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ORIGINAL ARTICLE

The emergency paediatric surgical airway

A systematic review

Lena Koers, Darja Janjatovic, Markus F. Stevens and Benedikt Preckel

BACKGROUND Although an emergency surgical airway is recommended in the guidelines for a paediatric cannot intubate, cannot oxygenate (CICO), there is currently no evidence regarding the best technique for this procedure.

OBJECTIVE To review the available literature on the paediatric emergency surgical airway to give recommendations for establishing a best practice for this procedure.

DESIGN Systematic review: Considering the nature of the original studies, a meta-analysis was not possible.

DATA SOURCES MEDLINE, EMBASE, Cochrane Central Register of Controlled Trials, Cumulative Index to Nursing and Allied Health Literature, Web of Science, Google Scholar and LILACS databases.

ELIGIBILITY CRITERIA Studies addressing the paediatric emergency surgical airway and reporting the following outcomes: time to tracheal access, success rate, complications and perceived ease of use of the technique were included. Data were reported using a Strengths, Weaknesses, Opportunities and Threats analysis. Strengths and Weaknesses describe the intrinsic (dis)advantages of the techniques. The opportunities and threats describe the (dis)advantage of the techniques in the setting of a paediatric CICO scenario.

RESULTS Five studies described four techniques: catheter over needle, wire-guided, cannula or scalpel technique. Mean time for placement of a definitive airway was 44 s for catheter over needle, 67.3 s for the cannula and 108.7 s for the scalpel technique. No time was reported for the wire-guided technique. Success rates were 43 (10/23), 100 (16/16), 56 (87/154) and 88% (51/58), respectively. Complication rates were 34 (3/10), 69 (11/16), 36 (55/151) and 38% (18/48), respectively. Analysis shows: catheter over needle, quick but with a high failure rate; wire-guided, high success rate but high complication rate; cannula, less complications but high failure rate; scalpel, high success rate but longer procedural time. The available data are limited and heterogeneous in terms of reported studies; thus, these results need to be interpreted with caution.

CONCLUSION The absence of best practice evidence necessitates further studies to provide a clear advice on best practice management for the paediatric emergency surgical airway in the CICO scenario.

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Background

Over the last few decades, airway-related deaths in anaesthesia have declined significantly by use of improved monitoring, training and the use of difficult airway algorithms. However, failed airway management and secondary hypoxia in children remains a significant cause of morbidity and mortality in paediatric anaesthesia and critical care.[1–5] Recently, several publications have emphasised the importance of a difficult intubation algorithm for children.[6,7] These guidelines provide anaesthesiologists with an invaluable framework during stressful, high-risk paediatric difficult airway scenarios. However, in spite of these guidelines, the major problem with

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From the Department of Anaesthesia, Academic Medical Centre, Amsterdam, The Netherlands (LK, MFS, BP) and Department of Anaesthesia, University Medical Centre, Ljubljana, Slovenia (DJ)

Correspondence to Dr. Markus F. Stevens, Department of Anaesthesiology, Academic Medical Centre, Meibergdreef 15, Amsterdam 1105 AZ, The Netherlands
E-mail: m.f.stevens@amc.uva.nl

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regards to the paediatric cannot intubate, cannot oxygenate (CICO) scenario is that there is currently no evidence regarding the best technique for performing a paediatric emergency surgical airway.

The true incidence of paediatric CICO is not known. The incidence of unexpected difficult endotracheal intubation is between 0.15 and 1.4%[8,9]; the need for a surgical airway extrapolated from these numbers will thus be very low. No absolute cut-offs for vital parameters can be given to indicate the need for establishing a surgical airway. However, ongoing deterioration with a continuing decline of oxygen saturation, bradycardia and ensuing haemodynamic compromise, in spite of all efforts to intubate or oxygenate the patient (i.e. laryngoscopy, fibreoptic or a supraglottic device and ongoing bag mask ventilation with 100% oxygen) and when waking up has failed or is deemed inappropriate because of the level of deterioration, indicates the need for a surgical approach.[6] Given that there is an intrinsic reluctance amongst anaesthetists to perform a surgical airway,[10] especially in the absence of evidence-based best practice recommendations, it is likely that there will be a significant delay or even inability to perform an emergency surgical airway in a paediatric CICO. This could ultimately result in serious patient harm and even death.

The aim of this study was to give an overview of current literature with regard to the best technique to perform a surgical airway in a paediatric CICO scenario.

Methods

Search strategy and study selection

A systematic review of the literature regarding the surgical airway in children in the CICO scenario was conducted. We included original studies that looked at performing a paediatric surgical airway technique, either in a human, animal or artificial model, and reported the following outcomes: time to tracheal access (defined as visual confirmation or presence of end tidal CO_2 and/or time to effective oxygenation or ventilation), the success rate, complications and perceived ease of use of the technique. Studies reporting on adult techniques were excluded because of the technical differences between a surgical airway in children and in adults. Two authors (LK and DJ) performed a comprehensive literature search using the MEDLINE, EMBASE, Cumulative Index to Nursing and Allied Health Literature, Web of Science, Cochrane Central Register of Controlled Trials, Google Scholar and LILACS databases with help of a clinical librarian at the authors institution. Search strategy included the terms:

[(airway) OR (Airway Management) OR (Intubation, Intratracheal) or (airway obstruction) or (difficult airway) OR (Respiratory Insufficiency) OR (Tracheostomy) AND (surgery) OR (anaesth*) or (anesth*) OR (cricothyreotomy) OR (trach)] AND [(Emergency Treatment) OR (Resuscitation) OR (emergen*) OR (problem*) OR (trauma) OR (acute) OR (life-threatening) OR (complication)] AND [(Child) OR (Pediatric*) OR (Paeditric*) OR (child*) OR (infan*) OR (neonate*) OR (newborn)].

We did not limit the search by language, publication status or publication date, as we expect the number of eligible studies to be limited. Additional literature was sought through hand searching via references of relevant articles, journals and authors known to be expert in the field, to identify further studies. Two review authors (LK and DJ) independently screened the titles and abstracts of all reports identified by electronic and manual searching. Articles that were evidently irrelevant were excluded at this stage. We retrieved and evaluated all potentially relevant studies, chosen by at least one review author, in full-text versions. Two review authors (LK and DJ) independently screened the full articles, identified relevant studies and assessed eligibility of studies for inclusion. We resolved disagreements on the eligibility of studies through discussion. A third review author was consulted (MFS) in case of disagreement. Details of irrelevant and thus excluded studies were recorded. Study identification and selection is summarised in the PRISMA flow diagram (Fig. 1).[11] Characteristics of the included studies can be found in Table 1. Study protocol and data coding sheets can be found as online Supplements, http://links.lww.com/EJA/A144.

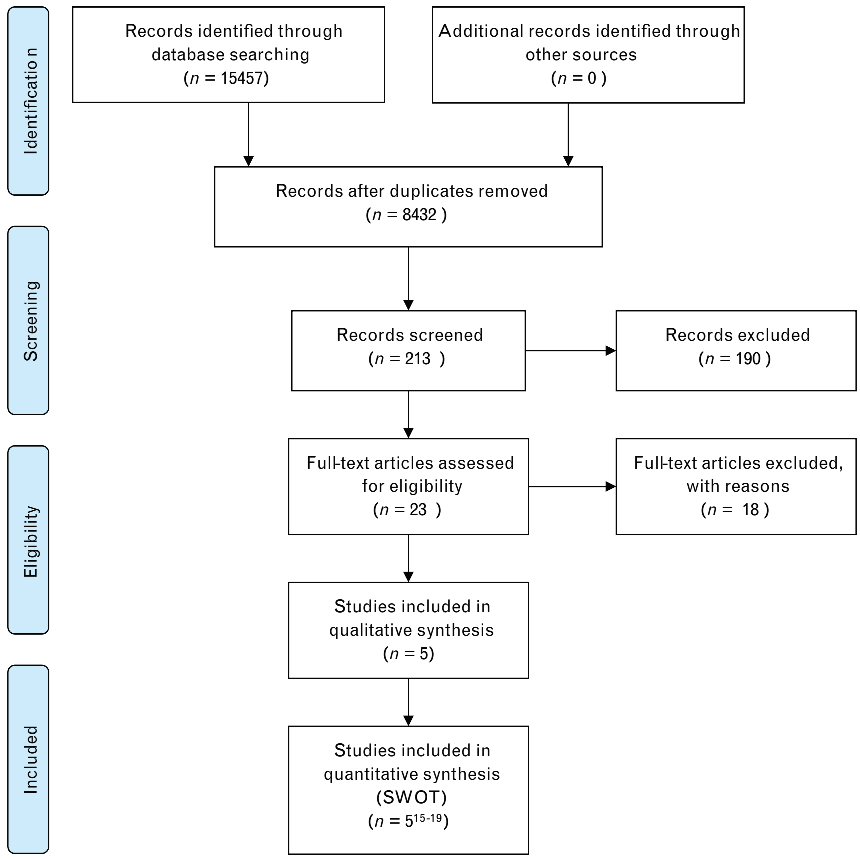
Assessment of study quality

Both review authors (LK and DJ) independently assessed risk of bias in the included studies using 'The Cochrane Collaboration's 'Risk of bias tool' outlined in Table 8.5c of the Cochrane Handbook for Systematic Reviews of Interventions.[12] The results of the risk of bias assessments of the included studies can be found in Table 2. Blinding was not appropriate due to the nature of the intervention, so this was not considered an insurmountable criterion. We used the ROBINS-I[13] for assessing the quality of the nonrandomised studies.

Data extraction and statistical analysis

During a pilot search, we identified that there were no high-quality randomised trials assessing the optimal devices used to perform a surgical airway. Due to the nature of these original studies it was therefore not possible to perform a meta-analysis. To organise the results in a meaningful way, data were reported as a SWOT-analysis to evaluate the strengths (S), weaknesses (W), opportunities (O) and threats (T) of the different surgical airway techniques in children. Strengths and weaknesses describe the intrinsic advantages and disadvantages of the techniques, respectively. The opportunities and threats describe the advantages and disadvantages of the techniques in the setting of a paediatric CICO scenario. We requested missing data from the authors of the original studies but did not receive

Fig. 1



Prisma flow diagram included studies.[11]

replies. We calculated the mean and SD from the reported medians and interquartile ranges (IQRs) by the method proposed by Wan *et al.*[14]

Results

From 144 potentially eligible studies, five[15–19] were included. These five studies described 251 interventions in both rabbit and piglet cadavers (range 3.2 to 8 kg). None of the studies retrieved involved human subjects. Four techniques were described: the catheter over needle (23 insertions), the wire-guided (16 insertions), cannula (154 insertions) and the scalpel technique (58 insertions). The catheter over needle technique is a technique with a plastic cannula inserted over a metal needle for direct placement in the trachea (for example Quicktrach baby). The puncture site was the cricothyroid membrane, which was palpated, the needle was then advanced at a 45° angle through the membrane, once air could be aspirated the device was advanced further and the cannula was slid into place over the needle. The metal needle was removed after insertion of the cannula.[17] The wire-guided insertion is a Seldinger technique. Although this technique was developed for use at the cricothyroid membrane, the included study used it below the cricothyroid membrane as in a tracheostomy.[18] The cannula technique is similar to the catheter over needle technique but uses a smaller diameter of plastic cannula and needle. Usually this is an intravenous cannula. Studies used a syringe and a percutaneous puncture of the trachea just below the cricoid cartilage at an angle of 45°. Aspiration of air was used to verify the position of the needle.[15,16,19] These three approaches are all blind techniques, in that the trachea is not visualised during the procedure, and confirmation of intratracheal placement is only possible at the end of the procedure with capnography and/or improvement of vital signs. The only open procedure is the scalpel technique. In one technique a vertical incision was made through the skin and the subcutaneous tissue from the upper part of the larynx to the sternal notch. The trachea was stabilised using a towel forceps and a vertical cut with sharp scissors made in the trachea 1 to 2 cm below the larynx to allow tube insertion.[15,16] In the other technique, the trachea was incised horizontally, and after turning the blade 90° to make space, a bougie was inserted facilitating tube placement.[18] All animals in the studies were placed supine and were supported in this position.[15–19]

Table 1 Characteristics of original studies

Refernce	Model (*n*, weight[a])	Study type	Intervention	Operator	Reported outcomes
Holm-Knudsen *et al.*[15]	(*n*=?) Piglet cadavers ±8 kg Tracheal Ø 10 mm	Randomised cross-over study	Insertion of 2 transtracheal cannulas Jet ventilation catheter for children (14 GA), VBM Medizintechnik GmbH, Sulz am Neckar, Germany BD Venflon Pro Safety (14 GA) Franklin Lakes, New Jersey, USA Tracheotomy Scalpel, scissors, 3 towel forceps, endotracheal tube	32 Anaesthesiologists median 12.5 (IQR 7 to 20) years of experience who attended paediatric difficult airway course	Time to tracheal access Success rate
Johansen *et al.*[16]	10 Piglet cadavers 8 kg Tracheal Ø 10 mm	Nonrandomised cross-over design	Insertion of transtracheal cannula BD Venflon Pro Safety (16/18 GA) Franklin Lakes, New Jersey, USA Tracheotomy Scalpel, scissors, 3 towel forceps, endotracheal tube	30 Physicians (10 for tracheotomy) who attended paediatric difficult airway course	Time to tracheal access Success rate
Metterlein *et al.*[17]	10 Rabbit cadavers 4.1 (IQR 3.5 to 5.4) kg Tracheal Ø 5.5 (5.1 to 6) mm Complications	Nonrandomised design[b]	Catheter-over-needle Quicktrach baby VBM Medizintechnik GmbH, Sulz am Neckar, Germany	2 (1st, 4th year) anaesthesia residents	Time to tracheal access Success rate
Prunty *et al.*[18]	8 Rabbit cadavers ±4 kg Tracheal Ø accomodating tube 3.5 to 4 (=4.5 to 5.5 mm) Complications	Randomised cross-over design	Wire guided (Seldinger) COOK 3.5 Melker Kit (Bloomington, Indiana, USA) Tracheotomy Scalpel, bougie, endotracheal tube	2 Consultant anaesthesiologists (experienced proceduralists)	Success rate
Stacey *et al.*[19]	5 Rabbit cadavers 3.9 (IQR 3.2 to 5.3) kg Tracheal Ø 3.5 (3 to 4) mm Complications Ease of use	Nonrandomised cross-over design	Insertion of 2 transtracheal cannulas BD Insyte (14 GA) Franklin Lakes, New Jersey, USA BD Insyte (18 GA) Franklin Lakes, New Jersey, USA Catheter-over-needle Quicktrach baby VBM	2 Consultant anaesthesiologists (experienced proceduralists)	Success rate

IQR, interquartile range. [a] Weight as reported by authors either as expressed as number in kg or median and interquartile range. [b] Study randomised on allocation of rabbits (albeit rabbit was standardised model), therefore considered as nonrandomised.

Time to tracheal access

One study reported time to tracheal access for the catheter over needle technique. Two intervals were reported; time for preparation of the procedure (from decision to perform a surgical airway to commencing the procedure) which was a median time of 12 [IQR 9 to 14] s and procedural time which was a median of 31 [23 to 43] s.[17] This resulted in a combined mean time of 44 s for the catheter over needle technique. The study on the wire-guided technique did not assess the outcome procedural time.[18] Two studies reported procedural times for three cannula techniques, which were a median of 69 [29 to 121], a median of 42 [26 to 121] and a median of 68 [35 to 95] s to insert a cannula into the trachea.[15,16] The mean time to insert an intratracheal cannula from these studies was 67.3 s.[15,16] Two studies reported time

Table 2 Risk of bias of original studies

Randomised interventional studies[a]	Random assignment	Allocation concealment	Blinding participants	Blinding outcome assessors	Incomplete outcome data	Selective reporting	Other bias
Holm-Knudsen *et al.*[15]	Unclear risk	Unclear risk	High risk	Unclear risk	Low risk	Low risk	Low risk
Prunty *et al.*[18]	Unclear risk	Unclear risk	High risk	Unclear risk	Low risk	Low risk	Low risk

Nonrandomised interventional studies[b]	Bias due to confounding	Bias due to participant selection	Bias in intervention classification	Bias due to deviations from intended interventions	Bias due to missing data	Bias in outcome measurement	Bias in selection reported result
Johansen *et al.*[16]	Moderate risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Metterlein *et al.*[c 17]	Moderate risk	Moderate risk	Low risk	Low risk	Low risk	Low risk	Low risk
Stacey *et al.*[19]	Moderate risk	Moderate risk	Low risk	Low risk	Moderate risk	Moderate risk	Low risk

[a] Higgins JPT, Altman DG, Gøtzsche PC, Jüni P, Moher D, Oxman AD *et al.* The Cochrane Collaboration's tool for assessing risk of bias in randomised trials BMJ 2011; 343: d5928. [b] Sterne Jonathan AC, Hernán Miguel A, Reeves Barnaby C, Savović Jelena, Berkman Nancy D, Viswanathan Meera *et al.* ROBINS-I: a tool for assessing risk of bias in nonrandomised studies of interventions BMJ 2016; 355: i4919. [c] Study randomised on allocation of rabbits (albeit rabbit was standardised model), therefore considered as nonrandomised.

outcomes for the scalpel technique, which were a median of 88 [76 to 128] and a median of 89 [71 to 200] s.[15,16] The mean time to perform a surgical airway with a scalpel was 108.7 s from these studies.[15,16]

Success rate

All studies that looked at the outcome time to tracheal access also defined a timeframe, wherein a device had to be in place, otherwise the procedure would be considered to have failed. The allowed time for a cannula technique was a maximum of 120 s,[15,16] for insertion of a catheter over needle technique this was a maximum of 180 s,[17] and for the scalpel technique this was 240 s.[15,16]

Reported success rates for the catheter over needle technique in which 10/10[17] and 0/13.[19] The overall success rate for the catheter over needle technique reported in the literature was 43% (10/23).[17,19] For the wire-guided technique, the reported rate was 100% (16/16).[18] The cannula technique had reported success rates of 21/32,[15] 22/32,[15] 8/30[16] and 36/60[19] giving a combined total of 56% (87/154).[15,16,19] Success rates for the scalpel technique in which 31/32,[15] 8/10[16] and 12/16[18] resulting in an overall success rate of 88% (51/58).[15,16,18]

Complications

Complications were recorded in the studies either by direct visualisation with bronchoscopy[15,17–19] or through anatomical examination.[17–19] Failure rates were not counted as complications as they are represented in the outcome 'success rate.' Complications described for the catheter over needle technique were one injury to the posterior wall of the tracheal mucosa[17] and two fractures of the cricothyroid cartilage with associated hematoma.[17] This resulted in a complication rate of 33% (3/10).[17] Studies assessing the wire-guided technique reported lateral and or posterior tracheal wall injury in 11/16 insertions accounting for a complication rate of 69%.[18] Complications secondary to intratracheal cannula insertion were tracheal perforations in 14/27 and 25/60 insertions,[15,19] vocal cord perforations in 2/37[15] and 14 misplacement of the catheter after 27 successful transtracheal placements.[15] This resulted in an overall complication rate of 36% (55/151).[15,19] Complications reported with the scalpel technique were a large tracheal defect with cartilaginous injury in 3/32[15] and 15/16 injuries to the posterior tracheal mucosa[18]: resulting in an overall complication rate of 38% (18/48).[15,18]

Perceived ease of the technique

Only one study reported on the ease of use of the cannula technique.[19] No significant differences in difficulties were reported between 18 and 14-gauge cannula use. However, data on this statement are not presented in the article.

Strengths, weaknesses, opportunities and threats analysis

Aggregated results for all studies can be found in Table 3. From the available evidence, the strength of the catheter over the needle technique is that it is fast which offers the advantage of establishing an airway rapidly in a paediatric CICO. The complication rate described is the lowest of all the techniques. However, it has a very high failure rate, so this technique has the disadvantage of a high likelihood of not being able to provide tracheal access at all. The wire-guided technique has a high first attempt success rate reported. Procedural time was not reported. The disadvantage of this technique is a high complication rate. The reported outcomes for the cannula technique indicate one of the lowest complication rates of all techniques. However, from the available evidence, this procedure has a high failure rate rendering uncertainty as to whether an airway can be established in a paediatric CICO. High success rates are described for the scalpel technique, complication rates are amongst the lowest among the four techniques. Reported procedural time is longer however.

Discussion

In general, there is a lack of high-quality evidence regarding the best technique for an emergency surgical airway in the management of a paediatric CICO crisis. There is no human data and the available data are heterogeneous and limited, thus these results need to be interpreted with caution.

The SWOT analysis of the five studies included in this systematic review[15–19] allows for the following conclusions:

The strength of the catheter over needle technique is that it is quick and offers the opportunity for rapid reestablishment of oxygenation and ventilation.[17] A weakness however is that it has a high failure rate; so, a threat of this technique is that it will fail to restore oxygenation and ventilation during a paediatric CICO.[17,19] Furthermore, the complications (i.e. tracheal wall injuries and fractures of the cricothyroid cartilage,

Table 3 **Aggregated results for mean time placement, success rate and complication rate for different surgical airway techniques from original studies**

	Mean time placement (s)	Success rate	Complication rate
Catheter over needle	44[17]	43% (10/23)[17,19]	34% (3/10)[17 a]
Wire-guided	Not reported[b]	100% (16/16)[18]	69% (11/16)[18]
Cannula	67.3[15,16]	56% (87/154)[15,16,19]	36% (55/151)[15,19]
Scalpel and bougie	108.7[15,16]	88% (51/58)[15,16,18]	38% (18/48)[15,19]

[a] Stacey *et al.*[19] did not report complication rate as failure rate was 100%. [b] No time was reported for the wire-guided technique.

tracheoesophageal fistula and secondary mediastinitis) described with this technique are significant[1] and can be life-threatening in themselves.

The strength of the wire-guided technique is the reported high success rate, offering the opportunity for effective reestablishment of oxygenation and ventilation.[18] However, this success rate is based on a limited number of insertions. The weakness of this technique is the high complication rate. There is no reported data on the insertion time for this device in the included studies. In an elective setting, the mean procedural time was 1200 ± 720 s in children[20] and 149.7 ± 44.2 s in 20 insertions in an emergency setting in adults.[21] This is a longer procedural time (in a technically less challenging airway) than any of the reported procedural times for the other three techniques presented in this study.

Strengths of the cannula technique are the low complication rates and the fact that this technique is well known through training in advanced paediatric life support courses. Furthermore, in terms of reversibility it has been suggested that a cannula technique allows for a second attempt at a surgical airway (any kind) more easily than a scalpel technique.[22] The opportunities of this technique are therefore the low complication rate and the lower threshold to perform the technique during a paediatric CICO. The major weakness of this technique is the high failure rate. It is, furthermore, only a temporising measure as it will not restore ventilation and hypercarbia will ensue. Complications like subcutaneous emphysema, pneumomediastinum and (tension) pneumothorax and lung injury can occur with the required oxygen flow rates even when cannula insertion in the trachea was successful, especially in children with a proximally obstructed airway.[23] There are reports, however, describing the use of the Ventrain device for emergency percutaneous transtracheal ventilation in critically obstructed airways as being able to provide effective oxygenation and ventilation at low airway pressures for at least 15 min.[24,25] Included studies also showed a 52% (14/27) dislocation rate after initial successful intratracheal positioning.[15] The major threat of this technique is failing to restore both oxygenation and ventilation with the superimposed risk of the above described complications when the technique is successfully performed.

Finally, the strength of the scalpel technique is its high success rate. It therefore offers the opportunity for effective reestablishment of oxygenation and ventilation. However, a weakness of this procedure is the longer procedural time and the potential for a high threshold for an anaesthetist to perform the procedure. Just as with the catheter over needle technique the complications described with this technique are significant (i.e. bleeding and tracheal injury)[17] and can be life-threatening themselves.

There were no data to comment on perceived ease of use of the different techniques.

A limitation of this study is that a quantitative assessment of publication bias was not performed due to the limited number of available studies. This study is further limited by the quality of evidence of available studies. It is questionable whether the animal models used in these studies make for robust translational simulations of the real-world paediatric CICO. The included studies used both postmortem rabbits and piglets. Most studies did not comment on the condition of their postmortem models. Two studies[15,17] specifically stated that they used fresh cadavers. However, in the cases in which the models had been frozen or embalmed prior to the study, the tissues would react very differently to the interventions. For instance, the tissues may be less elastic, rendering the incidence of inadvertent oesophageal puncture lower, and the incidence of cartilage fractures higher. Also, the amount of bleeding and haematoma interfering with the procedure cannot be properly determined with a postmortem model. Holm-Knudsen *et al.*[15] evaluated the similarity of their piglet model with the paediatric airway. The diameter of the trachea in the model was 10 mm which is similar to the diameter of a trachea of a 5 to 10 years old child.[26] The trachea was located 15 mm deeper and the larynx situated much lower in the neck than that of a younger child.[15] The studies using rabbit models[17–19] describe the diameter of the tracheas of their models as 3 to 6 mm similar to that of infants and children up to 2 years.[26,27] However, the external landmarks and hyoid to sternum distance are very different in rabbits versus young children. Also it is likely that children needing a surgical airway might present with anatomical abnormalities (i.e. malformations, tumours, swelling and or haematoma) which these models do not account for. Furthermore the surgical operators in the studies[15–19] range from 1st year anaesthesia trainees to difficult airway experts with 20 years of experience, and although this probably reflects reality, it makes it difficult to compare the success rates of the procedures.

There are several issues to consider for a paediatric CICO crisis. Anaesthetists are reluctant to perform a surgical airway procedure in general, let alone in children, due in part to the technical difficulty of the procedure. The identification of anatomical landmarks is troublesome due to the amount of subcutaneous fat and the hyoid bone and cricoid cartilages being often more prominent than the thyroid cartilage in children. The cricothyroid membrane in neonates is very small (about 2.6 to 3 mm)[28] and the larynx is high in the neck, so it can be difficult to have enough room to position the needle.[29] The paediatric trachea is also very mobile and compressible,[28] rendering inadvertent subcutaneous or oesophageal puncture and cannulation a likely complication, especially in techniques that require a blind, somewhat forceful puncture (catheter over needle, wire-guided and cannula techniques).[30] The reluctance to perform a surgical airway in children may also be due to the lack of training and lack of appropriate standardised equipment. There are no numbers on how much training would be required to safely perform a surgical airway in a child. To achieve an adult intubation success rate of 90% with direct laryngoscopy, anaesthetic trainees need to perform 60 endotracheal intubations.[31] Considering this, it is first of all questionable whether an airway failure rate of 10% is acceptable, and secondly, it is unlikely that anaesthesia trainees or even paediatric anaesthesiologists would receive similar training numbers in paediatric surgical airways. Equipment tailored to nonsurgeons is often percutaneous in hopes of lowering the threshold for performing the procedure. However, most of this equipment is designed for the adult airway. But even in the technically less challenging adult cricothyroidotomy, the NAP4 audit[32,33] found that the cannula technique had a failure rate of 65%. Some authors therefore advocate a scalpel technique in children under the age of 8 or suggest direct exposure of the cricothyroid membrane with a scalpel followed by cannulation under direct vision.[7]

Two case reports describe the need for a surgical airway in a child. Okada *et al.*[34] describe a case of a CICO in a 3-year-old boy presenting in cardiac arrest with an airway obstruction after anaphylaxis or angioedema. A surgical airway using a cannula technique did not seem feasible because there was not enough working space or an angle to perform the procedure through the cricothyroid membrane. A cricothyroidotomy was attempted with a scalpel and a tracheostomy tube with introducer (Mini-Trach II – Non Seldinger Kit; Smiths Medical, Minneapolis, Minnesota, USA); however, this failed because of the small size of the cricothyroid membrane (3 mm in length). A second insertion attempt below the cricoid after a vertical skin incision, blunt dissection to the trachea and an incision into the trachea resulted in the successful establishment of an airway. However, the child could not be revived after a total procedural time of 10 min. Santoro *et al.*[35] describe a case of CICO in a 4 years old boy with fibrodysplasia ossifcans progressiva after induction of general anaesthesia for a dislocated mandible secondary to temporomandibular joint disease. After all other attempts at achieving oxygenation were performed a cannula cricothyroidotomy was attempted by an Ear Nose and Throat (ENT) surgeon present in the operating room. However, this manoeuvre failed and a subsequent surgical tracheostomy was finally successful. Although there were no neurological sequelae in this child, he lost his ability to speak, likely due to the high placement of incision and large size of the tracheostomy tube. The authors from both case reports conclude that they would support the recommendation for an open surgical airway as a preferred rescue technique in the paediatric CICO.

The optimal technique for a paediatric surgical airway requires that it is rapid in establishing effective oxygenation (and ventilation) with minimal damage to the patients' tissues. Based on the available evidence, we are unable to recommend a specific surgical technique for performing an emergency surgical airway in children. An argument can be made for abandoning cricothyroidotomy in small children and performing a surgical airway below the cricothyroid membrane.[34,35] Ultimately, it is pivotal to formulate a local protocol and make a departmental decision on which equipment should be used for a paediatric CICO crisis. It should be stressed that training for unexpected difficult airway management is necessary to cover the basic knowledge and skills, such as optimal positioning, expert operating skills and role and use of muscle relaxants.[36] A differentiated algorithm for noninvasive difficult paediatric airway should also be followed.[7] However, if all other measures fail, we strongly believe that a child should not be allowed to die without an attempt at some form of surgical airway. Equipment for an emergency paediatric surgical airway should be standardised and available in a standardised (paediatric) difficult airway trolley allowing all materials to be found immediately during a CICO crisis. This is also described in the recent article by Sabato and Long[37] Expert help by an ENT specialist is often recommended in a paediatric CICO.[6,7] When formulating a local protocol on paediatric CICO, it should be taken into consideration whether ENT services are immediately available on a 24 h basis. The success of all techniques will likely increase and the reluctance to perform a surgical airway will decrease with regular training. Training should encompass both the technical skills for performing a surgical airway with the equipment of choice and the nontechnical skills to manage a paediatric CICO.

Conclusion

The absence of best practice evidence necessitates further studies in a standardised format to provide a clear advice on best practice management for the paediatric emergency surgical airway in the CICO crisis.

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