Critical review

State-of-the-art paediatric airway management

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Abstract

Introduction

The management of the paediatric airway has its own challenges compared to the adult airway. Recently, new tools have become available in managing airways during diagnostic tests and/or procedures. It is prudent for the paediatric provider to understand what the state-of-the-art is in regards to handling the airways in children and what strategies exist to address emergent issues that arise. The aim of this review was to discuss state-of-the-art paediatric airway management.

Conclusion

The principal goal of managing the paediatric airway is to maintain patency, in order to optimize oxygenation and ventilation. Careful evaluation needs to be performed in determining whether the administration of systemic analgesics and sedatives is safe in preparation for advanced airway procedures. The ideal paediatric respiratory condition to have a planned approach for is the 'Difficult Mask Ventilation' scenario.

Introduction

The management of the paediatric airway is typically straightforward, but, not infrequently, will require considerable knowledge and experience in dealing with children who are in severe respiratory distress or haemodynamically unstable. In fact, recent investigations of the neonatal intensive care and paediatric intensive care settings underscore the challenges

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involved with managing the paediatric airway[1–4]. This review provides the reader with the latest evidence on state-of-the-art paediatric airway management.

Discussion

The authors have referenced some of their own studies in this review. These referenced studies have been conducted in accordance with the Declaration of Helsinki (1964) and the protocols of these studies have been approved by the relevant ethics committees related to the institution in which they were performed. All human subjects, in these referenced studies, gave informed consent to participate in these studies.

Basic airway evaluation

The foundation of assessing the paediatric airway begins with a thorough and pertinent history (Table 1). The history can be particularly useful if the child has had prior breathing difficulties such as 'snoring' or other obstructive sleep patterns that could suggest an anatomical airway problem like adenoidal

and/or tonsillar hypertrophy. Frequent coughing, runny nose or 'colds' may offer insight into problems that may arise if a child is sedated. A history of hearing problems or ear anomalies is important due to their shared embryologic origin with airway structures. Certain craniofacial patterns such as Pierre Robin sequence or Treacher Collins syndrome are very well known to be associated with a difficult airway[5]. A group of medical conditions collectively known as mucopolysaccharidoses (e.g. Hurler's, Hunter's syndrome, etc.) are classically associated with challenging, if not impossible, airways to manage in an emergency[6,7]. Any trauma, specifically facial burn, craniofacial or neck injuries should be approached judiciously. Any history of irradiation of the soft tissue structures of the head and neck or concern for atlanto–axial instability should also be noted.

A complete physical examination should be performed with particular attention to craniofacial anomalies, the ability to open the mouth, neck flexibility, thyromental distance, jaw

Table 1 Pertinent history and physical findings in airway assessment	
History	Physical
Date and time of last meal and fluid intake	Ear anomalies
Snoring	Micrognathia (small jaw)
Nasal congestion or secretions	Mouth opening
Coughing spells	Thyromental distance
Elevated head or sitting up when sleeping	Neck flexion
Enlarged tonsils or adenoids	Mandible protrusion
Atlanto–axial instability	
History of irradiation	
Syndromes	
Pierre Robin Sequence	
Treacher Collins syndrome	
Goldenhar syndrome	
Mucopolysaccharidoses (e.g. Hurler's or Hunter's syndrome, etc.)	

mobility and the respiratory system. The size of the mouth opening is an indication of the ability to accommodate soft tissue structures such as the tongue while allowing airway devices (e.g. tracheal tubes) to be placed. The distance between the tip of the chin (mentum) to the most cephalad edge of the thyroid cartilage is known as the thyromental distance. Typically, if at least two of the patient's fingers can be placed within this area, it is predictive of sufficient space to displace the tongue if advanced airway management is indicated.

The range of motion of the patient's neck is important because proper alignment of the oropharyngeal space with the pharyngo–laryngeal axis facilitates uninterrupted air flow. Furthermore, if advanced airway intervention is indicated using direct laryngoscopy, then the ability to flex the neck optimises visualisation of the glottis. The mechanism of movement of the human mandible is a remarkably complex phenomenon. In regards to airway management, the ability to protrude the mandible forward is important in lifting the base of the tongue away from the posterior pharynx. The clinical techniques of the 'chin lift' or 'jaw thrust' exploit this 'protruding' characteristic of the mandible.

The status of the patient's respiratory system must be taken into consideration when assessing the airway. After all, if a patient becomes acutely hypoxic or haemodynamically unstable after induction of deep sedation or anaesthesia, then the time available to manage the airway effectively is significantly diminished. Invariably, 'trivial' nasal secretions or colds become problematic if they interfere with airway patency, trigger coughing spells or contribute to laryngospasm events. Patients with lung diseases characterised by poor compliance, such as, severe pneumonia or cystic fibrosis may be difficult to bag mask ventilate even when optimally sedated.

Anticipation of the difficult paediatric airway

The ability to respond to the difficult paediatric airway is just as important as trying to predict the problematic airway. Providers will inevitably be faced with a difficult paediatric airway with no preceding warning, despite performing an adequate history and physical examination. The initial goal of managing any airway is maintaining patency while facilitating sufficient oxygenation and ventilation.

Basic airway management

The fundamental physiological feature in maintaining a patent airway is to incorporate simultaneous neck flexion with either a chin lift or slight jaw thrust. This allows optimal alignment of the oral cavity, pharyngeal axis and tracheal axis, facilitating unobstructed air flow. In a sedated child, this basic manoeuvre is often all that is necessary to maintain the airway. Typically, a towel is used to support the base of the head for comfort, but in infants or small children, a small towel roll placed behind the shoulder blades can assist with proper airway alignment. On occasion, it may be necessary to incorporate adjuncts on the account of upper airway obstruction either from enlarged tonsils or a flaccid tongue. The commercially available airway adjuncts include nasopharyngeal and oropharyngeal airways.

Advanced airway management

Sedated vs. non-sedated patient

It is important to understand that after determining an advanced airway is necessary, a decision needs to be made on whether a patient is a safe candidate to be sedated. One of the key features of the Difficult Airway Algorithm guidelines from the American Society of Anaesthesiologists is to determine whether or not a patient should be kept awake or sedated during the intubation process[8]. In an emergency situation, the provider does not have the luxury of delaying advanced airway management (tracheal intubation or supraglottic airway placement). However, consideration should be given to applying local lidocaine spray to the pharynx with or without a sedative that has minimal impact on the respiratory drive.

Endotracheal intubation

Planning and preparation for an endotracheal intubation contributes to the success of a smooth and well-executed procedure. Steps to consider in the planning include initial patient positioning, pre-oxygenation, medication administration, laryngoscopy, endotracheal tube placement, confirmation and securing of the tube.

The paediatric patient is typically placed in the supine position with the provider managing the airway at the head of the bed. The patient is connected to a cardiorespiratory monitor along with a pulse oximetry probe prior to any medication administration. In a non-emergent situation, the child should have an empty stomach in order to avoid aspiration during the procedure. American Society of Anaesthesiologists guidelines recommend solid foods be avoided for 8 hours and oral fluid intake be held for at least 2 hours prior to an intubation attempt[9]. Recent studies have suggested that fasting for 4 hours after a light meal may be similar to the 6-hour fasting state in regards to gastric volume, but how this relates to aspiration risk is not clear[10]. A suctioning device should be ready for oral secretion management and the suctioning capability of the system tested prior to sedating the child. A Yankauer accessory tip is attached to the suctioning tubing and is preferable to a suctioning catheter due to its larger surface area and propensity to minimise soft tissue damage. In addition, steps are taken to immediately place either an orogastric or nasogastric tube after endotracheal intubation to deflate the stomach.

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The selection of an endotracheal tube is based on age and/or any anatomical features that may be known prior to an intubation attempt. When possible, cuffed endotracheal tubes are used to minimise aspiration and air leak during positive pressure ventilation. The determination of their size and depth of insertion is guided by the following formulas[11].

$$\text{Endotracheal tube (ETT) size} = \frac{4 + (\text{patient's age in years})}{4}$$

$$\text{Cuffed (ETT) size} = \frac{3 + (\text{patient's age in years})}{4}$$

$$\text{ETT position (cm) at lip} = 3 \times \text{ETT size (mm)}$$

$\Rightarrow$ For example,

4 mm ETT = 12 cm at the lip

The choice of a laryngoscope and blade is provider dependent. The laryngoscope can have either a thin, small circumference handle or a thick, large circumference handle. Short and thick handles are made to accommodate patients with large chests so the handle's range of motion is not hindered. The decision to use either a straight or curved blade again depends on the provider's experience. Both the blades are designed to assist the provider in visualising the supraglottic area and, in particular, the vocal cords which mark the entrance into the trachea. The straight laryngoscope blade (e.g. Miller blade) is designed to be placed posterior to the epiglottis so it can be lifted out of the line of vision during endotracheal tube insertion. The curved laryngoscope blade (e.g. Macintosh blade) is designed for the tip to be placed anterior to the epiglottis and into the vallecula allowing the median glossoepiglottic fold to be lifted, raising the epiglottis out of the line of vision.

Once these initial steps have been taken and everyone's role has been defined, the medications are administered. The choice of medications

depends on the patient's condition and age (Table 2). The analgesia and sedation strategy for airway management is similar to other procedures. The objective is to provide sufficient analgesia and sedation to keep the patient comfortable while optimising conditions for endotracheal intubation. This approach includes minimising any detrimental effects to oxygenation, ventilation, haemodynamics and other vital physiological functions. It is beyond the scope of this review to exhaustively review all the medications that can be used during endotracheal intubation. One approach is to have a medication plan depending on the main underlying medical condition after the patient has been assessed for any known medication intolerance or allergy (Table 2).

For infants with respiratory distress or failure who can be effectively bag mask ventilated, a combination of atropine, ketamine and rocuronium is a reasonable approach. The atropine is used to attenuate vagally-induced bradycardia during laryngoscopy and has the added effect of having antisialagogue properties. Ketamine is a dissociative anaesthetic agent with amnestic properties that has favourable haemodynamic effects due to its ability to cause endogenous catecholamine release.

In addition, it causes bronchodilation which is helpful in infants with reactive airways. Rocuronium is a non-depolarising paralytic agent that has a rapid onset, but which may last as long as 30–44 minutes[12]. In older children, combining midazolam along with ketamine may assist in blunting some of the emergence reactions associated with ketamine and it also has some amnestic properties as well. On the other hand, ketamine is known to have negative inotropic effects and some others have suggested using etomidate due to its minimal effects on blood pressure in patients with poor cardiac function. These medications have been used for endotracheal intubation in children and suggested doses are typically available (Table 3)[11].

Table 2	Candidate medications for paediatric clinical scenarios		
Condition	Infant	1–8 years	Greater than 8 years of age
Respiratory distress or failure	Atropine Ketamine Rocuronium	Midazolam Ketamine Rocuronium	Midazolam Ketamine Rocuronium
Increased intracranial pressure concerns	Atropine Fentanyl Rocuronium	Atropine Lidocaine Propofol Rocuronium	Atropine Lidocaine Propofol Rocuronium
Haemodynamic instability	Atropine Ketamine Rocuronium	Ketamine Rocuronium	Ketamine Rocuronium

Note: Benefits and risks of medications need to be carefully weighed for each individual patient.

Table 3	Medication dosages
Medication	Dosage
Atropine	0.02 mg/kg IM/IV/ET (maximum = 1 mg)
Lidocaine	1 mg/kg bolus IV/IO/ET
Midazolam	0.1–0.3 mg/kg (maximum = 5 mg) IV
Fentanyl	2–5 micrograms/kg IV
Propofol	1–2 mg/kg IV
Rocuroium	1 mg/kg IV

Reference[11,16]

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Laryngeal mask airway

The laryngeal mask airway (LMA) is an ideal tool in certain paediatric airway scenarios, including an airway that could be managed without tracheal intubation or in a situation where the operator is unable to intubate the patient[13]. The LMA comes in various sizes based on weight range. The advantage of using the LMA is that it does not require a separate piece of equipment for placement, such as a laryngoscope. In addition, the provider is not required to directly visualise airway landmarks including the vocal cords and glottis to place the device. However, it does require training to become proficient in its use, but it is an invaluable skill to possess in emergency situations.

Paediatric airway algorithms

Difficult mask ventilation

A 'Difficult mask ventilation' situation is an ideal paediatric condition to have a planned approach for both the outpatient and inpatient setting since it occurs on a somewhat frequent basis (Figure 1). The most important principle that underlies the care of a paediatric patient that is difficult to provide mask ventilation to is the realisation that both functional and anatomical airway obstruction factors must be considered[14]. Thus, interventions that address both conditions must be utilised. Repositioning the head with emphasis on performing either a chin lift or jaw thrust is paramount as well as instituting two-person bag mask technique if indicated. If the patient is being sedated, the need to deepen the level of sedation must be evaluated for the given procedure. Airway adjuncts that may be very helpful in children who are difficult to mask and ventilate include nasopharyngeal and oral airways. They are both rigid devices that are designed to assist in lifting the base of the tongue anteriorly so the airway is patent between the posterior pharyngeal
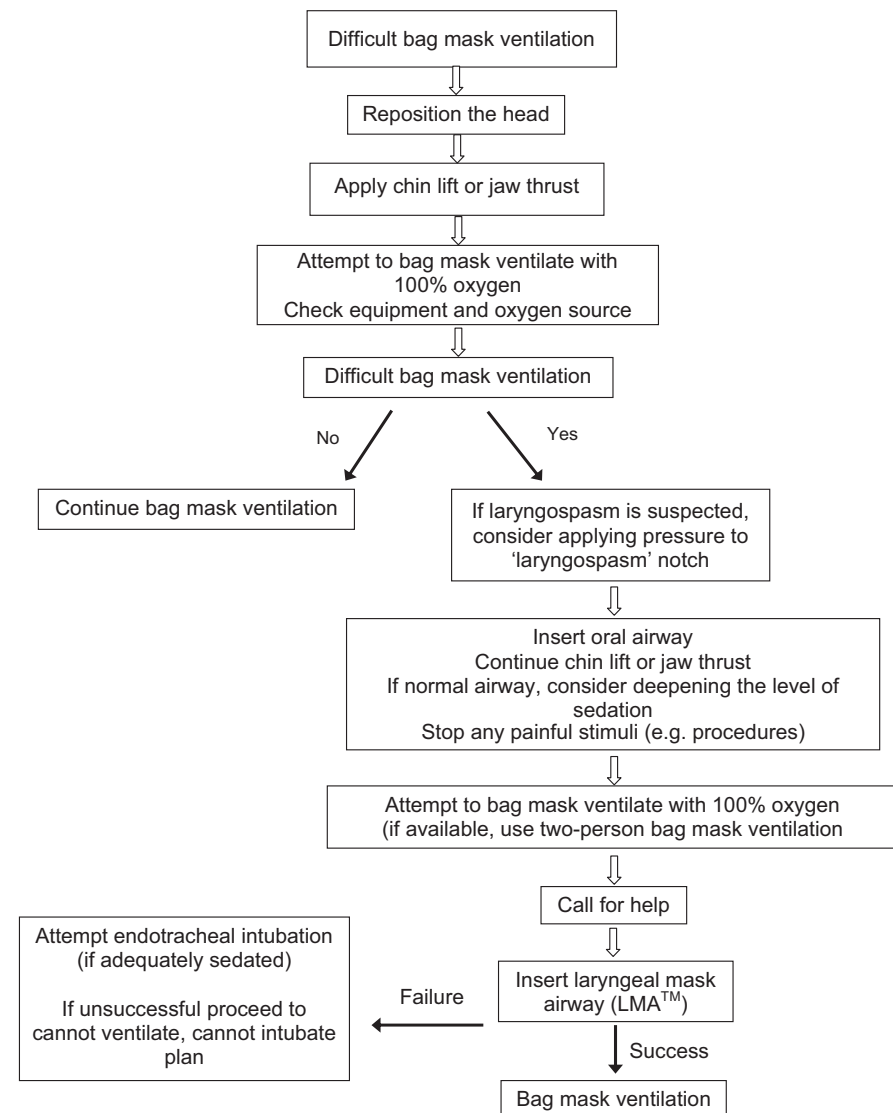

Figure 1: Difficult bag mask ventilation algorithm.

and tongue planes. The Association of Paediatric Anaesthetists of Great Britain and Ireland and the Difficult Airway Society have collaborated on a 'Difficult mask ventilation (MV)- during routine induction of anaesthesia in a child aged 1 to 8 years' guideline which is comprehensive and may be of interest to the non-anaesthesiologist[15].

Unanticipated difficult tracheal intubation

The unanticipated difficult paediatric airway understandably is one of

the most emotionally charged situations that will confront the clinician. Prompt repositioning of the head and clearing of the oropharynx are prudent under these scenarios. Ensuring that the patient is appropriately sedated is important if no prior expectation of a difficult airway was evident during the history and physical examination, and a functional obstruction may be occurring. It is generally recommended that no greater than two attempts at tracheal intubation by one expert provider be performed

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before considering the use of a supraglottic airway device, such as the LMA. If unsuccessful in establishing an airway and sufficient oxygenation and ventilation is not accomplished, then go to the 'cannot intubate cannot ventilate' algorithm.

Cannot intubate and cannot ventilate scenario

The 'cannot intubate cannot ventilate' paediatric patient is rare, but unfortunately will occur during a paediatric provider's career if he/she manages paediatric airways regularly. A 'cannot intubate and cannot ventilate' protocol needs to be individualised based on an institution's experience and resources. These scenarios emphasise the importance of a provider understanding and being aware of what rescue techniques are available at a given institution. The call for help to avail one or all of these resources is prudent and should not be delayed. The 'expert' at paediatric airways will vary in each setting, but knowing who will be able to provide a 'surgical airway' must be established and available. The use of a surgical airway is a critical decision and difficult even in the most experienced hands.

Conclusion

The principal goal of managing the paediatric airway is to maintain patency, in order to optimize oxygenation and ventilation. Careful evaluation needs to be performed in determining whether the administration of systemic analgesics and sedatives is safe in preparation for advanced airway procedures. The ideal paediatric respiratory condition to have a planned approach is the 'Difficult Mask Ventilation' scenario.

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