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ORIGINAL ARTICLE

Development of a guideline for the management of the unanticipated difficult airway in pediatric practice

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What is already known

- Pediatric airway management guidelines, produced from the available evidence base, are not currently available.

What this article adds

- This article collates the current evidence, the expertise of a dedicated Delphi panel, and the input of a second review panel to provide guidelines for the management of the unanticipated difficult airway in pediatric practice.
- Pictorial guidelines for three scenarios—difficult mask ventilation, difficult intubation, and CICV—are provided, and the justification for the design of each is addressed.

Implications for translation

- These guidelines can be used in any clinical context, will have a use in training, and can have a role in anesthesia, emergency care, and ICU.
- The pictorial guidelines were published on the APA and DAS websites in 2012.

Keywords
practice guidelines; pediatric anesthesia; supraglottic airway; intubation; intratracheal; cricothyroidotomy

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Summary

Background: Most airway problems in children are identified in advance; however, unanticipated difficulties can arise and may result in serious complications. Training for these sporadic events can be difficult. We identified the need for a structured guideline to improve clinical decision making in the acute situation and also to provide a guide for teaching.
Objective: Guidelines for airway management in adults are widely used; however, none have been previously devised for national use in children. We aimed to develop guidelines for the management of the unanticipated difficult pediatric airway for use by anesthetists working in the nonspecialist pediatric setting.
Method: We reviewed available guidelines used in individual hospitals. We also reviewed research into airway management in children and graded papers for the level of evidence according to agreed criteria. A Delphi panel comprising 27 independent consultant anesthetists considered the steps of the acute airway management guidelines to reach consensus on the best interventions to use and the order in which to use them. If following the literature review and Delphi feedback, there was insufficient evidence or lack of consensus, regarding inclusion of a particular point; this was reviewed by a Second Specialist Group comprising 10 pediatric anesthetists.

Results: Using the Delphi group's deliberations and feedback from the Second Specialist Group, we developed three guidelines for the acute airway management of children aged 1–8 years.
Conclusions: This paper provides the background, available evidence base, and justification for each step in the resultant guidelines and gives a rationale for their use.

Introduction

Successful management of the airway is the first priority when caring for sick, injured, or anesthetized children. The incidence of an unexpected difficult pediatric airway is low. Most children who have airways that are difficult to manage can be identified in advance; however, unanticipated difficulties in airway management do occur in children and may result in major morbidity and mortality (1).

Algorithms and guidance for the management of the adult airway have been available and used extensively since their publication by the ASA originally in 1993 (2) and the Difficult Airway Society (DAS) algorithm 2003 (3), but these adult guidelines are not designed for use in young children. Some anesthetic departments have modified various adult airway guidelines so as to be useful in the pediatric population and some examples have been published (4). The evidence base for management of the pediatric airway is limited and while recent work has provided some guidance (4), none are based on a recognized methodology.

Methods

The Association of Paediatric Anaesthetists of Great Britain and Ireland (APA) commissioned, and the DAS supported, a Working Group of anesthetic consultants to determine the clinical need for a specific national pediatric guideline for the management of the unanticipated difficult pediatric airway following induction of general anesthesia, and then to design such a guideline if indicated to do so. The target user group for the proposed guideline was defined as anesthetists, both trainees and consultants, who did not have regular pediatric practice, but who may be expected to anesthetize children on a sporadic basis (i.e., in a nonpediatric specialist setting such as a district general hospital). The Working Group comprised six anesthetic consultants, four of whom had specialist pediatric experience, one with an interest in pediatric anesthesia, and the remaining with a predominantly adult practice but with particular expertise in difficult airway management and guideline development, having been a prominent contributor to the 2004 adult DAS UK guideline (3).

The Working Group initiated an international survey, investigating whether a formal pediatric guideline would have clinical relevance and support, and identifying the existence of current pediatric airway management guidelines. Examples of guidelines in current use were collated. Each submitted guideline was critically assessed using the 'Appraisal of Guidelines for Research and Evaluation' (AGREE), collaboration instrument (5), and compared with the adult DAS UK guideline (3), the latter chosen as a comparator as its algorithmic structure was felt to be best suited to clinical practice. As a result of this survey, we determined that there was no existing pediatric guideline that satisfied the requirement for a simple, clear, and directed plan for management of the unanticipated difficult pediatric airway.

A literature review was done to ascertain the strength of available published evidence on the topic. This review revealed that there was insufficient quality data from randomized controlled trials on which to develop an evidence-based guideline. Therefore, a Delphi technique (6) was employed. Delphi uses expert consensus opinion, derived from careful consideration of all aspects of the guideline, so leading to agreed recommendations to be included in the final guideline. Members of a Delphi panel are required to give their independent opinion to each question and are advised not to confer with other panel members.

The Working Group established a separate panel of 27 consultant pediatric anesthetists, the 'Delphi Group', who undertook review of the airway management strategies using the Delphi process. This group comprised volunteers who responded to a request via the APA linkman system to take part in this project. It included anesthetists from 25 different hospitals in the UK and Ireland, who were from all types of hospital practice, and were able to commit to completing the Delphi process. The Delphi Group was asked to grade each step of an initial airway management algorithm. The individual steps were defined from the adult guideline (3).

The Delphi process allowed us to arrive at a conclusion on each point as to whether there was consensus (taken as 70% agreement across the panel), for or against the use of each step on the algorithm, and the level of consensus achieved (Table 1).

Table 1 Table for Delphi levels of consensus

C+ve	Consensus 'for' (≥70% respondents)
C−ve	Consensus 'against'
NC+ve	Near consensus 'for' (≥65% respondents)
NC−ve	Near consensus 'against'
TT+ve	Trend toward 'for' (≥50% respondents)
TT−ve	Trend toward 'against'
NOC	No consensus

The literature search provided papers relevant to each of the three clinical scenarios: firstly difficult mask ventilation (MV), secondly difficult intubation, and lastly cannot intubate and cannot ventilate (CICV). The six members of the Working Group worked in pairs to undertake reviewing and categorizing the literature related to one scenario. Each paper was further examined for their individual level of evidence by the pairs of authors responsible for each of the three clinical scenarios. After the initial assessment of each individual point by the Delphi Group, the Working Group circulated the literature review to the Delphi Group, to provide the available evidence-based information to support or refute each intervention. The evidence was used by the Delphi Group for further consideration of any points which still had not achieved sufficient consensus either for or against their inclusion in the relevant scenarios. In areas where there was both an absence of available evidence, and of Delphi consensus, a second invited panel of specialist pediatric anesthetists, (consisting of 10 experts and a chair, each from a different institution), the Second Specialist Group, were asked to provide expert opinion on these contentious topics. For each step in the final algorithms, we provide the supporting evidence from the above sources.

Results

The guidelines were developed for children from 1 to 8 years as there was strong consensus from the Delphi Group for this age banding and against including advice for those above 16 years. There was no clear consensus for the need for a separate guideline for the ages in-between. Using this methodology, the three separate scenario guidelines were developed. In all three guidelines, it is assumed that 100% oxygen will be administered and that immediate additional help has been requested.

The initial situation of the anesthetist having difficulty with providing adequate MV following induction of anesthesia in a child aged between 1 and 8 years was explored and the results were incorporated into guideline 1 (Figure 1).

Guideline 1: Difficult mask ventilation

The interventions used to achieve effective bag MV, and the order in which they should be used, have little published evidence base, although the incidence of unexpected difficult bag MV in children may be as high as 6% (7) (Figure 1). The Delphi process allowed each step to be considered not only just for efficacy but also to explore the order in which the individual adjustment would most usefully be made.

Step A

Step A takes account of three main areas of intervention: optimizing the head position, checking equipment, and ensuring an adequate depth of anesthesia.

Optimizing head position There was Delphi consensus that adjusting the airway by using a chin lift with or without a jaw thrust was useful in all ages. In children under 2, it has been shown that an increased tidal volume (VT) was achieved with this positioning (8). In addition to these maneuvers, use of the lateral position has also been shown to improve the airway in children with a known obstructive airway, due to adenotonsillar hypertrophy, as the airway size was increased with the combination of jaw thrust, chin lift, and the lateral position (9).

Delphi consensus was reached for the use of a shoulder roll in children <2 years of age, while a neutral position of the head was favored for those who were older.

It is known that in children, the degree of cricoid pressure exerted can inadvertently be such that the laryngeal inlet is distorted or occluded. In this circumstance, adjusting or even removing the cricoid pressure can be beneficial to achieve adequate ventilation. There was also consensus that using a two-handed technique for hand ventilation was useful to improve MV. Manikin studies have demonstrated an improved VT, although with a higher peak inspiratory pressure (PIP), when paramedics used a two-handed vs a one-handed MV technique (10). Specifically designed pediatric equipment has advantages in delivering better VT for a given PIP than adult equipment used in smaller patients (11).

Equipment It is standard practice to have checked all equipment prior to the induction of anesthesia. However, equipment failure is not uncommon and has been reported as a cause of failed ventilation (12). It has been recommended that when an anesthetist is unsure of the cause of difficulties with MV, it is reasonable to isolate the patient from the anesthetic equipment and revert to the use of a self-inflating bag for MV. It was of significant interest that although the Delphi had negative consensus on this and so refuted the idea of changing to

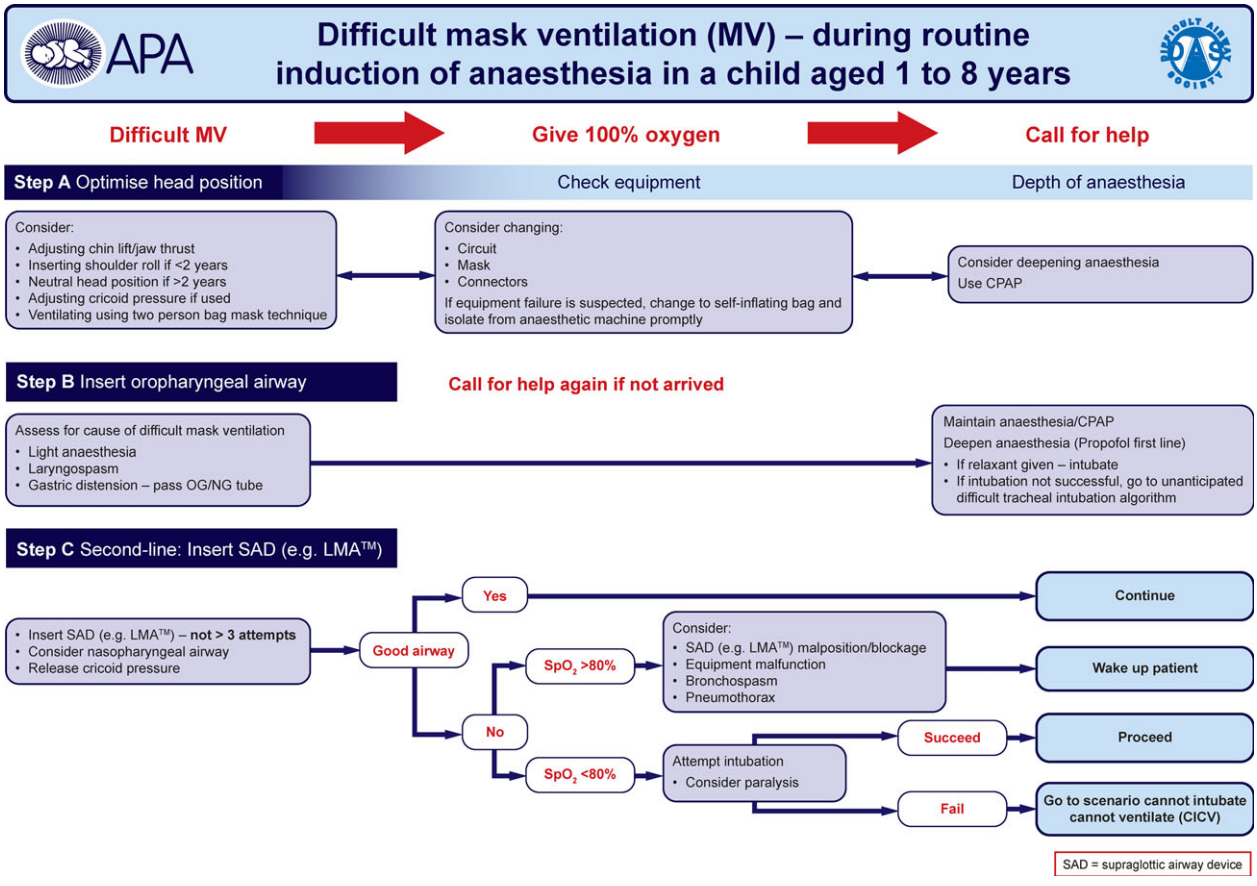

Figure 1 Guideline for the management of unanticipated difficult MV in a child 1–8 years resulting from Delphi analysis, literature review, and Second Specialist Group input.

a self-inflating bag, this response was specifically in the scenario, presented to the Delphi Group, of when equipment failure had been ruled out. However, in other circumstances when the clinical situation is evolving rapidly, and it may not be clear whether equipment failure is responsible for difficulty, it would be reasonable to isolate all current equipment from the patient, and change to a self-inflating bag and new angle piece.

There was positive consensus that common causes of difficult MV include insufficient depth of anesthesia, laryngospasm, and/or gastric distension and that these should be considered early. Often, the inability to adequately ventilate the child may be a result of these difficulties combined. Hence, deepening anesthesia and using continuous positive airway pressure (CPAP) should be early interventions started in step A and continued in step B.

Step B

Depth of anesthesia There was positive Delphi consensus that increasing the depth of anesthesia improves the success of ventilation and that the first intervention should be the insertion of an oropharyngeal airway. It was agreed that unexpected difficult MV is most likely due to a functional cause such as laryngospasm, inadequate depth of anesthesia, or poor positioning, as opposed to unidentified anatomical abnormalities. Laryngospasm is recognized as a cause of difficult ventilation following induction of anesthesia in the child. In the perioperative period, laryngospasm is commoner in children than in adults, the incidence may be up to 2%, and it is more common on emergence than on induction (13). Laryngospasm may be partial or complete. The causes are multifactorial, but may often be a result of inadequate depth of anesthesia or the presence of mild upper respiratory tract infection (13).

Various management scenarios were explored by the Delphi panel to determine the most appropriate management when laryngospasm was partial or complete and whether the intravenous (i.v.) access was, or was not, present. If there was partial laryngospasm, and i.v. access not yet established, there was consensus that the initial management recommended is to provide 100%

oxygen and CPAP followed by an increase in the depth of anesthesia by increasing the volatile anesthetic concentration. These adjustments are likely to be successful in the presence of partial laryngospasm, when there is at least some fresh gas flow entering the child, and in this clinical situation, when there is no i.v. access, there was no consensus from the Delphi group on the use of suxamethonium at this point.

It is sometimes suggested that, when there is no i.v. access, suxamethonium should be given by an alternative route in the emergency situation. This scenario was explored, but consensus was only achieved for using suxamethonium intramuscularly. Suxamethonium used either subcutaneously or via an intraosseous (IO) needle trended against consensus, while intralingual and sublingual had no consensus. These principles have been explored in the literature (14).

Although the use of rocuronium is recognized in the management of intubation and specifically in a rapid sequence induction in adults, its use in children is less widespread in the emergency situation. Rocuronium at a dose of 0.9–1.2 mg^{-1}. kg^{-1} is effective and work has shown that intramuscular doses, particularly if given in the deltoid muscle, are effective in producing laryngeal relaxation within 3 min (15). The use of intramuscular rocuronium, as an alternative to suxamethonium in this situation, was not supported by either the Delphi or the Second Specialist Group.

If the child has i.v. access, the Delphi panel felt that the airway management strategy for laryngospasm would be the same in starting with the application of CPAP and 100% oxygen, with use of a propofol bolus being strongly supported as the next step. Propofol has been recommended as a first-line strategy for the management of laryngospasm in a large case series in children (16). Use of suxamethonium in this situation did not reach consensus unless the situation had deteriorated such that the child's O_2 saturation was <70% and other measures had not helped. There has been recent debate that suxamethonium is now used so infrequently in routine pediatric practice that many practitioners would be inexperienced in its use, although a Cochrane review in 2008 favors its use to that of rocuronium for rapid sequence induction. (17).

The situation was clearer in the presence of complete laryngospasm and no gaseous flow, as with or without i.v. access, the combination of 100% oxygen, positive end expiratory pressure, and use of suxamethonium (by any route) was strongly agreed. Increasing the volatile agent was seen to be futile in this situation. When i.v. access was present, the early use of propofol was supported as the first choice in preference to suxamethonium. This results in the guideline recommendation to maintain anesthesia, 100% oxygen, CPAP, and the use of propofol as the first-line drug to deepen anesthesia.

Training in the management of laryngospasm is important. Training material developed for use in the simulator which addresses the clinical scenarios of both partial and complete laryngospasm explore the use of both suxamethonium and propofol (18).

Gastric distension Gastric distension is common in pediatric practice. Gases can easily enter the stomach, due to lax esophageal sphincters and the tendency, particularly if MV is difficult and there is an increase in PIP. Gastric distension results in further difficulty with MV due to splinting of the diaphragm. This has led to the common practice of using an oro- or naso-gastric tube for many pediatric cases. Gastric distension is most likely when prolonged or difficult facemask ventilation is used, or if high inflation pressures are used. When pediatric patients were ventilated with satisfactory placement of a supraglottic airway device (SAD), there was no difference in the amount of gastric distension as compared to a tracheal tube (TT); however, this has not been explored in the difficult airway scenario nor has the amount of gastric distension which occurs with ventilation via a facemask or SAD been explored (19).

If a muscle relaxant has been given, it is expected that MV would become easier; however, if this is not the case, then tracheal intubation would be the next step to be considered.

Step C

Use of a supraglottic airway device (SAD) There was clear consensus that the most appropriate second-line airway device is a SAD (e.g., laryngeal mask airway, either single use or Classic types). There was consensus that the use of a nasopharyngeal (NP) airway was not a first line strategy but there was a trend towards consensus for the use of a NP airway in the specific situation that there was insufficient mouth opening to allow use of an oral airway or a SAD. NP airways have been shown to be useful in pediatric airway management, and if carefully sized, are associated with a low incidence of complications; however, there was no clear consensus on their use, and the SAD was considered a superior choice if the oral airway was ineffective. There is an extensive literature supporting the use of the SAD in all ages (20,21) and many different models of SADs are available. Many are in clinical use in pediatrics (22) and some are reported to have advantages. Second-generation SADs allow better ventilation at lower PIP (23,24) and ease of placement or fixation (24), although second-generation devices such as the

ProSeal™ (Intavent, Venner Medical, Singapore) have not, at the time of the Delphi panel review, become established in pediatrics as a routine (25). Use of the SAD in the emergency setting has been reported as has their use in out-of-hospital situations when their ease of effective placement has been a significant advantage (26,27).

Successful placement of the SAD is a skill that can be rapidly acquired; however, there is a risk of misplacement, incorrect sizing, and local trauma associated with their use (28). In view of this, it is important that the number of insertion attempts is limited. The Delphi Group achieved consensus that at this stage, the maximum number of attempts should be three with negative consensus for any greater number of attempts.

If there is a failure to achieve a good airway, further action is guided by the oxygen saturation level. Having considered malposition, equipment malfunction, bronchospasm, and pneumothorax, if the oxygen saturation is >80%, a safe strategy would be to allow the child to wake up. There was feedback from the Second Specialist Group that minor transient decreases in oxygen saturation should not result in early abandonment of anesthesia. The Group felt that in many situations oxygenation could be rapidly and easily improved and should this be the case, it is reasonable, once the saturation has improved, to continue with anesthesia. As in many situations, this may be rapidly and easily resolved, and should that be the case, it is reasonable once the saturations have improved to continue.

If the oxygen saturation is <80%, there was strong consensus, in both the elective and emergency situation, that intubation should be attempted following paralysis. Successful intubation allows the procedure to be continued; however, if intubation attempts fail, this would lead to scenario 3 (CICV).

The Working Group next reviewed the literature, Delphi and Second Specialist Group input on the situation that, following induction of anesthesia in the child, the anesthetist while having adequate MV, has difficulty in achieving tracheal intubation. This resulted in Guideline 2 (Figure 2).

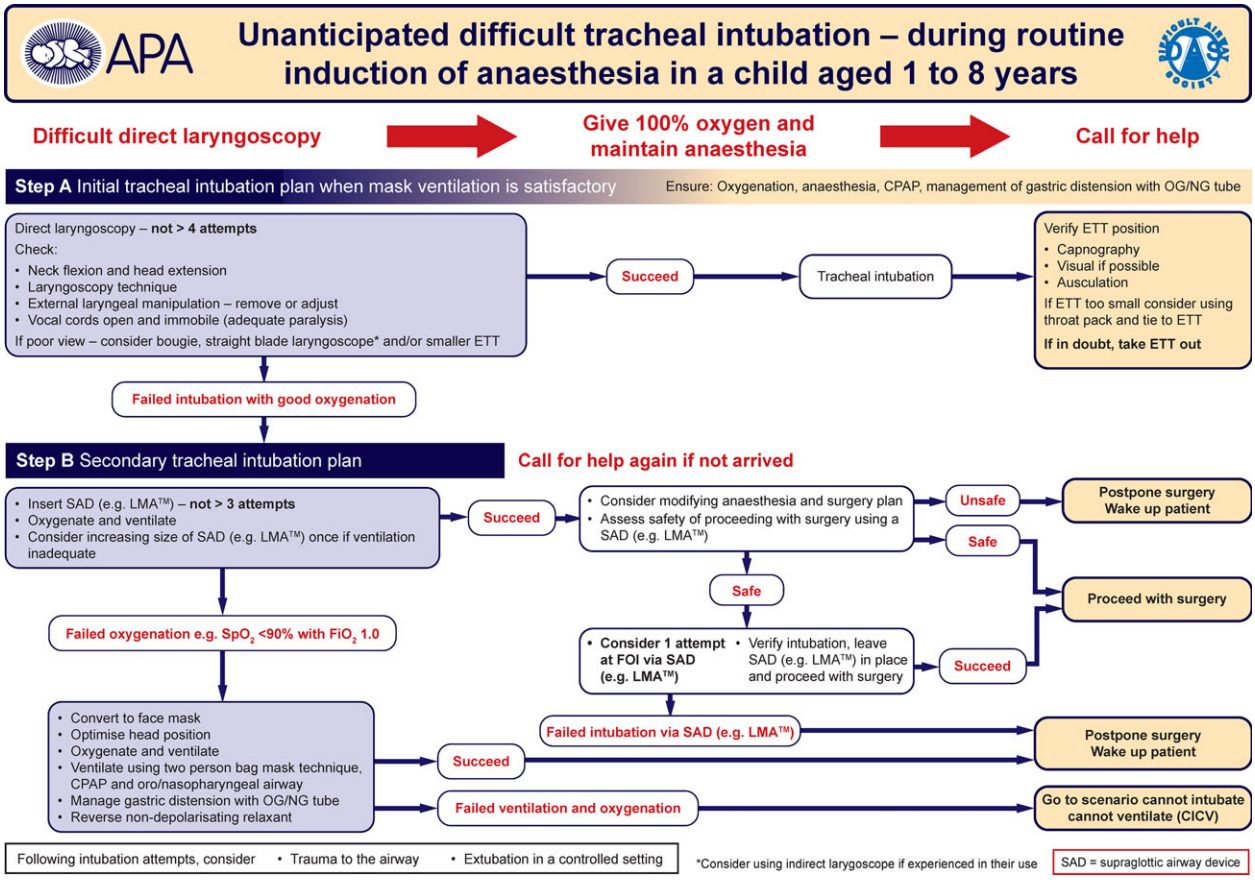

Figure 2 Guideline for the management of the unanticipated difficult tracheal intubation during routine induction of anesthesia in a child aged 1–8 years developed from feedback from the Delphi process, literature review, and input from the Second Specialist Group.

Guideline 2: Unanticipated difficult tracheal intubation during routine anesthesia in a child aged 1–8 years

The Delphi Group were asked to assume that before intubation is attempted, secure venous/IO access is present, full monitoring and appropriate assistance available, an orogastric, or nasogastric tube in place if indicated, and that there is adequate relaxation of the vocal cords (Figure 2). Good depth of anesthesia or paralysis is important to obtain the best view during direct laryngoscopy (29). The challenge in the child, particularly for the occasional pediatric anesthetist or trainee, may be that depth of anesthesia is insufficient leading to difficult intubation conditions, laryngeal spasm, and poor facemask ventilation. Maintenance of anesthesia throughout the whole scenario is also important to prevent awareness.

Step A

Initial intubation plan when MV is satisfactory There was Delphi consensus that when face MV remains easy, a specialist registrar (SpR) operator should call for help after the first failed intubation attempt, where the laryngoscopy is grade 3 or 4 in a child in the 1- to 3-year age group. This situation may occur relatively commonly, yet there are a finite number of attempts recommended at intubation (see below) and it is important to have the best help available early. Similarly, there was positive consensus from the Delphi panel recommending that a SpR or consultant operator should call for help from the most senior pediatric anesthetic colleague available after the second failed intubation attempt.

Number of intubation attempts The recommended maximum number of attempts at intubation is a difficult question both to study scientifically and to answer emphatically. Delphi had a trend toward consensus that the total number of attempts should be four in total from a consultant and trainee inclusive and total of two for a trainee. Overall, from the Delphi process, it was recommended that a third gentle attempt by a consultant may be reasonable with the proviso that good oxygenation was maintained.

Head and neck position Where the first direct laryngoscopy is difficult, optimizing the view by altering head and neck extension, laryngoscopy technique, and vector and external laryngeal manipulation are first-line management. The adjustment of head and neck extension with or without pillow and roll under the shoulders may improve intubating conditions. The Delphi process recommended that the optimum head position in children >2 years is the sniffing position and for children <2 years, head extension without elevation of the head (+/− roll under shoulders—the neutral position) provides optimal intubating conditions.

Laryngoscopy technique Much has been written about the laryngoscopy technique and vectors in adults but very little in children. A paraglossal approach has been successful in certain situations (30–32). However, there was no Delphi consensus for the use of this approach.

External laryngeal manipulation External laryngeal manipulation should be attempted in the first intubation attempt, where the laryngeal view is impaired (Delphi consensus positive). There is some support for this maneuver from the adult literature (33,34); however, laryngeal pressure can make intubating conditions worse in adults (35–39). In young children, the larynx may not only just be moved laterally as in adults making visualization of the cords difficult but also that the larynx or trachea may be distorted by excessive external pressure making intubation impossible. Early release or adjustment of cricoid pressure is recommended.

Laryngoscopes and adjuvants to aid intubation The use of the Macintosh laryngoscope from age 1 to 8 years was supported by the Delphi Group. Although there is little evidence in the literature, the Delphi reached near consensus (≥65% respondents) for the use of a straight blade in the 1- to 3-year age group, where there is a poor laryngeal view and there has been a failure to intubate using a Macintosh blade. However, there was a trend (>50%) against the use of a straight blade in the 3- to 8-year age group, and it is accepted that straight blade of an appropriate width and length may not be routinely available.

Use of different designs of laryngoscopes has been widely reported in the literature including Miller (31), Cardiff (40), video laryngoscope (41–43), Bullard (44), pediatric Glidescope (45–47), McCoy (48), Airtraq (49), and other devices (50). Newer indirect laryngoscopes are increasingly available for pediatric use. Although some of the evidence for their use is level 1, grade B, the low numbers and lack of consensus overall give little guidance as to the choice of these devices. No consensus emerged from the Delphi process on the use of a McCoy blade in children.

There was Delphi consensus supporting the use of bougies when there is a grade 1–4 laryngoscopy, with gum elastic preferable to single-use bougies. The possibility of blind intubation with a bougie, in the patient with grade 4 direct laryngoscopy view, was rejected for both 1- to 3 (trend toward consensus >50%) and 3- to 8-year (near consensus for >65%) age groups with

evidence from the Delphi process. The use of a blindly placed bougie in a patient with a grade 4 laryngoscopy was rejected by the Delphi panel in all age groups.

Endotracheal tube size The current formulae may under/overestimate pediatric TT sizes (51,52) and the anesthetist may initially select an incorrect size of TT, which may further complicate the difficult intubation scenario. We explored the use of a smaller tube after the first intubation attempt as well as the use of cuffed TTs in this situation (53–60). The Delphi consensus results recognized that a smaller tube may increase the success of intubation.

When exploring the use of cuffed TTs, there was no consensus about their use in the 1- to 3-year age group, but a near consensus for their use was acceptable in the 3- to 8-year age group. There was also agreement that the use of cuffed tubes may avoid the need to change them, because of incorrect sizing, and they are therefore more likely to be satisfactory for ventilation (56).

Successful intubation Verification of intubation is required; capnography is the established gold standard (61), alongside visualization of the cords when passing the TT. In the pediatric population, it is easier to unintentionally endobronchially intubate particularly in a difficult situation (62,63). If following placement of an uncuffed TT, there is an unacceptable leak and the initial intubation has been difficult, improved ventilation may be achieved by using a throat pack to decrease the leak ensuring that the pack is secured to the TT for safe removal on extubation. If there is any doubt about correct TT placement, the safest option is to remove the tube and maintain oxygenation via a facemask.

Step B

Secondary tracheal intubation plan At this point, the anesthetist would call for help again if it has not already arrived.

In the situation of having achieved adequate oxygenation but failed to intubate, there was strong consensus that the next step should be to insert a SAD. There was Delphi consensus that there should not be more than three attempts.

There are a number of different techniques reported in the literature to aid SAD insertion: with bougie (64), with laryngoscope (65), rotational insertion (66,67), part inflated (68), laterally inserted part inflated (69), and blind (70). Most of these relate to the classic laryngeal mask airway, but there is some limited evidence that the ProSeal™ is of use in children (24,70,71) and the Intubating Laryngeal Mask Airway, in children over 8 (42).

Once well positioned, the SAD allows maintenance of oxygenation and ventilation (72). If ventilation is inadequate, there was good Delphi consensus on increasing the size of SAD. Clearly, if the case can proceed safely using an SAD, then this could become part of the anesthetic plan.

If intubation is still necessary, fiberoptic intubation (FOI) via laryngeal mask airway was the only secondary intubation technique that was supported by positive consensus in Delphi. This technique is well reported (73,74). If a single-use laryngeal mask airway is available, rather than the classic laryngeal mask airway, it was agreed that this can still be used for FOI (Delphi consensus positive).

In the clinical situation where there is a satisfactorily placed SAD, cardiovascular stability, and adequate muscle relaxation, there was Delphi consensus recommending one attempt at FOI via SAD in the 3- to 8-year-old age group. The situation was not clear in the younger age group, 1–3 years; however, the Second Specialist Group agreed that if the anesthetist was trained in FOI in children and had the correct equipment available, they should attempt FOI using the SAD. There is agreement that this is not the time to use new equipment in this age group for the first time. If tracheal intubation is successful, verify intubation and proceed with the SAD *in situ* (75).

If there is a failure to intubate via SAD, then the procedure should be postponed and the patient woken up.

If following placement of the SAD there is inadequate oxygenation, i.e., SpO_2 <90% with FiO_2 1.0, then the SAD should be removed and facemask ventilation should be resumed—taking into account the recommendations of the difficult MV algorithm.

If at this stage oxygenation and ventilation is successful, it is wise to postpone surgery and wake the patient. In a child in whom intubation has failed, proceeding with surgery with a facemask/laryngeal mask airway (17,76–79) should only be considered if the surgery is immediately life or limb-saving. This particular situation was explored by the Delphi panel and there was positive consensus that it would be reasonable management in the 1- to 3-year age group with a trend to positive in the 3- to 8-year age group, acknowledging that there is a small risk of aspiration (80).

The final guideline was developed to consider the scenario of 'CICV' which is rare in children, particularly if clinically there has been no anticipated difficulty in airway management. The literature understandably contains a lack of good quality clinical evidence relating to this scenario in children. The NAP4 report 2011 included only five cases of children requiring an emergency surgical airway, of which two had predictable airway difficulties and only two were over 1 year of age (25). We used

the Delphi process to explore possible airway rescue techniques for CICV and also sought clarification of contentious points by the Second Specialist Group to decide which techniques were suitable to the pediatric population, taking into consideration both the expertise and general equipment likely to be available within UK non-specialist hospitals providing pediatric care. This information was incorporated into Guideline 3.

Cannot intubate and cannot ventilate In exploring this scenario, it is assumed that the secure venous/IO access is present together with full monitoring, that the child has been given an adequate dose of neuromuscular blocking agent, and that all attempts at intubation by the most experienced senior anesthetist available have failed, with attempts at manual ventilation remaining inadequate (Figure 3).

Step A

Continue to attempt oxygenation and ventilation. While advanced airway rescue techniques are considered and prepared for, attempts at manual ventilation should be continued with optimizing maneuvers performed as outlined above.

Step B

Attempt wake up if SpO_2 >80% No evidence was found in the literature review to guide the anesthetist when an attempt at 'wake up' should be considered. The Delphi Group reached consensus in advising 'wake up', while continuing efforts to oxygenate and ventilate, when the child's oxygen saturations were 80% or greater, and there was no associated hemodynamic compromise (e.g., bradycardia). It is important to stress that in tandem with any attempts at 'wake up', active preparations should be made for rescue subglottic airway access in the event that the child's condition deteriorates.

The use of sugammadex, to facilitate 'wake up' in a paralyzed child, only achieved a trend toward consensus in favor of Delphi. However, the Second Specialist Group reached consensus that it should be given if

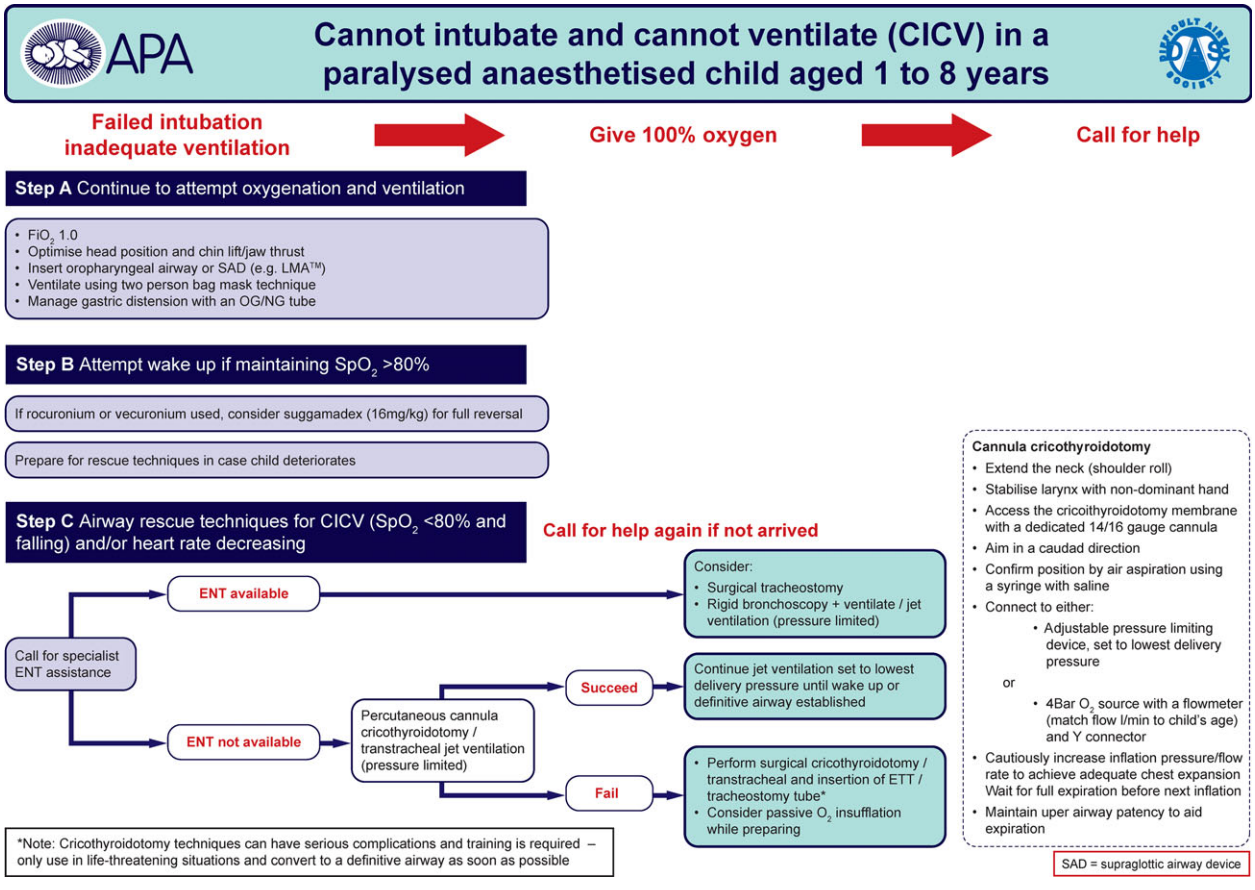

Figure 3 Guideline for the management of CICV when there is failure to intubate and failure to adequately ventilate an anesthetized and paralyzed child aged 1–8 years. This has been developed from input from the Delphi group, literature review, and input from the Second Specialist Group.

available, but not if the child is rapidly deteriorating with decreasing SpO_2 and hemodynamic compromise. In this circumstance, a surgical airway is the priority, and sugammadex use may interfere with rescue techniques and oxygenation. The reversal of neuromuscular blockade may take up time, as well as not guaranteeing a return to spontaneous ventilation, particularly where an anatomical cause of upper airway obstruction exists (e.g., Secondary to repeated attempts at tracheal intubation) (81–83). Its use is included in the CICV algorithm on the basis of the Delphi trend and Second Review Group comments, with the impression that it is justifiable in this critical airway management scenario, where the alternative rescue techniques have equally little evidence base.

Step C

Airway rescue techniques for CICV The Delphi Group were asked what criteria would indicate an immediate threat to the life of the child, and the need for attempts at subglottic airway rescue technique in this scenario, assuming that 'wake up' was deemed inappropriate or had failed. Delphi found consensus in favor of such techniques when the SpO_2 was <75% and decreasing and there was hemodynamic compromise, or the SpO_2 below 65%, in the absence of hemodynamic compromise. In both cases, it was assumed that attempts at ventilation with FiO_2 of 100% were continuing. These levels are in contrast to the DAS UK adult guidelines (3), where a SpO_2 of <90%, with increasing hypoxia, despite a FiO_2 of 100%, is the advised trigger. The Second Review Group's view was that the absolute SpO_2 levels were not as important as the recognition that despite all efforts, the child's oxygen saturations are still decreasing. Studies have shown that children's oxygen saturation decreases much faster than that of adults, due to a reduced functional residual capacity, and increased oxygen consumption, the younger the child, the shorter the apnea time to reach SpO_2 of 90% (83). Once below 90%, the oxygen saturation will rapidly decrease if ventilation fails, and the true SpO_2 will be less than the number displayed on the oximeter. It was the opinion of the Working Group that this discrepancy may reflect the unfamiliarity with the use of, and evidence for, such techniques in the pediatric population, as well as awareness of their practical difficulty and significant associated risks (84). A compromise of intervention with rescue techniques at a SpO_2 of 80% was agreed, to ensure airway optimization procedures as outlined above were attempted first.

Call for specialist ENT assistance The Delphi Group was asked to consider the next steps of the CICV scenario both with and without ENT assistance. If ENT specialists are available, a surgical tracheostomy is recommended. NAP4 highlighted the importance of readily available ENT specialist help in the setting of a child requiring an emergency rescue airway. Only four children reported to the NAP4 audit had an emergency airway attempted, three of which were managed successfully by ENT with emergency tracheostomy. There was only one case where a child had an emergency airway rescue technique performed by an anesthetist, and this was a needle/cannula cricothyroidotomy which was not successful. No surgical cricothyroidotomies by an anesthetist were reported in that audit (84).

Delphi also found consensus in promoting the use of rigid bronchoscopy with jet ventilation or standard ventilation, which is predominantly a technique restricted to specialist ENT personnel, instead of needle cricothyroidotomy (4,85).

The Delphi Group was also asked to consider the CICV scenario in the setting that ENT assistance was not immediately available.

The Delphi Group reached consensus in promoting percutaneous cannula cricothyroidotomy as the first-line technique for emergency airway access in the 1- to 8-year age group, although there was no consensus on whether the transtracheal route could also be used. Both access routes were felt to be equally applicable by the Second Specialist Group. The Delphi Group agreed that in the event of failure to site a percutaneous cannula cricothyroidotomy, or failure of subsequent oxygenation via it, the anesthetist should perform a surgical cricothyroidotomy or tracheostomy with placement of an appropriately sized endotracheal tube to allow ventilation, e.g., by connection to a standard self-inflating bag or anesthetic breathing system. This technique allows both oxygenation and ventilation via the TT, and can be used in the presence of upper airway obstruction.

ENT assistance should be sought as soon as they are available to attend as in the situation that a needle cricothyroidotomy has been successful, but "wake up" is not feasible, an ENT specialist is best placed to provide a definitive airway for longer term management.

There are two basic types of percutaneous cricothyroidotomy cannulas that can be used, either fine bore cannulas of <4 mm internal diameter or large bore cannulas of 4 mm or greater (86). The Delphi Group expressed a strong consensus in favor of the use of fine bore as opposed to large bore cricothyroidotomy cannulas in the 1- to 8-year age group.

Ventilation through a <4 mm ID cricothyroid/tracheotomy cannula requires the use of a high-pressure oxygen delivery source, such as an oxygen cylinder, common gas

outlet of an anesthetic machine, or wall-mounted oxygen flowmeters. All these provide a driving pressure of 400 kPa. The Delphi Group were asked about the use of three transtracheal jet ventilation systems, namely the Manujet III™ (VBM Medical, Sulz, Germany) and Sanders injector, both hand-triggered jet injectors employing pressure-regulated volume ventilation, and the use of wall-mounted oxygen flowmeters combined with oxygen tubing and a Y-connector [flow-adjusted volume ventilation—as described by the Advanced Life Support Group (ALSG)] (87). The Delphi reached consensus in supporting the use of the Manujet III™, which allows adjustment of the driving gas pressure between 0 and 400 kPa compared to the Sanders injector which has a fixed driving pressure of 400 kPa. The Delphi panel failed to reach any consensus as to whether the Sanders injector or wall-mounted oxygen flowmeters were suitable alternatives in the event of a Manujet III™ not being immediately available. The Second Review Group helped to clarify this situation, deciding that the nonpressure adjustable Sanders injector should not be used in children because of the increased risks of barotrauma particularly where upper airway patency is not assured; however, they did feel that the ALSG proposed wall-mounted oxygen flowmeters and Y-connector system was a valid alternative.

The literature seems to support the preferred use of the Manujet III™ for jet ventilation in this scenario when compared with both oxygen flowmeters and the Sanders injector. The Manujet III™ has been shown to be the only device capable of providing reliable ventilation and oxygenation, while at the same time providing a degree of extra safety by being capable of limiting both the driving pressure as well as the gas flow (87).

An implicit criterion for 'safe' transtracheal jet ventilation is the maintenance of upper airway patency, and therefore the guideline emphasizes the importance of this and suggests the use of an oropharyngeal airway or SAD to help facilitate it during jet ventilation. The ALSG recommends an active jet inflation to passive upper airway expiration time ratio of 1 : 4 s (87); however, it was the view of the Second Review Group that promoting a fixed ratio could distract the anesthetist from observing for adequate chest contraction (from passive expiration) before delivering the next gas jetting, risking barotrauma. Where a degree of upper airway obstruction exists, full passive expiration may be prolonged beyond 4 s.

The Manujet III™ has a driving pressure regulator, adjustable between 0 and 3.5 bar, adjusted for babies, children, and adults. The 'suitable range' for children aged 1–8 years is therefore not clearly defined from the 'adult' range. In common with all pressure-regulated volume ventilation injector devices, it can deliver high tidal volumes to small lung volumes with resultant dangerously elevated airway pressures (88). It was therefore the view of the Second Review Group that the injector should be initially set to the lowest possible delivery pressure, regardless of age, and then up-titrated slowly to achieve adequate chest expansion. In the case of the oxygen flowmeter and Y-connector delivery system, the Second Review Group agreed with the ALSG guidance (87), proposing an initial gas flow rate of 1 l min^{-1}. $year^{-1}$ of age, increasing in increments of 1 l if chest expansion is inadequate.

Oxygen injectors are unidirectional flow devices, incorporating a hand-trigger which allows the oxygen source to be stopped between delivery of jets. The wall-mounted oxygen flowmeter connected via oxygen tubing to the cricothyroid/tracheotomy cannula system is again unidirectional, but the incorporation of a Y-connector allows bidirectional flow and pressure release during patient passive expiration. The Second Review Group explicitly advised against the use of three-way stopcocks/valves in place of a Y-connector, as the 'released' side port of these devices does not allow sufficient inflation gas release and therefore can result in dangerously high cannula tip pressures (89).

Passive low-flow oxygen This was a controversial area. Animal studies have shown that temporary beneficial oxygenation may be achieved by passive low-flow oxygen insufflation, although rising $PaCO_2$ levels ultimately necessitate definitive ventilation to sustain life (90). The ALSG suggests its use in the CICV scenario where rescue percutaneous cricothyroid or tracheal access is achieved, but jet ventilation fails or is abandoned, e.g., because of upper airway obstruction. The Delphi Group ruled out its use as an alternative to jet ventilation when a jetting cannula had been successfully sited, but the Second Review Group felt that it was worth considering in the event of failed jet ventilation, while preparations for a surgical cricothyroidotomy are made; therefore, it is part of the guideline.

Ultimately, both transtracheal jet ventilation and passive oxygen insufflation are temporary measures, which must be accompanied by an action plan and preparations for either patient wake up and self-ventilation, if appropriate/feasible, or progressing onto a definitive airway, i.e., formal tracheostomy by specialist ENT personnel.

Discussion

There are situations and particular subgroups of patients that present known challenges with intubation;

however, outside these areas, difficult intubation in the pediatric population is extremely rare—0.045% in a study of 13 000 patients (91). The NAP4 report included few children, but it was striking from this audit that although few in number, the actual complications occurring in children were particularly serious and death occurred in three cases.

Unlike many guidelines which are developed using a good clinical evidence base, such as the pain management guidelines (92), there is little high-quality evidence available on pediatric airway management. Our literature search allowed us to use all relevant studies and incorporate them in a robust peer review process; however, we did not preclude any member of the Delphi panel accessing any other information they may have felt to be appropriate in furthering their decisions. Delphi is recognized to be an effective tool when consensus is required in the presence of equivocal evidence base. While it is possible for institutions to develop their own useful guidelines, we aimed to ensure these guidelines had a national and international relevance. Assessment of alternative guidelines in use against the AGREE criteria showed areas that justified the development of these guidelines.

Using the Delphi process enabled us to reach a consensus on the majority of algorithm steps, and those issues that required further exploration by the Second Specialist Group were usefully clarified. We aimed to make the membership of both advisory groups as broad as possible. The Delphi Group comprised of anesthetists who responded to a general request for input via the APA. While we recognize this may not have been truly representative of all areas of practice, given the level of commitment and time required, it was important to have a group committed to complete the process. The Second Specialist Group consisted similarly of volunteers who responded to the Linkman request from the APA, who are acknowledged experts in pediatric anesthesia. In the Delphi group, the anesthetists were from 25 different hospitals and the 11 members of the specialist group were all from different hospitals. This process allowed us to benefit from wide expertise and aimed to avoid significant institutional bias in airway management strategies.

It is the management of the unanticipated difficult pediatric airway that stands to benefit most from development of a straightforward plan. Unlike adults, in pediatric practice, most difficult airways are predictable, so the anesthetist is able to plan effectively and to organize appropriate help and equipment. We have not addressed the identification of the difficult pediatric airway in this paper, although there are good summaries available in the literature (93). Most anesthetists work in nonspecialist centers, and many ICU and emergency room doctors are the first responders to children requiring intubation in the emergency setting. While these guidelines were developed specifically for the nonspecialist anesthetist, it is expected that they will be of use more widely. In all scenarios, the anesthetist is advised to ask for help early if they are having any difficulty. It is important to call for the most appropriate expert help early; this may be another anesthetist or another person with pediatric airway experience such as an intensivist or an ENT colleague depending on the type of hospital. It was recommended in NAP4 (25) that if a patient's airway has previously been difficult to manage, it is important to ensure there is a written plan available by the child's bedside for an airway management strategy should that be needed in the future; similarly, good records should be kept and be readily accessible. As each area treating children should have an airway trolley and appropriate equipment, it is also important for each department to have a plan for whom to call for help, should an anesthetist need additional help in managing an unanticipated difficult pediatric airway.

The majority of the literature for pediatric airway issues is based on case reports or expert opinion; these do not represent higher grades of evidence; and the majority is related to management of predictably difficult airway cases—we excluded such papers from our results/analysis.

Inevitably, there is constant development of new airway equipment and departments tend to choose certain types of equipment relevant to their particular case mix and the enthusiasm of the local team. Departments provide training on their own collection of equipment. The development of numerous new indirect laryngoscopes is a case in point. We did not explore the relative merits of the many pieces of new equipment and various techniques available. Our feedback strongly supported using equipment the anesthetist is familiar with as the safest option when they are presented with an unexpected difficult airway following induction of anesthesia, while accepting that the future role of indirect laryngoscopes is likely to increase.

For consistency, the term SAD is used throughout. This reflects the large number of designs available in both first- and second-generation devices which may be of a single or reusable type.

The draft guidelines were posted on both the DAS and APA websites for 2 months for feedback prior to formal publication on both websites in 2012. This allowed widespread consultation. While the feedback was not used to alter the facts of the guidelines, which had undergone the robust development process, it was helpful to ensure clarity of the guidelines. We defined the age range as 1–8 years following consensus from Delphi, as adult guidelines developed by DAS and the ASA (2) were agreed to be acceptable above the age of

8 years. Similarly, infants were deemed beyond the scope of general pediatric guidelines. This is in keeping with the age banding of the Resuscitation guidelines in pediatric and adult practice (93). There were several areas that provoked considerable discussion.

Equipment isolation

It was of significant interest that although the Delphi had negative consensus and so refuted the idea of changing to a self-inflating bag, this was only in the scenario when equipment failure had been ruled out. In the rapidly evolving clinical situation, when it may not be clear whether equipment failure is responsible for difficulty, it would be reasonable to isolate all current equipment from the patient and change to a self-inflating bag and new angle piece. This is therefore included in the guideline.

Laryngospasm

The separate steps involved in managing laryngospasm were dissected out and addressed in depth. Laryngospasm, particularly when partial, is relatively common in pediatric practice. If it occurs soon after induction then vascular access may not be present. Previously use of suxamethonium was frequent and the practice of always drawing up an emergency dose commonplace. It was clear that the use of suxamethonium is on the wane and that propofol has become the first-line drug to use if i.v. access is present, while there was little current support for use of rocuronium, with sugammadex recovery, as these were considered to be infrequently used in most anesthetists' routine practice.

Number of attempts/task fixation

Delphi was extremely helpful in reaching consensus that the maximum number of attempts at SAD insertion is limited to three, direct laryngoscopy to four, and that one attempt at FOI via a well-positioned SAD is acceptable. This acknowledges the concern that task fixation can be very dangerous and provides an option for reassessment and change in plan when the current technique is not working.

Use of different equipment/newer techniques

To start using new techniques in an unexpected difficult intubation scenario may not be the best way of managing the situation. Utilizing well-honed techniques is the safest option, particularly as there is no great evidence that any special technique is of added benefit.

Levels of desaturation

We have used apparently didactic levels of oxygen saturation in all three guidelines and these were arrived at as the result of our Delphi questions. However, it is well known that saturation levels are, are in this situation, changing rapidly, and the monitor reading has an inevitable lag time so the actual number is of less relevance than the trend. For the purposes of both the Delphi questions and the guideline, it has been necessary to identify a clear level to prompt action.

Use of relaxants/sugammadex

Clinical use of suxamethonium has waned in recent years; however, the Delphi favored its use as first-line relaxant to facilitate ventilation and intubation. The use of rocuronium in this setting use was explored and consensus not reached. We suggest that this is because the use of sugammadex for reversal of the action of rocuronium has had little research in pediatrics. With increased clinical use of rocuronium, this may change. If there is the availability of sugammadex, this may be an advantage and hence its inclusion in the CICV scenario. Sugammadex has been studied in the pediatric population and has been shown to be useful when given in similar dosing regimens as that used in adults (94); it is only licensed in children over 2 years for the routine reversal of neuromuscular blockade induced by rocuronium (95). The immediate reversal of deep rocuronium-induced neuromuscular blockade using sugammadex has not been studied in children and is an unlicensed indication.

CICV

The management of CICV was an area of considerable contention and discussion, particularly from the Second Specialist Group. The resultant guidance is an amalgamation of information from both the Delphi and the Second Specialist Group.

CICV in pediatrics is very rarely a situation anesthetists find themselves in, and practicing for this eventuality is difficult. Simulator- and Manikin-based training is essential, although it is recognized that even high fidelity pediatric simulators do not always accurately replicate the real-life airway (96). Equipment for transtracheal techniques may be available in most anesthetic areas, but it is so rarely used that we believed it was important

to explore the options in some depth. The use of needle cricothyroidotomy and jet oxygenation is well established in adult emergency airway management (3). However, even in adults, it can be associated with significant complications, including surgical emphysema in cases of cannula misplacement, and pneumothorax and barotrauma where there is obstruction of the upper airway (97). It is believed that the pediatric population is at particular risk of these complications (4,98).

In young children, especially infants and neonates, the cricothyroid membrane is small and difficult to localize, often lying immediately under the mandible, making it a less than ideal site for emergency airway access (99). Needle tracheostomy is therefore commonly proposed in this age group as opposed to cricothyroidotomy (100), but the trachea is far smaller than in adults, more mobile, flaccid, and easily compressible, again making siting of a needle and cannula difficult and risking misplacement and posterior tracheal wall damage. Some experts suggest that percutaneous needle/cannula cricothyroidotomy/tracheostomy should not be used in children under the age of 6 years, preferring surgical cricothyroidotomy/tracheostomy (4); however, opinion is divided, with others promoting a percutaneous needle technique in younger children and reserving surgical cricothyroidotomy or tracheostomy for the postpubertal population, where the risk of damaging the cricoid cartilage is less (100). Many anesthetists are likely to be more adept at performing a percutaneous needle-based technique in the emergency scenario (100).

There are two basic types of percutaneous cricothyroidotomy cannulas that can be used—either fine bore cannulas of <4 mm internal diameter or large bore cannulas of 4 mm or greater (101). Examples of the former fine bore cannulas include the kink-resistant Patil (Cook) and Ravussin (VBM) cannulas. The ALSG has also supported the use of 14G intravenous cannulas in children (87), if specific cricothyroidotomy cannula-over-needles are not available. These fine bore cannulas require a high pressure oxygen source to allow jet ventilation, and the small cannula size means that passive exhalation via the cannula is not possible. Large bore percutaneous cricothyroidotomy cannulas include simple cannula-over-needle devices such as the VBM Quicktrach and Portex cricothyroidotomy kit, whereas others require a Seldinger technique, such as the Cook Melker. These larger cannulas can be connected to a standard anesthetic breathing system to allow ventilation, and for passive exhalation.

Work is needed in this area to look at the available equipment and techniques. It is likely that the present equipment needs updating (102) and bench testing in an animal model of various types of equipment may help us in deciding which techniques are more likely to be useful (103).

Conclusion

These guidelines reflect current expert consensus, advice, and published information on management of the pediatric airway. They have been developed to aid management in children with an unanticipated difficult airway and will be useful for teaching and training. They provide a validated structure to use in the unexpected situation and can be simply followed using familiar techniques and equipment. While it is difficult to do pediatric airway studies, it is important to increase our evidence base and provide information on pediatric airway techniques. Much interesting work has gone into the development of various SGA devices and newer TT, but there is scope for more research in the use of newer airway devices, such as video laryngoscopes in pediatric clinical practice.

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None declared.

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