

Received Date : 16-Aug-2015

Revised Date : 13-Apr-2016

Accepted Date : 18-Apr-2016

Article type : Educational review (commissioned)

Handling Section Editor: Dr Mark Thomas

An Institutional Approach to the Management of the 'Can't Intubate, Can't Oxygenate' Emergency in Children

- Running Head: Paediatric CICO approach
- Article Category: Educational Review (commissioned)
- Authors: Stefano C Sabato^{1,2}, Elliot Long^{2,3,4}

Author affiliations:

1. Department of Anaesthesia and Pain Management, The Royal Children's Hospital Melbourne, Parkville, VIC, Australia.
 2. Murdoch Children's Research Institute, Parkville, VIC, Australia.
 3. Department of Emergency Medicine, The Royal Children's Hospital, Parkville, Victoria, Australia.
 4. Department of Pediatrics, Faculty of Medicine, Dentistry, and Health Sciences, University of Melbourne, Victoria, Australia.
- Corresponding author: Dr. Stefano Sabato. Department of Anaesthesia and Pain Management. The Royal Children's Hospital Melbourne, 52 Flemington Rd. Parkville, VIC 3052, Australia. stefan.sabato@rch.org.au
 - Questions:
 - What is already known? Though uncommon in children, The 'Can't Intubate Can't Oxygenate' emergency is associated with poor outcomes and death. Airway clinicians require the ability to rescue the airway percutaneously via the front of the neck to reduce morbidity and mortality.
 - What this article adds? Given the paucity of evidence to guide current practice, this article provides a practical approach to the paediatric 'Can't Intubate and Can't

This is the author manuscript accepted for publication and has undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record. Please cite this article as doi: [10.1111/pan.12926](https://doi.org/10.1111/pan.12926)

This article is protected by copyright. All rights reserved

Oxygenate' Emergency. This approach may be adopted directly by institutions or adapted to suit local equipment and expertise.

Abstract

The 'Can't Intubate Can't Oxygenate' Emergency is rare in children. Nevertheless, airway clinicians involved in paediatric airway management must be able to rescue the airway percutaneously through the front of the neck should this situation be encountered. Little evidence exists in children to guide rescue techniques, and extrapolation of adult evidence may be problematic due to anatomical differences. This document reviews the currently available evidence, and presents a practical approach to standardizing equipment, techniques, and training for managing the 'Can't Intubate Can't Oxygenate' emergency in children.

MESH compliant key words: pediatric; difficult airway; airway; airway obstruction; airway devices; tracheotomy; cricothyroidotomy; transtracheal

Key Learning Points

- 1) Preparation is the key to avoiding and managing the 'Can't Intubate, Can't Oxygenate' emergency. An approach, both cognitive and technical, must be prepared in advance. The team managing the airway must understand this approach. Adequate preparation of *one* technique is more important than *which* specific technique is employed.
- 2) Equipment to perform the chosen technique should be readily available, and require no assembly in an emergency.
- 3) Transtracheal oxygenation via a narrow bore cannula risks barotrauma and volutrauma. An understanding of the physics and limitations of the equipment used is required. The goal is oxygenation rather than ventilation.
- 4) Scalpel-based techniques risk significant airway trauma and may render the airway unsalvageable. Clinician hesitancy with the use of the scalpel may be overcome through training.
- 5) Recognition of the important differences between children and adults in the management of the 'Can't Intubate, Can't Oxygenate' emergency.
- 6) Direction and links to obtain further information on how to perform each technique.

Introduction

The 'Can't Intubate, Can't Oxygenate' (CICO) emergency is a rare event in general anaesthetic practice, and is even less common in children. Major audits of airway management have demonstrated poor survival when a CICO emergency is encountered.^{1,2} These audits have led to the development and revision of airway management algorithms to help avoid CICO situations, and manage them should they occur. Paediatric Airway Algorithms, including a CICO algorithm, were

jointly released by the Difficult Airway Society UK and the Association of Paediatric Anaesthetists in 2012. The Delphi process by which these guidelines were generated provides insight into their recommendations, and highlights the lack of clear evidence for guidance.³ However, specific instructions on how to perform these techniques in children, and with which equipment, have not been included in the algorithms, and are not available in the literature. Until such time that this area can be guided by research, a practical approach to the CICO scenario is required.

There are many terms to describe airway rescue during a CICO emergency, and this can create confusion. The phrases “Percutaneous Emergency Oxygenation”, “Percutaneous Emergency Airway Access”, “Infraglottic Airway Rescue”, “Front of Neck Access”, “Emergency Cricothyroidotomy”, and “Emergency Surgical Airway” have all been used in recent publications. “Surgical Airway” is particularly confusing as some authors use it solely to refer to scalpel-based rescue techniques, while others use it to refer to all rescue techniques. “Cricothyroidotomy” can also be misleading, as it does not encompass airway rescue techniques performed through the anterior tracheal wall distal to the cricothyroid membrane. This document uses the phrase “Front of Neck Access” (FONA) to encompass all cannula and scalpel rescue techniques via the cricothyroid membrane or anterior tracheal wall.

Case reports of deaths due to CICO emergencies describe situations where rescue attempts have been performed too late, or have not been performed at all. Successful rescue of the CICO Emergency requires not only the technical skill of the procedure, but also a strong set of non-technical skills.⁴ Analyses of these cases reveal multiple contributing factors into why emergency procedures were not performed at the appropriate time. These include: environmental factors such as lack of familiarity and availability of equipment, patient factors such as diagnostic uncertainty in an emergency, and operator factors such as unfamiliarity with crisis resource management principles.⁴ In particular, an airway clinician may fear declaring a CICO emergency as this can be seen as a “failure” of airway management. On the contrary, the only “failure” would be not attempting FONA when airway rescue is indicated. FONA is a skill that is almost never performed in routine clinical practice, and one that is rarely rehearsed during training. A rarely practiced skill leads to indecision and uncertainty in an emergency. This in turn may lead to attempts at FONA being delayed, or omitted.

Improvement in the performance of non-technical skills, and mitigation of human factor errors such as fixation, requires a standardised approach, equipment, and training within each institution. Immediately available pre-prepared CICO equipment packs, scenario-based simulation training involving all members of the team, and a standardised institutional approach to FONA techniques allow the airway clinician to perform airway rescue when necessary, and increases the likelihood of success.⁵ This document presents an approach to the equipment, techniques, and training for the CICO emergency in children that can be directly adopted or adapted by any institution.

Main Article

Cannula versus Knife: A review of the evidence.

Surgical tracheostomy performed by an Ear, Nose, and Throat surgeon in the event of a CICO emergency is ideal. In their absence, there is currently insufficient evidence to prescribe one specific FONA technique over another. The biggest debate, whether to use a scalpel, a narrow bore cannula (e.g. BD Insyte™ Cannula, or Cook Emergency Transtracheal Cannula), a larger bore catheter (e.g. Quicktrach), or an emergency cricothyroidotomy set (e.g. Cook Melker Emergency Cricothyrotomy Set) as the first approach to airway rescue, is still yet to be conclusively determined. Even within each of these four categories of equipment, there are many choices as to the technique one would employ, and the specific proprietary kit one would use. For example, the descriptions of scalpel based techniques in the CICO literature range from simple single horizontal incisions into the cricothyroid membrane (CTM) followed by insertion of a bougie, to procedures involving tissue hooks and stomal dilators.^{6,7}

The 4th National Audit Project (NAP4) of The Royal College of Anaesthetists and The Difficult Airway Society (DAS)⁸ recommend a scalpel technique in a CICO emergency unless experienced in other techniques. This opinion has been echoed in an editorial,⁹ and meta-analysis.¹⁰ However, the generalizability of these recommendations to children is problematic, as most available evidence comes from small heterogeneous adult studies.^{9,11} Also, detailed analysis of the individual cases in NAP4 where FONA was performed suggests that the inferior success rate of the cannula technique, compared with the scalpel, was due to the fact that a scalpel technique was employed in many cases that were not true CICO emergencies.¹² Weiss and Engelhardt also recommend a scalpel technique in all children, with the option of a cannula technique in patients over 8 years of age in their paediatric airway algorithm.¹³ However, this recommendation is based on a reported high risk of complications in a case series of 20 patients where high frequency transtracheal jet ventilation, via a cannula, was *successfully* used for elective surgery.¹⁴ Also, Weiss acknowledges that a cannula may be more appropriate in neonates and small children due to the small size of the cricothyroid membrane. Levitan is also a proponent of a scalpel cricothyroidotomy in adults as the “cartilaginous cage” created by the cricoid and thyroid cartilages is protective of adjacent soft tissues.¹⁵ However, the softer cartilages of neonates and infants may not offer the same protection as in adults, and a tracheal approach offers no protective “cage”. Holm-Knudsen demonstrated better success rates with a scalpel technique compared with cannulae using piglets as a paediatric model.¹⁶ However, a scalpel FONA was allowed up to four minutes to perform, and still be deemed successful. Four minutes is too long. By the time a FONA attempt begins, a child will already be hypoxic and likely receiving chest compressions.

The combined APA and DAS guidelines recommend a cannula as the first FONA technique in the absence of an ENT surgeon.³ Recent evidence in a rabbit model of the infant airway demonstrated a high success rate of cannula tracheostomy, and supports the use of a cannula FONA in children.¹⁷ Navsa discourages the passing of a tracheal tube through the neonatal cricothyroid

membrane due to the small dimensions measured in cadavers.¹⁸(Table 1) However, these measurements were taken with the head and neck in a neutral position. Head and neck extension increases the sagittal length of the CTM (an effect that can be easily demonstrated by palpating one's own CTM during flexion and extension). Cote reviewed transtracheal and cricothyroidotomy devices available for children and described their use. Most of the devices reviewed were only suitable for larger patients and not neonates or infants.¹⁹

Anatomical Considerations in children.

The larynx in small children is more cephalad relative to that of an adult (Figure 1). The thyroid cartilage is underdeveloped in children compared with adults, and the hyoid bone may be more readily palpated.¹⁹ The relationship of the larynx to the mandible requires maximal extension of the head and neck to approach the CTM with a cannula or scalpel. When performing a cannula cricothyroidotomy, the steeper the angle of approach to the trachea, the greater the likelihood of a posterior tracheal wall puncture, and that the airway will be transfixated. Therefore, a flatter approach to the airway by the cannula is preferred. However, in neonates and infants, full extension of the head and neck may still not allow a flat enough approach to the CTM, and a cannula *tracheotomy* may be necessary. Also, the airway may be only partially palpable, or not palpable at all. In an adult this may be due to the body habitus of the patient. In children, it may be due to young age (short fat neck in normal infants and neonates), or due to pathologies such as trauma with subcutaneous emphysema, or tissue oedema secondary to Ludwig's angina. In the semi-emergent scenario, ultrasound may be used to identify the cricothyroid membrane. Impalpable anatomy necessitates a "blind" approach to the trachea and may result in a tracheotomy instead of a cricothyroidotomy. Evidence suggests that the further caudad along the trachea FONA is attempted, the lower the success rate for both cannula and scalpel techniques.^{20,21} Therefore, if the CTM is palpable, and can be approached by a flat enough angle of approach (45° or lower), a cricothyroidotomy is preferred to a tracheotomy. Remembering that the thyroid cartilage is far less prominent in children, the author recommends aiming for the most cephalad palpable airway structure (below the thyroid cartilage) that still allows for a flat angle of approach. The small size of the CTM in neonates and infants, relative to endotracheal tubes, has led to recommendations that a tracheotomy is preferable to a cricothyroidotomy to avoid damage to the cricoid and thyroid cartilages.²⁰ Further evidence is required before this suggestion can be endorsed as damage to the trachea would also occur during a tracheotomy.

Good quality research into the ideal technique in children has commenced,^{17,20} and hopefully in the near future, airway clinicians will have strong evidence recommending a specific technique. Until that time, anaesthetic departments, in conjunction with intensive care departments, emergency departments, and ENT surgeons should develop acceptable local procedures within an institution based on the evidence that is currently available. The chosen approach needs to be thoroughly understood by all involved, and the equipment readily available in an emergency. Before deciding on an individual or institutional approach, a thorough understanding of the anatomy, physiology, and physical principles is necessary. Video tutorials for the FONA techniques are available online.²² These techniques are best studied by observing the videos, and practicing on a part task trainer. Although these video tutorials use adult models, the principles of the techniques, and the common

This article is protected by copyright. All rights reserved

causes for mistakes described within, are applicable to children as well. After watching the videos consider the differences relevant to children discussed below.

Narrow Bore Cannula Techniques and Jet Oxygenation

Watch these videos prior to reading this section: Cannula Insertion, Cannulae Comparison, and Jet Oxygenation.²²

The authors recommend the 16g BD Insyte™ cannula for FONA in children. The BD Insyte™ is cheap, familiar, readily available, and reforms its shape rapidly after kinking.²² It also has a conical shaped hub that allows a wire to pass easily when performing a Seldinger conversion to a Melker airway. It is small enough for neonates and infants, and large enough for adults (Tables 1 and 2). The smaller the cannula used, the less tracheal compression that occurs during insertion. Tracheal compression may result in posterior tracheal wall puncture and a transfixed trachea.²¹ However, larger cannulae allow more flow at lower velocity. The 16g cannula allows for less tracheal compression than a 14g, and more flow than an 18g. Having only one choice of cannula eliminates yet another decision to be made in an extremely rare emergency. Subspecialty areas such as Neonatal Units may wish to stock an 18g cannula instead. The BD Insyte™ is recommended as the cannula of choice for cannula FONA techniques compared with VBM Jet Ventilation Catheter (“Ravussin cannula”) as it re-straightens after kinking that may occur during the insertion attempt.²² Its low cost and availability make it ideal to stock in numerous locations.

Stacey et al demonstrated a 60% overall success rate with cannula tracheotomy in a rabbit model of the infant airway with clinicians experienced at FONA. They did not employ an aspirate as you go technique in their study as they felt that an attached syringe inhibits fine control of the cannula tip. They performed aspiration after advancing the cannula off the trochar. They reported a high rate of posterior wall perforation (42%).¹⁷ Prunty et al demonstrated 100% success rate in a similar study using the Melker airway that requires cannulation prior to insertion of catheter via a Seldinger technique. They had a 50% rate of posterior wall injury.²⁰ These studies demonstrate that cannula tracheotomy can be used in an infant model. Reducing the high rate of tracheal injury using these techniques requires further study.

A successful cannula cricothyroidotomy is not a definitive airway, and must be held securely at all times. If the patient is not in the operating theatre, the author recommends that the ENT surgeon comes to the patient to perform a formal tracheostomy rather than transporting the patient to theatre. Conversion to a definitive airway using a Seldinger technique is another option.

The goal of cannula FONA is rapid and safe oxygenation. Oxygenation, as opposed to ventilation, is required to prevent end organ damage or death. During difficult airway management, ventilation may be compromised, but clinicians may still be able to oxygenate the patient, and FONA is not required. This distinction has led to use of the term “Can’t Intubate, Can’t Oxygenate”, rather than “Can’t Intubate, Can’t Ventilate”, to stress the importance of oxygenation over ventilation. During a CICO

This article is protected by copyright. All rights reserved

emergency, once a cannula is placed in the trachea, jet oxygenation is easily achieved but has a high risk barotrauma and volutrauma. Attempting to maintain age appropriate ventilation cycles of inspiration and expiration via a cannula will likely lead to dynamic hyperinflation of the chest due to impaired expiration (egress of inspired oxygen out the cannula or across the glottis).

Atmospheric pressure (1 atm) equals 760 mmHg, 1033 cm H₂O, 101 kPa, 1 bar, and 14.7 psi. Piped medical oxygen and cylinder oxygen are delivered at 4 bar, and are therefore over 4000 cm H₂O. Jet oxygenation techniques often use wall mounted oxygen flowmeters as their oxygen source. Flowmeters have an indicator ball that moves within housing marked on the side to indicate the l min⁻¹ of oxygen flow. Turning the knob on the flowmeter opens the flowmeter's valve increasing the flow of oxygen, and the indicator ball rises accordingly. The highest flow marking at the top of the housing is usually 15 l min⁻¹. However, continuing to turn the knob will open the valve further, and flow will continue to increase even though the indicator ball cannot rise above the 15 l min⁻¹ marking on the housing. Flow rates up to 96 l min⁻¹ have been described.²³ Flowmeters regulate *flow*, but they do not regulate *pressure*. Any obstruction to flow distal to the ball flowmeter will result in equilibration of pressure across the flowmeter. The higher the flow rate, the more rapidly the pressure will equilibrate. In a CICO emergency, complete, or near complete, upper airway obstruction is almost certainly occurring otherwise ventilation via a supraglottic approach would be possible. Therefore a patient receiving jet oxygenation via a cannula cricothyroidotomy may be exposed to 4000cm H₂O of airway pressure from a wall mounted oxygen flowmeter (if no oxygen escapes through the upper airway or cannula), and barotrauma will ensue. It is recommended that all attempts to maintain upper airway patency, such as the placement of an oropharyngeal airway or supraglottic airway, continue during the management of a CICO emergency to allow egress of the jetted oxygen across the glottis.

It is crucial to monitor the rise of the chest during jet oxygenation, and that the jet oxygenator has a "true off" switch. It is difficult to prescribe a duration of jet oxygenation in paediatrics as the volume of inspired oxygen to create an adequate inspiration will depend on the size of the child, and whether there is escape of inspired oxygen through the upper airway. Jet oxygenation should therefore be titrated to the chest rise. A "true off" switch means that, after the initial lung inflation, there is no further oxygen entering the lungs when the device is "switched off". The ideal device also provides tactile feedback in the event that the cannula becomes kinked, or if the cannula is incorrectly placed into the tissues adjacent to the airway. To avoid trauma to the lung, the subsequent inspiration should not begin until the chest has fallen and the oxygen saturation starts declining from its peak.³

Devices that use 3 way taps as the on/off switch to oxygenate patients are **contraindicated**. At age appropriate flow rates, oxygen will continue to inflate the chest even when the 3 way tap is not occluded. This occurs because the tap's opening is too narrow, and therefore creates a high resistance to outflow.³ Jet ventilators such as the VBM Manujet III are marketed for oxygenation via cannulae in a CICO emergency as well as for use in elective surgery. The Manujet has an adjustable pressure regulator (0 - 3.5 atm), and the ability to titrate flow higher by progressively squeezing the trigger until it is fully depressed.²⁴ The APA supports the use of the Manujet in children aged between 1 and 8 years in their algorithm despite recognizing that the "suitable range" of pressure for children is

not clearly defined. However, the Manujet has no outlet by which oxygen jetted into the trachea and lungs can be vented in the event of a completely obstructed upper airway. Bench tests of jet oxygenation via a Ravussin cannula using the Manujet with simulated upper airway obstruction demonstrate a rapid increase in airway pressure to dangerous levels, and an inability to ventilate the model.²⁵ In an emergency situation, unfamiliarity with the Manujet would make titration of low flows and pressures hard to achieve. Also, it is not cost effective to stock Manujets in all locations throughout a hospital where a CICO emergency could occur.

Two devices made specifically for oxygenation via a cannula meet the ideal requirements. These are the Enk Oxygen Flow Modulator (Cook[®]), and the Rapid O₂[™] Insufflator (Meditech Systems[®]). The Enk has a flute with five holes along its side that when occluded provide jet oxygenation. Oxygen flow is best controlled by occluding all five holes and starting with an initial oxygen flow of 1 l min⁻¹ year⁻¹. Eventual flow rates are likely to be indicated by the equation 1 l min⁻¹ year⁻¹ of age + 4 l min⁻¹.²⁶ Uncovering the holes switches off the device, but at oxygen flow rates greater than 15 l min⁻¹, the Enk does not completely switch off and jet oxygenation may still occur.²⁶

The Rapid O₂ Insufflator is a T-Piece with an extension that can attach to the cannula with a luer lock, and fixed oxygen tubing that cannot become disconnected during resuscitation. The single large opening of the T-Piece acts as an on switch when occluded, and an oxygen vent when not occluded. The Enk Oxygen Flow Modulator and T piece devices have been demonstrated to have the safest expiratory profile compared with the Manujet.^{25,27} The single large opening of T-Piece devices such as the Rapid O₂ insufflator provides immediate tactile feedback to the thumb in the event of kinking of the catheter or migration of the catheter into the tissues surrounding the airway.²² Their use is supported by expert consensus³ and the Advanced Paediatric Life Support group.²⁸ New devices regularly become available for use in airway management. The recently released Ventrain[®] is device that generates active expiration via the Bernoulli principle. One concern with the use of this device in small children is the need for high oxygen flow rates (above those required to achieve oxygenation) to achieve suction. Its efficacy and safety for use in children is yet to be fully established although its use has been described in case reports and bench tests.^{29,30}

Scalpel Techniques

Watch these videos prior to reading this section: Scalpel Bougie Technique, Cannula Fat Neck.²²

Many scalpel FONA techniques have been described. The DAS 2015 Guidelines detail a technique almost identical to that in Heard's video.⁸ This technique is even simpler than the rapid 4 step technique described by Holmes as it does not involve the use of a tissue hook⁷ and causes less trauma than other scalpel methods described.²¹ Until further evidence becomes available, this technique must be adapted for use in children.

Equipment that is an appropriate size for the child must be used. The size 10 scalpel blade is suitable in almost all paediatric situations. The shape of its blade provides a wide incision at a shallow depth. This is ideal in small tracheas. However, different sizes of bougies and endotracheal tubes are required, and are detailed below. Where airway anatomy is palpable, a horizontal stab incision is made through the CTM. The scalpel is turned to the sagittal plane and a bougie is gently inserted until "hold up" has been felt. This depth to which the bougie is inserted is dependent on the size of the child. Where possible, a hollow bougie that allows oxygenation should be used. This is not included in DAS 2015 Guidelines. However, desaturation and hypoxia-induced cardiac arrest occur more rapidly in children than in adults. Re-oxygenation via the bougie may allow for a less time pressured passage of the ETT over the bougie into the trachea. Cook® Airway Exchange Catheters and Frova Introducers allow oxygenation by attaching a 15mm Rapi-Fit Adaptor, and using an anaesthetic circuit to deliver an inspiratory breath prior to railroading the tube. The risk of barotrauma with a low pressure anaesthetic circuit and reservoir bag is small compared with jet oxygenation.

Where the airway structures are not palpable, or if previous FONA techniques have been unsuccessful, a vertical midline incision is required followed by blunt dissection to identify the trachea. Once the trachea and CTM have been identified either a cannula or scalpel can be used to access the airway as previously outlined. This is referred to as the Scalpel-Finger-Bougie/Cannula technique. The recommended length of the incision in adults is 8-10cm. In children, this will be too long in most instances. The skin incision should start at the base of the thyroid cartilage and continue to the top of the manubrium. This is the last attempt that can be made to save the patient's life. It will undoubtedly be a highly stressful situation. Many airway clinicians are concerned about bleeding, and the cosmetic effect of a long incision. While these are valid concerns, it is important to remember that if this fails, the patient will die. Nothing can prepare a clinician for this situation other than having personal experience. This is very difficult to provide by education and training. However, online video content is a useful tool to mentally prepare for this rare and stressful emergency.³¹

Percutaneous Cricothyroidotomy (Tracheotomy) and Seldinger

Techniques

Many devices, purpose built for the CICO emergency, are described for use in children with little published evidence.¹⁹ These can be divided into devices inserted using the Seldinger technique, and percutaneous cricothyroidotomy (tracheotomy) devices that directly puncture the skin and enter the trachea.

Seldinger devices are inserted over a wire that has been passed through a cannula into the trachea. Therefore, oxygenation via the cannula can be used prior to insertion of the definitive airway catheter. This is a useful bridging step because inserting an airway catheter by a Seldinger technique takes more time, and children desaturate rapidly.^{19, 32} The Cook Melker Emergency Cricothyrotomy Catheter Set is simple to use, available in 2 paediatric sizes, and has been used successfully in a rabbit model of the infant airway.²⁰ However, even the smallest Melker has an outer diameter of 5mm,

and is too large for use in neonates (Table 2). Also, the wire included in the Melker set will not pass through the tapered tip of an 18g intravenous BD Insite cannula. The author's experience with the Melker in dry and wet labs suggest that conversion from a successful cannula FONA to a Melker catheter is not always straightforward. The author recommends only converting to a Melker catheter if previously successful cannula jet oxygenation begins to fail due to gas trapping or blockage of the cannula with secretions or blood. If an ENT surgeon is not available to perform a formal surgical tracheostomy, then conversion to a Melker catheter should occur. Note that the Melker catheter is not packaged "ready to insert" and requires insertion of the dilator into the catheter prior to use (Figure 2).

Percutaneous devices utilize large bore trochars to puncture the skin and trachea. Due to the significant risk of tracheal compression and posterior wall puncture in young children, this may not be a safe initial approach.^{17,21} The APA advises against the use of needles greater than 4mm in the 1-8 year old age group.³ One percutaneous device, the Quicktrach (VBM), has recently been examined in rabbit models of the infant airway with widely conflicting results in two small studies.^{17,33} The Quicktrach catheter comes loaded onto a shorter and wider bore needle designed to allow percutaneous skin and tracheal puncture followed by immediate advancement of the catheter into the airway. The wider bore needle is marketed as allowing ventilation. The smallest of the three available sizes has an internal diameter of 1.5mm (approximately equivalent to a 14g cannula).

The numerous available kits on the market make familiarity difficult to achieve. Each institution must choose one kit and ensure that staff are trained in its use. Table 3 lists the smallest available size of each brand, and its insertion method.

Establishing an institutional approach to the paediatric CICO emergency

Preparation for the CICO emergency is vital. Training sessions involving the airway clinician, and their assistant, to familiarize themselves with the technique and equipment available will facilitate successful FONA in an emergency. As well as rehearsing the technical skills involved, scenario based simulation sessions can improve the non-technical skills (aka human factors and crisis resource management) of the team's performance.³⁴ Non-technical skills such as leadership, followership, and closed loop communication allow the team to follow the predetermined plan, and avoid becoming fixated or task focused. The small anatomy in the neonate and infant population will make all techniques difficult. Regular compulsory training for rarely encountered emergencies, such as CICO, has been introduced in the Australian and New Zealand College of Anaesthetists to ensure the anaesthetist maintains competency. Four emergency modules are specified, two of which need to be completed in every triennial Continuing Professional Development cycle. Even this may be too infrequent to maintain competency in a rarely used skill.³⁵ The lack of definitive evidence in the literature necessitates that the airway leads at each institution must decide on the technique and equipment to perform emergency FONA. Choosing one technique and ensuring that the airway clinicians and their assistants are all familiar with the procedure, and when to perform it, is probably more important than which specific technique is chosen as first attempt. The APA Guidelines for the

This article is protected by copyright. All rights reserved

Cannot Intubate, Cannot Ventilate in a paralysed child aged 1 to 8 years recommend the use of a cannula cricothyroidotomy/tracheotomy as the first FONA technique to be attempted if an ENT surgeon is not immediately available.³ The authors support the use of a cannula first. 1 – 2 cannula FONA attempts can be performed within 30s, and if unsuccessful, the physician can rapidly progress to a scalpel technique as per the APA guideline. A cannula is relatively non-invasive, and a failed attempt does not significantly impair subsequent needle or scalpel attempts provided jet insufflation of the paratracheal soft tissues has not occurred. Psychologically, a cannula may represent a less invasive technique for anaesthetists more familiar with cannulae than with scalpels, and therefore anaesthetists may be more likely to perform the technique when necessary.⁴

An example of a CICO pack available at the Royal Children's Hospital Melbourne (RCH) is shown (Figure 3) and described in video.(Video 1) The pack's contents are listed in Table 4. Hospitals that treat children need to cater for patients of all sizes. This necessitates having more equipment in a paediatric CICO pack than hospitals that only manage adults. Melker Sets are stocked separately in the difficult airway trolley (cart) as they are not used to establish immediate FONA.

The RCH has chosen the Rapid O₂ Insufflator (Meditech Systems[®]) to oxygenate via a cannula. It is cheap enough to stock in many locations, and is easy to use. The CICO pack contains endotracheal tubes (ETT) and "bougies" to perform the scalpel bougie technique in children of all sizes except premature neonates. Cuffed endotracheal tubes sizes 3.0, 4.0, and 5.0 are stocked in the CICO packs. A smaller ETT is preferable as it is easier to pass through a small incision, and less likely to get caught on tracheal wall during insertion (Table 5). The cuff can be used to generate a seal to prevent a leak although it is likely that there will be minimal escape of air/oxygen across the glottis in a CICO situation. The dimensions of the neonatal CTM with full neck and head extension may be greater than those measured by Navsa et al (Table 1). However, the CTM is still likely to be small, and the use of a smaller ETT for FONA than would otherwise be used for routine endotracheal intubation is recommended.

A "bougie" that allows oxygenation is preferable to one that does not. An oxygenating bougie allows the anaesthetist to give an inspiratory breath of 100% oxygen, by attaching a 15 mm Rapi-Fit adaptor, before attempting to railroad the ETT over it into the trachea. The 15mm adaptor allows the attachment of an anaesthetic circuit, and therefore low pressure oxygenation by squeezing the reservoir bag. Not only does this mean that oxygen enters the lungs earlier, it allows for oxygenation of the patient if railroading the ETT over the bougie proves to be difficult. However, both the smallest size Cook Airway Exchange Catheter, and the smallest size Cook Frova Intubating Introducer, are 8Fr. These do fit through the size 3.0 Kimberley Clark MICROCUFF Tube, but are a tight fit and risk dislodging the ETT upon removal. Therefore, the orange Portex 5Ch 50cm tracheal tube guide has been included in the pack to be used with the size 3.0 ETT. Although the 5Ch bougie does not allow for oxygenation, the author feels that trying to pass a 3.0 ETT over the 8Fr Frova Introducer would add confusion and difficulty if the ETT did not pass easily. The Frova Introducer is shorter than the Airway Exchange Catheter, and has a coude (angled) tip. This makes it easier to handle and insert than the Airway Exchange Catheter, and is therefore included in the CICO Pack. The 8Fr Frova passes easily

down a size 4.0 endotracheal tube. The larger Frova (blue colour) is 14Fr, and is the device recommended for the scalpel bougie technique in adults. However, the 14Fr Introducer will only fit down a size 6.0 ETT. Therefore, for larger children at RCH Melbourne, the 11Fr Cook Airway Exchange Catheter has been included instead. The disadvantages of using Cook Airway Exchange Catheters to perform the Scalpel-Bougie technique are that they are longer, and lack the coude tip. Units or wards that cater exclusively for neonates will only require the smallest endotracheal tube and bougie. These units may wish to stock a 2.5mm uncuffed ETT in their CICO pack instead (Table 2).

Summary

Performing FONA in an infant or neonate is one of the scariest and most emotionally traumatic experiences an airway clinician could encounter. Performing the actual technique in a child is more difficult than in an adult due to the smaller, compressible anatomy, and cephalad cricothyroid membrane. Thankfully, thorough assessment and planning usually avoids this situation, and the incidence of a true CICO emergency is extremely rare. Nevertheless, airway clinicians must have equipment, techniques, and training to rescue the airway should this emergency occur.

This research was carried out without funding.

No ethical approval required.

Conflict of interest: No conflicts of interest declared.

Reflective Questions

- 1) What is the first technique you would use to establish percutaneous emergency airway access (FONA)?
- 2) Is the equipment required to perform that technique, and establish oxygenation currently available in your hospital, and where is it currently stocked? How long would it take for it to arrive in your operating theatre?
- 3) During your CICO training, time how long it takes for you to successfully perform that technique once you have declared a CICO emergency.
- 4) List the required changes to equipment and practice necessary to establish an institutional approach to the CICO emergency in your hospital.

References

- 1) Cook TM, Woodall N, Frerk C. Major Complications of Airway Management in the UK. Part 1: Anaesthesia. *Br J Anaesth* 2011; 106: 617-3.
- 2) Peterson GN et al. Management of the Difficult Airway. A Closed Claims Analysis. *Anesthesiology* 2005; 103: 33-9.
- 3) Black AE et al. Development of a guideline for the management of the unanticipated difficult airway in paediatric practice. *Pediatric Anesthesia* 2015; 25(4): 346-362.
- 4) Greenland KB et al. Emergency surgical airway in life-threatening acute airway emergencies - why are we so reluctant to do it? *Anaesth Intensive Care* 2011; 39: 578-584.

- 5) Marshall SD and Flanagan B. Simulation-based education for building clinical teams. *J Emerg, Trauma, and Shock* 2010; 3(4): 360-368.
- 6) Kristensen MS, Tech WHL, Baker PA. Percutaneous emergency airway access; prevention, preparation, technique and training. *Br J Anaesth.* 2015; 114(3): 357-361.
- 7) Holmes JF et al. Comparison of 2 Cricothyrotomy Techniques: Standard Method Versus Rapid 4-Step Technique. *Annals of Emergency Med.* 1998; 32(4): 442-446.
- 8) Frerk C et al. Difficult Airway Society 2015 guidelines for management of unanticipated difficult intubation in adults. *Br J Anaesth.* 2015; 115(6): 827-848.
- 9) Crewdson K and Lockey D. Needle, knife, or device - which choice in an airway crisis? *Scand J Trauma Resusc Emerg Med* 2013; 21: 49-50.
- 10) Hubble MW et al. A Meta-Analysis of Prehospital Airway Control Techniques Part II: Alternative Airway Devices and Cricothyrotomy Success Rates. *Pre Hospital Emerg Care* 2010; 14: 515-530
- 11) Langvad S et al. Emergency cricothyrotomy - a systematic review. *Scand J Trauma Resusc Emerg Med* 2013; 21: 43-57.
- 12) Heard AM. Can't Oxygenate Scenario (CICO): Implications of the National Audit Project (NAP4) of the Royal College of Anaesthetists. *ANZCA Bulletin* September 2011.
- 13) Weiss M, Engelhardt T. Proposal for the management of the unexpected difficult pediatric airway. *Pediatric Anesthesia* 2010; 20: 454-464.
- 14) Depierraz et al. Percutaneous transtracheal jet ventilation for paediatric endoscopic laser treatment of laryngeal and subglottic lesions. *Can J Anaesth* 1994; 41: 1200-1207.
- 15) <http://emcrit.org/podcasts/levitan-surgical-airway>
- 16) Holm-Knudsen RJ et al. Emergency airway access in children – transtracheal cannulas and tracheostomy assessed in a porcine model. *Pediatric Anesthesia* 2012; 22: 1159-1165.
- 17) Stacey J et al. The 'Can't Intubate Can't Oxygenate' scenario in pediatric anesthesia: a comparison of different devices for needle cricothyroidotomy. *Pediatric Anesthesia* 2012; 22: 1155-1158.
- 18) Navsa N. Dimensions of the neonatal cricothyroid membrane - how feasible is a surgical cricothyroidotomy? *Pediatric Anesthesia* 2005; 15: 402-406.
- 19) Cote CJ and Hartnick CJ. Pediatric transtracheal and cricothyrotomy airway devices for emergency use: which are appropriate for infants and children? *Pediatric Anesthesia* 2009, 19 (Suppl. 1): 66–76
- 20) Prunty SL et al. The 'Can't Intubate Can't Oxygenate' scenario in pediatric anesthesia: a comparison of the Melker cricothyroidotomy kit with a scalpel bougie technique. *Pediatric Anesthesia* 2015; 25(4): 400-404.
- 21) Heard AM. Percutaneous Emergency Oxygenation in the Can't Intubate, Can't Oxygenate scenario. *The Definitive Guide for Anaesthetists.* 2013. ePub. Smashwords.
- 22) Heard Youtube Channel. <https://www.youtube.com/user/DrAMBHeardAirway>. Videos for all airway techniques described in the paper may be found here.
- 23) Bould MD, Bearfield P. Techniques for emergency ventilation through a needle cricothyroidotomy. *Anaesthesia* 2008; 63: 535-539.
- 24) Emergency Products Difficult Airway (brochure). VBM Medizintechnik GmbH .

- 25) Craven RM, Vanner RG. Ventilation of a model lung using various cricothyrotomy devices. *Anaesthesia* 2004; 59: 595-599.
- 26) Baker PA and Brown AJ. Experimental adaptation of the Enk oxygen flow modulator for potential pediatric use. *Pediatric Anesthesia* 2009; 19: 458–463.
- 27) Heard AM et al. Expiration following cannula cricothyroidotomy: a bench study of different jet oxygenation devices. *Anaesthesia* 2012; 67: 559.
- 28) Advanced Pediatric Life Support (APLS) The practical approach. 6th edn. BMJ books. Wiley-Blackwell, 2011. ISBN 978-1-4443-3059-5.
- 29) Willemsen MG, Noppens R, Mulder AL, Enk D. Ventilation with the Ventrain through a small lumen catheter in the failed paediatric airway: two case reports. *Br J Anaesth.* 2014; 112(5): 946-947.
- 30) Hamaekers AEW, Borg PAJ, and Enk D. Ventrain: an ejector ventilator for emergency use. *Br J Anaesth.* 2012; 108 (6): 1017-1021.
- 31) Scalpel Technique Video <https://vimeo.com/125228375> (in the peri-arrest situation)
- 32) Sulaiman L et al. Surgical vs. wire-guided cricothyroidotomy: a randomised crossover study of cuffed and uncuffed tracheal tube insertion. *Anaesthesia* 2006; 61: 565-570.
- 33) Metterlein T et al. Emergency cricothyroidotomy in infants - evaluation of a novel device in an animal model. *Pediatric Anesthesia* 2011; 21: 104-109.
- 34) Kennedy CC et al. Advanced Airway Management Simulation Training in Medical Education: A Systematic Review and Meta-Analysis. *Crit Care Med* 2014; 42(1): 169-178.
- 35) Kristensen MS et al. Percutaneous emergency airway access; prevention, preparation, technique and training. *Br J Anaesth.* 2015; 114(3): 357-361.
- 36) Tweedie DJ. Choosing a paediatric tracheostomy tube: an update on current practice. *J Laryngology & Otology* 2008; 122: 161-169.
- 37) Litman RS. Developmental Changes of Laryngeal Dimensions in Unparalyzed Sedated Children. *Anesthesiology* 2003; 98: 41-45.

Tables

Table 1: Dimensions of the neonatal trachea and cricothyroid membrane

Anatomical Structure	Dimensions
Neonatal Cricothyroid Membrane ¹⁸	Length 2.6mm Width 3.0mm
Neonatal Trachea ^{36,37}	Transverse Diameter 4.0-5.0mm Antero-Posterior Diameter 6.0mm

Table 2: Dimensions of devices described for front on neck access

Device	Outer Diameter (mm)	Inner Diameter (mm)
18g BD Insyte™ Cannula	1.30	0.84
16g BD Insyte™ Cannula	1.70	1.19
14g BD Insyte™ Cannula	2.10	1.60
3.5 Melker Cricothyrotomy Set	5.00	3.50
3.0 Kimberly Clarke Microcuff	4.3	3.0

Tube*		
4.0 Kimberly Clarke Microcuff Tube*	5.6	4.0
5.0 Kimberly Clarke Microcuff Tube*	6.7	5.0
2.5 uncuffed Mallinckrodt ETT	3.6	2.5

*Outer diameters of the Kimberley Clarke Microcuff Tubes are the same as Mallinckrodt™ uncuffed endotracheal tubes

Table 3: Seldinger and percutaneous cricothyrotomy kit dimensions and insertion technique

Device	Internal Diameter (mm)	Insertion Technique
Cook Melker	3.5	Seldinger
Portex Minitrach	4	Seldinger
Pedia-Trake	3	Percutaneous
Pertrach	3.5	Seldinger
Quicktrach	1.5	Percutaneous

Table 4: Royal Children's Hospital, Melbourne CICO Pack Equipment List

Equipment for cannula FONA	Equipment for scalpel FONA
16g BD Insite™ Cannula Rapid O ₂ ™ Insufflator (Meditech Systems Ltd) with included oxygen tubing 5 ml syringe 10ml Saline ampoule	Scalpel: 10 blade on a handle "Bougies" <ul style="list-style-type: none"> • Portex® 5Ch 50cm tracheal tube guide (orange) • Cook® Frova Intubating Introducer 8Fr 35cm (yellow with coude tip, stiffening cannula removed) with Rapi-Fit adaptor attached • Cook® Airway Exchange Catheter 11Fr 83cm (yellow without coude tip) with Rapi-Fit adaptor attached. Cuffed endotracheal tubes (Kimberly-Clark® MICROCUFF) sizes 3.0, 4.0, and 5.0 Lubricant

Table 5: Age based recommendations for size of bougie and ETT to perform a scalpel front of neck access.

Age of child	Recommended Bougie and ETT size
--------------	---------------------------------

Neonate – Infant	5Ch bougie 3.0 cuffed ETT
Small Child	8 Fr bougie 4.0 cuffed ETT
Large Child - Adult	11Fr bougie 5.0 cuffed ETT

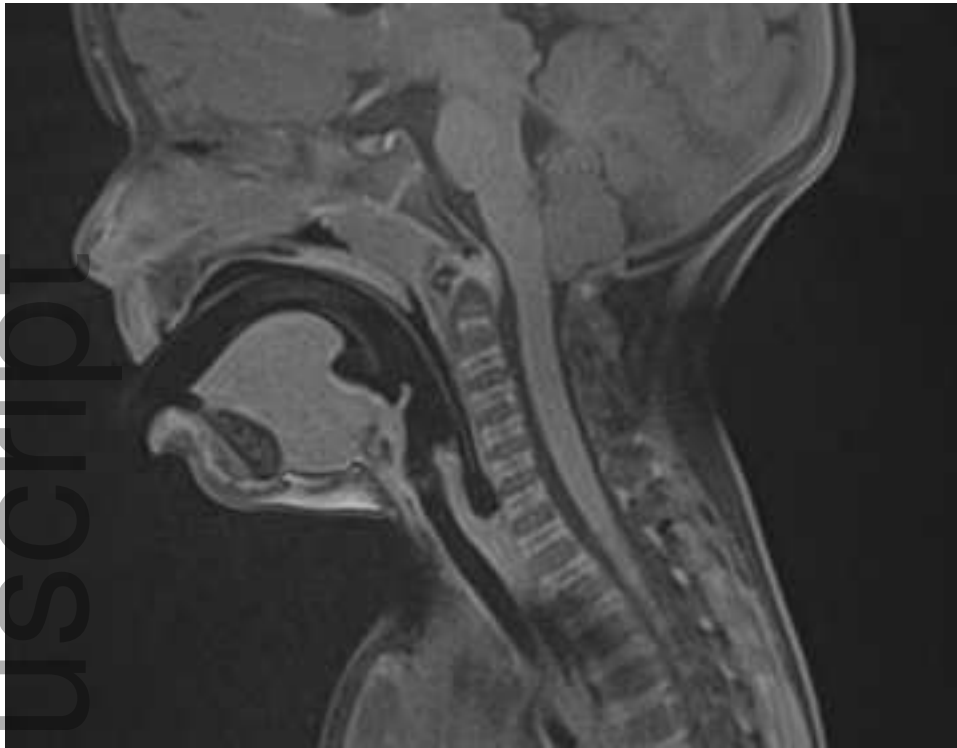
Figure Captions

Figure 1: lateral MRI of a 18 month child in the neutral position with normal airway anatomy, and a laryngeal mask in situ.

Figure 2: An open 3.5 mm Cook Melker Cricothyrotomy Set

Figure 3: An open CICO pack displaying two separate pouches. Each pouch contains the equipment necessary for each specific technique.

Author Manuscript



pan_12926_f1.tif



pan_12926_f2.tiff



pan_12926_f3.tiff

Author Manuscript