



Emergency cricothyroidotomy: a randomised crossover study of four methods

J. C. Dimitriadis¹ and R. Paoloni²

1 Emergency medicine registrar, Royal Prince Alfred Hospital, Sydney, Australia

2 Emergency physician, Concord Hospital, Sydney, Australia

Summary

Emergency physicians and registrars performed emergency cricothyroidotomy on an artificial airway model using a standard surgical approach and three common commercial products, participants had received no refresher training. The order in which the methods were used was randomised to minimise any learning effect. Three methods (standard surgical, Minitrach II, and Quicktrach) were universally successful in obtaining ventilation within 150 s, whilst the Melker kit had a 26% failure rate and significantly longer median time to ventilation (126 s vs ≤ 48 s for other methods, $p < 0.001$). Despite success in using the surgical method, the Quicktrach and Minitrach II were rated as first or second preference by the majority of operators (78% and 70% respectively). Without refresher training emergency physicians and registrars successfully performed emergency cricothyroidotomy using the standard surgical method, Quicktrach and Minitrach II kits however the use of the Melker kit under these conditions resulted in significant delays or failure to establish an airway.

Correspondence to: Dr Richard Paoloni

E-mail: rpao@bigpond.net.au

Accepted: 20 May 2008

The management of the difficult airway has been well outlined in clinical algorithms and continues to be modified in response to advances in new equipment [1, 2]. The 'can't intubate, can't ventilate' situation, at the end of these algorithms, is now a rare clinical occurrence. However, in this situation an immediate cricothyroidotomy is required to be performed as a life-saving procedure.

It is likely that the doctor facing this situation will not have had a recent training session on emergency airway techniques and will not have the opportunity to familiarise themselves with available equipment prior to performing the procedure. Previous surveys in the United Kingdom have indicated that commercial cricothyroidotomy kits are stocked by 36–63% of emergency departments (EDs) [3, 4].

The aim of our study was to evaluate four commonly available emergency cricothyroidotomy techniques to determine which method was the easiest and quickest to perform successfully without refresher training.

Methods

Study design

We conducted a prospective randomised trial of the use of four methods of cricothyroid access using an artificial airway model. The methods assessed were the standard surgical approach, the Quicktrach (VBM Medizintechnik, GmbH, Sulz, Germany), Melker's emergency cricothyroidotomy kit (Cook Inc, Bloomington, IL, USA), and the Minitrach II Seldinger kit (Smiths Medical Ltd, Hythe, UK). Each participant performed all four procedures, with the first method assigned at random to distribute any potential learning effect. Written informed consent was obtained from each participant to be part of a resuscitation study, including timed performance of procedures and the use of sharp instruments.

Participants

The study was conducted within five EDs in Sydney, Australia. Three of the EDs were major referral centres and two were urban district hospitals. The director of

emergency medicine at each site was informed on the nature of the study and consented to the study being conducted within their institution; however, as they were unblinded, they did not participate in the study. Emergency physicians and advanced trainees who would potentially be the senior medical officer on duty in the ED were approached. These doctors would be required to perform a surgical airway in an unanticipated 'can't intubate, can't ventilate' situation if no surgical back up was immediately available.

Study protocol

Previous experience in resuscitative procedures was assessed by a self-administered questionnaire conducted prior to the study. The questionnaire encompassed a wide range of resuscitation techniques so not to disclose the specific nature of the study to the participant.

The study attempted to mimic a real life situation, where a doctor may not have performed a cricothyroidotomy before and the choice of method may depend on the equipment available, rather than solely on operator preference. Participants were not provided with any refresher training or information regarding the equipment they would be using. They were also unaware of the platform on which they would perform the procedures (an artificial model). Participants were assessed individually. Once they had completed the study the doctor was separated from remaining participants to maintain blinding.

The scenario given was: 'This patient is apnoeic. You have attempted intubation but failed, in addition you have tried other difficult airway manoeuvres but are unable to ventilate the patient. They require an immediate cricothyroidotomy. The equipment you require to do this procedure is provided. Please begin'. Timing of procedures was commenced at this point.

Participants were randomised to start with either the Melker kit, the Minitrach II, Quicktrach or scalpel. At each station there was either a scalpel, artery forceps and a size 6.0 endotracheal tube (for standard surgical technique), or the individual kits with equipment inside its original packaging. Also provided were a dressing pack, antiseptic solution, sterile gloves (various sizes), a Laerdal bag, and appropriate ties/other materials to secure the airway. Equipment was re-used and returned to its packaging and sealed with tape – provided there was no visible evidence of damage. Other than the fact that the required equipment was immediately available there was no preparation of the equipment – participants had to remove the equipment from the packaging and familiarise themselves with it in real time.

The Quicktrach has the artificial airway pre-loaded over a hollow large bore needle. A direct puncture is

made of the cricothyroid membrane, air is aspirated to confirm position, and the needle is then removed. A short length of flexible tubing is provided which can be connected between the Quicktrach and the source of ventilation (bag, ventilator). The Minitrach II has a small scalpel with a long thin blade that is used to puncture the cricothyroid membrane. A hollow needle with syringe is inserted via this tract and is air aspirated to confirm position. The syringe is disconnected and a guidewire passed through the needle. The artificial airway is pre-loaded over a long semi-rigid guide/dilator which is passed over the guidewire. The wire and guide are then removed. The Melker kit also involves the cricothyroid membrane being punctured using a hollow needle attached to a syringe, air is aspirated to confirm position, the syringe is removed and the guidewire passed through the needle. The needle is retracted over the guidewire, followed by advancement of the artificial airway loaded over a dilator down the guidewire, followed by removal of the guidewire and dilator. The kit available at the time of this study required the dilator to be manually loaded into the artificial airway. Subsequently a kit with a pre-loaded dilator was produced.

Model airway

An artificial neck model was progressively developed by one of the authors (JD) based on the dimensions, layers and textures of an adult airway. Each version of the model was tested by several emergency physicians who practiced procedures on it and provided feedback on its properties compared with the adult human neck.

The model had an accurately shaped cricothyroid membrane, with an area of 296 mm² compared with reported adult human cricothyroid dimensions of between 200 and 300 mm² [5]. It had a subglottic tracheal diameter of 25 mm. The palpable landmarks of the tracheal and cricoid cartilages were reproduced (Fig. 1).

The trachea and larynx possessed mobility in all planes but particularly allowed lateral movement. Individual synthetic layers were used to mimic skin and tissue planes, and were easily replaced. The model was able to assess successful ventilation through the airway device by means of a balloon connected to the model trachea.

Outcome measures

The primary outcome was time to first ventilation (time to first lung inflation measured in seconds). Secondary outcomes were time to first incision/puncture, time to airway placement, rate of successful airway placement, complications, and operator preference. All timed measures began from the same baseline time point. Inability to establish ventilation within 210 s was deemed a failed procedure, and was assigned a time to ventilation of

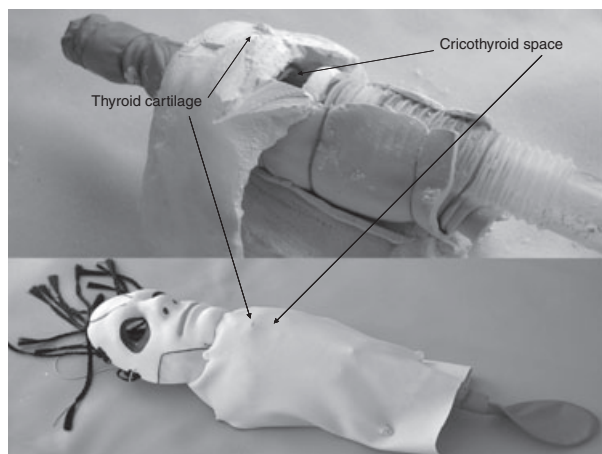


Figure 1 Model airway.

210 s for the purpose of analysis. Doctors preference was recorded as a numeric rating for the individual methods they would like to have available if faced with this situation in clinical practice, from 1 (preferred) to 4 (least desirable). Incorrect use of equipment was noted by the observer.

Data analysis

Categorical variables were assessed for statistical significance using chi square methods or Fisher’s exact method where expected values were small or where zero cells occurred. Raw time data is presented as medians with interquartile ranges. It was anticipated that time and doctor preference data would be not be normally distributed, and therefore were analysed for statistical significance using non-parametric methods (Wilcoxon rank sum and Kruskal–Wallis tests).

Results

Twenty-three doctors consented to participate in the study: seven emergency physicians, nine emergency medicine trainees within 2 years of completion of training, and seven more junior trainees. All participants attempted all four procedures. Self-reported previous experience included 33 attempts at cricothyroidotomy amongst the 23 participants, with only two attempts in non-simulated circumstances and a maximum of three attempts previously for one individual.

Table 2 Time to ventilation and failure rates for each seniority group. Values are median [interquartile range], or number (percentage).

	Junior trainee	Senior trainee	Emergency Physician
Number of participants	7 (30%)	9 (39%)	7 (30%)
Seconds to first ventilation	49 [43–78]	54 [39–97]	59 [35–97]
Failure rate	3 (11%)	1 (3%)	2 (7%)

Time data (time to incision, time to placement, time to ventilation) for each airway method is shown in Table 1. The shortest median time to ventilation was achieved using the surgical technique (34 s). However, the interquartile range for this technique was greater than both the Minitrach II and the Quicktrach. These three methods were universally successful in obtaining ventilation within 150 s (two and a half minutes). Use of the Melker kit was associated with the longest median time to achieve ventilation. The differences in median time to ventilation between methods was highly statistically significant ($p < 0.0001$). There was no significant difference in median time to ventilation according to level of training ($p = 0.96$, Table 2). The position of the equipment in the sequence did not significantly affect time to ventilation with that device.

Of the 92 procedures performed, there were six failures (6.5%), all of which occurred using the Melker kit, constituting a 26% failure rate for this method. There were no differences in failure rates between operators of different seniority ($p = 0.44$, Table 2). It was noted by the observer that incorrect technique occurred in 52% of attempts with the Melker kit. The most common problems were confusion between the two needles and attempting to place the airway without first loading it on the dilator.

Participant preferences for airway methods was divided between the Quicktrach and the Minitrach II devices, which were rated as either the first or second preference by 18 (78%) and 16 (70%) participants respectively. The Melker kit was rated as the least preferred by 18 (78%). The difference in preferences were highly statistically significant ($p < 0.0001$, Table 3). These preferences remained statistically significant in all groups when stratified by clinician seniority (data not shown).

	Surgical	Quicktrach	Minitrach II	Melker
Procedures performed	23	23	23	23
Seconds to incision	15 [10–18]	24 [20–26]	21 [16–30]	28 [25–42]
Seconds to airway placement	32 [27–60]	40 [30–58]	41 [36–48]	123 [97–210]
Seconds to first ventilation	34 [31–68]	48 [36–75]	48 [40–55]	126 [102–210]

Table 1 Time to ventilation for each surgical airway method. Values are raw numbers or medians [interquartile range].

Table 3 Participants preferences for each surgical airway method. Values are number (proportion) of participants.

	1 (preferred)	2	3	4 (least desirable)
Surgical	5 (22)	6 (26)	11 (48)	1 (4)
Quicktrach	10 (43)	8 (35)	2 (9)	3 (13)
Minitrach II	8 (35)	8 (35)	6 (26)	1 (4)
Melker	0 (0)	1 (4)	4 (17)	18 (78)

Analysis of time to ventilation within each preference rating group for individual operators showed that median times to ventilation were shortest in the most preferred method for that operator and highest in the least preferred method ($p < 0.0001$). When stratified by seniority group this relationship remained highly statistically significant for the senior trainee group ($p = 0.004$), but was non-significant in other seniority groups.

Discussion

Performance of an emergency cricothyroidotomy is a rare but life-saving procedure. It is imperative therefore that the method used for securing such an airway should be rapid, highly effective and intrinsically simple to perform. It is likely that any previous training will be remote in time and possibly poorly remembered in this highly stressful situation. There is unlikely to be any preparation time available and the operator may be forced to use whatever equipment is available, even if they are unfamiliar with the equipment.

Many emergency departments in the UK and Australia have one or more prepackaged cricothyroidotomy kits available, including the Quicktrach, Melkers airway and Minitrach II. All departments have equipment available for a standard surgical airway approach. This study assessed the timeliness and success rate of these four emergency airway methods by emergency medicine physicians and advanced trainees in a simulated, unexpected, time-pressured scenario.

The median times from the decision to perform the procedure to first ventilation was < 1 min for the Minitrach II, Quicktrach and surgical approach. Time to ventilation was most consistent using the Minitrach II with all participants achieving ventilation within 63 s. Participants showed a strong preference for the Quicktrach and Minitrach II devices over the standard surgical technique, despite similar success rates and times to ventilation. The reasons for their preferences were not ascertained as part of this study, however, the less invasive nature of the percutaneous needle methods may have influenced their responses.

The success rate of the Melker kit was only 74%, with 52% of participants incorrectly using the equipment. The median times to ventilation were longer (140 and 126 s respectively) in comparison to the other methods tested.

Drawing conclusions from the available literature is difficult due to variation in the methodology used. A similar previous study [6], in which participants had no pre-procedure refresher training, involved anaesthetic consultants and registrars performing emergency airway procedures using a human patient simulator. The four techniques compared were the Melker kit, Quicktrach, a transtracheal catheter and a Patils airway. Participants were allowed up to 5 min, starting when oxygen saturation fell below 80%, to achieve successful airway placement and P_{aO_2} of > 13.3 kPa (100 mmHg). Successful positioning was achieved with all except the Patils airway. The equipment which most rapidly achieved an airway was the Melker with a median of 38 s (IQR 30–54 s) followed by the Quicktrach at 51 s (IQR 42–73 s) despite the latter piece of equipment requiring less steps for its insertion. However, the time to adequate oxygenation was less with the Quicktrach (median 58 s, IQR 50–86 s) compared with 130 s (IQR 111–180 s) recorded for the Melker kit. The prolonged time between correct placement and adequate oxygenation (92 s) with the Melker kit is striking, particularly when compared with the Quicktrach device (7 s) which has the same internal dimensions.

The majority of their participants (60%) preferred the Quicktrach device. It is difficult to reconcile the speed with which the Melker kit was inserted in this study with the substantially longer times to insertion in our study. No participants in their study had previous experience with the emergency airway devices used but 40% of participants who favoured the Melker kit, commented on their familiarity with the Seldinger technique.

All other studies in this area involved some degree of immediate pre-study training, which influences the extrapolation of data from these studies to the real clinical situation. The study by Chan et al. [7] compared the Melker kit with the standard surgical procedure on fresh frozen human cadavers. Participants had a 15-min training session on the Melker kit (including a demonstration) and were then able to practice both techniques on a cadaver prior to the study procedure. Despite this training, and the equipment being already laid out for the operator, the mean time from incision to successful airway placement for the Melker kit was 75 s (95% CI: 63–86 s). The Melker kit was also compared with the standard surgical method by Sulaiman et al. [8] following a training video and live demonstration of each technique. Mean time to insertion was faster using the surgical technique (44 s) than with either the cuffed or

uncuffed Melker kit (87 s, $p < 0.001$). Eisenberger et al. [9] compared first time performance of the Arndt emergency cricothyrotomy kit and the standard surgical technique by intensive care physicians on cadavers. Participants received a 60 min training session, including time to ask questions and discuss issues, prior to the study procedures. The authors concluded that both methods showed equally poor performance. Paradoxically, Schaumann et al. [10] showed emergency physicians to be significantly faster with the Arndt catheter than when performing a standard surgical cricothyroidotomy. Fikkers et al. [11] provided anaesthetists and ear, nose and throat residents with a 10 min presentation and a practice session 1 month before comparing the Minitrach II with the Quicktrach on pig larynxes. This study found shorter preparation time, shorter time from first incision to first ventilation (48 s), and higher success rate using the Quicktrach device.

The effect of training on the success rate and time to completion of emergency surgical airways has also been studied. In a study of anaesthesia specialists and trainees Wong et al. sought to determine the number of repetitions required to achieve a plateau in the success rate with the Melker kit (defined as 40 s or less from start of skin palpation to tracheal insufflation) [12]. Participants received a 3-min video demonstration followed by the opportunity to ask questions, prior to performing the procedures. They found that the success rate reached a plateau at 96% following five attempts. Schaumann et al. [10] compared times to successful placement and ventilation, as well as success rates, for the Arndt kits and standard surgical technique on repeated attempts. Each participant received a 30-min training session and performed both procedures five times prior to the study period. During the study period each operator used each technique on five occasions within a 4-month period. They were unable to demonstrate a statistically significant difference in either of the outcome measures between the first and the fifth attempt, with mean times from start of the procedure to first ventilation of approximately 109 s in the Arndt group and 137 s with the surgical technique. In combination these studies suggest that short-term competency can be improved with training and repetition but that more sporadic on-going practice does not lead to incremental improvements.

In a simulated emergency surgical airway scenario with no preparation time emergency physicians and trainees had universal success in establishing an airway and achieving times to ventilation of < 150 s using the standard surgical technique, Quicktrach and Minitrach II. There were no statistically significant differences between these three methods. The Melker kit was associated with a substantial failure rate, frequent errors in the method of

insertion, and significantly longer times to ventilation. Participants showed a strong preference for needle-based methods over standard surgical technique.

All emergency departments have equipment available to perform a standard surgical airway. It would be our recommendation that EDs should, in addition, have available one of the needle-based emergency cricothyroidotomy kits (either Quicktrach or Minitrach II). All medical staff, particularly senior medical staff should be trained in their use periodically although the optimal method, intensity and frequency of this training has yet to be determined.

References

- 1 Practice guidelines for management of the difficult airway: an updated report by the American Society of Anesthesiologists Task Force on Management of the Difficult Airway. *Anesthesiology* 2003; **98**: 1269–77.
- 2 Henderson JJ, Popat MT, Latto IP, Pearce AC. Difficult Airway Society guidelines for management of the unanticipated difficult intubation. *Anaesthesia* 2004; **59**: 675–94.
- 3 Davies P. A stab in the dark! Are you ready to perform needle cricothyroidotomy? *Injury* 1999; **30**: 659–62.
- 4 Morton T, Brady S, Clancy M. Difficult airway equipment in English emergency departments. *Anaesthesia* 2000; **55**: 485–8.
- 5 Roberts J, Hedges J *Clinical Procedures in Emergency Medicine*. 4th edn. Philadelphia, PA: Saunders, 2004.
- 6 Vadodaria B, Gandhi S, McIndoe A. Comparison of four different emergency airway access equipment sets on a human patient simulator. *Anaesthesia* 2004; **59**: 73–9.
- 7 Chan T, Vilke G, Bramwell K, Davis D, Hamilton R, Rosen P. Comparison of wire-guided cricothyrotomy versus standard surgical cricothyrotomy technique. *Journal of Emergency Medicine* 1999; **17**: 957–62.
- 8 Sulaiman L, Tighe S, Nelson R. Surgical vs wire-guided cricothyroidotomy: a randomised crossover study of cuffed and uncuffed tracheal tube insertion. *Anaesthesia* 2006; **61**: 565–70.
- 9 Eisenburger P, Laczika K, List M, et al. Comparison of conventional surgical versus Seldinger technique emergency cricothyrotomy performed by inexperienced clinicians. *Anesthesiology* 2000; **92**: 687–90.
- 10 Schaumann N, Lorenz V, Schellongowski P, et al. Evaluation of Seldinger technique emergency cricothyroidotomy versus standard surgical cricothyroidotomy in 200 cadavers. *Anesthesiology* 2005; **102**: 7–11.
- 11 Fikkers B, van Vugt S, van der Hoeven J, van den Hoogen F, Marres H. Emergency cricothyrotomy: a randomised crossover trial comparing the wire-guided and catheter-over-needle techniques. *Anaesthesia* 2004; **59**: 1008–11.
- 12 Wong D, Prabhu A, Coloma M, Imasogie N, Chung FF. What is the minimum training required for successful cricothyroidotomy?: a study in mannequins. *Anesthesiology* 2003; **98**: 349–53.