Original Article

Time to oxygenation for cannula- and scalpel-based techniques for emergency front-of-neck access: a wet lab simulation using an ovine model

K. A. Rees,[1] **L. J. O'Halloran,**[1] **J. B. Wawryk,**[2] **R. Gotmaker,**[3] **E. K. Cameron**[1] and **H. D. J. Woonton**[1]

1 Consultant, Department of Anaesthesia, Monash Medical Centre, Melbourne, VIC, Australia
2 Consultant, Department of Anaesthesia, Townsville Hospital, Townsville, QLD, Australia
3 Consultant, Department of Anaesthesia, St. Vincent's Hospital, Melbourne, VIC, Australia

Summary

Emergency front-of-neck access to achieve a percutaneous airway can be a life-saving intervention, but there is debate about the preferred technique. This prospective, observational study was designed to compare the two most common emergency surgical airway techniques in a wet lab simulation using an ovine model. Forty-three doctors participated. After providing standardised reading, a lecture and dry lab benchtop training, participants progressed to a high-fidelity wet lab simulation. Participants entered an operating theatre where a 'cannot intubate, cannot oxygenate' situation had been declared and were directed to perform emergency front-of-neck access: first with a cannula technique (14-gauge cannula insertion with ventilation using a Rapid-O2® cricothyroidotomy insufflation device); and subsequently, a scalpel-bougie technique (surgical incision, bougie insertion into trachea and then tracheal tube passed over bougie, with ventilation using a self-inflating bag). The primary end-point was time from declaration of 'cannot intubate, cannot oxygenate' to delivery of oxygen via a correctly placed percutaneous device. If a cannula or tracheal tube was not placed within 240 s, the attempt was marked as a failure. There was one failure for the cannula approach and 15 for the scalpel-bougie technique (OR 0.07 (95%CI 0.00–0.43); $p < 0.001$). Median (IQR [range]) time to oxygenation, if successful, was 65 (57–78 [28–160]) s for the cannula approach and 90 (74–115 [40–265]) s for the scalpel-bougie technique ($p = 0.005$). In this ovine model, emergency front-of-neck access using a cannula had a lower chance of failure and (when successful) shorter time to first oxygen delivery compared with a scalpel-bougie technique.

Correspondence to: K. A. Rees
Email: kimrees72@me.com
Accepted: 30 April 2019
Keywords: cannula; CICO; eFONA; scalpel-bougie; simulation
Twitter: @purplekimbo72, @bigsaratoga, @warkwarkwark, @rg141421, @erinkateb, @whooneuw

Introduction

The inability to oxygenate a patient using facemask ventilation, supraglottic airway device or tracheal tube requires the clinician to progress to an emergency front-of-neck access (eFONA) surgical airway [1]. Several guidelines have been produced to guide clinicians in such a situation [1–4]. In 2015, the Difficult Airway Society (DAS) presented its guidelines for management of unanticipated difficult tracheal intubation and recommended a scalpel-based technique as the first-line eFONA technique. The authors also stated that "*there are, however, other valid techniques for front of neck access, which may continue to be provided in some hospitals where additional equipment and comprehensive training programmes are available*" [3], citing evidence from the Fourth National Audit Project (NAP4) [5] for this decision.

The Australia and New Zealand College of Anaesthetists (ANZCA) requires mandatory training in 'cannot intubate, cannot oxygenate' (CICO) management, and many Australian centres continue to teach both cannula- and scalpel-based techniques, having developed courses based on the CICO algorithm described by Heard et al. [2]. In its 2016 statement, ANZCA stated "*It is fully accepted that individual situations, skills and environments will differ and a specialist is unquestionably entitled to choose either a 'scalpel-first' or a 'needle-first' approach,*" going on to recommend that both techniques should continue to be taught [6].

The Department of Anaesthesia in the Monash Medical Centre has developed a structured one-day surgical airway course for doctors (both consultants and registrars), borrowing heavily from the Royal Perth Hospital's CICO programme [2]. Retrospective data from previous work suggest that participants perform eFONA more quickly using a cannula-based technique compared with a scalpel-based approach [2], which is in agreement with our experience.

Despite much anecdotal support for a cannula-based eFONA technique, prospective studies are lacking. Thus, this prospective observational study was undertaken to compare time to oxygenation using cannula- and scalpel-based eFONA techniques in a live animal wet lab simulation.

Methods

Ethical approval had been obtained previously from the Monash University Animal Ethics Committee for the surgical airway course. Prospective human ethical approval was obtained and all participants provided written informed consent. The study was conducted between February 2018 and February 2019. The Monash Surgical Airway Course is open to all advanced anaesthetic registrars (in their third year of training or above), and consultants in anaesthesia, critical care or emergency medicine at Monash Health. Course participation was strictly voluntary. Critical care doctors from other Melbourne hospitals who approached the surgical airway course were also welcomed as participants, but the course was not actively advertised outside the Monash hospital network. A maximum of four participants attended each session.

The airway course composed of four parts: (1) pre-course reading and video tutorials; (2) lecture on the morning of the course; (3) dry lab benchtop instruction in cannula- and scalpel-based eFONA techniques in manikins using techniques outlined previously [2]; and (4) wet lab high-fidelity simulated theatre environment with anaesthetised animal subjects.

For the wet lab simulation, two separate operating theatres equipped with an anaesthetic machine and piped oxygen were run simultaneously with two participants per theatre (taking turns to perform eFONA and act as an observer or assistant). Anaesthesia was induced in the sheep using a jugular injection of thiopentone with maintenance of anaesthesia with isoflurane (in at least 70% nitrous oxide to a minimum alveolar concentration (MAC) of 4). Neuromuscular blocking agents were not administered. Each sheep's trachea was intubated and the tracheal tube remained in place during eFONA attempts; the tracheal tube was positioned with the distal part approximately 26–28 cm from the teeth. Sheep often have up to 30 tracheal rings, so all eFONA were performed in the 'high' superficial part of the trachea. Monitoring included end-tidal gas analysis, audible ECG, pulse oximetry (S_pO_2) and bronchoscopy (Ambu® aScope™; Ambu, Ballerup, Denmark) to confirm correct placement of percutaneous device. The tracheal tube was clamped at the beginning of each scenario when ventilation was ceased. When the sheep reached an oxygen saturation of 90%, course participants (waiting outside) were called in to help with a CICO event (time 0) and directed to a position in the neck distal to the tracheal tube to perform either a cannula or scalpel-bougie eFONA technique. To maximise educational opportunities and to comply with animal ethics, candidates were directed first to perform a cannula technique and subsequently a scalpel-bougie technique. Both techniques are described in full in the supporting information (Appendix S1). In brief, the cannula technique involved the insertion of a 14-gauge 45-mm cannula (BD Insyte™ Autoguard™ BC; BD, Sydney, Australia) with ventilation using a Rapid-O2® cricothyroidotomy insufflation device (Meditech Systems Ltd, Shaftsbury, UK). The scalpel-bougie technique consisted of an incision using a size-10 scalpel with insertion of a bougie (Frova intubating introducer; Cook Medical, Bloomington, IN, USA) into the trachea with subsequent railroading of a tracheal tube (internal diameter 6.0 mm) and ventilation using a self-inflating bag. Participants were required to specifically ask their assistant for equipment as needed or prepare it themselves. If no definitive eFONA was achieved after 240 s, an animal ethics overseer stepped in and the eFONA attempt was abandoned and recorded as a failure. The sheep was then re-oxygenated, end-tidal carbon dioxide reduced to 5.3 kPa and depth of anaesthesia returned to baseline level.

Debriefing of participants occurred after each eFONA intervention and at the end of the airway course.

The primary outcome measure was time to delivery of oxygen via a correctly placed percutaneous device. This was chosen because as the wet lab simulation went on there was more likely to be blood in the animal's airway and lungs, delaying first change in S_pO_2 and time to peak S_pO_2.

Secondary outcome measures were failure rate and time to initiation of eFONA.

Based on preliminary data, a sample of 35 participants was required to detect a difference of 40 s in the primary outcome measure assuming a standard deviation of 70 s (power 90% and significance $p < 0.05$). In order to account for a 20% failure rate, we aimed to recruit 42 participants. The distributions of continuous variables were checked graphically. Normally distributed variables were compared using a paired t-test and a difference of mean values (95% CI) reported. For skewed data, log transformation was performed to achieve approximate normality and mean values compared with a paired t-test. Results were back transformed and reported as a ratio of group median values (95%CI). Paired categorical data were summarised using frequencies and proportions and compared using the McNemar test. All analyses were performed using Stata 14 (StataCorp LLC, College Station, TX, USA).

Results

This study included 43 doctors (26 male): 21 anaesthetic registrars; 14 anaesthetic consultants; six emergency medicine consultants and two intensive care consultants.

Outcome measures are shown in Table 1. Although time to commencing eFONA was longer for the cannula compared with the scalpel-bougie technique, the time to first oxygenation (if the percutaneous airway placement was successful) was faster for the cannula technique compared was the scalpel-bougie technique (median (IQR [range]) 65 (57–78 [28–160]) s vs. 90 (74–115 [40–265]) s, respectively; $p = 0.005$).

Participants had lower odds of failure using the cannula technique compared with the scalpel-bougie technique (OR 0.07 (95%CI 0.00–0.43); $p < 0.001$). There was only one failure in achieving oxygenation using the cannula technique; this occurred in a sheep with a large blood vessel overlying the trachea where the blood vessel (but not the trachea) was cannulated repeatedly. On 15 occasions participants either needed to troubleshoot their cannula placement with simple manoeuvres or required a second attempt before achieving success. In four cases the cannula needed to be withdrawn slightly from the posterior wall of the trachea, in two cases a clot in the cannula was recognised (withdrawn and aspirated) and in one case a kink was recognised. A second attempt was required by eight participants. Failure of oxygenation using the scalpel-bougie technique occurred in 15 scenarios. The most common cause for failure was paratracheal passage of the bougie and tracheal tube (n = 8). Oxygen delivery via ventilation in these devices resulted in surgical emphysema in the neck, making repeated attempts more difficult. Two failures occurred after initial tentative scalpel incision requiring repeated attempts at bougie insertion. Two failures were eFONA attempts that resulted in massive blood loss from the neck, precluding any further attempts at eFONA and necessitating euthanasia of the sheep. One scalpel-bougie failure occurred after likely inadequate fixation of the trachea, with a lateral approach resulting in oesophageal intubation (confirmed using bronchoscope). A narrow inter-tracheal ring space preventing passage of the tracheal tube over the bougie was the cause of a further failure. One failure occurred after a participant abandoned the attempt and repeatedly asked for a cannula instead.

Discussion

In this live animal simulation involving 43 critical care doctors, a cannula technique was found to be more successful and faster than a scalpel-bougie approach at achieving eFONA, after video tutorials and extensive benchtop model training in both techniques.

Previous data have shown cannula-based techniques in CICO situations to have a 65% failure rate [5], usually in perimortem cases [7]. We ascribe our high success rate with the cannula technique to clinicians' familiarity with handling cannulae, in addition to the pre-procedural training that participants received. Simple troubleshooting strategies taught in the dry lab setting for the cannula technique were required in seven situations, with eight participants requiring a second attempt at insertion before success. Despite these interventions, it was significantly quicker to achieve oxygenation with a cannula. Oxygen delivery using the Rapid-O2 cricothyroidotomy insufflation device gave participants crucial tactile feedback where there was a clot, kink or the cannula abutted the posterior

Table 1 Procedural times for emergency front-of-neck access (eFONA) using a cannula- and scalpel-based technique for a simulated 'cannot intubate, cannot oxygenate' scenario using an ovine model. Values are median (IQR [range]).

	Cannula-technique	Scalpel-technique	Ratio (95%CI)	p value
Time to commence eFONA; s	33 (27–39 [15–59])	22 (18–25 [10–54])	1.53 (1.36–1.72)	< 0.001[a]
Time to successful oxygen delivery after eFONA; s	65 (57–78 [28–160])	90 (74–115 [40–265])	0.69 (0.54–0.89)	0.005[a]

[a]Paired t-test was performed on log-transformed times. The difference on the log scale has been back transformed and is interpreted as the ratio of medians between the two methods.

wall, with the sensation of resistance when placing the thumb over the side port alerting participants to an obstruction. This would not be appreciated with other jet-ventilation devices. Successful cannula placement with oxygen delivery using the Rapid-O2 cricothyroidotomy insufflation device has been described in a recent CICO case report [8]. The dry lab teaching of the pitfalls associated with cannula use and troubleshooting strategies were important to the success of this technique.

There was a 35% failure rate with the scalpel-bougie technique. We found failures mostly fell into two groups: marked tissue trauma (including false passage); and human factors. In 11 out of the 15 failures, the initial scalpel attempt resulted in tissue trauma that made any subsequent success unlikely. Eight of these failures were due to paratracheal passage of the bougie and tracheal tube, where ventilation resulted in subcutaneous emphysema and a grossly distorted neck. Two cases of catastrophic haemorrhage and oesophageal passage of bougie and tracheal tube after a lateral scalpel incision (anecdotally never before seen by our group) also resulted in situations that were unable to be redeemed. These 11 failures using the scalpel-bougie technique contrast with the cannula technique where simple manoeuvres or a second attempt often resulted in success after an initial failure. A high rate of false passage of bougie and tracheal tube (65%) has been shown in an obese porcine benchtop model using a scalpel-bougie technique [9]. The chance of false passage increases when the trachea is found deep within tissues [10] (as occurs in obesity) which is relevant to the difficult airway [11, 12]. In addition, a deep trachea makes it more difficult to ensure the tip of the bougie abuts the scalpel blade and enters the trachea [10], as does blood obscuring vision of the bougie tip, as occurred in our live model. We would expect higher rates of failure with the scalpel-bougie technique when the trachea is not superficially situated. Two scalpel-bougie failures occurred where participants were hesitant with initial scalpel incisions and required repeated attempts. No neck distortion or major bleeding resulted in these cases, but these attempts were judged unsuccessful as no correctly placed percutaneous airway was sited within 240 s. Another failure occurred where a participant, not achieving success on first attempt, abandoned the procedure and asked for a cannula instead. These three cases may support the hypothesis that anaesthetists are more comfortable with a cannula, and that there is a ‘cognitive hurdle’ to using a scalpel [13], despite rigorous training on a benchtop model.

The median time of 90 s (when successful) for participants to achieve scalpel-bougie eFONA is similar to the time to achieve cricothyroidotomy in several benchtop model studies [14–16] and a wet lab study [17].

The optimal technique for eFONA continues to be controversial. The DAS guidelines endorse a scalpel-bougie approach with a lack of support for cannula-based techniques, citing a high failure rate in anaesthetists’ hands [3]. Further criticism of the cannula technique relates to the airway complications associated with the use of jet-ventilation via the cannula to achieve oxygenation [5, 18]. The evidence supporting scalpel techniques comes from situations performed predominantly by surgeons (not anaesthetists) and not necessarily using the scalpel-bougie technique now recommended [3, 5]. Supporters of the cannula technique note that anaesthetists are more comfortable and prefer using a cannula rather than a scalpel [19] (with a hypothesis of improved dexterity and clinical experience with a cannula) with less of a cognitive hurdle to progress to an eFONA technique. There are also more clinical opportunities to perform cannula cricothyroidotomies on human subjects in the elective setting [13], especially in those patients at high risk of difficult airway management. Furthermore, a failure at a cannula-based eFONA does not preclude further attempts at placing a percutaneous airway with a scalpel technique. Our findings in sheep support the safety, reliability and low complication rate of the cannula technique. Equipment advances such as the Rapid-O2 cricothyroidotomy insufflation device markedly simplify jet-ventilation and are becoming readily available. This is likely to significantly reduce any jet-ventilation complications, but requires further study.

There were some limitations to this study. We are mindful that it would have been preferable to randomly allocate participants to either cannula or scalpel techniques first. The constraints of limited resources, animal ethics and the need to maximise eFONA training opportunities meant that participants were directed to cannula techniques first, as our past experience has shown this less is likely to result in airway damage and blood in the lungs, thereby increasing the number of subsequent attempts for participants. It could be argued that participants might be less hesitant and more practised when embarking on subsequent attempts leading to faster times for scalpel techniques. Participants were significantly quicker to commence the scalpel-bougie technique; this may be due to fewer steps involved (picking up a scalpel vs. preparing a syringe with saline and attaching to a cannula). However, we cannot exclude an order effect, as participants performed scalpel-bougie as their second eFONA technique. In comparison with benchtop training, wet lab simulation gives participants a markedly different sensory experience. The warmth of tissue, blood on incision, 'pop' of air when a scalpel pierces the trachea and distortion of subcutaneous tissue when oxygen is delivered via an incorrectly placed paratracheal airway is appreciably closer to the experience of working on a human airway. Although there are similarities between sheep and human airways, we acknowledge that a sheep's trachea is longer, more mobile and superficial, with narrower intertracheal ring spaces. In order to maximise airway attempts, participants were directed to a specific area of the neck to commence eFONA (tracheal, rather than cricothyroid membrane), potentially making percutaneous airway placement more difficult. Studies in humans, however, show that clinicians (including trauma surgeons) are inaccurate at identifying the cricothyroid membrane [20–22].

This prospective study showed that, in a wet lab CICO simulation, participants had lower odds of failure using a cannula technique, compared with a scalpel-bougie approach, and, if successful, were faster to achieve oxygenation. These results challenge current DAS recommendations regarding eFONA. A cannula-based technique should still be considered a first-line eFONA option for achieving oxygenation in a CICO event, with the important caveat that appropriate oxygenation equipment should be available.

Acknowledgements

No external funding or competing interests declared.

References

1. Chrimes N. The Vortex: a universal 'high-acuity implementation tool' for emergency airway management. *British Journal of Anaesthesia* 2016; **117**(Suppl 1): i20–7.
2. Heard AM, Green RJ, Eakins P. The formulation and introduction of a 'can't intubate, can't ventilate' algorithm into clinical practice. *Anaesthesia* 2009; **64**: 601–8.
3. Frerk C, Mitchell VS, McNarry AF, et al. Difficult Airway Society 2015 guidelines for management of unanticipated difficult intubation in adults. *British Journal of Anaesthesia* 2015; **115**: 827–48.
4. ANZCA. Guidelines for the management of evolving airway obstruction: transition to the can't intubate can't oxygenate airway emergency. 2016. http://www.anzca.edu.au/getattachment/resources/professional-documents/ps61_guideline_airway_cognitive_aid_2016.pdf (accessed 12/02/2018).
5. 4th National Audit Project of the The Royal College of Anaesthetists and The Difficult Airway Society. Major complications of airway management in the United Kingdom, Report and Findings. Royal College of Anaesthetists, London. 2011.
6. CICO and front of neck access. 2016. http://www.anzca.edu.au/front-page-news/cico-and-front-of-neck-access (accessed 01/03/2019).
7. Cook TM. Strategies for the prevention of airway complications – a narrative review. *Anaesthesia* 2018; **73**: 93–111.
8. Wexler S, Hall K, Chin RY. Prineas SN Cannula cricothyroidotomy and rescue oxygenation with the Rapid-O2 oxygen insufflation device in the management of a can't intubate/can't oxygenate scenario. *Anaesthesia and Intensive Care* 2018; **46**: 97–101.
9. Yeow C, Greaney L, Foy C, King W, Patel B. Evaluation of a novel cricothyroidotomy introducer in a simulated obese porcine model: a randomised crossover comparison with scalpel cricothyroidotomy. *Anaesthesia* 2018; **73**: 1235–43.
10. Heard A, Dinsmore J, Douglas S, Lacquiere D. Plan D: cannula first, or scalpel only? *British Journal of Anaesthesia* 2016; **117**: 533–5.
11. Cook TM, Woodall N, Harper J, Benger J. Fourth National Audit P Major complications of airway management in the UK: results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 2: intensive care and emergency departments. *British Journal of Anaesthesia* 2011; **106**: 632–42.
12. Kelly FE, Cook TM. Front of neck airway: the importance of the correct (obese) models and (trained) participants in study design. *Anesthesiology* 2017; **126**: 986–7.
13. Timmermann A, Chrimes N, Hagberg CA. Need to consider human factors when determining first-line technique for emergency front-of-neck access. *British Journal of Anaesthesia* 2016; **117**: 5–7.
14. Pairaudeau CF, Mendonca C, Hillermann C, et al. Effect of palpable vs. impalpable cricothyroid membranes in a simulated emergency front-of-neck access scenario. *Anaesthesia* 2018; **73**: 579–86.
15. King W, Teare J, Vandrevala T, Cartwright S, Mohammed KB, Patel B. Evaluation of a novel Surgicric® cricothyroidotomy device for emergency tracheal access in a porcine model. *Anaesthesia* 2016; **71**: 177–84.
16. 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.
17. Hill C, Reardon R, Joing S, Falvey D, Miner J. Cricothyrotomy technique using gum elastic bougie is faster than standard technique: a study of emergency medicine residents and medical students in an animal lab. *Academic Emergency Medicine* 2010; **17**: 666–9.
18. Duggan LV, Ballantyne Scott B, Law JA, Morris IR, Murphy MF, Griesdale DE. Transtracheal jet ventilation in the 'can't intubate can't oxygenate' emergency: a systematic review. *British Journal of Anaesthesia* 2016; **117**(Suppl 1): i28–38.
19. Wong DT, Mehta A, Tam AD, Yau B, Wong J. A survey of Canadian anesthesiologists' preferences in difficult intubation and "cannot intubate, cannot ventilate" situations. *Canadian Journal of Anesthesia* 2014; **61**: 717–26.
20. Law JA. Deficiencies in locating the cricothyroid membrane by palpation: we can't and the surgeons can't, so what now for the emergency surgical airway? *Canadian Journal of Anesthesia* 2016; **63**: 791–6.
21. Aslani A, Ng SC, Hurley M, McCarthy KF, McNicholas M, McCaul CL. Accuracy of identification of the cricothyroid membrane in female subjects using palpation: an observational study. *Anesthesia and Analgesia* 2012; **114**: 987–92.
22. Hiller KN, Karni RJ, Cai C, Holcomb JB, Hagberg CA. Comparing success rates of anesthesia providers versus trauma surgeons in their use of palpation to identify the cricothyroid membrane in female subjects: a prospective observational study. *Canadian Journal of Anesthesia* 2016; **63**: 807–17.

Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Appendix S1. Specifics of emergency front of neck access (eFONA) techniques.

Track Haemoglobin Changes in Real Time

Noninvasive and Continuous Haemoglobin (SpHb®) Trend Monitoring

Root® also offers analog view

SpHb trend monitoring may provide additional insight between invasive blood samples when:

- The SpHb trend is stable and the clinician may otherwise think haemoglobin is dropping
- The SpHb trend is rising and the clinician may otherwise think haemoglobin is not rising fast enough
- The SpHb trend is dropping and the clinician may otherwise think haemoglobin is stable

In a randomised trial involving 327 patients undergoing elective orthopaedic surgery, researchers found that the use of continuous SpHb monitoring reduced the rate of blood transfusions as compared to standard care without SpHb monitoring.[1]

SpHb monitoring is not intended to be used as the sole basis for making diagnosis or treatment decisions. Clinical decisions regarding red blood cell transfusions should be based on the clinician's judgment considering among other factors: patient condition, continuous SpHb monitoring, and laboratory diagnostic tests using blood samples.

www.masimo.co.uk/sphb

For professional use. See instructions for use for full prescribing information, including indications, contraindications, warnings, and precautions.

 [1] Ehrenfeld et al. *J Blood Disorders Transf* 2014. 5:9.

Masimo

PLCO-002997/PLMM-11098A-0719
PLLT-10028F