



BRIEF REPORT

Ultrasound-guided, Bougie-assisted Cricothyroidotomy: A Description of a Novel Technique in Cadaveric Models

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Abstract

Background: Ultrasound (US) has well-documented utility in critical procedures performed in the emergency department. It has been described as a “skill integral to the practice of emergency medicine” in the 2007 Model of Clinical Practice of Emergency Medicine. One of the ideal uses for US in critical care may be in the performance of emergent cricothyroidotomy. To the best of our knowledge there is currently no description of how to perform an US-guided open cricothyroidotomy in the literature.

Objectives: This study aimed to develop and describe an US-guided technique for emergent open cricothyroidotomy and evaluate the time to completion and failure rate of this technique.

Methods: This study was performed in a cadaver lab on 21 cadavers. The procedure was performed by two independent operators with US guidance using a linear transducer in the longitudinal orientation placed on the anterior midline of the neck. The cricothyroid membrane was incised with a No. 20 scalpel and a bougie with a coude tip was inserted into the trachea. A 6.0 endotracheal tube was then advanced over the bougie and the cuff was inflated. Endotracheal tube placement was confirmed by dissection. The procedure was timed to evaluate the length of time to identification of the cricothyroid membrane and completion of the procedure. There was no control group for this study.

Results: There were 12 female and nine male cadavers. The mean body mass index (BMI) was 21.9 (range = 12.2 to 44.9). There was a median time to identification of the cricothyroid membrane of 3.6 seconds (interquartile range [IQR] = 1.9 to 15.3 seconds) and median time to completion of the procedure of 26.2 seconds (IQR = 10.7 to 50.7 seconds). The failure rate was 1 out of 21, with one incision placed between the cricoid cartilage and the first tracheal ring. In this case, the trachea was still cannulated. Similar completion times were obtained with high- and low-BMI cadavers.

Conclusions: Ultrasound-guided bougie-assisted cricothyroidotomy is a novel technique that may be beneficial in emergent open cricothyroidotomy. The data suggest that this technique is rapid, with a median time to completion of 26.2 seconds. The data also suggest that the procedure may have a low failure rate, with 20 of 21 cadavers undergoing successful cricothyroidotomy.

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Ultrasound (US) has gained popularity in airway management of the critically ill patient.¹ A study of confirmation of endotracheal intubation with visualization by US compared with capnography showed an accuracy rate of 98.2% for identifying endotracheal

intubation when compared to capnography.² US has also been shown to accurately and easily identify laryngeal structures. Nicholls et al.³ demonstrated that emergency physicians who received training on a cadaveric model were then able to identify the cricothyroid membrane in 50 out of 50 live patients. Although the literature to date is scant with regard to US-guided cricothyroidotomy, Kleine-Bruegggeny et al.⁴ published a study of needle percutaneous tracheal puncture under US guidance in cadaveric models with successful wire cannulation in all models. While conventional cricothyroidotomy has been widely taught, there is literature to support bougie-assisted cricothyroidotomy as being the faster technique with a comparable success rate. Hill et al.⁵ reported a 67-second versus 149-second time to cricothyroidotomy with a failure rate of 1 out of 10 for bougie-assisted versus 3 out of 11 for conventional cricothyroidotomy.

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An ideal use for US in airway management may be in the performance of emergent cricothyroidotomy. Studies have evaluated US in tracheostomy, but to the best of our knowledge, there is currently no description of how to perform an US-guided open cricothyroidotomy in the literature. This study attempts to describe such a technique.

METHODS

Theoretical Model of the Problem

The main landmark of the laryngeal anatomy is the thyroid cartilage, which is a prominent structure under US visualization. In the longitudinal plane the thyroid cartilage is easily identified by its anterior and superior position. The cartilage moves deep more inferiorly, and where the cartilage abruptly ends, there is an echogenic horizontal line representing the cricothyroid membrane. The air/tissue interface of the cricothyroid membrane leads to a hyperechogenic signal, which stands out from surrounding structures. Just caudal to the membrane is the cricoid cartilage visualized as an ovoid structure of varying density (see Figure S1, available as supporting information in the online version of this paper).

Study Design

This was a laboratory study design of a convenience sample of cadavers obtained from the University of Utah Anatomical Services. We elected to perform the procedure on 21 cadavers due to time limitations and limited number of available cadavers. This study was conducted with cadavers; therefore, it was not necessary to obtain institutional review board approval.

Study Setting and Population

Training before attempting the procedure consisted of a brief review of identification of the cricothyroid membrane with US on a live volunteer, and a single untimed attempt of the entire procedure on a cadaver. The study procedure was performed on 21 cadavers in the cadaver lab over a period of 1 month by two operators with no prior anatomic or US visualization of the cadaver on which the procedure was being performed. One operator was an emergency medicine attending physician who had previously completed an US fellowship. The other was a second-year emergency medicine resident with no US training beyond the integrated US curriculum offered during residency training.

A convenience sample of cadavers was conglomerated by the anatomy staff at the University of Utah. The staff were not blinded to the procedure attempted on the cadavers, but were instructed to provide whatever cadavers were available independent of body habitus or the goals of the procedure. Cadavers were excluded only if there was evidence of a prior anterior neck incision; the only other exclusion criterion was age <18 years. One cadaver was excluded by this criterion, and all other cadavers chosen by the anatomy staff were included in the study. The cadavers were embalmed and had been obtained by the university 1 month prior to the study.

Study Protocol

A linear transducer was used to most quickly and accurately identify the cricothyroid membrane. Additional equipment used included a No. 20 scalpel, a bougie with coude tip, a 10-mL syringe, and a 6.0 cuffed endotracheal tube.

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 cricothyroid membrane. The cricothyroid membrane was centered on the screen of the US machine (see Figure S2, available as supporting information in the online version of this paper).
2. A single horizontal incision was made medial to the probe with the scalpel through the membrane. The middle of the probe was used as the landmark for incision of the cricothyroid membrane.
3. The US probe was released and the scalpel was rotated 90°.
4. The bougie was inserted into the incision just medial to the scalpel, the scalpel was removed, and hold-up was felt with the bougie.
5. The 6.0 endotracheal tube was placed over the bougie and inserted into the trachea just beyond the level of the cuff, the cuff was inflated with 10 cc of air, and the bougie was removed.
6. Endotracheal tube placement was confirmed by dissection.

The procedure was timed with time zero beginning with reaching for the probe and ending with inflation of the cuff after removal of the bougie. Identification of the cricothyroid membrane was also timed by an independent observer. Only one incision was attempted during the procedure. Dissection was used to confirm correct placement through the cricothyroid membrane. Basic cadaveric characteristics were recorded including age and sex. The body mass index (BMI) was calculated, although accuracy of BMI in cadavers is uncertain. This was a descriptive study without a control for direct comparison.

Data Analysis

Cadaver BMI and procedure times were measured and reported as medians with interquartile ranges (IQRs). Raw data of time to performance of the procedure and cadaver BMI were plotted on a simple x-y graph for comparison.

RESULTS

Twenty-one cadavers were included in the study. Twelve were female and nine were male. BMIs ranged from 12.2 to 44.9. There were no pediatric or young adult cadavers. Data from the 21 US-guided cricothyroidotomies revealed a median time to identification of the cricothyroid membrane of 3.6 (IQR = 1.9 to 15.3) seconds and a median time to endotracheal intubation of 26.2 seconds (IQR = 10.7 to 50.7 seconds; Table 1). The failure rate for the US-guided technique was 1 out of 21, with the one failure consisting of placement between the cricoid cartilage and the first tracheal ring with a time to

Table 1
Weight, BMI, Time to Identification of the Cricothyroid Membrane, and Time to Completion of the Procedure

	n	IQR				
		Min	0.25	Median	0.75	Max
Weight (lbs)	20	90	112.5	132.5	165.0	270.0
BMI	21	12.2	17.8	21.9	23.6	44.9
Time to visualizations (seconds)	21	1.9	2.5	3.6	8.3	15.3
Time to completed cricothyrotomy (seconds)	21	10.7	21.4	26.2	36.7	97.0

Data are reported as a median (IQR).
BMI = body mass index; IQR = interquartile range.

completion of 25.5 seconds. The largest cadaver had a BMI of 44.9, with 1.74 cm of pretracheal tissue, and had a time to complete cricothyroidotomy of 37 seconds.

DISCUSSION

Ultrasound-guided bougie-assisted cricothyroidotomy is a novel technique that may assist emergency physicians with cricothyroid identification during difficult airway management. A recent study by Elliott et al. attempted to correlate precise anatomical identification of the cricothyroid membrane by US marked with an invisible fluorescent marker and identification of the cricothyroid membrane by anesthesiologists without the assistance of US.⁶ Only 30% were able to correctly identify the cricothyroid membrane without US guidance, and only 11% of those accurately identified the midline of the membrane.⁷ This would suggest that it is difficult to correctly identify the ideal anatomic location for emergent cricothyroidotomy.

Although US represents an additional step to the anatomic guided technique in a time-sensitive procedure, our data suggest that US-guided cricothyroidotomy is a rapid technique. This study revealed a median time to identification of the cricothyroid membrane of 3.6 seconds and median time to endotracheal intubation of 26.2 seconds.

Furthermore, the study was suggestive that no relationship exists between BMI and time to procedure completion (see Figure S3, available as supporting information in the online version of this paper). This suggests that in patients with difficult airway anatomy, US guidance would produce similar procedure times to those in patients with normal anatomic landmarks. An obvious algorithm might be to use US as a means of identification of the anatomy, prior to attempted intubation, or to use US as direct guidance in patients with high BMI and suspected difficult landmarks. It is of course important to consider the time necessary for turning on and setting up the US machine, and this should be performed before the procedure if at all possible. The times recorded in this study reflect a scenario where the US machine is on and a linear transducer is selected.

LIMITATIONS

This was a small cadaveric study with two operators, one of whom is US fellowship trained. It is possible that in translation to human patients, the US visualization of

the cricothyroid membrane may be more difficult. It is possible that this study may not be reproducible by an emergency physician without previous US experience and therefore may require some US training. This study should be reproduced with a greater operator number to evaluate the reproducibility among operators. Furthermore, a direct comparison, using the same operators in anatomic versus US-guided cricothyroidotomy would be beneficial to directly compare timing and complication rates. This study focused on endotracheal tube placement within the trachea. The study design and methodology do not address proper positioning of the endotracheal tube tip in the trachea or adequacy of ventilation.

CONCLUSIONS

Ultrasound-guided bougie-assisted cricothyroidotomy is a novel technique that appears to be accurate and quick to complete. Further studies are needed to validate this technique with direct comparisons to other methods of surgical cricothyroidotomy.

References

1. Sustić A. Role of ultrasound in the airway management of critically ill patients. *Crit Care Med.* 2007; 35(5 Suppl):S173–7.
2. Chou HC, Tseng WP, Wang CH, et al. Tracheal rapid ultrasound exam (T.R.U.E.) for confirming endotracheal tube placement during emergency intubation. *Resuscitation.* 2011; 82:1279–84.
3. Nicholls SE, Sweeney TW, Ferre RM, Strout TD. Bedside sonography by emergency physicians for the rapid identification of landmarks relevant to cricothyrotomy. *Am J Emerg Med.* 2008; 26: 852–6.
4. Kleine-Brueggeney M, Greif R, Ross S, et al. Ultrasound-guided percutaneous tracheal puncture: a computer-tomographic controlled study in cadavers. *Br J Anaesth.* 2011; 106:738–42.
5. 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. *Acad Emerg Med.* 2010; 17: 666–9.
6. Elliott DS, Baker PA, Scott MR, Birch CW, Thompson JM. Accuracy of surface landmark identification

for cannula cricothyroidotomy. *Anaesthesia* 2010; 65(9):889–94.

7. McGill J, Clinton JE, Ruiz E. Cricothyrotomy in the emergency department. *Ann Emerg Med.* 1982; 11:361–4.

Supporting Information

The following supporting information is available in the online version of this paper:

Figure S1. Cricothyroid membrane under ultrasound. The ultrasound probe is in the longitudinal orientation and the probe marker is toward the patient's head.

Figure S2. Identifying the cricothyroid membrane with ultrasound. An operator locating the cricothyroid membrane with US in a cadaver with difficult anatomy and 2 cm of pretracheal tissue.

Figure S3. BMI vs. time.

The figures are in JPG or TIF format.

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