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Comparison of color flow with standard ultrasound for the detection of endotracheal intubation

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ABSTRACT

Introduction: Intubation is a frequently performed procedure in emergency medicine that is associated with significant morbidity and mortality when unrecognized esophageal intubation occurs. However, it may be difficult to visualize the endotracheal tube (ETT) in some patients. This study assessed whether the addition of color Doppler was able to improve the ability to visualize the ETT location.
Methods: This study was performed in a cadaver lab using three different cadavers chosen to represent varying neck circumference. Cadavers were randomized to tracheal or esophageal intubation. Blinded sonographers then assessed the location of the ETT using either grayscale or color Doppler imaging. Accuracy of sonographer identification of ETT location, time to identification, and operator confidence were assessed.
Results: One hundred and fifty intubations were performed and each was assessed by both standard and color Doppler techniques. There were 78 tracheal intubations and 72 esophageal intubations. The standard technique was 99.3% (95% CI 96.3 to 99.9%) accurate. The color flow technique was also 99.3% (95% CI 96.3 to 99.9%) accurate. The mean operator time to identification was 3.24 s (95% CI 2.97 to 3.51 s) in the standard approach and 5.75 s (95% CI 5.16 to 6.33 s) in the color flow technique. The mean operator confidence was 4.99/5.00 (95% CI 4.98 to 5.00) in the standard approach and 4.94/5.00 (95% CI 4.90 to 4.98) in the color flow technique.
Conclusion: When added to standard ultrasound imaging, color flow did not improve accuracy or operator confidence for identifying ETT location and resulted in a longer examination time.

1. Introduction

Endotracheal intubation is a common procedure in emergency medicine. Unintentional esophageal intubation is a dangerous complication of this procedure with the potential for significant morbidity and mortality if not immediately recognized. Historically, the location of the endotracheal tube (ETT) has been identified using capnography. However, end-tidal capnography has several limitations, including false positives with hypopharyngeal placement and false negatives during cardiac arrest [1-3]. Additionally, the use of positive pressure ventilation to confirm placement with capnography has the potential to further distend the stomach and increase aspiration risk if the ETT is incorrectly placed in the esophagus. Finally, quantitative end-tidal capnography may not be widely available in many Emergency Departments [4,5].

As a result, ultrasound has been increasingly studied as an alternate modality, as it can allow for rapid confirmation without the need for additional ventilations [6-12]. The most common approach involves identification of the endotracheal tube after intubation using the static, grayscale imaging technique. However, it may be challenging to identify the ETT in some patients and the addition of color flow has been suggested to assist with the identification the correct location by highlighting the movement of the ETT within either the esophagus or trachea [13]. Color flow has been demonstrated to improve the accuracy of pneumothorax detection [14], but has not been formally assessed for the identification of endotracheal intubation. This study aimed to determine whether the addition of color flow compared with standard grayscale sonography improved the accuracy of ETT identification. Secondary outcomes included differences in time to identification and operator confidence.

2. Methods

This study was a blinded, randomized, controlled trial performed in the cadaver lab of an academic hospital in Chicago, IL. Three cadavers were utilized with different neck circumferences to simulate the

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variation in real patient populations. Cadaver #1 had a neck circumference of 29 cm, cadaver #2 had a neck circumference of 31 cm, and cadaver #3 had a neck circumference of 39 cm. Local institutional review board approval was obtained for this study with waiver of informed consent.

A random number generator was utilized to determine a priori whether the ETT would be placed into the trachea or esophagus, with the goal of having equivalent numbers of tracheal and esophageal intubations in order to best define the test characteristics. One investigator with extensive intubation experience intubated each cadaver with a size 7.0 ETT using video laryngoscopy prior to the study sonographers entering the room. The intubator would leave the room after each intubation to avoid any potential reaction to bias the sonographers. After intubation, one sonographer would assess the location of each intubation using the standard, grayscale approach. The second sonographer would repeat the assessment using color Doppler. Sonographers would alternate techniques after each attempt. Only one sonographer was present in the room at a time and both sonographers were blinded to the ETT location.

Two sonographers with prior experience in the use of ultrasound for ETT confirmation performed the assessments. A Zonare Z1Pro ultrasound machine with an L14-5 linear transducer was utilized for all assessments. For the standard (grayscale) technique, sonographers would place the transducer across the neck at the suprasternal level and visualize the trachea. The ETT would be twisted with the nondominant hand to visualize for motion artifact within the trachea. Visualization of motion artifact within the trachea confirmed tracheal intubation (Fig. 1, Video 1). The probe was also moved laterally in each direction to identify the esophagus. The presence of an ETT with motion artifact within the esophagus confirmed esophageal intubation (Fig. 2, Video 2). For the color flow technique, color Doppler was turned on and the color box was placed in the center of the screen extending from the front of the neck to the spine in the anteroposterior direction and medial to the carotid arteries in the lateral direction. Presence of color artifact within the trachea confirmed tracheal intubation (Fig. 3, Video 3). Presence of color artifact within the esophagus confirmed esophageal intubation (Fig. 4, Video 4).

A research assistant recorded the study subject prediction of ETT location, time to ETT prediction, and operator confidence. Operator confidence was assessed utilizing a Likert scale ranging from 1 to 5 with 1 signifying "not confident at all" and 5 signifying "very confident". Comparison between the predicted and actual location was performed after study completion.

With an estimated 150 readings each for standard and color flow techniques, 95% level of significance, and a moderate effect size (0.3), the expected power for the study was above 90%. Microsoft Excel and SPSS statistical software was utilized to conduct the analysis. We utilized descriptive statistics, chi-square test, *t*-test, and linear regression to analyze the relationships between the ultrasound standard and color flow techniques and accuracy of correctly identifying location of intubation, operator time to identification, and operator confidence. In addition, we included moderating variables such as operators, cadaver number, and actual location of the intubations in the analysis.

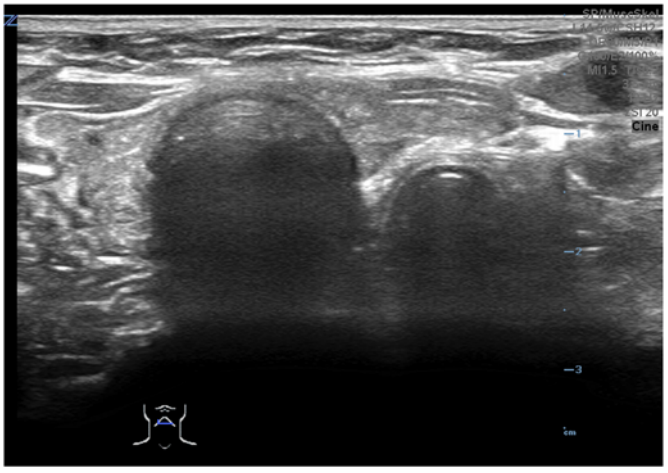

Fig. 2. Esophageal intubation using grayscale ultrasound.

3. Results

One hundred and fifty total intubations were performed, with each intubation assessed via both the standard and color flow techniques. There were 78 tracheal intubations and 72 esophageal intubations. Both standard and color flow techniques were 99.3% (95% CI 96.3% to 99.9%) accurate. There was no statistical difference in correctly identifying the location of the intubations between the standard and color ultrasound flow techniques. The mean operator time to identification was 3.24 s (95% CI 2.97 to 3.51 s) in the standard flow technique and 5.75 s (95% CI 5.16 to 6.33 s) in the color flow technique. After controlling for location of intubation, operators, and cadaver number, the time to identification of the intubation was significantly longer (i.e., 2.51 s with a 95% CI of 1.9 to 3.12 s) for color flow technique as compared to standard flow technique. The mean operator confidence was also statistically significantly higher for standard flow technique (i.e., 4.99/5.00 with a 95% CI of 4.98 to 5.00) as compared to color flow technique (i.e., 4.94/5.00 with a 95% CI of 4.90 to 4.98).

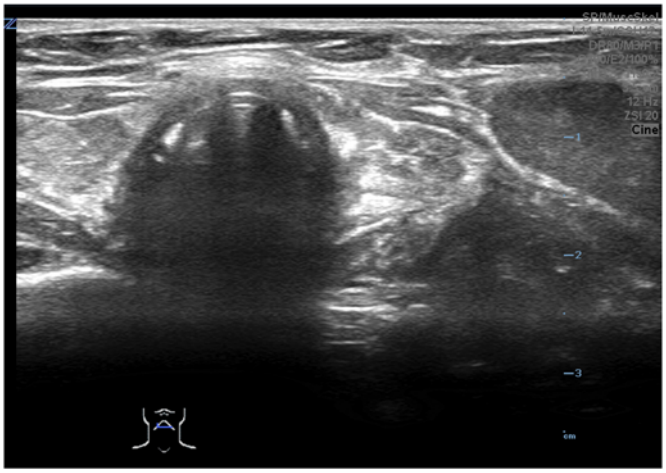

Fig. 1. Tracheal intubation using grayscale ultrasound.

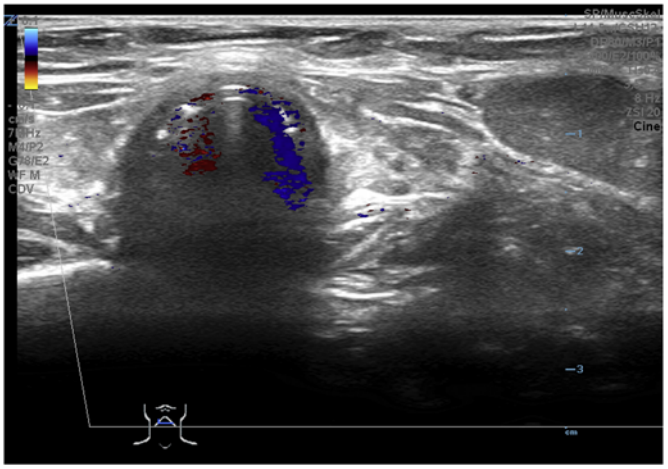

Fig. 3. Tracheal intubation using color Doppler ultrasound.

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