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Original Contribution

Variation in the accuracy of ultrasound for the detection of intubation by endotracheal tube size

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ABSTRACT

Introduction: Rapid and accurate confirmation of endotracheal tube (ETT) placement is a fundamental step in definitive airway management. Multiple techniques with different limitations have been reported. Recent studies have evaluated the accuracy, time to performance, and physician confidence for ultrasound in both cadaveric models and live patients. However, no study to date has measured the effect of ETT size. Our study is the first to measure the accuracy of ultrasound for ETT confirmation based on ETT size.
Methods: This study was performed in a cadaver lab using three different cadavers chosen to represent varying neck circumferences. Cadavers were intubated in a random sequence with respect to both the location of intubation (i.e., tracheal vs esophageal) and sizes of ETT. Three ETT sizes were utilized: 6.0-, 7.0-, and 8.0-mm. Blinded sonographers assessed the location of the ETT using the static technique. Accuracy of sonographer identification, time to identification, and operator confidence were assessed.
Results: 453 assessments were performed. Overall, ultrasound was 99.1% (95% CI 97.8% to 99.7%) accurate in identification of correct location of intubation. The mean time to placement was 6.45 s (95% CI 5.62 to 7.28). The mean operator confidence level was 4.72/5.0 (95% CI 4.65 to 4.78). There was no significant difference between ETT sizes with respect to any of the outcomes.
Conclusion: The diagnostic accuracy of ultrasound for ETT confirmation did not vary with the use of different ETT sizes. Further studies are needed to determine if the accuracy would change with more novice providers or in specific patient populations.

1. Introduction

The rapid and accurate confirmation of correct endotracheal tube (ETT) placement is a fundamental step in definitive airway management. A number of confirmatory techniques have been proposed. However, each has been noted to have unique limitations in specific situations [1]. While capnography is frequently used to identify the location of the ETT, there are several limitations, including false positives with hypopharyngeal placement and false negatives during cardiac arrest [2-4]. Additionally, the positive pressure ventilations utilized to confirm placement with capnography can distend the stomach and increase the aspiration risk if the ETT is incorrectly placed in the esophagus.

As a result, point-of-care ultrasound has been increasingly studied to confirm correct ETT location. In fact, ultrasound to confirm ETT placement was included as a reasonable alternative to continuous waveform capnography in the 2015 American Heart Association Advanced Cardiac Life Support Guidelines [1]. In both cadaveric models and live patients, investigators have repeatedly demonstrated that ultrasound is accurate, fast, and straightforward to learn [5-10]. However, no study to date has evaluated the effect of ETT size on the accuracy of location confirmation. Our study is the first to specifically evaluate the effect of ETT size on the accuracy of ultrasound for the confirmation of ETT location.

2. Methods

This study was a blinded, randomized, controlled trial performed in the cadaver lab of an academic hospital in Chicago, Illinois. Three cadavers were utilized with different neck circumferences to simulate the variation in patient populations. Cadaver #1 had a neck circumference of 30 cm, cadaver #2 had a neck circumference of 35 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,

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with the goal of having equivalent numbers of tracheal and esophageal intubations in order to best define the test characteristics. Additionally, intubators were randomized to use either a size 6.0-, 7.0-, or 8.0-mm ETT. One of two attending physician investigators with extensive intubation experience intubated each cadaver 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, a sonographer would assess the location of each intubation using the static technique.

Four attending physician sonographers with prior experience in the use of ultrasound for ETT confirmation independently performed the assessments. A Zonare Z1Pro ultrasound machine with an L14-5 linear transducer was utilized for all assessments. For the ultrasound technique, the sonographer would place the transducer across the neck at the suprasternal level and visualize the trachea. The ETT would then be twisted with the non-dominant hand to visualize for motion artifact within the trachea. Visualization of motion artifact within the trachea confirmed tracheal intubation (Fig. 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). Videos 1–6 demonstrate examples of ultrasound examinations for all three ETT sizes (Videos 1–6).

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.

Assuming an effect size of 0.15 with 95% level of significance, 80% power, and a two-tailed alpha of 0.05, we determined that we would need 432 total assessments for the study. Microsoft Excel and SPSS statistical software was utilized to conduct the analysis. We utilized descriptive statistics, chi-square test, *t*-test, and ANOVA with post hoc test to analyze the relationships between the sizes of the ETT 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.

3. Results

Four-hundred and fifty-three assessments were performed, comprising 228 esophageal intubations and 225 tracheal intubations. There were 155, 153, and 145 intubations with a 6.0-, 7.0-, and 8.0-sized ETT, respectively. Overall, ultrasound was 99.1% (95% CI 96.9% to 99.8%) sensitive and 99.1% (95% CI 96.8% to 99.8%) specific in identification of correct location of intubation. The mean time to placement was 6.45 s (95% CI 5.62 to 7.28). The mean operator confidence level was 4.72/5.0 (95% CI 4.65 to 4.78).

There was no significant difference in correctly identifying the location of intubations between groups with respect to ETT size. Among 6.0-size ETTs, ultrasound was 97.7% (95% CI 91.9% to 99.4%) sensitive and 98.6% (95% CI 92.2% to 99.7%) specific. Among 7.0-size ETTs, ultrasound was 100% (95% CI 94.6% to 100%) sensitive and 98.8% (95% CI 93.7% to 99.8%) specific. Among 8.0-size ETTs, ultrasound was 100% (95% CI 95.1% to 100%) sensitive and 100% (95% CI 94.8% to 100%) specific.

There was no significant difference in mean time to identification between groups with respect to ETT size. Among 6.0-size ETTs, the mean time to identify the ETT with ultrasound was 6.10 s (95% CI 4.88 to 7.31). Among 7.0-size ETTs, the mean time to identify the ETT with ultrasound was 7.71 s (95% CI 5.87 to 9.56). Among 8.0-size ETTs, the mean time to identify the ETT with ultrasound was 5.49 s (95% CI 4.37 to 6.61).

There was no significant difference in mean operator confidence between groups with respect to ETT size. Among 6.0-size ETTs, the mean operator confidence was 4.7/5.0 (95% CI 4.59 to 4.8). Among 7.0-size ETTs, the mean operator confidence was 4.69/5.0 (95% CI 4.58 to 4.79). Among 8.0-size ETTs, the mean operator confidence was 4.77/5.0 (95% CI 4.66 to 4.87).

4. Discussion

In the Emergency Department, it is essential to rapidly and accurately confirm ETT placement. Ultrasound has been previously demonstrated to be highly accurate for the confirmation of ETT placement [5]. However, most studies were limited to larger-sized ETTs and no study has directly compared the accuracy between larger- and smaller-sized ETT. As some patients may require the use of smaller ETT due to anatomic limitations (e.g., tracheal stenosis, anaphylaxis,

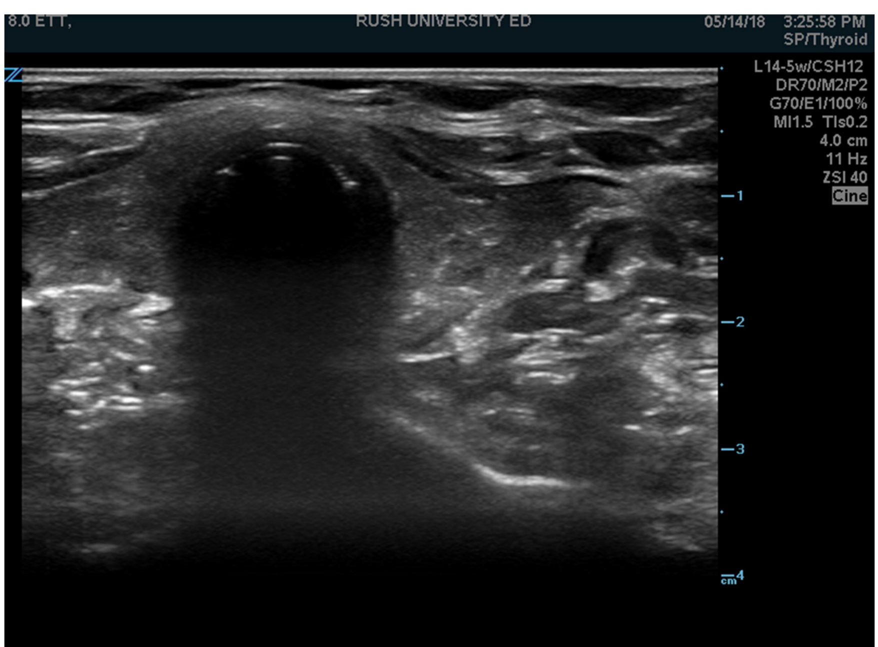

Fig. 1. Ultrasound image of tracheal intubation.

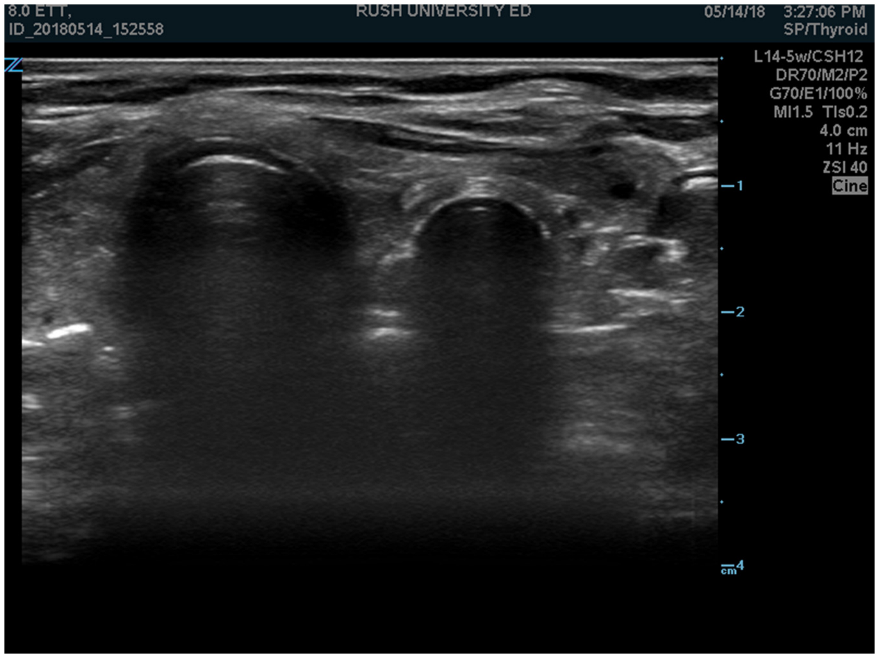

Fig. 2. Ultrasound image of esophageal intubation.

angioedema), it is important to understand whether smaller ETT sizes would maintain similar accuracy with this technique.

This was the first study to directly compare the accuracy of ultrasound for ETT confirmation between smaller and larger ETT sizes and demonstrated no significant difference between the groups. While one may anticipate that using a smaller ETT size may result in increased difficulty with visualizing ETT placement, the current data supports that accuracy is not significantly affected by the use of a smaller ETT. Additionally, sonographers were able to identify the ETT without a significant difference in time to confirmation or operator confidence.

A prior systematic review and meta-analysis by Das and colleagues demonstrated that ultrasound was 98% accurate among a sample of 969 patients [5]. Our study demonstrated similar accuracy to previous studies. Three of the four misidentified ETT placements occurred with the smaller-sized ETT, while none of the largest-sized ETT were misidentified. It is possible that there may be a small difference in accuracy that was not detected by the current study. However, this was an adequately powered study with a sample size of 453 assessments, so it is unlikely that any clinically significant difference is present. Further studies should evaluate whether other anatomical factors or performance by more novice providers would affect the diagnostic accuracy, as well as whether the results would vary in a live patient population.

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 [6-10]. Additionally, only three cadavers were utilized in this study and it is possible this may not fully reflect the broader population. However, we intentionally utilized cadavers with significant variations in neck sizes to best reflect the differences represented in the larger population. Furthermore, this study was performed by four 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 [11]. Nonetheless, further studies are recommended to determine whether the accuracy of identifying smaller ETT differs in less-experienced providers.

6. Conclusion

The diagnostic accuracy of ultrasound for ETT confirmation did not vary with the use of different ETT sizes. Further studies are needed to determine if the accuracy would change with more novice providers or in specific patient populations.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ajem.2018.07.026.

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Meetings

None.

IRB

Approved.

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