A comparison of three techniques for cricothyrotomy on a manikin

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Background: Cricothyrotomy can either be performed by an “open” cricothyrotomy technique, or by a needle (Seldinger) technique. Clinical uncertainty exists regarding which technique is more effective. We compared three different techniques for cricothyrotomy, performed by anesthesiologists on a manikin.

Methods: The techniques studied include an open surgical technique, the Melker Cricothyrotomy kit (Cook), and the Portex Cricothyroidotomy Kit (Smiths Medical). Participants were randomized to the order they performed each technique. Each procedure was videotaped and the time to first ventilation recorded. The participants completed a 10-point scale following the performance of all techniques to assess the subjective level of difficulty of each technique and to indicate which technique they would prefer in a real clinical CICO scenario.

Results: Mean time to ventilation was significantly faster with the surgical cricothyrotomy technique, when compared with both the Portex and Melker techniques (Mean difference: Portex–surgical = 18 s, 95% CI (1, 36) and Melker–surgical = 42 s, 95% CI (31, 54)). The Portex technique was significantly faster than the Melker technique (Melker–Portex = 24 s, 95% CI (11, 37)). Six of the 11 (55%) participants preferred the Melker procedure, four (36%) preferred the surgical procedure, and only one anesthesiologist (9%) preferred the Portex procedure.

Discussion: The surgical technique was faster than both the Portex and Melker techniques. The surgical technique was also more successful than the Melker technique. The preferred technique among the participants was the Melker technique, despite being the slowest, least successful, and rated most difficult by participants and observers. This suggests that although the surgical technique may not be preferred by many airway practitioners, it has been shown to be the most likely technique to achieve the primary goal of the procedure: establishing oxygenation and preventing death.

Implication statements: This research examines three techniques for cricothyrotomy in the “Can’t Intubate, Can’t Oxygenate” scenario. Our data, as well as data from other studies, suggest that a practice shift towards a surgical technique, and away from needle based techniques, may be warranted.

Key Words: airway management; emergency; cricothyrotomy; manikin; surgical airway

INTRODUCTION

Significant respiratory adverse events are associated with difficulty in airway management [1–4]. It is imperative that an airway practitioner is able to perform a surgical airway. Oxygenation and ventilation can generally be provided by one of four methods: through bag–mask–ventilation, through an extraglottic device (e.g., laryngeal mask airway), through an endotracheal tube, and if everything else fails through a surgical airway [5]. A surgical airway in the “Can’t Intubate, Cannot Oxygenate” (CICO) scenario can be accomplished by tracheotomy (typically performed by a surgeon) or by cricothyrotomy (commonly performed by non-surgical practitioners such as anesthesiologists or emergency physicians). Cricothyrotomy can either be performed by an “open” cricothyrotomy technique or by a needle (Seldinger) cricothyrotomy technique.

Clinical uncertainty exists regarding which technique is more effective. An open surgical technique has been reported to be faster and more successful in several studies [6–12], while others showed no difference [13, 14] or that a needle-guided technique is faster or more successful [15, 16]. Interestingly, in several studies where the surgical technique was shown to be faster, participants preferred a needle technique [10, 13]. The Seldinger technique has been shown to be the preferred technique by anesthesiology practitioners [17].

According to the Fourth National Audit Project audit, anesthesiologists failed to secure a surgical airway in 16 out of 25 attempts (64%) [3]. In this study, we compare three different techniques for cricothyrotomy performed by attending anesthesiologists on a manikin. Our primary outcome measure was time to ventilation, as we feel this best predicts the ability of the given procedure to advance the ultimate goal of establishing oxygenation and preventing death.

MATERIALS AND METHODS

We obtained research ethics board approval at Nova Scotia Health Authority in Halifax in July of 2014. After providing consent, staff anesthesiologists performed three cricothyrotomies on a manikin. The three techniques studied include an open surgical technique (scalpel, trousseau dilator, endotracheal tube), the Melker Cricothyrotomy kit (Cook Medical, Bloomington, IN), and the Portex Cricothyroidotomy Kit (Smiths Medical, Dublin, OH).

The open surgical technique consisted of palpating the cricoid thyroid membrane (CTM), making a vertical incision over the CTM, making a horizontal incision in the CTM, dilating the CTM with the trousseau dilator, and then inserting the endotracheal tube. A trach hook was not used as participants did not have an assistant available to hold it.

The Melker kit was used by filling the syringe with 2 mL of saline. The needle was inserted perpendicularly across the CTM until air was aspirated. The needle was directed caudad at a 45-degree angle as the guidewire was inserted. The airway and dilator were advanced over the guidewire follow by removal of the dilator.

The Portex kit was used by first locating the CTM and then making a small horizontal incision in the skin to facilitate insertion of the device. The Veress needle, dilator, and cricothyrotomy tube were inserted perpendicularly to the CTM until the needle indicator disappeared. This indicated entry into the trachea. The airway was advanced further until the needle indicator appeared again, which indicated contact with the posterior tracheal wall. The device was then directed caudal and advanced a further 1–2 cm. The needle was removed and the airway advanced over the dilator.

We used the Laerdal SimMan manikin (Laerdal Medical Canada, Ltd., Toronto, ON) because it was available at our institution (the Queen

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Elizabeth II Atlantic Health Training and Simulation Centre) and was used in a previous surgical airway simulation study [17]. The artificial skin that covers the site of the cricothyrotomy was replaced between each procedure.

Participants watched a standardized 20-minute instructional video demonstrating each of the three cricothyrotomy techniques. The participants were not allowed to practice any of the techniques prior to participation. The cricothyrotomy kit needed for the technique was opened but not assembled at the beginning of each procedure. The participants were randomized to the order they performed each technique by choosing a sealed envelope.

Following completion of each intubation, an investigator inspected the manikin with a bronchoscope and recorded the position of the airway device and any trauma to the manikin. Success was defined as the airway device being successfully inserted into the trachea, without trauma to the manikin. We specified no upper limit of time to perform the procedure in our definition of success. The participants completed a 10-point scale following the performance of all techniques to assess the subjective level of difficulty of each technique and to indicate which technique they would prefer in a real clinical CICO scenario.

Each procedure was videotaped. Two independent investigators reviewed the videos, and recorded the time to first ventilation which was defined as the time from initial skin puncture or incision to first ventilation. The rationale for these time points is that our goal was to examine the difference between procedural techniques, which would be confounded if we included the time it took various practitioners to assemble the necessary equipment.

Power analysis for pairwise comparisons indicated that 30 cricothyrotomies were needed to detect a mean difference of 30 s between techniques with a standard deviation of 25 s [8], an alpha value of 0.05 and power of 0.80.

Inter-rater reliability across the two observers coding time to ventilation was assessed using absolute agreement intraclass correlations (ICCs) [18]. Hypotheses were tested using generalized estimating equations (GEE). In the present analysis, we specified a gamma distribution with a log link to account for positive skewness, robust estimates of standard errors using the Huber-White sandwich estimator, and an unstructured covariance matrix. In these models, type of procedure (i.e., Portex, Melker, or surgical) was entered as a categorical predictor of outcomes.

RESULTS

Twelve staff anesthesiologists participated in this study. The mean number of years practicing as a staff anesthesiologist was 10. One participant had performed a cricothyrotomy in a real CICO scenario in the past. The data from one participant was removed from the analysis due to improper preparation of the manikin resulting in an outlying data point.

Inter-rater reliability for time to ventilation was adequate, ICC = 0.999, 95% CI (0.998, 0.999). Thus, we averaged scores across both raters, and used these mean scores in subsequent analyses.

The results are summarized in Table 1 with means, standard errors, and pairwise comparisons using a sequential Bonferroni method. Mean time to ventilation was significantly faster with the surgical cricothyrotomy technique when compared with both the Portex and Melker techniques. This is reported here as a mean difference between techniques (Portex-surgical = 18 s, 95% CI (1, 36) and Melker-surgical = 42 s, 95% CI (31, 54)). The Portex technique was significantly faster than the Melker technique (Melker-Portex = 24 s, 95% CI (11, 37)).

Overall, participants generally preferred the Melker procedure (n = 6, 54.5%), followed by the surgical procedure (n = 4, 36.4%), and only one person (9.1%) preferred the Portex procedure. Descriptive statistics suggested that success rates were highest for the Portex procedure (100% success), followed by the surgical procedure (82% success), and the Melker procedure (73% success).

Even though the order to perform the cricothyrotomies was randomized, there was a potential confounding variable of order effect. In a set of exploratory analyses, a 3 × 3 GEE model with type of procedure (Portex, Melker, or surgical), order of the procedure performed (first, second, or third) and their interaction entered as predictors of each of the four dependent variables. Wald χ² testing main effects and interactions are presented in Table 2. For all three variables, the same pattern of results for type of procedure was found when controlling for order effects as reported in Table 1. There were no significant order effects or type order interactions for time to ventilation or participant ratings.

DISCUSSION

Our data showed that the surgical technique was faster than both the Portex and Melker techniques. The surgical technique was also more successful than the Melker technique. This is consistent with data from other similar studies [6–12]. The preferred technique among the participants was the Melker technique, despite it being the slowest, least successful, and rated as most difficult by participants and observers. This is likely due to pre-existing familiarity with Seldinger-based procedural techniques by the anesthesia practitioners [17].

The data from our study, and other similar studies, suggest the need to consider a change in practice in cricothyrotomy to move away from needle-based techniques in favour of surgical techniques. Emergency cricothyrotomy is rarely performed by airway practitioners and the continued improvement of technical skills with airway adjuncts in difficult airway management will not likely improve the efficacy of cricothyrotomy in the practice of airway management [19]. Only 1 of the 11 anesthesia staff in our study had performed a cricothyrotomy in their careers using the Melker kit. It is challenging to choose the best technique for a procedure that is rarely performed. In our opinion, it is difficult to support the

| TABLE 1 |
| --- |
| Means, standard deviations, and pairwise comparisons |
| | Mean (SD) | n = 11 |
| **Outcome** | **Portex** | **Melker** | **Surgical** | **Melker–Portex (95% CI)** | **Pairwise comparisons** |
| Time to ventilation | 62.71 (29.77) | 86.49 (24.09) | 44.22 (11.25) | p < 0.001 (11.02, 36.54) | p < 0.001 (30.71, 53.83) |
| Participant-rated difficulty | 3.73 (2.45) | 4.00 (2.45) | 1.82 (0.87) | p = 0.783 (~1.66, 2.21) | p = 0.005 (3.83, 0.53) |
| Observer-rated difficulty | 1.82 (1.60) | 2.09 (1.51) | 1.09 (0.30) | p = 0.618 (~0.80, 1.34) | p = 0.029 (1.92, 0.08) |

| **TABLE 2** |
| Overall tests of model effects when controlling for order effects |
| **Outcome** | **Mean effect for type** | **Mean effect for order** | **Type–order interaction** |
| Time to ventilation | χ²(2) = 305.64, p < 0.001 | χ²(2) = 3.51, p = 0.17 | χ²(4) = 9.46, p = 0.051 |
| Participant-rated difficulty | χ²(2) = 27.40, p < 0.001 | χ²(2) = 5.46, p = 0.07 | χ²(4) = 0.42, p = 0.98 |
| Observer-rated difficulty | χ²(2) = 13.18, p = 0.001 | χ²(2) = 2.01, p = 0.37 | χ²(4) = 6.36, p = 0.17 |
individual preference of technique. We question how one would come to determine what is best in their hands given the rarity of clinical exposure to the techniques, as well as the lack of formal training and opportunity to practice various techniques. A technique that is successful on a manikin or cadaver may not work on a patient.

In the observational study reported by Lockey et al. [20], the investigators presented a large dataset of physician-led prehospital advanced airway management with a standard operating procedure. When a single best-look direct laryngoscopy attempt failed an extraglottic device (iGel, Intersurgical, UK) would be placed, and if the extraglottic device failed a surgical cricothyrotomy technique would be performed. All surgical cricothyrotomies were successful. While not directly applicable to the operating room setting, the fact that nonanesthesiologist practitioners were able to achieve a 100% success rate in the CICO scenario using the surgical technique, something that has not been demonstrated with needle-based techniques [4], even in a low-fidelity simulation setting, is impressive. This suggests that while the surgical technique may not be preferred by many anesthesia practitioners, it has been consistently shown to be the most successful technique to achieve the primary goals of the procedure: establishing oxygenation and preventing death.

Needle-based techniques require that airway practitioners accurately locate the CTM by palpating surface landmarks. This can be very difficult in those with distorted neck anatomy or obesity. These types of patients are more likely to be difficult to intubate and require a cricothyrotomy. Studies suggest that anesthesiologists are unable to accurately locate the CTM the majority of the time, particularly in obese and female patients [21, 22].

There were some limitations to our study. The sample size is small, affecting the power of the data. Larger scale studies and studies utilizing other airway simulators are required to confirm the findings of this study. The study manikin was changed during the study, as there was significant damage to the posterior tracheal wall as a result of one of the procedures with the Melker device. This created a false passage and would likely affect subsequent cricothyrotomy procedures. The need to change the manikin during the study impacts the standardization of the procedures for all participants. It is unlikely that the need to change the manikin significantly impacted the final data analysis. It is unknown how transferable data collected on manikins is to real clinical practice. A technique that is effective on a manikin may not be effective in a real CICO situation. Our study did not investigate all commercially available techniques for cricothyrotomy, nor did it investigate any modified techniques that could be employed in a real situation.

The limitations we experienced with a manikin model suggest that the development of a cost-effective and realistic model for cricothyrotomy training is needed. Wong et al. [23] found that when learning the skill, cricothyrotomy should be performed five times to achieve a reasonable success rate. The cost of five cadavers would be prohibitive to many institutions. However, damage to a manikin that requires it to be replaced is undesirable and a disposable biologic model may be the appropriate compromise as described by Cho et al. [24].

In conclusion, our results demonstrate that open cricothyrotomy provides more rapid airway access and comparable success when compared with needle access methods, despite less familiarity with the open technique among our participants. Larger scale studies and meta-analyses of existing data are needed to further examine various techniques for cricothyrotomy in the CICO scenario. Based on the results of this study, and various other studies on the topic, we feel it warranted that airway training courses emphasize the open technique as a primary technique.

DISCLOSURES
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