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SHORT REPORT

Emergency surgical cricothyroidotomy: 24 successful cases leading to a simple 'scalpel–finger–tube' method

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Abstract

Surgical airway access justifiably remains the final option for managing the 'can't intubate can't ventilate' situation, but available techniques are often complicated and might require special equipment. This paper reports on the real world experience of two experienced Australian medical specialists with backgrounds in Anaesthesia and Aeromedical Retrieval who performed 24 surgical airways, mainly under adverse prehospital conditions, over a combined 40 years of practice. All attempts were successful, the majority through a simple open 'scalpel–finger–tube' method, which is described here.

Key words: *airway management, intubation intra-tracheal, tracheostomy.*

Introduction

Emergency cricothyroidotomy is the final step of most 'can't intubate can't ventilate' (CICV) algorithms.[1–4] The real world CICV incidence, with the consequent need to proceed to cricothyroidotomy, is however low, with estimates ranging from approximately 1/50 000 intubations in anaesthesia[5] to 1/100 intubations in the ED,[6] although prehospital rates might be higher.[7,8] In consequence, when suddenly required to perform an emergency cricothyroidotomy, the practitioner might have no prior practical experience to draw upon.[9] Nevertheless, failure to open the airway surgically might rapidly lead to the patient's death. As such, emergency surgical airway access might be regarded as a core skill for all practitioners who perform intubations.

There is little consensus in the literature as to which surgical airway technique should be used, with a variety of cannula over needle,[3,10] cannula over wire,[11,12] and open surgical methods described.[3,7,13–15] In this paper, the authors describe their experience with 24 successful emergency surgical airway cases, which has led to their adopting a simple 'scalpel–finger–tube' method for cricothyroidotomy. Given the rapidity and simplicity of the technique, and its high success rate in multiple settings, it would appear to be a useful technique not only for trauma patients, but indeed for all occasions where emergency surgical airway access is required.

The authors are both registered medical specialists in Anaesthesia in Australia, with wide career experience encompassing in-hospital Anaesthesia and Intensive Care, field and ED care of trauma patients, and prehospital Medical Retrieval. Neither are surgeons, with the lead author receiving no surgical training, although the second author completed 1 year of basic surgical training as a junior doctor. Both received their original surgical airway training according to the Advanced Trauma Life Support protocol, which advocated either transtracheal jet ventilation (TTJV) or open surgical cricothyroidotomy.[16]

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Methods

This paper discusses all nine emergency surgical airways attempted by the lead author from 1992 to 2011, and all 15 by the second author from 1989 to 2011. In all cases, an open surgical technique was successfully used. All patients were adults. In the majority of cases, we used our simple 'scalpel–finger–tube' method.

The first step of the 'scalpel–finger–tube' method is to stabilize the larynx with the non-dominant hand, identify the cricothyroid membrane visually and by palpation, and to incise horizontally all the way through skin and cricothyroid membrane into the laryngeal lumen in one motion (Fig. 1). In the emergency situation, neither skin antiseptics nor local anaesthesia are used. Any suitable blade can be used, either on or off the handle. The incision is extended laterally until judged large enough to accommodate the tip of the operator's gloved little finger, that is, approximately 15 mm. The second step is to remove the scalpel and insert the tip of the operator's little finger into the incision (Fig. 2), confirming by palpation that the incision has penetrated into the laryngeal lumen, and that the incision is large enough to accommodate the finger, and therefore, an endotracheal tube. Finally, in the third step, a cuffed oral endotracheal tube is fed through the hole into the trachea, directed somewhat caudally (Fig. 3). The size of the tube can vary, with tubes ranging in size from 6.0 to 9.0 mm internal diameter successfully passed in our series.

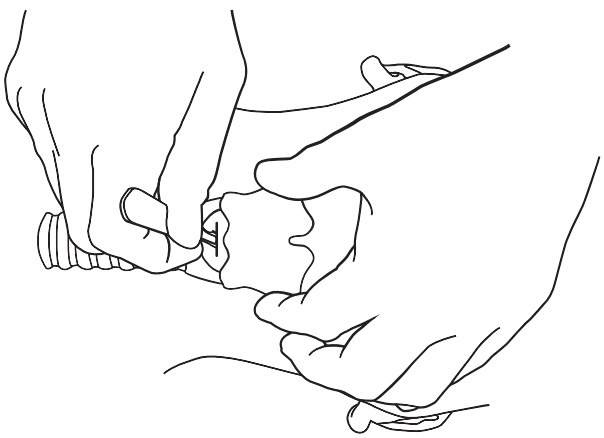

Figure 1. Make a transverse incision over the cricothyroid membrane, passing through all layers and into the laryngeal lumen in one motion.

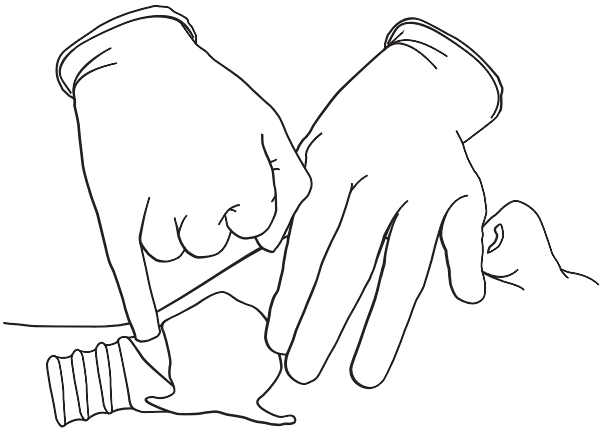

Figure 2. Insert the tip of the operator's little finger into the incision, confirming it reaches the lumen and is large enough to allow passage of the tube.

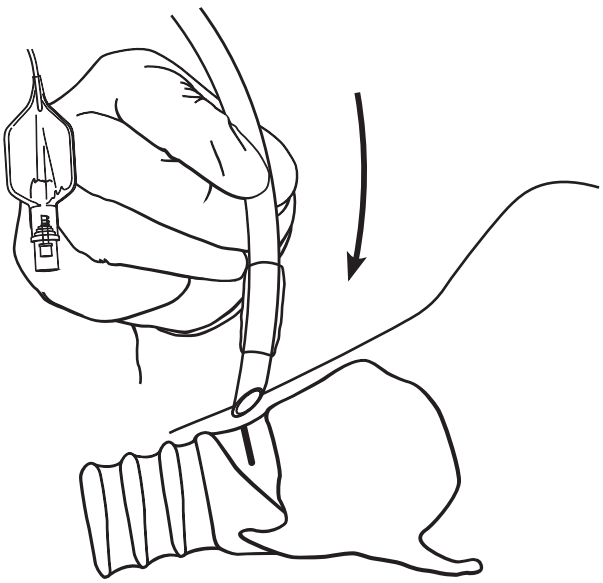

Figure 3. Insert a suitable endotracheal tube, directed somewhat caudally, until the cuff just disappears.

Results

Over a combined 40 years of practice, we performed emergency surgical airways on 24 occasions (Table 1). All of the patients were adults, and 21/24 were male. Vehicular trauma was the most frequent precipitating condition, accounting for 17/24 cases. There were also two cases of adult epiglottitis, one of massive allergic oro-facial oedema, one cranial gunshot injury, one

Table 1. Characteristics of 24 patients undergoing emergency surgical airways

Patient	Place	Reason surgical airway needed	Technique	Complications	Outcome
Adult man: motor vehicle crash (MVC): traumatic brain injury (TBI)	ED	Intubator unskilled – failed oral intubation – failed TTJV – surgical airway	TTJV then scapel–finger–tube	Incision too cranial: resited	Airway successful, good recovery
Elderly man: cardiac arrest	ED	Anatomically difficult airway – failed oral intubation – surgical airway	Scapel–finger–tube	None	Airway successful, died in ED
Elderly man: MVC: TBI	ED	Anatomically difficult airway – failed oral intubation – surgical airway	Scapel–finger–tube	None	Airway successful, died of injuries in ED
Adult man: MVC, facial fractures and multisystem failure, accidental extubation	ICU	Poor view – vomitus in airway – failed oral intubation, LMA sited but inadequate due to vomitus – surgical airway	Scapel–finger–bougie–tube	None	Airway successful, good recovery
Adult man: MVC: TBI and chest injury	Roadside	Poor view – blood in airway – failed oral intubation – surgical airway	Scapel–finger–tube	None	Airway successful, good recovery
Adult man: MVC: TBI	Roadside	Entrapment – airway totally obstructed by blood – primary surgical airway	Scapel–finger–tube	None	Airway successful, died later of injuries
Adult man: MVC: multiple injuries	Roadside	Attempted oral intubation Poor view due to blood in airway and bright ambient light – chest compliance poor, unconvinced tube in trachea – surgical airway	Scapel–finger–tube	None	Airway successful, died on scene of injuries
Elderly man: massive haematemesis	Country hospital ED	Poor view – blood in airway – failed oral intubation – surgical airway	Scapel–finger–tube	None	Airway successful, died in ED from gastrointestinal bleeding
Adult man: MVC: TBI and chest injury	Roadside	Entrapment – blood in airway – no laryngoscope – primary surgical airway	Scapel–finger–tube	None	Airway successful, poor recovery from brain injury
Elderly man: epiglottitis: undergoing CPR on arrival	ED	Failed oral intubation due to swelling – TTJV sited but ineffective – surgical airway	TTJV then scalpel–handle–forceps–tube	None	Airway successful, brain dead subsequently
Adult man: facial and airway angiooedema from peanut allergy, respiratory arrest	ED	Failed oral intubation due to massive oral swelling – surgical airway	Scalpel–handle–tube	Bleeding from incision, conservative Rx	Airway successful, good recovery
Adult man: MVC: TBI	Roadside	Trismus, no relaxants – primary surgical airway	Scalpel–handle–tube	None	Airway successful, good recovery
Adult woman: MVC: TBI and laryngeal #	Roadside	Failed oral intubation due to laryngeal fracture and swelling – surgical airway	Scalpel–finger–bougie–tube	ETT difficult to feed due to laryngeal injury	Airway successful, died of injuries

Table 1. Continued

Patient	Place	Reason surgical airway needed	Technique	Complications	Outcome
Adult man: MVC: TBI	Roadside	Trismus, no relaxants – primary surgical airway	Scalpel–finger–bougie–tube	ETT difficult to feed as incision too small, bleeding from incision, conservative Rx	Airway successful, good recovery
Adult man: MVC: TBI	Roadside	Trapped in car in darkness – poor access – primary surgical airway from seat behind patient	Scalpel–finger–tube	None	Airway successful, good recovery
Adult man: epiglottitis	Country hospital operating theatre	Gas induction – failed oral intubation – LMA sited but inadequate due to oedema – surgical airway	Scalpel–finger–bougie–tube	Difficult to feed ETT due to laryngeal oedema	Airway successful, good recovery
Adult man: MVC: TBI	Roadside	Trapped in car – poor access – primary surgical airway	Scalpel–finger–tube	None	Airway successful, good recovery
Adult man: MVC: TBI and facial fractures	Roadside	Trapped in car – poor access – massive blood in airway – failed oral intubation – surgical airway	Scalpel–handle–tube	None	Airway successful, died of TBI
Adult man: MVC: TBI	Roadside	Trapped in car – poor access – primary surgical airway from behind patient through rear window	Scalpel–finger–tube	None	Airway successful, died on scene from injuries
Adult man: MVC: multiple injuries	ED	Obese – anatomically difficult airway – blood in airway – failed oral intubation – surgical airway	Scalpel–finger–forceps–bougie–tube	Initial incision over cricoid cartilage – repositioned	Airway successful, good recovery
Adult man: gunshot wound to head	ED	Blood in airway – failed oral intubation – surgical airway	Scalpel–finger–tube	None	Airway successful, died of injury
Adult man: MVC: TBI	Roadside	Anatomically difficult airway – blood in airway – primary surgical airway	Scalpel–finger–tube	Bleeding from incision: conservative Rx	Airway successful, good recovery from TBI
Adult woman: MVC: TBI	Roadside	Trapped in car – poor access – blood in airway – primary surgical airway	Scalpel–finger–tube	none	Airway successful, died of injuries
Adult woman: sepsis and respiratory failure from ischaemic bowel, CREST syndrome with 'Parrot beak mouth'	Country hospital ED	Anatomically difficult airway – failed intubation after three plastic laryngoscope blades broke – airway soiled with gastric content – surgical airway	Scalpel–finger–tube	Bleeding from incision: conservative Rx	Airway successful, good initial recovery, died later of pulmonary embolism

LMA, laryngeal mask airway; TTJV, transtracheal jet ventilation.

primary cardiac arrest, one respiratory failure and one massive haematemesis. The majority of procedures, 13/24, were performed in the field, with 9/21 in the ED, one in the intensive care unit and one in the operating theatre. The only case encountered in the traditional anaesthesia environment was an adult man, the airway of whom was lost during a gaseous induction for obstructing epiglottitis in the operating theatre of a small country hospital before aeromedical retrieval. The predominance of men suffering from vehicular trauma in this group mirrors other series.[7,8,17,18] The majority of our cases had multiple factors complicating airway management, including difficult access due to vehicular entrapment, environmental factors, such as darkness, and gross airway soiling with blood or vomitus. Several patients in extremis were intubated serendipitously at the roadside without access to intubating drugs or a laryngoscope. In most cases, equipment for TTJV was also not immediately available. We attempted TTJV on only two occasions. Notably, these two occasions represented the first attempted emergency surgical airway by each author. In one case, a 16g cannula was sited successfully, but immediately judged insufficient to manage the blood soiled airway of the unconscious trauma patient in question. In the other case, a 12g cannula was sited in a patient with epiglottitis, but kinked and failed to ventilate the patient. Both cases were immediately rescued with open surgical cricothyroidotomies, and neither author has attempted TTJV since for adult emergency surgical airway access. Similarly, in most of our cases we judged that managing the airway with a laryngeal mask airway (LMA) would fail, usually because of major airway soiling. We only attempted this on two occasions in our series, both without success. The majority of our cases, 15/24, represented rescue procedures after failed oral intubations; the other nine were undertaken as the primary airway intervention.

The majority of our surgical airways, 15/24, were successfully completed using solely our 'scalpel–finger–tube' method. Early in our series, in keeping with early Advanced Trauma Life Support teaching,[16] we did use the scalpel handle or artery forceps to dilate the wound on 5/24 occasions, but since have come to prefer the tip of the operator's little finger. As described by other authors,[19,20] we also used an intubating bougie to assist in feeding the endotracheal tube on 5/24 occasions, once without clear clinical need, and four times upon finding difficulty feeding the endotracheal tube. On one occasion, this difficulty was encountered because our initial incision was too small, and on three others because the larynx was excessively swollen because of injury or infection. In one such case, swelling was evident externally over the larynx, and in the others was detectable by the absence of a palpable laryngeal lumen when the tip of the little finger was inserted through the cricothyroid membrane.

Immediate complications of surgical airways procedures might include malposition, local bleeding, injury to other structures, excessive time taken and outright failure.[18,21–23] In only two of our cases was the initial incision found to be misplaced, being over the thyroid cartilage in one and the cricoid cartilage in the other. These were easily recognized and the incisions correctly resited immediately. Although we routinely make our skin incision horizontally, in 2/24 cases we used an initial vertical incision. Both were done because the cricothyroid membrane could not be palpated through the skin. Re-palpation after this vertical incision enabled the cricothyroid membrane to be easily identified and a transverse incision then made through it. In only 4/24 cases did we encounter significant bleeding from the incision, three times from our usual horizontal incision, and once when an initial vertical incision was used. All were successfully managed conservatively. There were no cases of unintended injury to adjacent structures, or late complications, including infection, voice changes or airway compromise, particularly from subglottic stenosis.[7,14] We acknowledge that the high rate of death in our series might have masked some complications. High death rates have been reported in other surgical airways series also.[8,22]

We note that 12/24 of our patients made good recoveries from airways obstructions that were immediately life-threatening before our interventions, and that despite the parlous condition of many patients at the scene, and the predominance of traumatic brain injury, most of the survivors had a good neurological outcome. The majority of procedures were completed very swiftly, usually in less than 30 s, even under generally adverse conditions. None of our attempts at open surgical cricothyroidotomy failed to open the airway within a short period of time.

Discussion

Emergency surgical access to the airway has been advocated as a rescue technique for nearly a century, and for much of that time, following the influence of the US ENT surgeon Chevalier Jackson, tracheostomy was held as the method of choice, with cricothyroidotomy

regarded as unacceptably dangerous for fear of later tracheal stenosis.[13] Jackson advocated a simple, rapid, two-step emergency tracheostomy. First, the skin of the anterior neck was widely opened vertically in the midline, and then a finger was used to palpate a suitable gap between the tracheal rings 'in the pool of blood that fills the wound'. Later evidence suggested that the risk of tracheal stenosis related largely to inflammatory airway obstructions, or to transection of the cricoid ring. Cricothyroidotomy for acute airways obstruction is now acknowledged as not only a safe technique,[14] but, because of the superficial nature of the cricothyroid membrane, one that is faster and simpler than formal tracheostomy.[2,3,10,24] It is now widely accepted that cricothyroidotomy is the procedure of choice for emergency surgical access to the airway, and a variety of techniques have been described.[6–8,17,18,20,22,25]

In general terms, emergency cricothyroidotomy might take one of three forms. It can involve inserting a small calibre cannula percutaneously, a large calibre cannula percutaneously, or an open surgical incision. Small calibre cannula or 'needle' cricothyroidotomy involves the percutaneous insertion of an i.v. cannula through the cricothyroid membrane, followed by the injection of high pressure oxygen into the trachea. Small calibre devices are unsuited to low-pressure ventilation, such as by self-inflating bag, and instead require jet insufflation through a high-pressure oxygen source to provide adequate inspiration.[26,27] They also rely on an unobstructed upper airway for expiration,[28] have no cuff to seal off an airway at risk of soiling, do not prevent hypercapnoea,[29] and are only suitable for patients with normal pulmonary function.[3] At best, TTJV through small calibre cannula might provide an alternative route for oxygenation over short periods in patients for whom the airway obstruction is the primary, and temporary, problem. It cannot be regarded as a satisfactory solution for a multiply injured patient with an obstructed airway that is significantly soiled with blood or vomitus. Disturbingly, the recent UK Fourth National Audit project reported that although the small cannula technique was the preferred surgical airway option for UK anaesthetists, it failed to reopen the airway in 65% of real world occasions.[5] In our series, we attempted the needle cricothyroidotomy technique only twice, and found it to be insufficient on both occasions, necessitating rescue by open surgical cricothyroidotomy.

Large calibre cannulas are proprietary devices of at least 4 mm internal diameter, which are inserted through the cricothyroid membrane, often after a preliminary skin incision, and sometimes wire-guided. At 4 mm internal diameter, they are large enough to allow inspiration with a low-pressure source and expiration if the upper airway is blocked.[9] Newer models include a cuff to seal the airway, but can be complex to insert, and all require prior familiarity and immediate availability at each and every location where intubation might be attempted. Both small and large cannula methods have been promoted as potentially preferable by 'non-surgical' practitioners who might be apprehensive about wielding a scalpel when under duress.[30] On no occasion in our series did we attempt large calibre cannula cricothyroidotomy. We could see no advantage to their use over our open method, and because of the unexpected nature of our cases, the relevant equipment sets were generally unavailable when needed.

Open surgical cricothyroidotomy uses an incision through the cricothyroid membrane to allow the insertion of a tracheostomy tube or conventional endotracheal tube directly into the trachea below the vocal cords. In common with the non-surgical, cannula cricothyroidotomy techniques, many open emergency surgical airway techniques are complex, time-consuming and require special equipment that might deter the operator, particularly the non-surgeon, even before beginning. McGill's surgical airway method of 1982 included a vertical skin incision over the larynx, exposure of and identification of the cricothyroid membrane, a horizontal skin incision through the membrane, dilatation of the hole with scissors, insertion of a Trousseau dilator and finally the passing of a tracheostomy tube.[17] Since then, many techniques described have continued to include the initial vertical incision,[15,24,31] identification of the cricothyroid membrane, a horizontal incision through the membrane,[15,24,31] and a variety of special tools, dilators and hooks.[15,25,31] Given the time-critical nature of the emergency surgical airway, it can be argued that any technique used should be as simple and rapid as possible, and that no special equipment be required. With this principle in mind, we have simplified existing surgical cricothyroidotomy techniques to produce a rapid three-step 'scalpel–finger–tube' method, which has proven very successful in our hands. It requires no special equipment, generally only a scalpel blade, a regular oral endotracheal tube and a syringe to inflate the cuff. The use of the tip of the operator's little finger, rather than the scalpel handle or other surgical tool, to dilate the wound, is preferable in that it is a readily available, appropriately sized and sensate dilator, which can be used to confirm that the incision has penetrated into the laryngeal lumen, and is of sufficient size to allow passage of the endotracheal tube. We have also

found the sensitivity of the fingertip helpful in allowing us to identify the presence of intra-laryngeal pathology by palpation, particularly mucosal oedema, which might hinder the passage of the endotracheal tube. We encountered this in two cases, both successfully managed by inserting an intubating bougie before feeding the endotracheal tube. On at least two occasions, where the surgical airway procedure was performed without direct vision of the neck because of darkness or patient entrapment, the tactility of the finger was critical to its success.

Most failed intubation algorithms advocate the intermediate use of supra-glottic devices, such as the LMA before resorting to surgical airway access in the CICV situation.[1–3] We attempted this on only two occasions, and in both instances we successfully sited LMAs, but found them insufficient to adequately ventilate our patients because of heavy airways soiling. We would conclude that, as for small calibre TTJV, the use of the LMA as a temporary measure might be considered in patients for whom the primary problem is an obstructed airway because of soft tissue collapse, but not for those with significant airway soiling or intra-laryngeal pathology, particularly if accompanied by severe head or chest injuries.

In the past, the complexity of traditional multistage open surgical cricothyroidotomy techniques has been justified as a means to minimize bleeding.[15,32] Having located the larynx, they advocated first a midline vertical incision over the anterior neck in order to reduce the risk of cutting the anterior jugular veins. After dissection, the cricothyroid membrane was then identified and incised horizontally over its lower part to minimize the risk of injury to the cricothyroid arteries present over its upper surface. However, we feel the extra vertical incision and dissection is only indicated when the cricoid membrane is difficult to identify percutaneously. Using our single, full thickness horizontal incision, with no attempt to preserve the vessels, resulted in significant bleeding in only 3/22 cases, all of which were successfully managed conservatively. Given the time pressures involved in the CICV situation, we feel that separate vertical and horizontal incisions add unnecessary complexity and are not justified. It should be noted that we found gross upper airway soiling with blood to be a frequent contributor to the need for the surgical airway, and the operator may well find significant drainage of blood when the incision is made. This should not be mistaken for fresh haemorrhage from the incision.

Anatomical studies have indicated that the typical dimensions of the adult cricothyroid membrane are of the order of 9–19 mm horizontally and 9–20 mm vertically.[29,33] In consequence, most methods advocate the passage of a relatively small tube, generally of not greater than 6.0 mm internal[3] or 8.5 mm external diameter.[33] In this series, for reasons of availability, we often used larger oral endotracheal tubes, of either 7.0 or 8.0 mm internal diameter (approximately 10–11 mm external diameter) with success and without apparent injury. We believe our use of the operator's little fingertip to check the adequacy of the size of the incision was helpful in ensuring the endotracheal tube would feed easily. In patients with serious airway soiling, a somewhat larger tube might be preferable to minimize the risk of tube obstruction.

When passing the tube through the cricothyroid membrane, it is important to remember that the cricothyroidotomy incision is located below the vocal cords, and to avoid feeding the tube too far in, producing an endobronchial intubation. This is very easy to do for an inexperienced operator under duress. We pass the tube only until the cuff disappears into the tracheal lumen. It is then secured with a linen tie around the neck, similar to an orotracheal tube. If there is an ongoing need for airway management, options include keeping the tube in the cricothyroid space, or replacing it with either a formal tracheostomy or an oral or nasal endotracheal tube. Although there is a growing body of evidence that long-term cricothyroidotomy tubes are safe,[14,18,34] they are generally regarded as temporary devices to be replaced with either an oral endotracheal tube or a formal tracheostomy as soon as practicable.

Conclusions

Emergency cricothyroidotomy is justifiably regarded as the final option for securing the airway after less invasive manoeuvres have failed. Often the patient presents unexpectedly, and with multiple airway difficulties, including trismus, gross airway soiling and vehicular entrapment. The definitive solution is to site a cuffed tube below the cords. Ideally, the technique chosen should be simple, rapid, effective and require no special equipment or skills. The method should be easy to teach and well retained, even after the passage of time. It should be possible to complete the procedure within 60 s without prior preparation. Open surgical cricothyroidotomy through our simple 'scalpel–finger–tube' method meets all of these criteria, and has proven very successful in this series.

Competing interests

None declared.

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