Pediatric Rapid Sequence Intubation
A Review

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Abstract: Pediatric rapid sequence intubation is a skill of great importance to emergency medicine physicians. Developing a systematic strategy for approaching an emergent airway aids in the proper handling of this event. This paper is a review of the current recommendations for pediatric rapid sequence intubation including current medications and surgical rescue techniques.

Key Words: intubation, resuscitation, airway

BACKGROUND

Rapid sequence intubation (RSI) was developed as a means of handling the airway of a decompensating patient in the emergency department. It should be differentiated from rapid sequence induction, which is the classic anesthesia term used to describe the induction of anesthesia.[1] RSI is now a standard part of training in emergency medicine residencies[2] and is increasingly taught in pediatric resuscitation courses.

The goal of RSI is to take a patient from their starting level of consciousness to an unconscious, neuromuscularly blocked state and perform tracheal intubation without intervening positive-pressure ventilation. Because most emergency department patients are not fasting, these patients are at increased risk of aspiration if positive-pressure ventilation is performed before airway control, and air is allowed to enter the stomach. In most situations, correctly performed RSI allows a clinician to manage a patient's airway without positive-pressure ventilation until the endotracheal (ET) tube is secured in the patient's trachea. RSI also increases the chance of successful placement of the ET tube through relaxation of the patient's musculature by neuromuscular blockade and gives the clinician the ability to manage the physiologic response of the body to laryngoscopy by the addition of various pharmacologic agents.

PATIENT HISTORY

When assessing a child in respiratory distress, it is imperative to begin by obtaining a good history before intubation. The etiology of the patient's distress can greatly alter the medication used to initiate rapid sequence intubation, and a systematic means of obtaining a history will facilitate obtaining important facts quickly. A focused history can be obtained by remembering the AMPLE mnemonic (**A**llergies, **M**edications, **P**ast history, **L**ast meal, **E**vents leading to the need for intubation) outlined in the most recent PALS[3] guidelines. The AMPLE system enables a provider to obtain a quick, focused history that directs the choice of medications and other airway management decisions. Important specific historical points to ascertain are patient or family history of muscular dystrophy or malignant hyperthermia, patient history of renal disease, and possibility of head trauma. A good rule of thumb is to consider every patient as having a full stomach and therefore at risk for regurgitation and aspiration.

PREOXYGENATION

As soon as the need for intubation is recognized, assure that the patient is preoxygenated with 100% oxygen. This reduces the chance of rapid oxygen desaturation when intubation is attempted.

Preoxygenating a patient causes oxygen to replace nitrogen in the lungs and produces a functional residual capacity of O_2 that serves as an oxygen reservoir. A 95% washout of nitrogen will occur in just 2 minutes, giving the practitioner an additional 3 to 4 minutes of apnea before the patient becomes hypoxemic in patients who have maintained a normal functional residual capacity.[4] Although hypoxia is reduced with preoxygenation, hypercarbia still will develop. Clinicians must remember this especially when dealing with patients who have raised intracranial pressure where hypercarbia could be particularly harmful.

Preoxygenation can be accomplished by many means, but 100% oxygen delivered by nonrebreathing mask for

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5 minutes is the preferred method. If circumstances preclude the use of a full 5 minutes for preoxygenation, 8 vital capacity breaths with high-flow oxygen can achieve approximately the same apnea times in adults.[5] This technique is very difficult to achieve in infants and young children, because cooperation is required.

EQUIPMENT

While the patient is being preoxygenated, the necessary equipment for an RSI should be assembled. Essential equipment is listed in Table 1.

The size of the equipment varies from patient to patient, and various ways of predicting proper size have been developed. ET size can quickly be estimated by the following calculation: (16+ age)/4. Most experts choose uncuffed tubes in children younger than 8 years old, except in cases of severe lung disease. This is due to the subglottic portion of these patients being the tightest portion of the airway, which forms a seal with the uncuffed tube. Whether the currently used ''low pressure–high volume'' cuffed tubes increase airway complications in younger children is not known. Laryngoscope blade size is shown in Table 2. Some authors suggest KY jelly be placed on the tip of the ET tube before tube insertion to help facilitate tube placement.[6] Tube lubrication with KY jelly or other water-soluble gel has also been shown to decrease the incidence of pulmonary microaspiration, but whether this affects the incidence of complications such as pneumonia is not known.[7]

MEDICATIONS

Once the equipment is obtained, attention can be turned to the choice of drugs to initiate the procedure and proper positioning of the patient. Proper positioning entails placing the patient in the classic ''sniffing'' position with the neck slightly held in extension. The goal of positioning is to align the external auditory meatus with the anterior border of the shoulder. This can be more easily accomplished in infants and toddler patients by placing a towel roll beneath the shoulders. As young children have proportionally larger heads than adults, the towel increases the chances of successful intubation by aligning the airway-mouth axis. In older children and adolescents, a towel placed beneath the head will improve alignment.

TABLE 1. Essential Equipment for RSI

- Suction
- Functional intravenous access
- A 10-mL syringe to inflate the endotracheal tube balloon after tube placement
- Properly sized endotracheal tube and 1 size smaller and larger than expected available
- Properly sized stylette
- Bag valve mask with oxygen reservoir
- Functioning laryngoscope of proper size
- Secondary confirmation device (capnograph, colorimetric CO_2 detector or, in adolescents, an esophageal detector device)

TABLE 2. Laryngoscope Blade Size by Age[3]

Age	Laryngoscope Blade Size
Preterm infant	Miller 0
Term infant	Miller 0–1
6 months	Miller 0–1
1 year	Miller 1
2–10 years	Miller 2
	Macintosh 2
Adolescent	Miller 3
	Macintosh 3

Medications used in RSI can typically be divided into 2 categories: induction agents and neuromuscular blocking agents. The induction agents fall into many classifications, but all serve to sedate the patient to intubate. The most commonly used induction agents are the benzodiazepines (midazolam, lorazepam, and diazepam), thiopental, ketamine, etomidate, and the narcotics. Each has its advantages and disadvantages in specific clinical scenarios. All are given after the patient is preoxygenated but before any neuromuscular blockers are administered. The clinician must be familiar with the indications and common side effects of these medications and know when a situation calls for a specific agent. Clinical scenarios to keep in mind are the hypotensive patient, the patient with raised intracranial pressure, and the patient in status asthmaticus.

The benzodiazepines are sedative/hypnotic drugs often used in clinical practice to control seizure activity. They are efficient sedatives and amnestic agents but do not provide any pain control. Their rate of onset depends on the agent but midazolam (Versed) has the quickest onset and shortest duration of the group. Midazolam (Versed; 0.1 to 0.2 mg/kg IV) is extremely versatile and can be given via oral, intravenous, intramuscular, subcutaneous, and intranasal routes. The most common side effects with benzodiazepines are respiratory depression (most often seen with diazepam) and hypotension. The patient should be observed for a fall in blood pressure. For this reason, the benzodiazepines should be used with caution in patients with severe cardiovascular compromise such as those with septic shock or multiple trauma.

Thiopental (Pentothal; 3 to 5 mg/kg IV) is a barbiturate that has been commonly used as an induction agent in RSI.

It also can cause hypotension but is a very useful agent in protecting patients with increased intracranial pressure. It is the drug of choice in normotensive patients with isolated head injuries or raised intracranial pressures of infectious origin. It produces significant cardiovascular depression and should be avoided in patients with volume depletion or hypotension.

Ketamine (Ketalar; 1 to 2 mg/kg IV over 1 to 2 minutes) is a dissociative amnestic agent similar to the street-drug phencyclidine.[8] It induces a ''dissociative amnesia'' in patients, which is described as a sensation in which the mind is ''separated'' from the body. Ketamine increases the release of catecholamines, which helps thwart the usual bradycardia commonly seen in pediatric patients when the insertion of a laryngoscope causes vagal stimulation and helps to dilate the small airways through beta-2 receptor activation. Ketamine is very useful in patients with status asthmaticus but should not be used in patients at risk for increased intracranial pressure (ICP) as it tends to increase ICP secondary to the adrenergic surge. It should also be avoided in patients with a history of glaucoma due to the risk of raising the intraocular pressure. Furthermore, hypersalivation and emergence reactions consisting of visual and/or auditory hallucinations have been observed. Emergence reactions are most pronounced in adolescent females. Some experts report that combining ketamine with benzodiazepines reduces these reactions, although this has been called into question in children.[9]

Because of an increased risk of laryngospasm, ketamine is frequently avoided in procedural sedation in patients with upper airway disease.[10] However, when ketamine is used in RSI, a neuromuscular blocking agent is also given, so laryngospasm is avoided.[11]

Etomidate (Amidate; 0.2 to 0.3 mg/kg IV) is a more recent addition to the RSI armamentarium and is classified as an imidazole hypnotic agent. The benefit of using etomidate is that it does not cause either hypotension or an increase in intracranial pressure. This useful characteristic makes etomidate an ideal drug for the multitrauma patient at risk for closed head injury and hypotension, and these favorable hemodynamic benefits seem to extend even to young children.[12] Care must be taken, however, when using this drug in patients with adrenal suppression, as etomidate can cause further adrenal suppression by directly inhibiting the conversion of cortisol from 11-deoxycortisol in the adrenal gland. This phenomenon has been documented even after a single dose of etomidate, although its clinical significance is still unknown.[13]

Narcotics such as fentanyl (Sublimaze; 1 to 3 μg/kg slow IV) and morphine (0.05 to 0.1 mg/kg IV) have been used in the past for induction, but large doses are required to have significant sedative effects. They are sometimes combined with benzodiazepines. This combination causes a drop in systemic vascular resistance and therefore should be avoided in patients with cardiovascular compromise. For this reason, the other agents previously mentioned are preferred in the setting of RSI.

The paralytics can be divided into depolarizing and nondepolarizing agents. All work at the neuromuscular junction to paralyze the muscle. Succinylcholine (Anectine, Quelicin; 1.5 to 2 mg/kg IV) is the classic depolarizing agent and works to bind to the neuromuscular receptor and depolarize the fiber to render it immune to further stimulation. Its strengths are its quick onset (approximately 30 to 60 seconds) and short duration (5 to 10 minutes). It has been shown to induce a rise in potassium of approximately 0.5 to 1.0 mEq/L[14,15] and cause a slight increase in intracranial pressure as well as slightly increase airway secretions. It should, therefore, be used with caution in any patient at risk for hyperkalemia as succinylcholine-induced arrythmias are well documented.[14–20] It should be avoided in patients with a history of renal failure, paralysis, a significant burn older than 48 hours, or confined to bed. Because an undiagnosed myopathy may lead to respiratory failure and the need for RSI, some authorities recommend avoiding succinylcholine in pediatric patients, especially males.[21–24]

The rise of intracranial pressure by succinylcholine can be blunted by pretreatment of the patient with lidocaine (Xylocaine; 1.5 mg/kg IV) 3 minutes before the succinylcholine is administered. Lidocaine should be strongly considered in the management of patients at risk for increased intracranial pressures, although the exact mechanism by which the drug attenuates a rise in ICP is not definitely established.[25] Atropine (0.02 mg/kg IV) should be given to all patients under 5 years before inducing neuromuscular blockade to block the bradycardia secondary to vagal stimulation by laryngoscope blade insertion. Atropine also blocks the increased secretions caused by succinylcholine and ketamine. In the past, a nondepolarizing agent was also given at a low ''prefasciculating'' dose to patients with raised ICP in the pretreatment phase, but this practice is controversial and usually not recommended.[26] Muscle fasciculations after the administration of succinylcholine are much more pronounced in adults.

Panuronium (Pavulon; 0.1 mg/kg IV), rocuronium (Zemuron; 1.0 to 1.2 mg/kg IV), and vecuronium (Norcuron; 0.15 mg/kg IV) are the most commonly used nondepolarizing agents and bind to the neuromuscular receptor causing blockade but no depolarization. All act less quickly and last much longer than succinylcholine. Of these drugs, rocuronium has the fastest onset of action (60 to 90 seconds) with a duration of action of approximately 30 to 45 minutes. Pancuronium has the slowest onset and longest duration of action lasting up to 60 to 90 minutes. Mivacurium (0.15 to 0.25 mg/kg IV), another nondepolarizing agent, can also

be used in RSI. While this drug has an onset of action similar to the other nondepolarizers, its duration of action is only twice as long as succinylcholine.[25] Mivacurium causes histamine release and may cause hypotension,[27] but this side effect seems to be attenuated when the medication is given slowly over 30 seconds or more.[28]

There is no risk of raising potassium levels or intracranial pressure with these nondepolarizing agents making them ideal when succinylcholine is contraindicated. Due to their long duration of action, though, it is essential to have a secondary means of oxygenating and ventilating the patient close at hand in case the ET tube cannot be placed. In patients who are difficult to ventilate with a bag valve mask, a laryngeal mask airway (LMA) may be helpful to oxygenate and ventilate before repeat laryngoscopy.[29]

In RSI, it is particularly important to protect the patient's airway before neuromuscular blockade. This is accomplished by refraining from manually ventilating the patient while they are spontaneously breathing and by applying cricoid pressure after the sedation is given and throughout the administration of the paralytic. The cricoid pressure (also called the Sellick maneuver) is applied by having an assistant place his or her thumb and index finger on the patient's cricoid cartilage and applying light pressure posteriorly to obstruct the esophagus and help prevent aspiration in the event of emesis. The maneuver should be continued throughout the intubation procedure and not released until the tube is verified as being in place. Cricoid pressure can cause emesis in conscious patients, so this maneuver should be delayed until the patient is sedated.

TUBE INSERTION

When the drugs have been given and the patient becomes apneic, the mouth is opened carefully and the laryngoscope is inserted. The clinician must refrain from positioning the blade against the teeth or crushing the lips. The tube is then inserted and observed to pass between the vocal cords. When using a curved (Macintosh) blade, the tip is placed in the vallecula, while the straight blade (Miller) is used to lift the epiglottis.

Correct tube placement is verified by listening for breath sounds over both sides of the chest, watching for chest rise and fall, and the absence of breath sounds over the stomach. Secondary confirmation is accomplished through use of a colorimetric capnometer (EasyCap) or capnograph. When using a colorimetirc capnometer, note the color change from purple to yellow, and persistence of the yellow color after 6 breaths indicates the presence of carbon dioxide and proper placement; then, confirm the tube position radiographically with a chest radiograph. In cardiac arrest situations, detection of carbon dioxide with these devices may be altered by the lack of sufficient pulmonary blood flow and can lead to false negatives—lack of color change indicating esophageal placement when in fact the tube is properly placed.[30–32] Other confirmation devices used for esophageal detection such as a self-inflating rubber bulb or Toomey syringe have been shown to be both highly sensitive and highly specific for detection of esophageal intubation in adults.[30,33] These devices take advantage of the anatomic differences between the trachea's stiff rings of cartilage that resist collapse when air evacuation is performed and the easily collapsible esophagus. While the current PALS guidelines do not recommend routine use of an esophageal detector device (EDD) in infants and children, 2 recent studies by Sharieff et al[34,35] seem to indicate that EDDs have a high sensitivity and specificity in this patient population.

If breath sounds are absent on the left side, the tube was most likely inserted too deeply and was placed within the right lung main stem bronchus. Correct this by pulling the tube back 1 to 2 cm, depending on the size of the patient. The tip of the ET tube should lie just superior to the carina. The depth for correct insertion can be estimated by multiplying the tube size by 3 (eg, 15 cm for a 5.0 tube).

When the tube is in place and the patient is ventilating and oxygenating well, care must be taken to tie or tape the tube properly. It is important that if a tie is used, it is not placed too tightly around the neck, especially in patients with increased intracranial pressure, as this could cause partial obstruction of the jugular veins and increase the patient's ICP by impeding venous return from the brain.

RESCUE PROCEDURES

If RSI is induced and the patient is neuromuscularly blocked and the ET tube cannot be placed correctly, the airway must be established through other means. The first option is to ventilate the patient through use of a bag valve mask. Most patients can be ventilated until the neuromuscular blocker has worn off, and at the minimum, this technique can serve as a bridge to ventilate the patient until a definitive airway is established.

Another technique is the insertion of an LMA. Studies have demonstrated that an LMA can be used effectively to ventilate a patient with a difficult airway when tracheal intubation has failed.[29,36–38] The LMA consists of a tube with a small, inflatable mask attached to the distal end. It is inserted into the pharynx until it reaches resistance in the hypopharynx. The mask is then inflated, effectively sealing the hypopharynx and placing the distal portion of the tube just above the opening of the airway allowing proper ventilation to be performed. While an LMA does not provide complete protection against aspiration, data have indicated that they might protect more than bag valve mask in patients undergoing in-hospital cardiopulmonary resuscitation,[39] and their placement seems to be an easier skill to learn overall than ET intubation.[36,40,41]

If all else fails, a surgical procedure might be necessary to establish a patient's airway. In children older than 8 years, a surgical cricothyrotomy can be performed. This involves finding the cricothyroid membrane and making a vertical incision through the skin just cephalad to the membrane and extending the incision just caudal to it. The scalpel can then be used to make a lateral incision through the membrane and either the blade or the handle inserted and rotated to create a space large enough through which an ET tube can be passed. Commercially available sets such as the Melker set allows percutaneous insertion with a needle, followed by a dilator and cricothyrotomy tube.

In children under the age of 8 years, needle cricothyrotomy with jet insufflation is preferred, although this technique is fraught with complications in infants and young children. With needle jet insufflation, a 14-gauge catheter is inserted through the cricothyroid membrane, and then a 1-second burst of high-pressure oxygen is given followed by a 3- to 4-second period to allow for exhalation; this serves to oxygenate a patient but not adequately ventilate them. Retrograde intubation may be accomplished by inserting a needle through the cricothyroid membrane and directing a wire superiorly through the vocal cords and out of the mouth. An ET tube is then passed down over the wire into the trachea and the wire removed as the tube is advanced.

CONCLUSIONS

While management of a child who requires RSI can be technically difficult and mentally challenging, knowledge of proper techniques and alternatives can facilitate the procedure. Clinicians should have an alternative plan in mind in the event that an ET tube cannot be placed in a sedated, neuromuscularly blocked patient to avoid a disastrous outcome.

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