Accuracy of ultrasound-guided marking of the cricothyroid membrane before simulated failed intubation

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Abstract

Background: Interest in the use of dynamic ultrasound (US) for cricothyrotomy has sparked a debate regarding its applicability in a crash airway situation. Ultrasound-guided marking of the cricothyroid membrane (CTM) as a preintubation procedure may be better than the dynamic method. No prior study has evaluated the accuracy of using US to premark the CTM before attempted intubation.

Objectives: To determine the feasibility of US-guided marking of the CTM before attempted simulated intubation so that this marking may be used as the location for the initial incision after failed intubation.

Methods: Resident and attending physicians participated. Ultrasound was used to identify and mark the CTM with an invisible pen. Failed intubation was simulated, and the same operator then identified the CTM with US and marked the location with a black pen. The difference in the preintervention and postintervention markings was measured in millimeters. The length of the CTM was also measured as a reference.

Results: Twenty-three models and operators were used for data collection. The average CTM sagittal length was 13.9 mm (95% confidence interval [CI], 13.4-14.4). The average sagittal and axial differences before and after simulated intubation were found to be 0.91 mm (95% CI, 0.35-1.47) and 1.04 mm (95% CI, 0.38-1.7), respectively. The sagittal variability is 1/15 the total length of the CTM.

Conclusions: Ultrasound marking of the CTM of healthy volunteers before simulated intubation accurately identifies the CTM after neck manipulation expected during a failed intubation. Further research is indicated to determine the clinical applicability of this model.

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1. Introduction

Ultrasound (US) is gaining popularity in airway management of the critically ill patient [1]. Recent literature has demonstrated that emergency physicians who trained on a cadaveric model were then able to identify the cricothyroid membrane (CTM) using US in 50 of 50 live patients [2]. Kleine-Brueggeney and colleagues [3] published a study of needle percutaneous tracheal puncture under US guidance in cadaveric models with successful wire cannulation in all models. The bougie-assisted cricothyrotomy (CRIC) has proven to be faster than the traditional technique, with a reported 67 vs 149-second time to CRIC and an improved failure rate [4]. Last year, a cadaveric study described the US-assisted bougie-assisted CRIC as a novel method for dynamic US-guided CRIC [5].

Since the publication of the US-assisted bougie-assisted CRIC technique, some authors have suggested that the addition of the US machine into a chaotic environment may be counterproductive and not feasible for use in such an emergent procedure [6,7]. Their argument is that using dynamic US adds another element to the procedure and may increase the likelihood of error. These authors have suggested the possibility of a static rather than dynamic US-guided approach. Although studies have evaluated the ability of providers to identify the CTM, no study has determined if marking the membrane before attempted intubation is a safe and accurate method for determining the location of the CTM after failed intubation. This study attempts to describe such a technique.

2. Methods

2.1. Theoretical model of the problem

Ultrasound has been shown to be more accurate than landmark technique for identifying the location of the CTM [8]. However, the use of US to identify the CTM during an emergent CRIC is problematic in that it adds another step to an already time-sensitive procedure. A possibly advantageous use of US may be to visualize and mark the...
CTM before attempted intubation in patients with a predicted difficult airway. If the marking were still accurate after failed intubation, no landmark or US-guided identification of the CTM would be needed before open or percutaneous CRIC. This would, in effect, remove a step from the procedure.

2.2. Study design

This was a laboratory study design of a convenience sample of 23 resident and attending physicians at the University of Utah. Participants acted as both operators and models in the study design. They were not blinded to the procedure. Institutional review board (IRB) approval was obtained.

2.3. Study setting and population

Training consisted of a brief review of identification of the CTM with US by watching a short video on US-guided CRIC created by the Ultrasound Podcast [www.ultrasoundpodcast.com] [6]. The study was performed by 23 resident and attending physicians over a 4-hour simulation laboratory. Each participant acted as both an operator and a model for simulated intubation. Experience level ranged from first-year resident with minimal US training to US fellowship-trained attending physician.

2.4. Study protocol

Before simulated intubation, the operator used a linear high-frequency probe in the axial and sagittal planes to identify and mark the CTM with an invisible pen. Failed intubation was simulated by cricoid pressure, flexion, extension, and rotation of the model’s neck. After this simulation maneuver, the same operator then identified the CTM with US, just as before, and marked the location with a black pen. The difference in the preintervention and postintervention markings was measured in millimeters. The length of the CTM was also measured as a reference.

1. The linear transducer was held in the nondominant hand in the longitudinal orientation with the probe marker toward the patient’s head just lateral to the midline of the trachea to identify the CTM and center it on the US screen (Fig. 1).

2. A single horizontal (axial) line was then drawn with an invisible marker on the patient’s neck, marking the center of the CTM (Fig. 2).

3. The US probe was then rotated 90° so that the indicator was pointed to the operator’s left, and the CTM was again identified and the peak of the membrane placed in the center of the US screen.

4. Another invisible line was drawn in the center of the probe, this time in the sagittal plane, indicating the midline of the patient’s neck and the CTM.

5. Simulated intubation: after invisible marks were placed on the patient’s neck, a failed intubation attempt was simulated with full extension and flexion of the neck, along with a jaw thrust and laryngeal manipulation.

6. Markings were then repeated, again using the US for guidance. Postsimulated failed intubation markings were made with a black marker so that the distance between the presimulation and postsimulation markings could be measured.
2.5. Data analysis

Study variables included US-guided axial and sagittal CTM markings before and after simulated intubation. The distance between these markings was measured in millimeters, and the length of the CTM was also measured in millimeters in the sagittal plane. Raw data and means with 95% confidence intervals (CIs) of the measured difference between markings in both planes are reported.

3. Results

Twenty-three models and operators were used for data collection. Eighteen men and 5 women participated in the study as both operators and models. The mean CTM sagittal length was 13.9 mm (95% CI, 13.4–14.4). The range of CTM lengths were 10.6 to 17 mm. All female participants’ CTM sagittal lengths were below the mean for the entire group.

After simulated intubation, the difference in the sagittal and axial markings was measured and the mean difference was found to be 0.91 mm (95% CI, 0.35–1.47) and 1.04 mm (95% CI, 0.38–1.7), respectively. The range for both the sagittal and axial measurements was 5 mm. Because an axial incision has been described in the bougie-assisted CRIC method, the sagittal variability should be the most important. Based on these data, the sagittal variance is 1/15 the total length of the CTM.

4. Discussion

Previous research has already described the ability of minimally trained providers to identify the location of the CTM with US. A recent study by Elliott and colleagues [8] attempted to correlate precise anatomical identification of the CTM by US marked with an invisible fluorescent marker and identification of the CTM by anesthesiologists without the assistance of US. Only 30% were able to correctly identify the CTM without US guidance and only 11% of those accurately identified the midline of the membrane. This would suggest that it is difficult to correctly identify the ideal anatomical location for emergent CRIC without US.

Although US represents an additional step to the anatomical guided technique in a time-sensitive procedure, our data suggest that US-guided CRIC can be performed using a static method where the CTM is marked before attempted intubation. This could be exceedingly useful in suspected difficult airways.

The authors envision this procedure to be an alternative to the dynamic US-guided bougie-assisted CRIC. This static technique can be used to mark the CTM membrane before attempted intubation so that the CTM is already marked if an emergent CRIC needs to be performed in a “can’t intubate, can’t ventilate” situation. Our data suggest that the CTM marking is consistent after attempted intubation so that the static US identification of the CTM can occur before neck and laryngeal manipulation, saving time when the CRIC is emergent.

5. Limitations

This was a small laboratory study with healthy volunteers. Furthermore, the study protocol uses simulated intubation through manipulation of the larynx and neck flexion and extension. While every effort was made to adequately manipulate the subjects’ neck, it is possible that they unintentionally kept their neck in a more neutral position. It is possible that, in translation to actual attempted failed intubation, the simulation is insufficient and the preintubation markings are no longer accurate. It is also possible that this study may not be reproducible in an elderly population with less anterior neck soft tissue to allow for adequate probe placement or if the examination is performed by an emergency physician without US experience. This study should be reproduced using actual intubations to determine accuracy in a real patient population.

6. Conclusions

Ultrasound marking of the CTM of healthy volunteers before simulated intubation accurately identifies the CTM after neck and larynx manipulation expected during a failed intubation. Further research is indicated to determine the clinical applicability of this model in patients actually undergoing emergent CRIC after a predicted failed airway.

References