1.0 is generally continued during the initial stabilization and transport of the patient. An adequate oxygen supply must be ensured prior to starting transport. An extra tank should be brought along if there is any question that the transport time will be prolonged.

If poor ventilation or abnormal pulmonary compliance is noted, an immediate evaluation is necessary. The first step should be auscultation of breath sounds to rule out mainstem intubation. This is more likely to be a problem in younger patients. A suction catheter should be passed through the endotracheal tube to ensure that the endotracheal tube is not kinked or that secretions/blood have

not blocked the tube. A chest x-ray is indicated to rule out a pneumo/hemothorax. If a pneumothorax is suspected, either because of lack of movement of the chest wall or absence of breath sounds, needle aspiration should be carried out followed by thoracostomy tube placement. There may not be time to obtain a chest film if the child's ventilatory or cardiovascular function is deteriorating. Even with adequate airway management and effective ventilation, there may still be hypoxia and arterial desaturation due to pathologic right-to-left shunting through damaged pulmonary tissue, acid aspiration, pneumonia, or lung contusion. Although these latter problems will require subsequent evaluation and treatment, the initial approach is the same: secure the airway and maintain adequate ventilation with 100% oxygen.

Summary

Several factors increase the difficulty and urgency of airway management in children in the emergency setting. Early and appropriate airway management are of prime importance in improving the eventual outcome of such patients. The major decision points of airway management include one's assessment of the airway and the ability to successfully perform endotracheal intubation. If the airway is judged to be normal, oral endotracheal intubation following sedation and neuromuscular blockade is suggested. Rapid sequence intubation to prevent acid aspiration should be employed. While the medications for airway management are generally administered intravenously, it should also be kept in mind that the intraosseous route is an acceptable alternative for the administration of several different agents including those used for endotracheal intubation.²⁵

If the airway cannot be secured following the administration of anesthetic and neuromuscular blocking agents, the ASA algorithm for the "cannot intubate/cannot ventilate" scenario should be followed (figure 1). When the airway is judged to be abnormal, one of the above described awake techniques may be employed. While there is ample literature concerning these techniques in adults, their use in children has been limited. Most importantly, considerable practice may be required to become and stay facile with these "alternative techniques" of airway

management. In certain circumstances, surgical cricothyrotomy should be considered as an alternative to airway management. Regardless of the technique chosen, appropriate personnel and preparation are mandatory to ensure the safe and effective management of the airway in the pediatric emergency patient. Due to the various skills and expertise of different subspecialists, a multidisciplinary approach to such patients is recommended. Such an approach may include pediatricians, emergency room physicians, surgical subspecialists, anesthesiologists, and critical care physicians.

References

1. Nakayama DK, Gardner MJ, Rowe MI. Emergency endotracheal intubation in pediatric trauma. *Ann Surg* 1990;211:218-223.
2. Tobias JD. Airway management in the pediatric trauma patient. *J Intensive Care Med* 1998;13:1-14.
3. Davies JAH, Howell TH. The management of anaesthesia for the full stomach case in the casualty department. *Postgrad Med J* 1973;49:58.
4. Hastings RH, Marks JD. Airway management for trauma patients with potential cervical spine injuries. *Anesth Analg* 1991;73:471.
5. Minton MD, Grosslight K, Stirt JA, Bedford RF. Increases in intracranial pressure from succinylcholine: Prevention by prior nondepolarizing blockade. *Anesthesiology* 1986;65:165-169.
6. Magorian T, Flannery KB, Miller RD. Comparison of rocuronium, succinylcholine, and vecuronium for rapid sequence induction of anesthesia in adult patients. *Anesthesiology* 1993;79:913-917.
7. Wechsler RL, Dripps RD, Kety SS. Blood flow and oxygen consumption of the human brain during anesthesia produced by thiopental. *Anesthesiology* 1951;12:308-314.
8. Sebel PS, Lowdon JD. Propofol: A new intravenous anesthetic agent. *Anesthesiology* 1989;71:260-277.
9. Brussel T, Theissen JL, Vigfusson G, Lunkenheimer PP, Aken HV, Lawin P. Hemodynamic and cardiodynamic effects of propofol and etomidate: Negative inotropic properties of propofol. *Anesth Analg* 1989;69:35-40.
10. Bergen JM, Smith DC. A review of etomidate for rapid sequence intubation in the emergency department. *J Emerg Med* 1997;15:221-230.

11. Pennant JH, White PF. The laryngeal mask: Its uses in anesthesiology. *Anesthesiology* 1993;79:144.
12. Tobias JD. The laryngeal mask airway: A review for the emergency room physician. *Pediatr Emerg Care* 1996;12:370-373.
13. Inada T, Fujise K, Tachibana K, Shingu K. Orotracheal intubation through the laryngeal mask airway in paediatric patients with Treacher-Collins syndrome. *Paediatric Anaesthesia* 1995;5:129-132.
14. Heath ML, Allagain J. Intubation through the laryngeal mask: A technique for unexpected difficult intubations. *Anaesthesia* 1991;46:545-548.
15. Brimacombe J. Cricoid pressure and the laryngeal mask airway (letter). *Anaesthesia* 1991;46:986-987.
16. Allison A, McCrory J. Tracheal placement of a gum elastic bougie using the laryngeal mask airway (letter). *Anaesthesia* 1990;45:419-420.
17. Tobias JD, Higgins M. Capnography during transtracheal needle cricothyrotomy. *Anesth Analg* 1995;81:1077-1078.
18. Benumof JL. Management of the difficult adult airway with special emphasis on awake tracheal intubation. *Anesthesiology* 1991;75:1087-1110.
19. Meschino A, Devitt JH, Koch JP, Szalai JP, Schwartz ML. The safety of awake tracheal intubation in cervical spine injury. *Can J Anaesth* 1992;39:114-117.
20. Saunders PR, Giesecke AH. Clinical assessment of the adult Bullard laryngoscope. *Can J Anaesth* 1989;36:S118-S119.
21. Borland LM, Casselbrandt M. The Bullard laryngoscope: A new indirect oral laryngoscope (pediatric version). *Anesth Analg* 1990;70:105-108.31.
22. Ellis DG, Jakymec A, Kaplan RM, et al. Guided orotracheal intubation in the operating room using a lighted styles: A comparison with direct laryngoscopic technique. *Anesthesiology* 1986;64:823-826.

23. Holzman RS, Nargoizian CD, Florence FB. Lightwand intubation in children with abnormal upper airways. *Anesthesiology* 1988;69:784-787.
24. Tobias JD, Garrett J, McDuffee A, Lynch A. End-tidal carbon dioxide monitoring during intra-hospital transport of children. *Pediatr Emerg Care* 1996;12:249-251.
25. Tobias JD, Nichols DG. Intraosseous succinylcholine for orotracheal intubation. *Pediatr Emerg Care* 1990;6:108-110.

Table 1: Suggested laryngoscope sizes based on patient weight

<u>Patient weight</u>	<u>Laryngoscope</u>
0 to 3 kg	Miller 0
3 to 5 kg	Miller 0,1
5 to 12 kg	Miller 1, Wis-Hipple 1.5
12 to 20 kg	Wis-Hipple 1.5, Macintosh 2
20 to 30 kg	Macintosh 2, Miller 2
greater than 30 kg	Macintosh 3, Miller 2

Table 2: Intubating medications and dosesNeuromuscular blocking agents

succinylcholine	2 mg/kg
pancuronium	0.15 mg/kg
vecuronium	0.1 to 0.3 mg/kg
rocuronium	1.0 mg/kg

Amnestic/analgesic agents

ketamine	0.5 to 2 mg/kg
pentothal	2 to 6 mg/kg
propofol	2 to 3 mg/kg
etomidate	0.2 to 0.3 mg/kg
midazolam	0.2 mg/kg

Miscellaneous medications

lidocaine	1 to 1.5 mg/kg
atropine	0.01 mg/kg
glycopyrrolate	0.005 to 0.01 mg/kg

Table 3: Contraindications to succinylcholine

1. Hyperkalemia
2. Muscular dystrophies
3. Burns
4. Metabolic acidosis
5. Paraplegia/quadriplegia
6. Denervation injury
7. Metastatic rhabdomyosarcoma
8. Parkinson's disease
9. Disuse atrophy
10. Polyneuropathy
11. Degenerative CNS diseases
12. Purpura fulminans

Table 4: Non-depolarizing muscle relaxants

Aminosteroid compounds:

pancuronium

vecuronium

rocuronium

pipecuronium

Benzylisoquinolinium compounds:

tubocurarine

metocurine

atracurium

mivacurium

doxacurium

Table 5: Suggested anesthetic agents for airway management

Normal ICP*/normal CV: pentothal/propofol	Normal ICP/abnormal CV: ketamine
Increased ICP/normal CV: pentothal/propofol	Increased ICP/abnormal CV: etomidate

ICP = intracranial pressure

CV = cardiovascular function

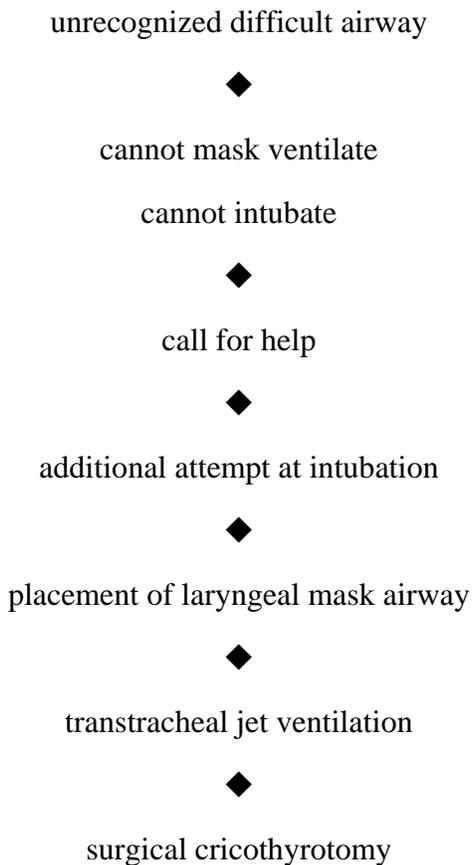
Table 6: Description of the different sizes of laryngeal mask airways

<u>Mask size</u>	<u>pt weight (kg)</u>	<u>internal diameter (mm)</u>	<u>cuff vol (ml)</u>
1	less than 6.5	5.25	2 to 5
1.5	6.5 to 10	6.0	5 to 7
2	10 to 20	7.0	7 to 10
2.5	20 to 30	8.4	10 to 15
3	30 to 70	10	15 to 20
4	70 to 90	10	25 to 30
5	greater than 90	11.5	30 to 40

Table 7: Physical features suggestive of difficult intubation

1. Short neck
2. Limited neck mobility
3. Limited mouth opening
4. Micrognathia
5. Large tongue
6. Small mouth

Figure 1: The "cannot intubate/cannot ventilate" scenario



At any point along the pathway, if oxygenation is restored, the effects of the anesthetic and neuromuscular blocking agents may be allowed to dissipate. Once the patient resumes spontaneous ventilation, the airway may be secured with an awake technique (see text). If the LMA or transtracheal jet ventilation are successful, alternative means of airway management can be employed. These may include retrograde intubation, endotracheal intubation through the LMA, use of the Lightwand, video laryngoscopes, or fiberoptic bronchoscopic techniques.