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Original Contribution

Impact of endotracheal tube twisting on the diagnostic accuracy of ultrasound for intubation confirmation

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ABSTRACT

Introduction: Ultrasound is a readily-available technique used to identify accurate placement of an endotracheal tube (ETT) after an intubation attempt. There is limited research on using manipulation of the ETT to improve the diagnostic accuracy of ETT location confirmation. Our study sought to directly assess whether ETT twisting during the standard grayscale technique influenced the accuracy of intubation confirmation by ultrasound.
Methods: The study was performed using two different fresh cadavers. During each trial, the cadavers were randomized to either tracheal or esophageal intubation. Three blinded, ultrasound fellowship-trained sonographers assessed the location of the ETT post-intubation alternating between using either a technique with no ETT movement or a technique with ETT twisting. In the latter technique, the sonographers manipulated the ETT in using a side-to-side, twisting motion while performing the ultrasound exam. The study measured the accuracy of ETT location identification, time to identification, and sonographer confidence.
Results: 540 assessments were performed with equal numbers of tracheal and esophageal intubations. The accuracy of ultrasound using the static technique was 97.8% (95% CI 95.2% to 99.0%) and the accuracy using the ETT twisting technique was 100% (95% CI 98.6% to 100%). The ETT twisting group showed a faster time to identification with a mean time to identification of 4.97 s (95% CI 4.36 to 5.57 s) compared to 6.87 s (95% CI 6.30 to 7.44 s) for the static ETT group. Operator confidence was also higher in the ETT twisting group at 4.84/5.0 (95% CI 4.79 to 4.90) compared to 4.71/5.0 (95% CI 4.63 to 4.78) in the static ETT group.
Conclusion: There was no statistically significant difference in the accuracy of ETT location identification between the two groups. However, utilizing the ETT twisting technique showed a statistically significant improvement in the time to identification and sonographer confidence.

1. Introduction

Endotracheal intubation is a frequently performed procedure in the emergency department. However, unrecognized esophageal intubation may have disastrous consequences. Traditionally, verification for endotracheal tube (ETT) location has been performed with capnography. However, capnography has several limitations, including false positives with hypopharyngeal placement and false negatives during cardiac arrest [1–3]. Additionally, capnography requires several "breaths" be delivered with positive pressure for confirmation. If the ETT is inappropriately placed in the esophagus this can increase gastric distention, which can lead to vomiting and aspiration.

The increasing prevalence of ultrasound in emergency departments has led to the investigation of point-of-care ultrasound (POCUS) for the rapid verification of correct ETT placement while reducing the number of positive pressure ventilations [4–12]. The most common method uses static, grayscale imaging to visualize the location of the ETT after placement [12]. However, anatomical variation may create challenges to visualization. The addition of a twisting motion has been suggested to aid with the identification of the correct location based on the movement of the ETT within either the esophagus or trachea [6,7]. This study aimed to determine whether the addition of ETT twisting 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 was a blinded, randomized control trial performed in the cadaver lab of an academic center in Chicago, IL. Two cadavers were utilized with different body habitus and neck circumferences to simulate the variation in real patient populations. Cadaver #1 had a neck circumference of 40 cm and cadaver #2 had a neck circumference

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of 42 cm. The study was deemed exempt by the local institutional review board.

The ETT placement was determined a priori using a random number generator with a goal of having equivalent numbers of tracheal and esophageal intubations in order to best define the test characteristics. One investigator with extensive intubation experience performed all of the intubation attempts. The investigator intubated each cadaver with a size 7.0 ETT using video laryngoscopy prior to the study sonographers entering the room. The intubator left the room after each intubation in order to avoid any potential reaction to bias the sonographers. After intubation, one sonographer would assess the location of each ETT using the standard, grayscale technique. The sonographer would alternate between using either ETT twisting or no movement of the ETT (ie, static technique) with each assessment. The subsequent sonographers would repeat this assessment after the first sonographer. Only one sonographer was present in the room at a given time and all sonographers were blinded to the ETT location.

Three sonographers with prior experience in the use of ultrasound for ETT confirmation performed the assessments. Each sonographer performed 180 total assessments. A Zonare ZS-3 with an L14-5 linear transducer was utilized for all of the assessments. For the static technique, sonographers would place the ultrasound transducer across the neck at the suprasternal notch and visualize the trachea. The probe was then moved laterally to identify the esophagus. Presence of a set of double rings within the trachea was utilized to identify a tracheal intubation (Fig. 1), while the presence of a second ETT artifact in the esophagus was suggestive of esophageal intubation (Fig. 2). A similar protocol was utilized for the ETT twisting group, with the exception that the ETT was gently twisted side-to-side to induce motion artifact in this group (Videos 1 and 2). Motion within either the trachea or esophagus was used to identify the location. Importantly, the ETT was not moved forward or backward during manipulation.

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

Assuming an effect size of 0.3 with a 95% level of significance, 540 samples (270 each of static and ETT ultrasound twisting techniques), and a two-tailed alpha of 0.05, we estimated power of the study to be above 90%. Microsoft Excel and SPSS statistical software were utilized to conduct the analysis. We utilized descriptive statistics, chi-square test, and *t*-test to analyze the relationships between static and ETT twisting ultrasound techniques and the accuracy of correctly identifying the location of intubation, operator time to identification, and operator confidence. In addition, we analyzed moderating variables (ie, operators and the actual location of the intubations) in the analysis.

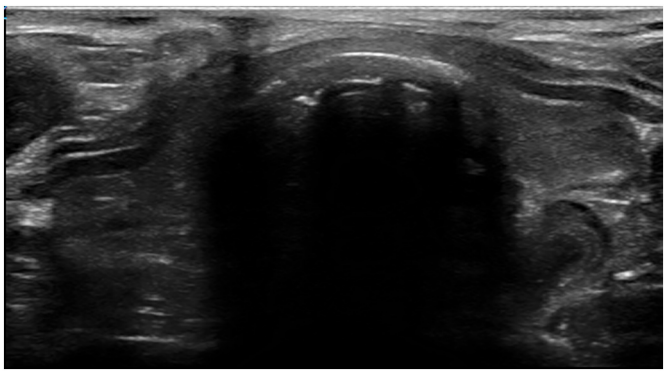

Fig. 1. Ultrasound image of an endotracheal intubation.

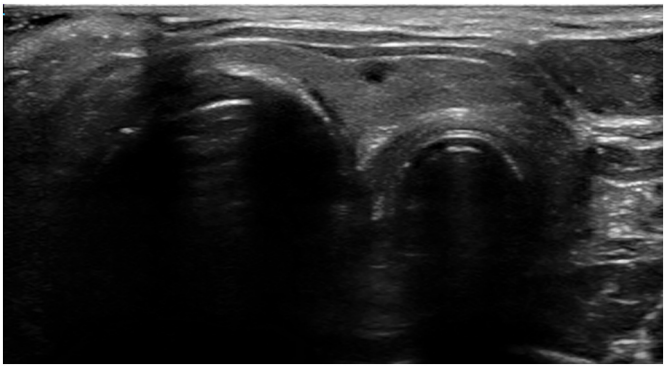

Fig. 2. Ultrasound image of an esophageal intubation.

3. Results

Five hundred and forty total intubations were performed, with each intubation assessed via both the static and ETT twisting techniques. There were 270 tracheal intubations and 270 esophageal intubations.

Overall, ultrasound was 98.9% (95% CI 97.6% to 99.5%) accurate. There was not a statistically significant difference in correctly identifying the location of intubations between the static and ETT twisting techniques. Among the static ETT group, ultrasound was 97.8% (95% CI 95.2% to 99.0%) accurate. Among the ETT twisting group, ultrasound was 100% (95% CI 98.6% to 100%) accurate.

There was a statistically significant difference in the mean time to identification between the static and ETT twisting techniques. Among the static ETT group, the mean time to identify the ETT with ultrasound was 6.87 s (95% CI 6.30 to 7.44 s). Among the ETT twisting group, the mean time to identify the ETT with ultrasound was 4.97 s (95% CI 4.36 to 5.57 s).

There was also a statistically significant difference in the mean operator confidence between the static and ETT twisting techniques. Among the static ETT group, the mean operator confidence was 4.71/5.0 (95% CI 4.63 to 4.78). Among the ETT twisting group, the mean operator confidence was 4.84/5.0 (95% CI 4.79 to 4.90).

4. Discussion

Successful intubation of critically ill patients necessitates rapid and accurate confirmation of ETT placement. Ultrasound has been shown to be a reliable method for identifying tracheal or esophageal location of an ETT [12,13]. In the setting of cardiac arrest, the American Heart Association recommends ultrasound as a diagnostic alternative in situations where the accuracy of end-tidal capnography is uncertain [14].

This study evaluated over 500 intubation attempts comparing the static technique with the ETT twisting technique for intubation confirmation. While there was no difference in the accuracy ETT identification, we found greater operator confidence and shorter time to identification when a twisting motion was used.

Ultrasound during intubation has been described in the literature both as a static imaging technique [4,5] and one that is assisted by a gentle twisting motion of the ETT [6,7]. While it is possible for the ETT to be visualized on a static grayscale image, it has been postulated that motion artifact from the twisting technique may aid in confirmation of ETT placement, especially in patients with anatomic variations [6,7]. It was previously unknown whether this extra twisting maneuver influenced the accuracy, time to confirmation, or operator confidence. To our knowledge, this is the first study to directly compare the accuracy of ETT confirmation on grayscale imaging between a fixed static position of the ETT with a twisting movement of the ETT.

While there was not a statistically significant difference in the diagnostic accuracy, it is important to note that all of the misidentified

ETT placements occurred in the static group and were tracheal in location. This may be due to the more limited ability to visualize the ETT in the trachea without movement, as opposed to the esophagus. Therefore, it is possible that the study may have been underpowered to detect this difference despite a large number of intubation assessments. Additionally, the twisting maneuver resulted in shorter time to identification and higher operator confidence. We hypothesize that the motion artifact resulting from gentle twisting of the tube allowed for improved visualization of the ETT. The twisting maneuver performed by the sonographer did not add significant time to the diagnostic procedure, and in fact allowed the sonographers to identify the ETT location more quickly and confidently. While the clinical importance of a two second difference in confirmation time is unclear, this study was performed by expert sonographers. Consequently, it remains to be determined whether this would be more profound among less experienced sonographers and further studies are needed to evaluate this among more novice users. Given these findings, we believe the twisting technique is a valuable component to the transtracheal ultrasound exam for intubation confirmation.

5. Limitations

It is important to consider several potential limitations with respect to this study. First, this was performed in a cadaver model. As a result, it may not fully reflect the characteristics of a live patient. However, cadaver models have been used extensively for the evaluation of ultrasound for ETT confirmation and have demonstrated similar test characteristics to live patients for this modality [6–11]. Additionally, only two cadavers were utilized in this study and it is possible this may not fully reflect the broader population. Future studies should examine this among patients with a wider range of neck circumferences. Furthermore, this study was performed by three sonographers with prior experience using ultrasound for ETT confirmation and it is possible that the results may have differed if less-experienced sonographers were utilized. However, the use of ultrasound for ETT confirmation has been suggested to have a rapid learning curve [15].

6. Conclusion

The diagnostic accuracy of ultrasound for ETT confirmation did not significantly differ between the static approach and ETT twisting technique. However, the ETT twisting technique was associated with reduced time to confirmation and greater operator confidence. Future studies are needed to determine whether this finding would differ among novice sonographers or in specific patient populations.

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Meetings

None.

IRB

Approved

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ajem.2019.10.032.

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