Review Article

Paediatric airway management: What is new?

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ABSTRACT

Airway management plays a pivotal role in Paediatric Anaesthesia. Over the last two decades many improvements in this area have helped us to overcome this final frontier. From an era where intubation with a conventional laryngoscope or blind nasal intubation was the only tool for airway management, we have come a long way. Today supraglottic airway devices have pride of place in the Operating Room and are becoming important airway devices used in routine procedures. Direct and indirect fibreoptic laryngoscopes and transtracheal devices help us overcome difficult and previously impossible airway situations. These developments mean that we need to update our knowledge on these devices. Also much of our basic understanding of the physiology and anatomy of the paediatric airway has changed. This article attempts to shed light on some of the most important advances/opinions in paediatric airway management like, cuffed endotracheal tubes, supraglottic airway devices, video laryngoscopes, rapid sequence intubation, the newly proposed algorithm for difficult airway management and the role of *Ex Utero* Intrapartum Treatment (EXIT) procedure in the management of the neonatal airway.

Key words: Cuffed endotracheal tubes, paediatric airway, video laryngoscopes

INTRODUCTION

A good airway management technique is an essential skill for the anaesthetists taking care of the children for surgery. The difficult airway is an important contributor to both patient morbidity and mortality. Significant advances in our understanding of the airway assessment, difficult airway algorithm, newer modes of airway management in children, and development of newer airway devices suitable for paediatric patients have occurred in the past decade. The changes have affected the perioperative management of paediatric patients and a review of these advances is warranted.

Cuffed endotracheal tubes

The use of cuffed endotracheal tubes in children has been a revolutionary change in Paediatric Anaesthesia. Cuffed endotracheal tubes (ETT) were once thought to cause mucosal ischaemia, and hence, post extubation, oedema and stridor. However, now, it has been shown that the modern low pressure high volume cuff does not cause mucosal ischaemia, and on the other hand, uncuffed tubes do not totally eliminate the risk of mucosal edema. Therefore, it is now accepted that this complication is rather a result of the poorly designed paediatric cuffed endotracheal tubes, which are just a miniature version of the bigger adult size tubes. The study by Newth[1] *et al*. has shown that there is no increase in morbidity with cuffed endotracheal tubes, even when used in sick children and in those with longer ventilator needs. Some even believe that cuffed ETT are safer.

With cuffed tubes, the tube exchange rate is drastically reduced from 25 to 2%.[2] This saves cost and time and also causes less trauma and intubation stress.[3] Cuffed ETT helps in reducing the consumption of expensive volatile anaesthetics, making low flow anaesthesia possible. There is also reduced levels of gases and volatile anaesthetics in the Operating Room, and therefore, a decreased level of environmental pollutants.[3] Cuffed ETT helps in reliable lung function monitoring and capnography. This is important as hypocapnia has been found to have more detrimental effects on neonates than what has been thought earlier. Cuffed ETT also reduces pulmonary soiling.

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The few disadvantages associated with cuffed ETT, are clearly outweighed by their benefits. Cuffed ET tubes are more expensive, but as they reduce the number of tube exchanges and consumption of volatile anaesthetics, they are ultimately more cost-effective. The inner diameter is smaller, causing an increase in the work of breathing and difficulty in tracheal suctioning. There are also some problems with the cuff design like a very high positioned cuff and absence of clear or wrong intubation depth marking.[4] Furthermore, as active over-inflation by Nitrous Oxide diffusion can cause laryngeal complications, constant and precise monitoring of cuff pressure is essential. We now have simple cuff pressure release valves or automated cuff inflators to control the cuff pressure. These disadvantages slowly being overcome, and with its benefits, cuffed ETT is now becoming an attractive option. The American Heart Association (AHA) and the International Liaison Committee on Resuscitation (ILCOR), in their 2005 guidelines, recommended the use of cuffed tubes in paediatric resuscitation and as an accepted alternative to uncuffed tubes.[5,6]

Video laryngoscopy: The future

Securing a patent airway in patients undergoing general anaesthesia is routinely performed using direct laryngoscopy with a Macintosh or Miller laryngoscope blade in children. However, successive intubation attempts to pass the vocal cords can have a tremendous impact on patient outcome. A good laryngeal view is often a prerequisite for successful intubation. It is quite evident from the medical literature that video laryngoscopy is gaining popularity as an airway device for a paediatric patient.[7] Some anaesthesiologists have incorporated the use of video laryngoscopy into their routine airway management of the paediatric patient. For others, video laryngoscopy may be reserved for a difficult paediatric airway. The impact of video laryngoscopy in airway management is significant and continues to grow.

The introduction of the technology of video laryngoscopy has provided anaesthesiologists with an all inclusive view of the airway. As video laryngoscopy offers an expanded and high resolution view of the airway it is rapidly becoming a part of the airway armamentarium. Several studies, correspondence and case reports demonstrate the successful use of video laryngoscopy among paediatric patients.[7,8] The evidence supporting the use of video laryngoscopy in the adult patient population is far more voluminous than that in the paediatric population.

Anaesthesiologists need to learn to intubate on the monitor, as it is an indirect intubation method. Video laryngoscopy offers the opportunity for others in the Operating Room to also look at the monitor, so that they know better what to do and the teacher can see what the intubator is doing during the act of intubation. Some video laryngoscopes have the extra modality of recording still images or video clips, which may be helpful if one wants to discuss the procedure afterwards. However, differences among video laryngoscopes do exist, as not all video laryngoscopes result in the same outcome. Some need extra adjuncts to intubate the patients. It is known that extra equipment, such as stylets, can result in damage to the oropharynx and larynx.

The available video laryngoscopes for airway management in paediatric practice are the GlideScope (Verathan Medical), C. Mac (Karl Storz), Truview (Truphatec), The McGRATH® Series 5 (LMA North America) and Pentax AWS (Pentax Co.). Airtraq is a cost-effective video laryngoscope successfully used in many difficult airways in children.[9] To date, there are more cases in the literature citing the use of the GlideScope in paediatric patients than any other.[8,10,11] However, at present, with the introduction of Miller 1 and D-blade in MAC3[12] size by the C-Mac, more of these video laryngoscopes are used in children.[13] Truview is also being used for managing difficult airways in children. Mcgrath 5 and Pentax AWS are used in adolescents, but their use in smaller infants and neonates has not been documented. Video laryngoscopy is shown to have promising features. We believe that video laryngoscopy will one day become a standard device used for all intubations, and not only for those predicted to be ‘difficult’. The ‘Difficult Airway Algorithm’ guidelines may have to be adjusted to include new tools in our practice.[14] As the laparoscope and thoracoscope are the future of surgical practice, it seems to us that a video laryngoscope is the future of airway management in anaesthetic practice.

Video laryngoscopes are best for oral intubation and require some mouth opening. Often the issues with them are fogging and blood and secretions obscuring the view. They all have a learning curve and often the problem is having an excellent view of the glottis, but having trouble advancing the tube into the trachea.

Supraglottic airways in children

Modern anaesthesia practice in children was made possible by the invention of the endotracheal tube (ET), which made lengthy and complex surgical procedures feasible without the disastrous complications of airway obstruction, aspiration of gastric contents, or asphyxia. For decades, endotracheal intubation or bag-and-mask ventilation were the mainstays of airway management. In 1983, this changed with the invention of the laryngeal mask airway (LMA), the first supraglottic airway device (SGA) that blended features of the facemask with those of the ET, providing ease of placement and hands-free maintenance, along with a relatively secure airway. The invention and development of the LMA, by Dr. Archie Brain, has had a significant impact on the practice of anaesthesia, management of the difficult airway and cardiopulmonary resuscitation in children and neonates.

Supraglottic airway management devices comprise a family of medical devices that facilitate oxygenation and ventilation without endotracheal intubation.[15] The word ‘supraglottic’ means ‘above the glottis’ or ‘above the larynx’. Some of the authors refer to these products as ‘extraglottic’ devices. Supraglottic airway devices have become prevalent in children because they are typically more user-friendly than a face mask and avoid many of the problems associated with endotracheal intubation.[16] The LMA Classic and the LMA ProSeal have an established record of safety and efficacy for routine cases in paediatric patients. The LMA ProSeal may provide a better airway seal and protection against aspiration than the LMA Classic. Over the last two decades, the enormous success of the LMA has been followed by the proliferation of other supraglottic airway devices, each claiming advantages over the devices already in use. Many new Supraglottic Airway Devices (SADs), with the exception of the ProSeal laryngeal mask airway (PLMA), appear to offer little or no benefit for the clinician or patient, over the existing ones; and evidence supporting their efficacy and safety is often absent or inadequate. The PLMA has yet to be outperformed by any other SAD, making it the premier SAD in children and the benchmark by which newer second generation devices must now be compared. The recently developed non-inflatable devices, the Streamlined Liner of the Pharynx Airway (SLIPA) and thei-gel, await more clinical trials to establish their suitability in children. In the quest for an ideal SAD, the newest devices that separate the alimentary and respiratory tracts are uniquely innovative. The routine use of SAD with gastric access may be evolving to a new standard of care.

Rapid sequence induction in paediatric anaesthesia

Rapid sequence induction (RSI) of anaesthesia is the ‘gold standard’ technique for preventing aspiration of gastric contents, prior to the endotracheal intubation of unfasted patients requiring emergency surgery.

Rapid sequence induction followed the introduction of suxamethonium, in 1951, and the description of cricoid pressure in adults by Sellick, in 1961.[17] The Confidential Enquiry into Maternal Mortality highlighted the danger of aspiration during Caesarean section in the UK, and RSI became the norm for all emergency surgeries. Salem subsequently reported the efficacy of cricoid pressure in children, in 1972.[18] At that time there were few alternatives for preventing aspiration, however, the risks associated with the use of suxamethonium, especially in children, have become apparent and with more agents available to improve the intubating conditions, many anaesthetists are avoiding the use of suxamethonium.[19]

Propofol[20] provides better induction characteristics than thiopentone for RSI. Propofol is often used in elective paediatric surgery, with a short-acting powerful opioid such as fentanyl for endotracheal intubation, without muscle relaxants. Sevoflurane is also used as a sole agent for induction and intubation in infants and children at low risk of aspiration.[21] However, the most important agents developed since the 1970s, to provide good intubating conditions with minimal side effects, have been non-depolarising neuromuscular blocking agents (NDMB). These have a quicker onset in infants and children compared to adults. Unfortunately, vecuronium, atracurium and mivacurium do not act as quickly as suxamethonium, and therefore, produce less reliable intubating conditions. ‘Priming’ doses have been used, but may expose the patient to unpleasant side effects and increased risk of aspiration. Rocuronium (rapid onset-curonium) provides excellent-to-good intubating conditions at 60 seconds and in simulated RSIs,[22] although it has a slower onset electrophysiologically, compared with suxamethonium. Rapacuronium, which has a very short electrophysiological onset and produces excellent intubating conditions, has been withdrawn 18 months after its introduction in the USA, because it could induce bronchospasm rarely.[23]

A novel chelating agent, Sugammedex, with a high specificity for Rocuronium, offers the potential for early reversal of an intubating dose of Rocuronium.[24]

Thus, at present, RSI, as described in adult practice, is less frequently used in children. Pre-oxygenation is more difficult because of non-compliance, especially in toddlers. Furthermore, although small infants need a shorter time to denitrogenate they also desaturate quicker when apnoeic.[25] The role of cricoid pressure is controversial, because of concerns that it leads to a fall in lower oesophageal sphincter tone, and inexperienced assistants may distort the airway making intubation more difficult, and the timing of and force required to be effective is uncertain. Brock-Utne has recently reviewed cricoid pressure in children and concluded that its most significant role is to ensure that an anaesthetic assistant is readily available to help the anaesthetist.[26] It is clear that 50-60%, of experienced paediatric anaesthetists do not use cricoid pressure in patients traditionally thought to be at risk of aspiration.[27] Despite these difficulties, aspiration during general anaesthesia in infants and children is a rare event. Warner relates the incidence of aspiration to gagging or coughing during airway manipulation when muscle relaxation has either not been present or inadequate.[28] Therefore, the indications for RSI have reduced; The concept of 'crash induction' is disappearing, certainly in paediatric practice, where there are few truly emergency surgical conditions. There is better training for anaesthetists and assistants, including the rationalisation of paediatric surgical and anaesthetic services.[29] Increasingly, senior clinicians are directly involved in the care of children, with better individualisation of anaesthesia to suit the child and the avoidance of dogmatic regimens of care. Traditional RSI may still be the 'gold standard' for emergency surgery associated with bowel obstruction or bleeding post tonsillectomy in children. Many experienced paediatric anaesthetists routinely adapt their technique to suit the individual patient and clinical setting, and may even avoid intubation altogether. The consequences can be catastrophic unless measures are readily available to achieve oxygenation and ventilation.[30]

Proposed algorithm for unanticipated difficult airway in children

The incidence of unanticipated difficult or failed airway in otherwise healthy children is rare and routine airway management in paediatric patients is easy in experienced hands. However, difficulty with airway management is one of the main causes of morbidity and mortality in the hands of non-paediatric anaesthesiologists. The airway problems in children are slightly different from those in adults and a protocol for managing an unexpected difficult airway in children has been proposed by Markus Weiss *et al*.[31] This proposal focuses on problems commonly encountered by non-paediatric anaesthesiologists. Although largely based on the adult difficult airway algorithm it includes three sections — A. Oxygenation and Ventilation, B. Tracheal intubation, C. Rescue. A and B have prevention and basic rules to overcome problems.

Oxygenation and ventilation

The basic rules to prevent failed Oxygenation/ Ventilation include assessment to rule out common problems, like anatomical problems, such as large adenoid/tonsils, which can be overcome by opening the mouth, two-hand face mask ventilation including jaw thrust, mouth opening and chin lift. We need to train anaesthesiologists in mask ventilation. The second important cause for failed oxygenation and ventilation is the need to identify functional airway problems[32] that are common in children (like inadequate depth of anaesthesia and laryngospasm in the upper airway and chest wall rigidity, bronchospasm and distended stomach). Early recognition and remedying of these in the form of deepening the anaesthetic and administering muscle relaxants would make face mask ventilation possible.[33]

The difference between paediatric and adult airway management in children is that, in children it is often oxygenation and ventilation that are problems rather than tracheal intubation.[34] Failed oxygenation is addressed by calling for help, attempting to visualize the glottis and passing the endotracheal tube. If this fails plan B involves LMA insertion and ventilation through it or attempting fibreoptic scopy through LMA.

The importance of learning mask ventilation and the ability to identify functional airway problems and their management cannot be overemphasized.

Tracheal intubation

The main concern during tracheal intubation in children is to use age-appropriate equipment and position for laryngoscopy. The larynx in a child is fairly mobile and can be moved with Optimum External Laryngeal Manipulation (OELM) to improve the laryngoscopic view. In the event of a failed tracheal intubation, alternative blades and techniques may be tried. Now there are video laryngoscopes available, which play a big role in unexpected paediatric difficult airway intubation. Fibreoptic intubation through LMA by itself is still the final frontier in a failed intubation scenario. Emergency cricothyroid puncture and surgical cricothyroidotomy is the emergency surgical procedure of choice,[35] if oxygenation/ventilation via facemask or LMA is not satisfactory.

Rescue

If oxygenation/ventilation cannot be maintained with a facemask/oropharynx airway/LMA or intubation–surgical tracheostomy may be done. For surgical tracheostomy we need a skilled ear, nose and throat (ENT) surgeon. Rigid bronchoscopy can also be used as a temporary surgical airway and the bronchoscope channel can be used to insert the tube exchanger and the endotracheal tube can be threaded over the exchanger. Finally, for successful difficult airway management in children, regular training and the instant availability of a suitable difficult airway trolley/bag in every anaesthetic department caring for the children is essential. No one should forget that unlike adults, children come in all shapes and sizes.

Ex-utero intrapartum treatment

Intrapartum ultrasonography permits the prenatal diagnosis of a number of problems, including, giant neck masses (teratomas, lymphangiomas) and congenital high airway obstruction syndrome.[36,37] Due to the time needed to secure an airway at the time of delivery, these conditions are generally fatal. The *ex-utero* intrapartum treatment (EXIT) is an approach that maintains uteroplacental respiration for the foetus at the time of delivery until the infant's airway can be secured and transtracheal oxygen delivery and carbon dioxide elimination established. Operation on placental support and airway management on placental support have also been used to describe the EXIT method.[37,38]

Performing tracheal intubation when foetal respiration is maintained, with an intact uteroplacental circulation, has been utilized since the early 1990s.[39] In addition, a variety of other procedures can be accomplished if needed.[40] The approach has been well-described in the paediatric surgical literature.[41] In a simple form, it involves delivery of the general anaesthetic to the mother using a technique designed to maintain uterine relaxation. A hysterotomy is then accomplished and the head, neck and shoulders of the foetus are delivered, while maintaining the chest and lower portion of the foetus within the uterus with an intact uteroplacental circulation. While the mother and foetus are continuously monitored, the infant's airway can be established nasally, orally, or surgically. Infants have been maintained on uteroplacental respiratory exchange using the EXIT method for 60 minutes, with good outcomes.

An EXIT procedure requires major organizational efforts.[42] At a minimum, a maternal anaesthesiologist, an obstetrician, a paediatric anaesthesiologist, a neonatologist and appropriate airway management physicians (second paediatric anaesthesiologist, paediatric otolaryngologist, paediatric surgeon) in addition to nurses, surgical technicians and respiratory therapists must be involved. A careful airway management plan should be designed and equipment and personnel for all eventualities should be available.

Extensive equipment preparation must be in order before the procedure. The salient points that must be kept in mind with this approach: (1) The obstetrician must work to deliver the foetal head in a direction that provides good access to the paediatric anaesthesiologist assigned to manage the foetal airway; (2) the pharynx and trachea are fluid-filled and remain so until after intubation and ventilation; (3) while the foetus remains well oxygenated from an *in-utero* perspective (critical *in-utero* Sp02 threshold is about 30%),[43] the tissue color at laryngoscopy is grayish–purple as opposed to the usual pink and occasional blue seen when conducting laryngoscopy; (4) to have a transport method including oxygenation, ventilation, monitoring and infant support ready for use after the airway is established; (5) to determine the desired depth of tube placement and keep a grip on the tube to maintain that depth until after the infant's face is cleaned of vernix and other fluids and the tube can be securely positioned. In summary, the EXIT procedure can provide 60 minutes or more of time, to allow for securing the foetal airway, prior to separation from the uteroplacental circulation. This can be a critically important time to have available for a foetus with severe neonatal airway obstruction. Careful planning, organization and cooperation are essential.

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