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Research Article

Dilator-Assisted Versus Bougie-Assisted Endotracheal Tube Placement During Surgical Cricothyrotomy on Live Pigs Performed by Anesthesia Residents with no Previous Experience in the Procedure

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Abstract

Background: Cricothyrotomy is a life-saving emergency procedure used in Cannot Intubate, Cannot Ventilate (CICV) situations.

Methods: Anesthesia residents (n = 57) with no previous experience in cricothyrotomy were trained in scalpel-dilator and scalpel-bougie surgical techniques. After the training, residents selected one technique to practice cricothyrotomy in vivo on anesthetized pigs. Time to complete the procedure and complications were recorded.

Results: Twenty-eight residents chose to perform the scalpel-dilator technique, and 29 residents chose the scalpel-bougie technique. The average time to complete cricothyrotomy was 128 ± 22.8 seconds (mean ± SD) with the dilator and 122 ± 22.7 (mean ± SD) seconds with the bougie (p-value: 0.33). Only one false passage (4%) occurred during the dilator-assisted technique while 7 (24%) false passages occurred during the bougie-assisted technique (p-value = 0.052).

Conclusion: Time needed to complete cricothyrotomy was similar for dilator and bougie-assisted techniques. However, the bougie-assisted technique may be associated with an increased rate of false passage of the endotracheal tube.

Abbreviations: ASA: American Society of Anesthesiologist; BACT: Bougie-Assisted Cricothyrotomy; CICV: Cannot Intubate, Cannot Ventilate; ETT: Endotracheal Tube; IACUC: Institutional Animal Care and Use Committee; RFST: Rapid Four-Step Technique; SD: Standard Deviation; UCSD: University of California in San Diego

Introduction

Cricothyrotomy is a life-saving emergency procedure used in "Cannot Intubate, Cannot Ventilate" (CICV) settings. [1] Situations requiring cricothyrotomy are rare, therefore rescuer's skills may be limited. Techniques that allow rapid completion of the procedure and that minimize complications, especially among inexperienced rescuers are needed. Indeed, training rescuers to perform cricothyrotomy on cadavers, manikins, or animal models may increase rescuer's confidence and limit complications. In order to prepare our anesthesia residents to respond to emergent CICV situations and to identify the optimal cricothyrotomy technique, we developed a training project s that compares two surgical techniques. Surgical cricothyrotomy is a valuable last-step rescue tool, and typically involves the incision of skin, subcutaneous tissues, and cricothyroid membrane; dilation of the opening; and the insertion of a tube/cannula into the airway. In the scalpel-finger-bougie technique the index finger is inserted into the trachea to confirm the airway access by palpating the tracheal rings before the bougie is inserted [2]. Emergency cricothyrotomy can also be performed percutaneously by inserting a catheter into the airway over a needle or a wire guide, such as in the Seldinger technique. Commercial percutaneous cricothyrotomy kits usually contain an uncuffed cannula with internal diameter > 3.5 mm. In the needle cricothyrotomy method, a smaller cannula - usually a 13-/16-gauge catheter - is inserted over a needle. This method requires the availability of jet ventilation and is associated with high risk of barotrauma and failure rate. [3,4]

Uncuffed cannulas provide less effective ventilation than cuffed endotracheal tubes (ETTs). Surgical techniques may be

associated with higher success rates, and with faster and safer tube insertion compared to percutaneous methods when performed on human cadavers by inexperienced health-care providers [5-7]. Furthermore, larger tubes used in the surgical procedure allow a better manual ventilation with low pressure in situations where jet ventilation is not available. The rapid four-step technique (RFST) is a modified version of the surgical technique which does not include blunt dilation of tissues but involves tube insertion into a single stab incision through the skin and cricothyroid membrane, assisted by caudal traction with a tracheal hook [8]. According to a study on 32 emergency medicine trainees with no experience in the procedure, the RFST performed on human cadavers required a third of the time compared to the standard method (mean: 43 vs. 134 seconds) with similar rates of success and complication. However, more severe complications, including complete transection of the cricoid cartilage and posterior tracheal/esophageal perforation, were observed during RFST [9]. A later study on 21 inexperienced residents and medical students suggests that the RFST may be improved by using a bougie to assist tube placement. Rescuers using the bougie technique completed the procedure faster than rescuers using the standard dilator technique (median [interquartile range]: 67 [55-82] vs. 149 [111-201] seconds, respectively) [10]. The bougie technique was rated easier to perform and had complication rates similar to the standard procedure [10]. While a bougie-modified RFST appears to be associated with a quicker procedure, it remains unclear whether bougie-assisted insertion is associated with a higher rate of complications or more severe complications. Two practitioners experienced in surgical airway management compared the bougie-assisted cricothyrotomy (BACT) to a percutaneous technique using the Tracheo Quick Plus cricothyrotomy kit on anesthetized minipigs. They reported no difference in the total success rate, but the BACT was faster (median: 69 vs. 178 seconds) and less traumatic than the percutaneous technique [11]. In order to better understand the role of the bougie in cricothyrotomy and to evaluate the role of the bougie as a mechanism of procedure complication, we compare bougie- assisted tube insertion and dilator-assisted tube insertion during standard surgical cricothyrotomy procedures performed on anesthetized pigs by novice rescuers.

Methods

This study was performed in a research area of the University of California in San Diego (UCSD), an academic tertiary referral center and teaching hospital. Data were collected from 2015 to 2018. A teaching protocol using anesthetized pigs was approved by the Institutional Animal Care and Use Committee (IACUC) of UCSD. Cricothyrotomy was performed on pigs and therefore it was not necessary to obtain Institutional Review Board approval.

Study Design

Anesthesiology residents with no previous experience in cricothyrotomy were elected to perform either the scalpel-dilator or scalpel-bougie surgical cricothyrotomy on anesthetized pigs. All residents were trained on both invasive airway techniques. Twenty- eight residents performed the scalpel-dilator method and 29 residents performed the procedure using the scalpel-bougie method. Only one procedure per resident was performed. None of the residents had any experience in performing a cricothyrotomy procedure or accessing a tracheal airway prior to this project. As part of their pre-procedure education, residents received reading material, practiced cricothyrotomy on manikins, and watched a video describing and demonstrating the steps of both surgical techniques. During the procedures, pigs were anesthetized, intubated, and monitored using standard American Society of Anesthesiologist (ASA) monitors (blood pressure, heart rate, pulse oximeter, and end-tidal CO_2). The average weight of the pigs was 45-50kg.

Scalpel-Dilator Technique

During the scalpel-dilator technique, the neck of the animal was extended, and palpated. A superficial vertical incision was made using a #15 blade. The cricothyroid membrane was palpated, and the tissue was blunt dissected with fingers. A horizontal incision was made with the blade to cut through the cricothyroid membrane and then the blade was rotated 90 degrees with the sharp edge caudally. A tissue dilator was used to expand the incision and maintain airway exposure. The oral ETT was pulled back and the tracheal lumen was palpated with the fingertip. A cuffed6 mm ETT with stylet was inserted into the airway and the cuff of the tube was inflated (Figures 1 & 2).

Figure 1: Equipment for dilator-assisted technique.

Figure 2: Dilator-assisted technique.

Scalpel-Bougie Technique

During the scalpel-bougie technique, the neck of the animal was extended, and palpated. A superficial vertical incision was made using a #15 blade. The cricothyroid membrane was palpated, and the tissue was blunt dissected with fingers. A horizontal incision was made with the blade to cut through the cricothyroid membrane and then the blade was rotated 90 degrees with the sharp edge caudally. The straight tip of a 15 F bougie was inserted alongside the blade and slid with an angle into the tracheal lumen. A cuffed 6 mm ETT was railroaded over the bougie into the airway and the cuff of the tube was inflated (Figures 3 & 4).

Figure 3: Equipment used during bougie-assisted technique.

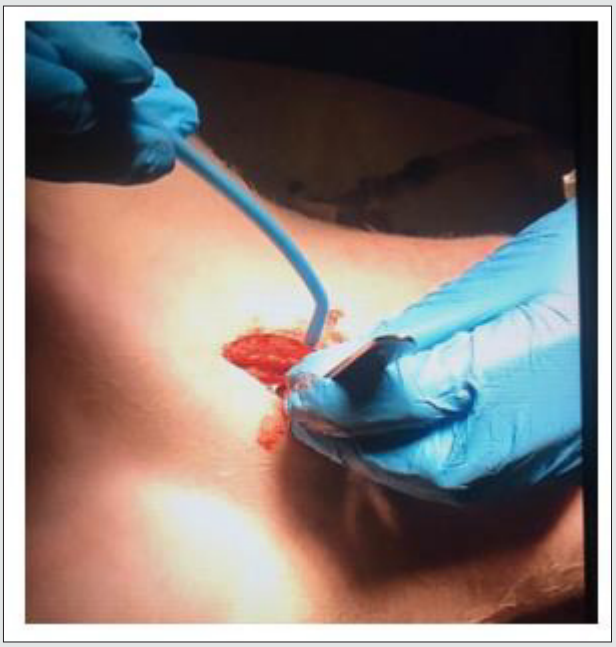

Figure 4: Bougie-assisted technique

Outcomes

The primary outcome was time to procedure completion. Skin incision was defined as the start of the procedure, and the end of the procedure was defined by the attachment of the ETT to the ventilation circuit. Successful ETT placement was assessed by the presence of end-tidal CO_2. Failure to confirm placement of the tube in the trachea was considered as false passage. If a false passage was created, the tube was withdrawn, and insertion was reattempted through the existing incision. For procedures where a false passage occurred, procedure time included the time required to identify and correct a false passage. End- tidal CO_2 was achieved for all animals. No pigs died during the procedure. A supervising instructor assessed the occurrence other complications during the procedure.

Statistical Analyses

A two-sided independent sample t-test was used to compare procedure times, and a Fisher's exact test was used to compare the rate of false passage between study groups. Statistical significance was evaluated at the 0.05-alpha level.

Results

There was no statistically significant difference in time to cricothyrotomy completion between residents using the scalpel-dilator technique and residents using the scalpel- bougie technique. Procedure completion from skin incision to attachment of the endotracheal tube to a ventilation circuit took an average of 128 ± 22.8 (mean ± SD) seconds for residents using the scalpel-dilator technique and of 122 ± 22.7 (mean ± SD) seconds for residents

using the scalpel-bougie technique (p-value = 0.33; Table 1 & Figure 5). False passage of the endotracheal tube occurred more frequently during bougie-assisted tube insertion than during dilator-assisted tube insertion. Although not statistically significant, 7 false passages (24%) occurred when using the scalpel-bougie technique while only one false passage (4%) occurred when using the scalpel-dilator technique (p- value = 0.052; (Table 1), Figure 5. All residents completed the procedure, and no other complications were observed.

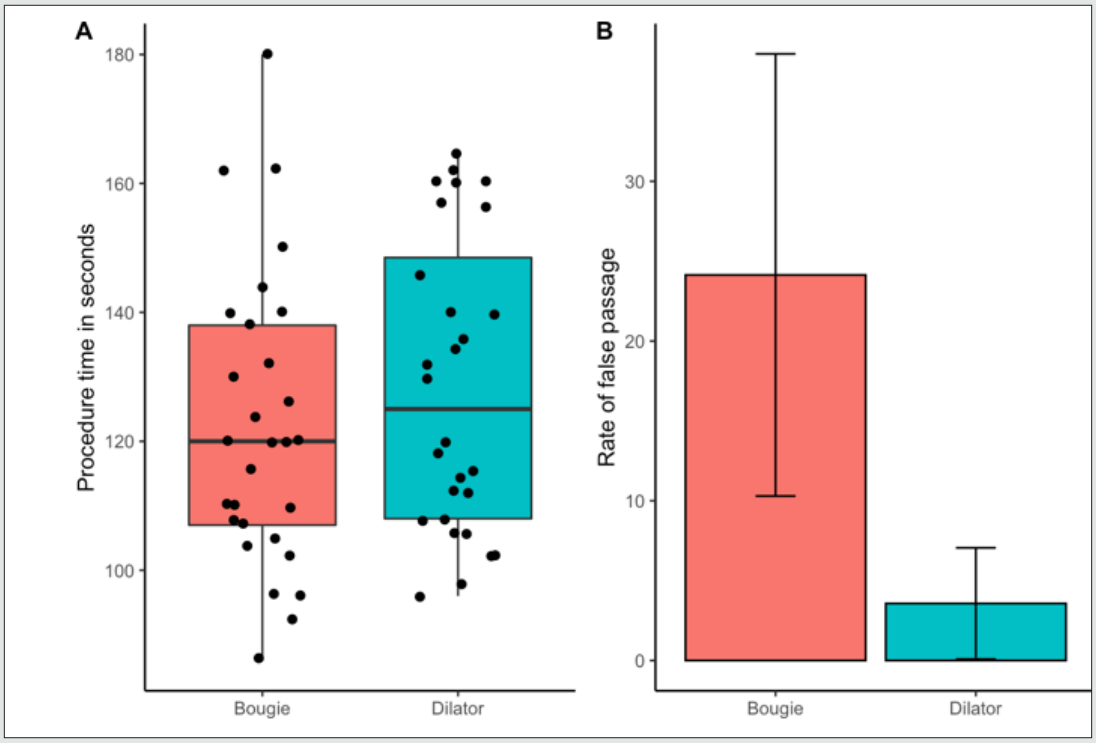

Figure 5: A) Boxplots of time to procedure completion in seconds for Bougie-and Dilator-assisted cricothyrotomy techniques. B) Bar plots showing rate of false passage by cricothyrotomy method. Error bars represent 95% confidence intervals.

Table 1: Time to procedure completion and rate of false passage for bougie-assisted versus dilator-assisted surgical cricothyrotomy techniques.

	Bougie-assisted	Dilator-assisted	
	N = 29	N = 28	*p*-value
Procedure time (seconds), Mean (SD)	122 (22.7)	128 (22.8)	0.325
False passage, Freq. (%)	7 (24%)	1 (4%)	0.052

SD: standard deviation, freq: frequency

Discussion

According to the Difficult Airway Society guidelines, surgical cricothyrotomy is the preferred rescue method in CICV situations. 2-4, 7 Emergent surgical airway is a life- saving, time-sensitive procedure that is usually performed under stressful conditions. A rehearsed technique is more likely to be performed successfully under such conditions [1]. Due to the rarity of situations requiring emergent surgical airway, rescuer training on humans is impractical. Therefore, we aimed to teach anesthesia residents to perform a surgical airway using anesthetized pigs. In order to identify the optimal surgical cricothyrotomy procedure, we compared the completion time and the rate of complication between the scalpel-dilator and scalpel-bougie techniques. We found that standard surgical airway access using dilator-assisted tube insertion took approximately the same amount of time as bougie-assisted tube insertion. On average, our residents completed the procedure in 128 seconds when using the scalpel-dilator technique and in 122 seconds when using the scalpel-bougie technique. Although not statistically significant, the false passage rate was higher in the scalpel-bougie group. These findings support the use the scalpel-dilator technique and suggest that bougie-assisted tube insertion may be a mechanism of complication among rescuers with minimal experience.

False passage of the ETT is one of the main reasons for failed rescue. Insertion of a breathing tube into the trachea through the surgical opening may require force which may result in posterior (membranous) wall rupture and positioning of the tube in the mediastinum. Increased subcutaneous tissue anterior to the trachea may provide the space for a false tract and a malpositioned tube [12,13]. Pigs usually have larger necks and more adipose tissue surrounding the airway. This unique anatomy may have the effect of increasing the rate of false passage but may also better prepare trainees to correctly place an ETT under challenging circumstances. The use of a tissue dilator to maintain airway exposure after incision may reduce the chances of tube misplacement. Notably, false passage was the only complication observed in our study, whereas complications described in both Hill et al. (2010) and Holmes et al. (1998) also included inability to pass the tube, and inability to pass the bougie.9,10 Additional complications observed in Hill et al. (2010) and Holmes et al. (1998) may be related to the stab incision rather than to the use of bougie or to differences in pre-procedure training and rescuer experience level [4] Henlin et al. (2017) reported that although there was no difference in total success rate, there was a 94% success rate during the first attempt with the BACT vs 18% when using the Tracho Quick Plus cricothyrotomy kit. 11 Also, they observed posterior wall trauma only one time with the BACT and 5 times with the percutaneous technique [11]. The difference may lie in the specific design of the cannula used (stiffer and less curved than the ETT) rather than the technique itself. If they had compared the BACT technique to the surgical technique using a 6.0 mm ETT the complication rates might have been similar.

Although we also used live porcine models, we can't really compare the results of the two studies since we compared two different techniques and the experience gap in between the performers in the two studies was relevant. It is possible that experience plays a big role when using the bougie technique and is responsible for the complication difference in the BACT between the two studies. A pool of international airway experts used a a modified Delphi method to develop a BACT checklist for novice instruction. They suggested, after making a vertical incision through the skin and a transverse incision through the cricothyroid membrane, inserting the index finger into the transverse incision and slide the coude tip of the bougie beside the finger into the airway [14]. We noted that a better exposure of the airway, after cricothyroid membrane incision, with either the index finger as described above, or a tracheal hook as used in the Hill study, 10 may lead to higher success rates. Cricothyrotomy performed on anesthetized animal s may be more challenging than procedures performed on manikins or cadavers. The presence of blood in the field may obscure vision and prolong the completion of the procedure or increase the risk of complications [1,3,4,6]. Limitations of this study include the small sample size and a non-randomized design.

Conclusion

This study suggests that there is no difference in the time to procedure completion between dilator- and bougie-assisted methods. Additionally, our data suggest that the use of a dilator may reduce the rate of false passage. Additional studies are needed to confirm our results. The low frequency of cricothyrotomy interventions makes teaching using human models unfeasible. Here, we have demonstrated that animal models provide a training alternative when investigating the most appropriate technique for novice rescuers.

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