



Role of ultrasonography in an impalpable tissue larynx model during a simulated front-of-neck access scenario: a randomized simulation study

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Abstract

Purpose A large vertical incision is recommended when performing front-of-neck access in patients with impalpable neck landmarks during a cannot intubate–cannot oxygenate (CICO) scenario. We investigated the impact of ultrasonography on vertical incision size of a front-of-neck access on an ultrasound-compatible impalpable porcine larynx model.

Methods Emergency medicine and anesthesia trainees were randomized to the Ultrasound (US, $n=21$) and Non-Ultrasound (NUS, $n=21$) groups. Within 1 week after a teaching session on airway ultrasound and Scalpel-Bougie-Tube (SBT) technique, participants were instructed to perform cricothyroidotomy on the model during a simulated cannot intubate–cannot oxygenate scenario. The primary outcome was a vertical size incision. Secondary outcomes were procedural completion time, horizontal size incision, tissue injury severity, and correct tube placement.

Results The ultrasound group performed a significantly smaller vertical incision [median (IQR), 35.0 (15, 40) vs 65.0 (52, 100) mm (95% CI) – 30.0 (– 55.1, – 4.9), $p=0.02$] and took longer total time to complete the procedure [median (IQR), 200.5 (126, 267) vs 93.5 (71.0, 167.5) secs (95% CI) 91.0 (3.73, 178.3), $p=0.04$]. Tissue injury severity and correct tube placement were similar between groups.

Conclusions Ultrasound-guided identification of the cricothyroid membrane significantly reduced the recommended vertical incision size with similar success rates. However, there was an increased time when performing a Scalpel-Bougie-Tube cricothyroidotomy on an impalpable porcine larynx model by physicians in training. Ultrasonography should not be used in an emergency scenario of airway rescue. Its potential use to pre-mark the cricothyroid membrane should be considered in difficult airway management of impalpable neck.

Keywords Ultrasonography · Cricothyroid membrane · Cricothyroidotomy · Front-of-neck access · Simulation

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Résumé

Objectif Il est recommandé de pratiquer une grande incision verticale lors de l'accès à l'avant du cou chez les patients dont les repères du cou sont impalpables, dans le cadre d'un scénario d'intubation impossible à oxygéner (CICO). Nous avons étudié l'impact de l'échographie sur la taille de l'incision verticale d'un accès à la face avant du cou sur un modèle de larynx porcine impalpable compatible avec l'échographie.

Méthodes Des stagiaires en médecine d'urgence et en anesthésie ont été répartis de manière aléatoire entre les groupes "échographie" (US, n = 21) et "non-échographie" (NUS, n = 21). Une semaine après une session d'enseignement sur l'échographie des voies aériennes et la technique Scalpel-Bougie-Tube (SBT), les participants ont reçu l'instruction de réaliser une cricothyroïdectomie sur le modèle lors d'un scénario simulé d'impossibilité d'intubation et d'oxygénation. Le résultat primaire était une incision de taille verticale. Les résultats secondaires étaient le temps de réalisation de la procédure, la taille horizontale de l'incision, la gravité de la lésion tissulaire et le placement correct du tube.

Résultats Le groupe échographie a réalisé une incision verticale significativement plus petite [médiane (IQR), 35,0 (15,40) vs 65,0 (52,100) mm (IC à 95 %) -30,0 (-55,1, -4,9), p = 0,02] et a pris un temps total plus long pour terminer la procédure [médiane (IQR), 200,5 (126, 267) vs 93,5 (71,0, 167,5) secondes (IC à 95 %) 91,0 (3,73, 178,3), p = 0,04]. La gravité des lésions tissulaires et le placement correct du tube étaient similaires entre les groupes.

Conclusions L'identification échoguidée de la membrane cricothyroïdienne a réduit de manière significative la taille de l'incision verticale recommandée avec des taux de réussite similaires. Cependant, il y avait une augmentation du temps lors de la réalisation d'une cricothyroïdectomie Scalpel-Bougie-Tube sur un modèle de larynx porcine impalpable par des médecins en formation. L'échographie ne doit pas être utilisée dans un scénario d'urgence de sauvetage des voies respiratoires. Son utilisation potentielle pour pré-marquer la membrane cricothyroïdienne devrait être envisagée dans la gestion des voies aériennes difficiles du cou impalpable.

Mots clés échographie · Membrane cricothyroïdienne · Cricothyroïdectomie · Accès par l'avant du cou · Simulation

Clinician's capsule

What is known about the topic?

Difficult airway guidelines recommend a large vertical incision when performing front-of-neck access in patients with impalpable neck landmarks.

What did this study ask?

Does ultrasound-guided identification of the cricothyroid membrane modify the vertical incision size of cricothyroidotomy on an impalpable porcine larynx model?

What did this study find?

Ultrasound-guided identification of the cricothyroid membrane led to a significant decrease in the size of the vertical incision of cricothyroidotomy, but longer completion time, on an impalpable porcine larynx model.

Why does this study matter to clinicians?

The use of ultrasound is a useful tool in front-of-neck-access, and its pre-emptive use should be considered in impalpable necks in anticipation of a difficult airway, but not in emergency scenarios.

Introduction

Airway management is a crucial skill for several medical specialties, including emergency medicine, anesthesia, and critical care medicine. Failure to achieve first pass success occurs in up to 15% of adults' intubation attempts in the emergency department [1]. The scalpel cricothyroidotomy technique has been recommended for emergent surgical airways because it is the fastest and most reliable method of securing the airway in an emergency [2]. One of the critical steps to achieving success and minimal complications while performing a cricothyroidotomy is accurately identifying the cricothyroid membrane [3]. Misidentification of the cricothyroid membrane by external palpation increases the risk of failed cricothyroidotomies and adverse outcomes [3]. Moreover, performing a cricothyroidotomy in a patient with impalpable neck landmarks is challenging and can result in a longer time and greater failure rates [4]. The Difficult Airway Society guidelines recommend a large midline vertical incision in patients with impalpable neck landmarks to perform a cricothyroidotomy [2]. However, it is possible that the large incision can lead to more significant injuries and complications, such as bleeding [5].

In patients with difficult or impalpable neck landmarks, ultrasonography can identify the cricothyroid membrane

with significantly greater accuracy than conventional external palpation [4, 5]. We hypothesize that ultrasound use can lead to a smaller vertical incision on a neck with impalpable landmarks. The primary objective of this study was to assess the impact of ultrasonography on the vertical incision size of a cricothyroidotomy during a simulated emergent airway scenario in an impalpable neck tissue model that is ultrasound compatible. Secondary outcomes were procedural completion time, horizontal size incision, tissue injury severity, and correct tube placement.

Methods

Study design

This study is a prospective randomized control trial (RCT) conducted at Mount Sinai Hospital (Toronto, Ontario, Canada) and approved by the Hospital Research Ethics Board (REB 18-0141-E).

Population

Emergency medicine and anesthesia residents (postgraduate years 1–3) and anesthesia fellows were recruited for the study. Written informed consent was obtained from all participants. Participants who had performed a cricothyroidotomy in a simulation or on a patient within the past 6 months of the recruitment were excluded.

Study protocol

We have developed a tissue larynx model with impalpable neck landmarks that is ultrasound compatible, allowing easy identification of the porcine larynx anatomy (see details in Appendix 1). A computer-generated randomization process randomized participants into two groups: Ultrasound (US $n=21$) and Non-Ultrasound (NUS $n=21$). All participants in both groups received a 1-hour teaching session (see details in Appendix 1).

Within 1 week after the teaching session, each participant attended the simulation session (see details in Appendix 1). All cricothyrotomy performances were videotaped for analysis of procedural time. Participants' characteristics, including gender, and training specialty, were collected.

Outcomes measures

After termination of each cricothyroidotomy performance, two study investigators assessed the porcine model for incision size, the severity of tissue injury, and tube placement. The model was evaluated in a separate room from the participants such that the study investigators were

blinded to group allocation. The primary outcome was the size (mm) of the vertical incision on the model's skin-like membrane. Secondary outcomes were procedural completion time, horizontal size incision, tissue injury severity, and correct tube placement (Details in Appendix 1).

Statistical analysis

We calculated the sample size based on the primary outcome as the size of the vertical incision on the model's skin (Details in Appendix 1). The data analysis for this RCT study was based on the intention-to-treat principle. We summarized the study population descriptively. The participant's characteristics were compared descriptively without testing between intervention and control groups as the CONSORT (Consolidated Standards of Reporting Trials) statement's suggestion. Results were reported in medians and interquartile ranges (IQR) as the data had non-normal distribution. The outcomes were compared between two groups using the chi-squared test for the categorical outcome and the Wilcoxon rank-sum test for continuous outcomes. The differences (95% CI) in the rates/medians of outcomes between the two groups were estimated using linear probability models for binary outcomes and quantile regression models for continuous outcomes. All analyses were performed using SAS 9.4 (SAS Institute, Inc., Cary, NC). A p value of <0.05 was considered statistically significant.

Results

A total of 45 participants were recruited. Three participants were not enrolled for randomization due to scheduling conflicts. Demographics were similar between ultrasound and non-ultrasound groups (Table on Appendix 2). The ultrasound group performed a significantly smaller vertical incision on the skin of the model [median (IQR), 35.0 (15, 40) vs 65.0 (52, 100) mm, (95% CI) -30.0 ($-55.1, -4.9$), $p=0.02$], but a larger horizontal skin incision [median (IQR), 14.0 (0, 25) vs 0 (0, 30) mm, (95% CI) 14.0 (0.07, 27.9), $p=0.049$]. Both groups had the same rate of moderate–severe tissue injuries (42.86%, $p=0.99$) and similar rate of correct tube placement [52.38% vs 66.67%, (95% CI) -14.4 ($-43.7, 15.1$), $p=0.34$]. In addition, the ultrasound group took longer in total time to complete the procedure [median (IQR), 200.5 (126, 267) vs 93.5 (71.0, 167.5) secs, (95% CI) 91.0 (3.73, 178.3), $p=0.04$]. The time (median (IQR) to perform the ultrasonography alone was 49.0 (23, 79) secs, while the time of Scalpel-Bougie-Tube technique in isolation in the ultrasound group was 120.0 (91, 191). Due to unintentional corruption of four video files, time analyses were based on 18 files for ultrasound and 20 files for non-ultrasound group (Table 1).

Table 1 Comparison of outcomes

Outcome	Ultrasound (<i>n</i> = 21)	Non-ultrasound (<i>n</i> = 21)	Difference (95% CI) (ultrasound vs non-ultrasound)	<i>P</i> value
Size of incision (vertical) (mm), median (IQR)	35.0 (15, 40)	65.0 (52, 100)	− 30.0 (− 55.1, − 4.9) ^d	0.02 ^b
Size of incision (horizontal) (mm), median (IQR)	14.0 (0, 25)	0 (0, 30)	14.0 (0.07, 27.9) ^d	0.049 ^b
Post-procedure airway tissue damage, % (<i>n/N</i>) ^c	42.86 (9/21)	42.86 (9/21)	0.0 (− 29.9, 29.9) ^c	0.99 ^a
Total time of procedure (sec), median (IQR)*	200.5 (126, 267)	93.5 (71.0, 167.5)	91.0 (3.73, 178.3) ^d	0.04 ^b
Time of ultrasound use (sec), median (IQR)*	49.0 (23, 79)	–	–	–
Time of Scalpel-Bougie-Tube in isolation (sec), median (IQR)*	120 (91, 191)	93.5 (71.0, 167.5)	11.0 (− 60.9, 82.92) ^d	0.76 ^b
Correct tube placement, % (<i>n/N</i>)	52.38 (11/21)	66.67 (14/21)	− 14.4 (− 43.7, 15.1) ^c	0.34 ^a

IQR interquartile range, *CI* confidence interval

*Four videotape files were corrupted (three from ultrasound group and one from non-ultrasound)

^aChi-squared test

^bWilcoxon rank sum

^cLinear probability model

^dQuantile regression models

^e*n* number of larynges with moderate to severe injuries, *N* total number of larynx assessed

Discussion

Interpretation of findings

The main finding of our study was that the use of ultrasound compared with conventional palpation technique to identify the cricothyroid membrane significantly decreased the length of vertical incision, with similar success rates, similar severity of tissue injury, and longer completion time, when performing a Scalpel-Bougie-Tube cricothyroidotomy on an impalpable porcine larynx model during a simulated cannot intubate-cannot oxygenate scenario.

Comparison to previous studies

Airway guidelines recommend an 8–10 cm midline vertical incision starting from the sternal notch in patients with impalpable neck landmarks when performing a cricothyroidotomy [2]. We found a median of 3.5 cm vertical incision with the use of ultrasound. A study looking at the computerized tomography scans of 264 patients demonstrated part of a major vessel anterior to the trachea in the suprasternal notch in 53% of the necks [6]. With a cricothyroid membrane to sternal notch distance ranging from 5 to 8 cm [7], our finding of a smaller size vertical skin incision anterior to the cricothyroid membrane would likely avoid any major artery. Furthermore, the possibility of performing a smaller vertical incision might minimize the psychological barrier to executing a cricothyroidotomy since evidence demonstrated that it is not the procedure itself but the reluctance to perform it that often leads to poor patient outcomes [8]. Although the

ultrasound group performed a larger horizontal incision, this measure reflects the skin incision and does not necessarily translate into an incision of the same extent in the cricothyroid membrane. Even if it translated into the membrane, it would be well within its horizontal width of 22–33 mm in the adults [9]. Regarding the cricothyroidotomy completion time, our findings are congruent with a recent meta-analysis that demonstrated that ultrasonography prolongs the time to identify the cricothyroid membrane but improves the success rate [10]. The success rate of correct tube placement appears to be low in both groups and a trend towards smaller success rates (not statistically significant) was observed in the ultrasound group. Incorrect tube placement might be explained by the increased angle observed between the thyroid and the cricoid cartilage in the porcine larynx, which makes the bougie and tube insertion more challenging.

Clinical implications

Our results lend further support to current evidence that using ultrasound can identify the cricothyroid membrane more accurately in an impalpable neck model. It has been suggested by other authors that pre-procedural ultrasound should be the standard practice in patients with impalpable neck landmarks who may require intubation as part of their management and based on our results we agree. This approach could minimize operator's anxiety and tissue damage in the event of a cricothyroidotomy [4, 5]. However, our findings do not support the use of ultrasound during the front-of-neck procedure in an emergency. The main goal of the front-of-neck-access is to avoid hypoxemia-induced brain

injury and death [2]. In a real-life scenario, when cricothyroidotomy is indicated, the patient is already hypoxic, and use of the ultrasound may delay the life-saving intervention.

Strengths and limitations

Our study has limitations. Although the porcine larynx model provides airway anatomy similar to a human larynx, it lacks some anatomic features that help orient the participants, such as jaw, chin, and shoulders. Additionally, our model did not include a bleeding component, which can make a cricothyroidotomy more challenging. Furthermore, we did not collect data on or assess the participants' experience in ultrasonography, which could have affected their ability to identify the cricothyroid membrane by ultrasound. However, as this was a randomized clinical trial, we believe the study was protected from selection bias.

Conclusions

The use of ultrasound-guided identification of the cricothyroid membrane in a cannot intubate-cannot oxygenate scenario led to a significant decrease in the vertical incision, similar success rates, but a longer time to completion when performing a Scalpel-Bougie-Tube cricothyroidotomy on an impalpable porcine larynx model. Our study supports pre-procedure ultrasonography's role in identifying the cricothyroid membrane of patients with impalpable neck landmarks in anticipation of a difficult airway, but not during emergency scenarios.

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Author contributions FBZ, DL, NS, VSP, and KEYT: conceptualized and planned the study. KEYT: supervised all stages of the study. FBZ, DL, and KEYT: participated in data acquisition. FBZ, XYY, and KEYT: participated in the data analysis. FBZ and KEYT: participated in writing the manuscript draft. FBZ, DL, NS, VSP, XYY, and KEYT: reviewed, edited, and approved the final version of the manuscript.

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Declarations

Conflict of interest The authors have no conflicts of interest to declare.

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