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The formulation and introduction of a 'can't intubate, can't ventilate' algorithm into clinical practice

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Summary

Both the American Society of Anesthesiologists and the Difficult Airway Society of the United Kingdom have published guidelines for the management of unanticipated difficult intubation. Both algorithms end with the 'can't intubate, can't ventilate' scenario. This eventuality is rare within elective anaesthetic practice with an estimated incidence of 0.01–2 in 10 000 cases, making the maintenance of skills and knowledge difficult. Over the last four years, the Department of Anaesthetics at the Royal Perth Hospital have developed a didactic airway training programme to ensure staff are appropriately trained to manage difficult and emergency airways. This article discusses our training programme, the evaluation of emergency airway techniques and subsequent development of a 'can't intubate, can't ventilate' algorithm.

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Difficult airway scenarios may result in significant morbidity and mortality, and require prompt intervention. Respiratory, and particularly airway, complications have been highlighted as a leading cause of morbidity and mortality in the US closed claims analysis. Caplan [1] suggested that most were preventable with improved monitoring and a strategy for dealing with difficult intubation. As a result, the American Society of Anesthesiologists (ASA) [2] and at a latter date the Difficult Airway Society (DAS) [3] provided frameworks for the anaesthetist to manage the unanticipated difficult airway. Both guidelines end with the 'can't intubate, can't ventilate' (CICV) scenario, recommending either a needle or surgical cricothyroidotomy as the next step.

In 1991, the incidence of the CICV scenario was estimated as 0.01–2 per 10 000 cases [4]. Since then the Laryngeal mask airway (LMA) has been shown to provide rescue ventilation in many CICV scenarios [5]. As a result the incidence of CICV may have fallen further. A Canadian survey of 971 experienced anaesthetists found that only 57% had personally experienced a CICV [6] so most anaesthetists will rarely encounter this scenario. This makes the acquisition and maintenance of clinical skills difficult.

In 2001 a critical incident in the recovery room highlighted the need to improve the airway training for both junior and senior anaesthetic staff at Royal Perth Hospital (RPH). A structured training programme was put into place to ensure all anaesthetic staff had adequate training to deal with crisis airway management. This training took the form of a 'dry lab' manikin based teaching session, tailored towards learning fibre-optic techniques and advanced airway manoeuvres, and a 'wet lab' animal session for training in the CICV scenario.

There are a number of ideal standards a technique should meet to make it suitable for use in the CICV setting. Firstly one should be able to rapidly access the airway, using equipment that is readily available that complements the motor skills of the user. One should subsequently be able to oxygenate the patient before securing the airway with a cuffed airway device if necessary. In addition the technique should be minimally invasive and as such have a low complication rate. To evaluate rescue airway techniques we recorded performance data of consenting registrar and consultant anaesthetists. Each technique was evaluated against this set of 'gold standards', and as a consequence we developed a system to audit both established techniques and those developed at RPH.

Procedural skills are often acquired through manikin based teaching. There are however limitations with this style of training regardless of the level of fidelity the manikin provides. As a consequence few anaesthetists will have contemplated what they would do when faced with a CICV situation or if their primary procedure fails. The aim of this paper is to discuss the CICV scenario – the development of a training programme, the evaluation of techniques, our institute's management algorithm and the introduction of this into clinical practice.

Methods

The CICV session consists of two parts. A 1-h manikin session introduces the scenario, before describing a number of airway rescue techniques. Each technique is taught in a didactic fashion, with participants encouraged to proceed through a number of critical steps. Tables 1–4 outlines the critical steps for cannula cricothyroid puncture (CCP), scalpel bougie (SB), Melker (MK) emergency cricothyroidotomy kit (Cook Critical care, Bloomington, IN, USA) and the scalpel finger needle (SFN) technique.

Table 1 Cannula cricothyroidotomy.

Cricothyoid puncture	
1	Identify cricothyroid membrane and stabilise with non-dominant (ND) hand
2	Hold 5-ml syringe barrel in dominant (D) hand
3	Insert needle through skin at approximately 45° caudally
4	'Aspirate as you go' advancing into airway
5	Endpoint: free aspiration of air up full barrel of syringe
6	Stabilise cannula hub with ND hand. Do not release cannula hub for remainder of procedure
7	Place D hand against patient and use to immobilise trochar
8	Advance cannula over needle into trachea with ND hand and remove trochar
9	Repeat free aspiration of air to ensure correct placement

Table 2 The scalpel bougie.

Scalpel bougie	
1	Identify cricothyroid membrane and stabilise with non-dominant (ND) hand
2	With scalpel in dominant (D) hand make a horizontal stab incision through cricothyroid membrane
3	Rotate blade through 90° so that the blade points caudally
4	Pull scalpel towards you, maintain perpendicularity-producing a triangular hole
5	Switch hands so that the ND hand now stabilises the scalpel
6	With the bougie pointing away and parallel to the floor, insert tip into trachea using the blade as a guide
7	Rotate and align bougie to allow insertion along the line of the trachea
8	Reoxygenate via bougie with jet ventilator
9	Railroad lubricated 6.0 ETT (remove 15-mm connector to aid passage over bougie). Continually rotate tube to facilitate placement
10	Remove bougie
11	Reattach 15-mm connector and ventilate via circuit
12	Secure tube and check bilateral ventilation

Table 3 The melker technique.

Melker size 5.0 seldinger airway	
1	Insert wire through cannula
2	Remove the cannula
3	Make a stab incision caudally with a scalpel
4	Pass Melker tube ⁄ dilator assembly device over the wire
5	Ensure the dilator is fully and completely seated inside the airway
6	Grip airway assembly device preventing the dilator moving back when it is advanced
7	Advance the assembly with moderate force over wire throught the skin and into the airway
8	Remove the wire and introducer
9	Inflate cuff
10	Attach self inflating bag or circuit and ventilate

Table 4 Scalpel finger needle.

Scalpel finger needle	
1	Stabilise neck in midline with the left hand
2	Make vertical midline incision of at least 6 cm caudal to cranial through skin and subcutaneous tissue
3	Insert fingers of both hands to separate strap muscles by blunt dissection
4	Identify airway structures with left hand and stabilise with index and middle fingers
5	Insert 14G Insyte^{TM} with D hand using a 'aspirate as you go' technique
6	Secure, insert and confirm position of the cannula as per needle cricothyroidotomy technique
7	Attach to jet ventilator
8	Once stabilised can convert to melker 5.0 cuffed tube

This is followed by a training session using anaesthetised sheep, with the participant encouraged to complete all critical steps for each technique. The 'wet lab' resembles a normal theatre environment, with an anaesthetic machine, piped oxygen, audible pulse oximetry, suction and a difficult intubation trolley. Anaesthetised sheep are cannulated, intubated and venesected for the purpose of preparing blood agar plates for the microbiology department at RPH. Animal ethics approval was gained to perform a CICV training session prior to euthanasia under the supervision of a resident veterinary practitioner. There are usually two trainees allocated per session with attendance on a strictly voluntary basis.

The sheep are anaesthetised on the instructions of a supervising veterinarian and are subsequently extubated. Once oxygen saturation has fallen to 70%, participants are required to cannulate the cricothyroid membrane, with subsequent ventilation performed with either a high flow Manujet jet ventilator, or a low flow system using oxygen tubing and a three way tap. During the course of any training session, participants are timed from commencement of procedural intervention to first effective ventilation, with the oxygen saturation called out by the instructor as rescue airway measures are attempted.

Upon completion of successful cricothyroid cannulation, teaching moves onto Seldinger and surgical airway techniques, each following a standardised training format.

A difficult anatomy scenario is created by infiltrating 1 l of crystalloid into the sheep's anterior neck, rendering it impossible to palpate any anterior neck anatomy. All other aspects of the training session are identical. Candidates are allowed five attempts at 'blind' cannulation, before being encouraged to attempt a vertical incision, with subsequent blunt dissection until neck anatomy structures are palpable. Upon identification of the cricothyroid membrane or trachea, a cannula is inserted into the airway with ventilation performed as previously described (SFN).

We evaluated the techniques described in Tables 1–3, surgical cricothyroidotomy (SC) technique (taught in accordance to ATLS guidelines), and the Mini-trach II kit (MT) (Smiths Medical Ltd, Hythe, UK) against our audit gold standards in sheep with normal neck anatomy. Additionally we evaluated CCP and SFN in sheep with difficult neck anatomy.

On each of these occasions, 10 participants were allocated to each treatment modality and subsequently shown a video outlining the key steps to the technique. The procedure was started when oxygen saturations reach 70%. The procedure was terminated if the time taken exceeded 4 min. We recorded time to first effective ventilation, time to oxygen saturation > 90%, the number of attempts and the complications. For the techniques evaluated with difficult neck anatomy, participant had previously attended wet lab teaching sessions and for that evaluation the maximum time allowed was 3 min.

Results

Our wet lab teaching sessions began in November 2003 and since then there have been 340 registrars and consultant from Royal Perth Hospital, with visiting consultants from other departments and hospitals in Western Australia. We have supervised approximately 2040 CCP, 512 SB, 680 MK, 100 Mini-trachs, 100 SC and 84 difficult neck anatomy scenarios. The results for each technique can be seen in Table 5.

Discussion

The ASA and DAS unanticipated difficult airway algorithms are based on expert or consensus opinion, anecdote and literature review. Although they make sense clinically, few are validated prospectively. Combes et al. [7] validated a simple algorithm for the management of the unanticipated difficult intubation. They concluded that adherence to practice guidelines relied upon the simplicity of the algorithm, efficiency and easiness of the techniques and the initial information and educational process.

The flowchart described in this document represents the result of four years experience of crisis airway teaching in a simulated animal laboratory, combined with evidence from the current literature. During the formulation of this algorithm and subsequent introduction, we have adopted the principles outlined by Combes. Unfortunately, due to the nature of the CICV, prospective evaluation in patients would be impossible.

Both the ASA and DAS algorithms end at the CICV scenario with a dichotomy- recommending either cannula or scalpel cricothyroidotomy. The skills of a surgeon with a scalpel blade are far greater than those of an anaesthetist. Conversely the skills of an anaesthetist using a cannula on the end of a syringe are usually far greater

Table 5 Results from the airway technique evaluation audits. Performance data was evaluated for 10 participants for each technique.

Technique	Success rate (%)	Mean (SD) time in seconds to successful placement	Significant complications
Scalpel bougie	100	39 (6)	
Surgical cricothyroidotomy	80	61 (20)	Six individuals created tracts too small for tube placement
Melker emergency cricothyroidotomy kit	90	118 (26)	
Mini-trach II	90	163 (34)	
Cannula cricothyroid puncture (difficult neck)	40	106 (33)	Major blood vessel punctured on two occasions
Scalpel finger needle technique (difficult neck)	100	86 (38)	Moderate haemorrhage

than those of a surgeon. Hence it makes sense that an algorithm for anaesthetists may be different than that for a surgeon or other specialties.

Cannula cricothyroidotomy or tracheotomy

For our CICV algorithm (Figure 1) we have adopted a simple stepwise progression, which involves using the simplest and least invasive procedure in the first instance followed by oxygenation and stabilisation – safe, simple and fast oxygenation (SSFO). This adheres to the basic principles highlighted in the DAS guidelines – maintain oxygenation and minimising further trauma to the airway [3]. Once the patient has been reoxygenated, where appropriate the airway can be secured using a second line technique. As a result, we feel that the ideal first-line technique when faced with a CICV is the cannula cricothyroidotomy or tracheotomy. This technique fulfils the criteria listed above and uses equipment readily available to most clinicians regardless of clinical setting. In addition, by having one procedural choice only, it removes any decision making from this potentially stressful situation. Traditional teaching focuses on the rescue technique being performed through the cricothyroid membrane, as this is often the most superficial and consequently identifiable landmark. But, if landmarks are difficult to distinguish, needle placement anywhere within the subglottic airway is perfectly acceptable.

The characteristics of the ideal cannula in this setting include minimal flow resistance, durability, ease of identification of catheter kinking and minimal obstruction to facilitate secondary procedures. Physical principles dictate that the longer, thinner catheters would increase flow resistance. In practise there is no significant difference between 13–15-G catheters [8]. The Ravussin jet ventilation catheter (VBM Medizintechnik, Tuttlingen, Germany) is designed specifically for the management of the CICV. It includes a 15-mm connector for manual bag ventilation. Catheter flow rates are significantly higher with wall oxygen at both 10 and 15 l.min^{-1} administered through oxygen tubing as compared to bag ventilation [9], making this connection surplus to requirement in most clinical settings. The 15-mm connector also has

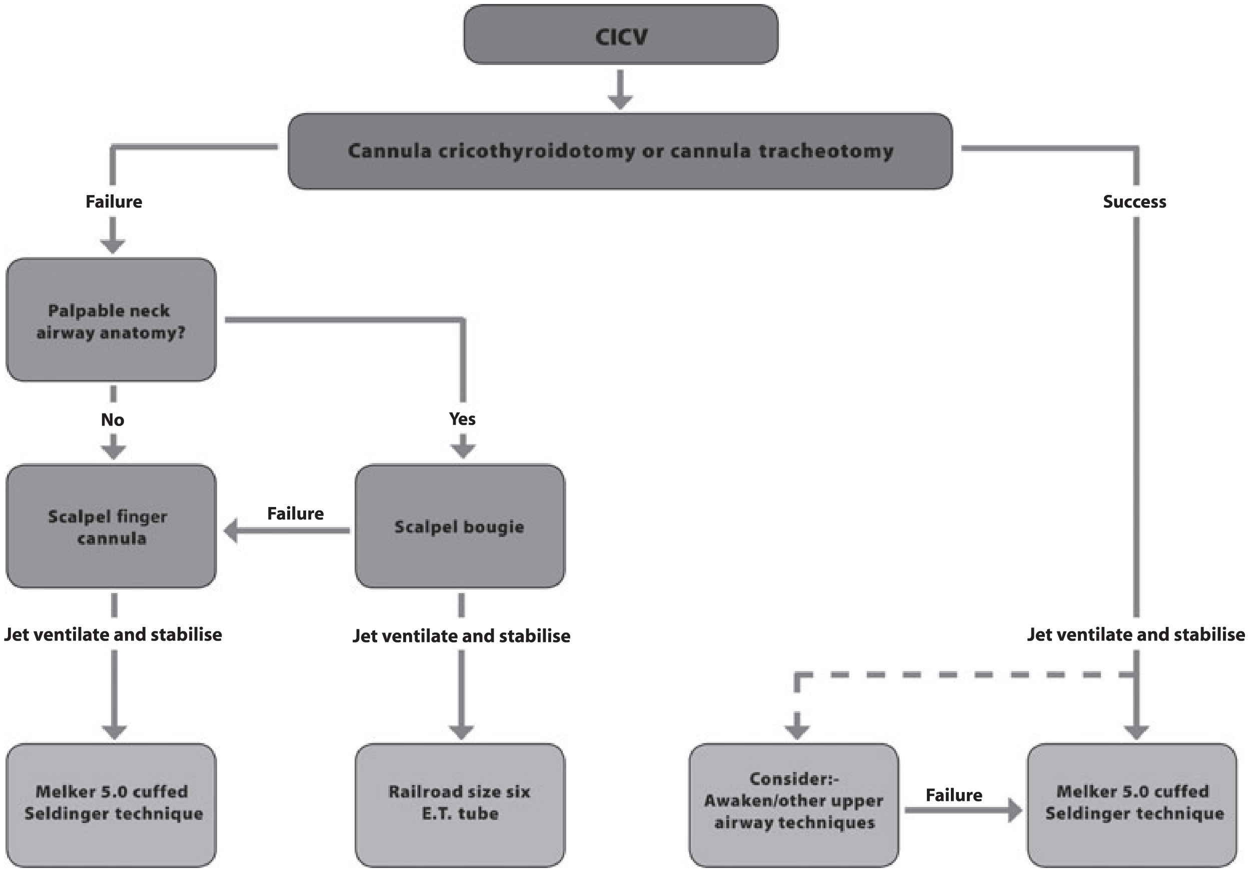

Figure 1 CICV Algorithm.

the added disadvantage of hiding any potential catheter kinks at the skin. The 14-G Insyte^{TM} catheter (Becton Dickinson UK Ltd., Oxford, UK) has the advantage of being readily available and has a strong memory for its initial shape after kinking. Also the Insyte^{TM} compares favourably to cannula with injection ports. The latter have a raised area within their lumens that have the potential to impede wire placement if secondary seldinger techniques are to be performed.

A survey of Canadian anaesthetists' experience of the CICV concluded that cricothyroidotomy by IV catheter has become the first choice infraglottic airway technique due to it's availability and lack of complexity [6]. This technique, however, has limitations. Such cannulae are difficult to fixate, offer no airway protection, lack a conduit for suction, are associated with the risk of barotrauma, and require a special attachment for jet ventilation [6]. Metz [10] presented two case reports in which the 14-G cannulae failed to provide rescue ventilation. Both patients required surgical tracheostomy because of failure of the cannula technique. This was due to catheter kinking and a lack of syringe plunger within the catheter over needle assembly kit to allow confirmation of intratracheal placement. These case reports also highlight that the operator must be familiar with the equipment available and the process of using it. This clinical governance issue is not only the individual's responsibility, but also that of the department.

Jet oxygenation and stabilisation

Successful cannula placement directs us down the right hand side of the algorithm. Upon cannula placement we advocate jet ventilation and reoxygenation. We recommend jet ventilation as the optimal way of achieving rapid reoxygention following each primary procedure. However, a recognised complication of jet ventilation is barotrauma [11, 12]. During trans-tracheal jet ventilation (TTJV) expiration relies on the elastic recoil of the lungs through a patent upper airway and as a consequence complete airway obstruction is considered a contraindication. In this setting, there are a number of reasons why the patient may have airway obstruction, be it complete or partial. Some are reversible with simple airway manoeuvres such as chin lift or laryngeal mask placement, where as others, such as upper airway pathology may be fixed. If the effective trachea diameter is 4.0–4.5 mm, then regardless of any given set of lung or jet ventilation factors, air trapping will not occur [13]. A study in dogs evaluating the effect of graded airway obstruction on pulmonary mechanics during jet ventilation demonstrated that progressive obstruction improved delivered tidal volumes with a consequent decrease in arterial carbon dioxide, concluding that TTJV is a safe technique under conditions of partial upper airway obstruction. However, due to an increase in functional residual capacity and a reduction in mean arterial blood pressure concern still exists as one nears total airway obstruction [14]. A frequent question cited during teaching sessions is – 'How often should I jet in this setting?' Dworkins [13] postulated that where airway size is critically small a respiratory rate of 12 breath. min^{-1} and expiratory time of 4 s may be appropriate. Adopting a prescriptive algorithm is difficult, with rate of jet ventilation determined by the expiratory time of each individual patient. It must also be remembered that the degree of airway obstruction may be dynamic. Glottic aperture size may increase due to changes in transtracheal pressure, or there may be sudden complete obstruction due to the presence of clot, or progressive airway swelling due to repeated upper airway instrumentation. Therefore, in order to maintain safe practise the operator must pay close attention to chest wall dynamics at all times.

Ryder et al. [15] showed that jet ventilation might be the only way to effectively ventilate a patient via a cannula. However, jet ventilators may not always be available, or compatible with ward oxygen outlets. A number of alternative systems have been evaluated, with inspiratory volume delivered relating to the pressure generated within the system [16]. Numerous studies have demonstrated that although low flow rate apparatus may fail to maintain normocarbia, oxygenation is achievable [17–19].

A review by Scarse [20] concluded that in the pre-hospital setting the ideal technique for the CICV was a surgical cricothyroidotomy with ventilation via a self-inflating bag. This conclusion was based on the fact that low-pressure systems via oxygen tubing were ineffective at ventilation. Frerk [21] raised the point that if low flow ventilation via a cannula is inadequate for para medics then why should the anaesthetic community adopt it? It is difficult to draw parallels between the pre-hospital, hospital and certainly the theatre environment. It is hard to envisage that any theatre suite can deliver safe patient care without the provision of a difficult intubation trolley, which should include a jet ventilator. Regardless of this, our primary goal is oxygenation which can be achieved by a variety of means, with adequate ventilation of less importance.

Awaken or upper airway techniques

Having re-oxygenated the patient, one must now decide how to proceed based on the clinical circumstance. It may be appropriate at this juncture to maintain oxygenation until such time that the patient will wake. If however one must secure the airway there are two options. Firstly one could attempt to intubate the patient conventionally, use a laryngeal mask or fibre-optic techniques. In a retrospective series of 29 CICV, 23 had rescue ventilation provided by trans-tracheal jet ventilation. Of these 23, 20 were subsequently successfully orally intubated [22]. The reason postulated is that higher tracheal pressures may open a closed glottis, so facilitating visualisation of the glottic aperture [22, 23]. Additionally, high pressure causes the glottic edge to flutter facilitating the identification of structures [23]. The alternative is to proceed with a seldinger technique and secure the airway with a cuffed Melker.

Melker size 5 cuffed Seldinger technique

Recently a number of seldinger based emergency airway techniques have been introduced, aiming to overcome some of the drawbacks of cannula techniques. Ala-Kokko et al. [24] described two cases in which a mini-tracheotomy was successfully used to provide an emergency airway in patients with partial airway obstruction. Fikkers et al. compared Mini-Trach with the catheter-over-needle (Quiktrach; VBM Medizintechnik GmbH) demonstrating a 85% and 95% success rate and time to successful placement of 150 and 48 s, respectively. This study highlighted a number of limitations of the Mini-Trach in this setting. The technique involves a number of discrete steps, making it relatively complicated especially when the operator is unfamiliar with the equipment. As the needle is blunt, it has to be placed centrally to avoid submucosal positioning. The wire does not have a J-tip and consequently there is a possibility of airway perforation [25]. Other recognised complications include haemorrhage, pneumothorax and subcutaneous emphysema [24].

Studies comparing Seldinger airway techniques with surgical cricothyroidotomy both in manikins and cadavers draw differing conclusions. Suliaman [26] favoured a surgical cricothyroidotomy technique. Schaumann [27] found time to completion and success rates better when using the Arndt Emergency cricothyroidotomy set (Cook critical care) compared to a surgical technique. In contrast both Eisenburger et al. [28] and Chan et al. [29] found that the time to completion of percutaneous rescue techniques and surgical cricothyroidotomy were similar.

By splitting the Seldinger technique we address many of the weaknesses of the Seldinger airway techniques when compared to surgical techniques. The first stage of any Seldinger technique involves cannulation of the airway. Following the basic principles of primary procedure (in this instance cannula cricothyroidotomy) and oxygenation followed by secondary procedure, an overall reduction in hypoxia time results if oxygenation occurred at the initial cannula placement. In Eisenburger's [28] study described above, the mean time to cricothyroid puncture was 30 s with time to first effective ventilation 100 s. If oxygenation had been undertaken at initial cricothyroid puncture, hypoxia time would have been reduced with a mean of 70 s. In our opinion, Seldinger techniques should not represent a first line technique, but are appropriate as a second line procedure. We have found the Melker to be the only effective airway device for securing a cuffed airway in this circumstance. Vadodario et al. compared the Quiktrach, Transtracheal airway catheter (Cook), Patil's Airway and Melker in a human simulator. The Melker and Quiktrach both had a 100% success rate, with a median time to achieving a patent airway of 38 and 51 s respectively [30]. There was a higher incidence of complications in the Quiktrach group. Within this study, they used an uncuffed Melker kit. The strength of the cuffed Melker is the fact that, having achieved rapid reoxygenation via the cannula, it is possible to secure the airway with a 5-mm internal diameter airway. The introduction of the cuffed Melker has revolutionised the use of the cannula in this setting. Prior to this, primary oxygention with the cannula would have been followed by either an upper airway technique, or a surgical intervention.

Cannula failure

For both the cannula and Seldinger techniques the end point for successful placement is aspiration of air. Experience in our sheep work has shown us that this is not always possible. The presence of blood, clot or gastric content all make the operator unsure as to the exact location of their needle tip. Failure of our primary technique leads us down the left hand side of the algorithm, and means we must adopt a technique which relies upon a different endpoint. Where anatomical landmarks are identifiable, we recommend the 'scalpel bougie'. Although this has more of a surgical bias, the amount of scalpel manipulation required is minimal. It also provides a familiar endpoint for most anaesthetists, namely intermittent resistance provided by the tracheal rings, or carinal hold up. Upon successful bougie placement we recommend reoxygenation using a jet ventilator, with the airway secured using a size six internal diameter tracheal tube (railroaded over the bougie). Morris [31] described two cases both in the trauma setting where a gum elastic bougie was successfully placed through a surgical incision made through the cricothyroid membrane, with subsequent placement of a standard tracheal tube.

Failure to identify anterior neck structure

The identification of anterior neck airway anatomy is not always possible. In an obese population it has been shown that those who are difficult to intubate also have a larger amount of pretracheal tissue as quantified by ultrasound, and a larger neck circumference [32]. From this we can conclude that where it is difficult to intubate patients routinely, it may also be difficult to perform emergency airway techniques. Oedema, surgical emphysema, torticollis and clot may also obscure or deform structures. In this setting if the primary technique is failing, it is important to limit how many times the same technique is tried before attempting a different approach in order to avoid fixation error. We recommend a total of five attempts and to try wherever possible to maintain a systematic approach to management.

Where landmarks were absent Shannon et al. [33] described their experience of a surgical cricothyroidotomy technique that involved an extended surgical incision with subsequent dissection until the cricothyroid membrane is identified. The technique involved an incision in the superior aspect of the neck to avoid the superior thyroid artery, with tracheostomy guided by a finger and stylet. The 'scalpel finger needle' technique is a variant of the above. An initial midline incision is followed by blunt dissection using the finger tip, followed by cannula placement. Although this represents an invasive procedure, the risks of trauma and bleeding are outweighed by the priority to establish oxygenation.

Logistic and ethical reasons preclude conducting a randomised prospective trial in humans to evaluate equipment or techniques in this emergency setting. As a result we must use a simulated setting. The majority of our training is based in live anaesthetised sheep. This model has the advantage of providing realistic simulation of this critical event with bleeding, aspiration of gastric contents and real time oxygen saturations. There are however slight anatomical differences. Although cadavers may offer anatomical advantages, they are a poor simulation of emergency airway management and formalin preparation renders the corpse less realistic [25].

Although we have focused on a management strategy for the CICV scenario, the importance of training can't be underestimated, not only for this scenario, but also other aspects of the unanticipated difficult intubation. There appear to be two distinct phases to dealing with failed ventilation firstly recognition and secondly the procedure itself [21]. Once recognised the decision to proceed to the front of the neck in this life-threatening emergency can be equally difficult. We feel that familiarity and a pre-established management plan will both contribute to a successful outcome. Skills are relatively easy to acquire [34]. However, performance fade has been demonstrated after three months (Prabhu AJ, Correa RK, Wong DT, Chung F; Cricothyroidotomy; learning and maintaining the skill for optimal performance. Difficult Airway Society Annual Scientific Meeting, Oxford 2001), so frequent retraining is mandatory.

The process of providing effective airway governance involves a number of discreet steps with the production of a guideline just one part. The successful introduction of this algorithm into clinical practice has been facilitated by both a comprehensive airway skills training programme and a process of continually evaluating both the procedural skills and equipment provision. As a result we have been able to continually refine our algorithm which will hopefully reduce patient morbidity and mortality. The CICV scenario is a rare occurrence within elective anaesthetic practice but it behoves us all to maintain both our own skills and those of our junior staff.

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