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Accuracy of ultrasound for endotracheal intubation between different transducer types

Michael Gottlieb MD [a,*], Dallas Holladay DO [a], Katharine Burns MD [b], Stephen R. Gore MD [a], Collin Wulff DO [a], Shital Shah PhD [a], John Bailitz MD [c]

[a] Department of Emergency Medicine, Rush University Medical Center, Chicago, IL, United States of America
[b] Department of Emergency Medicine, Advocate Christ Medical Center, Chicago, IL, United States of America
[c] Department of Emergency Medicine, Feinberg School of Medicine, Northwestern Memorial Hospital, Chicago, IL, United States of America

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ABSTRACT

Introduction: Ultrasound has been increasingly utilized for the identification of endotracheal tube (ETT) location after an intubation attempt, particularly among patients in cardiac arrest. However, prior studies have varied with respect to the choice of transducer and no studies have directly compared the accuracy between transducer types. Our study is the first to directly compare the accuracy of ETT confirmation between the linear and curvilinear transducer.

Methods: This study was performed in a cadaver lab using three different cadavers chosen to represent varying neck circumferences. Cadavers were randomized to tracheal or esophageal intubation. Blinded sonographers assessed the location of the ETT using either a linear or curvilinear transducer in an alternating sequence. Accuracy of sonographer identification, time to identification, and operator confidence were assessed.

Results: Four hundred and five assessments were performed with 198 (48.9%) tracheal and 207 (51.1%) esophageal intubations. The linear transducer was 98% (95% CI 95.1% to 99.2%) accurate. The curvilinear transducer was 95% (95% CI 91.1% to 97.3%) accurate. The mean time to identification was significantly lower with the linear transducer [7.46 s (95% CI 6.23 to 8.7 s)] as compared with the curvilinear transducer [11.63 s (95% CI 9.05 to 14.2 s)]. The mean operator confidence was significantly higher with the linear transducer [4.84/5.0 (95% CI 4.76 to 4.91)] than with the curvilinear transducer [4.44/5.0 (95% CI 4.3 to 4.57)]. All operators preferred the linear transducer over the curvilinear transducer.

Conclusion: The diagnostic accuracy of ultrasound for ETT confirmation did not significantly differ between ultrasound transducer types, but the curvilinear transducer was associated with a longer time to confirmation and lower operator confidence. Further studies are needed to determine if the accuracy would change with more novice providers or in specific patient populations.

1. Introduction

Endotracheal intubation is a commonly performed procedure in Emergency Medicine. However, unintentional esophageal intubation is a dangerous complication that can result in significant morbidity and mortality if not immediately recognized. While end-tidal capnography has historically been the gold standard for confirming endotracheal tube (ETT) location, this modality has several limitations, including false positives with hypopharyngeal placement and false negatives during cardiac arrest [1-3]. Additionally, the positive pressure ventilations used to confirm placement with capnography can potentially distend the stomach and increase the risk of aspiration if the ETT is incorrectly placed in the esophagus.

As a result, ultrasound has been increasingly studied as an alternate confirmatory test because it can allow for rapid confirmation without the need for additional ventilations [4-11]. Prior studies have varied with respect to using a linear [8-10] or curvilinear transducer [4,5] for the ultrasound examination, and it is unclear which transducer is more accurate for this technique. This study aimed to compare the linear transducer with the curvilinear transducer to determine which was the most accurate for ETT identification. Secondary outcomes included differences in time to identification, operator confidence, and operator preference.

* Corresponding author at: 1750 West Harrison Street, Suite 108 Kellogg, Chicago, IL 60612, United States of America.
E-mail address: MichaelGottliebMD@Gmail.com (M. Gottlieb).

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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 actual patient populations. Cadaver #1 had a neck circumference of 31.5 cm, cadaver #2 had a neck circumference of 40.5 cm, and cadaver #3 had a neck circumference of 31 cm. This study was deemed exempt by the local institutional review board.

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 7.5 ETT using video laryngoscopy. Each intubation was performed prior to the study sonographers entering the room. The intubator was not present in the room while the study sonographers performed their ultrasounds. This prevented the intubator's reaction from biasing the sonographer's responses. After intubation, one sonographer assessed the location of each intubation using the standard, grayscale approach and then stated aloud the perceived location of the ETT. The sonographer alternated between using the linear and curvilinear transducers for each examination. This was repeated with three additional sonographers. Only one sonographer was present in the room at a time and all four sonographers were blinded to the ETT location.

Four attending physician sonographers with prior experience in the use of ultrasound for ETT confirmation independently performed the assessments. A Zonare ZS-3 ultrasound machine with an L14-5 linear transducer was utilized for the linear transducer assessments and a Zonare ZS-3 ultrasound machine with a C6-2 curvilinear transducer was utilized for the curvilinear transducer assessments. For the ultrasound technique, the sonographer placed the transducer across the neck at the suprasternal level to visualize the trachea. The ETT was then twisted with the non-dominant hand to assess for motion artifact within the trachea. Visualization of motion artifact within the trachea confirmed tracheal intubation (Figs. 1 and 2). The transducer 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 and 4). Videos 1–4 demonstrate examples of ultrasound examinations with both the linear and curvilinear transducers (Videos 1–4).

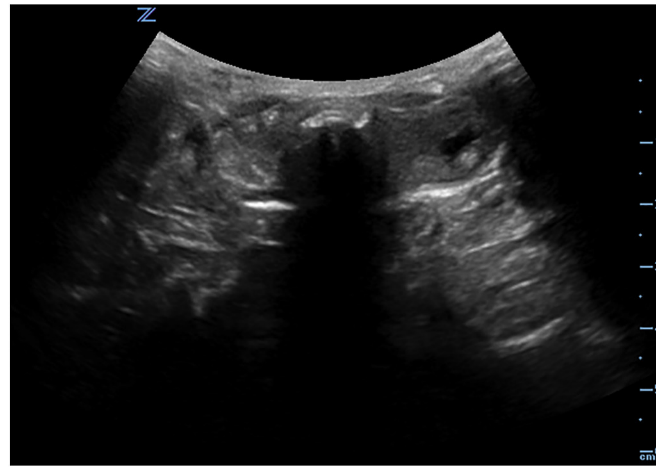

Fig. 2. Endotracheal intubation assessed with a curvilinear transducer.

A research assistant recorded the sonographer's 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. Providers were also asked at the end of the study which transducer they preferred.

Assuming an effect size of 0.3 with 95% level of significance, 405 samples, and a two-tailed alpha of 0.05, we estimated minimum power of the study to be 85%. 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 the ultrasound transducer type and accuracy of correctly identifying location of intubation, operator time to identification, and operator confidence. In addition, we analyzed moderating variables such as operators, cadaver number, and actual location of the intubations in the analysis.

3. Results

Four hundred and five assessments were performed, comprising 207 (51.1%) esophageal intubations and 198 (48.9%) tracheal intubations. Overall, ultrasound was 96.5% (95% CI 94.3% to 97.9%) accurate. The mean time to identification was 9.53 s (95% CI 8.1

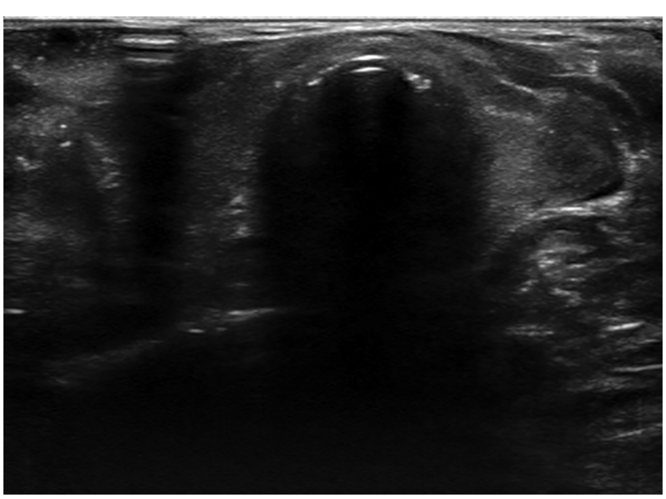

Fig. 1. Endotracheal intubation assessed with a linear transducer.

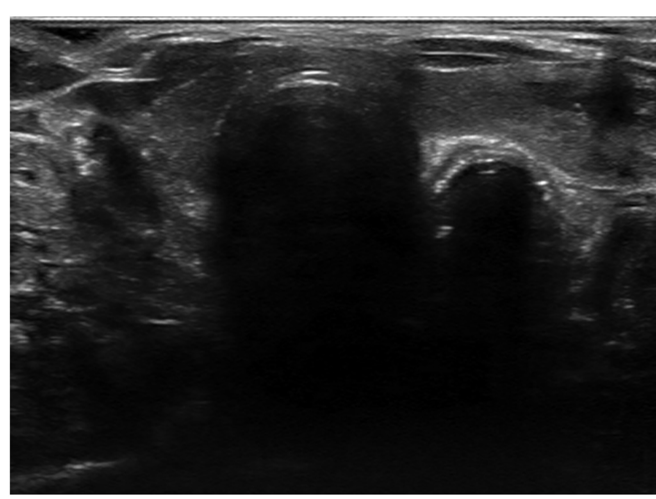

Fig. 3. Esophageal intubation assessed with a linear transducer.

Fig. 4. Esophageal intubation assessed with a curvilinear transducer.

to 10.96 s). The mean operator confidence level was 4.64/5.0 (95% CI 4.56 to 4.72).

There was no statistically significant difference in correctly identifying the location of intubations between the linear and curvilinear transducers. Among the linear transducer group, ultrasound was 98% (95% CI 95.1% to 99.2%) accurate. Among the curvilinear transducer group, ultrasound was 95% (95% CI 91.1% to 97.3%) accurate.

There was a statistically significant difference in mean time to identification between the linear and curvilinear transducers. Among the linear transducer group, the mean time to identify the ETT with ultrasound was 7.46 s (95% CI 6.23 to 8.7 s). Among the curvilinear transducer group, the mean time to identify the ETT with ultrasound was 11.63 s (95% CI 9.05 to 14.2 s).

There was a statistically significant difference in mean operator confidence between groups with respect to the linear and curvilinear transducers. Among the linear transducer group, the mean operator confidence was 4.84/5.0 (95% CI 4.76 to 4.91). Among the curvilinear transducer group, the mean operator confidence was 4.44/5.0 (95% CI 4.3 to 4.57). All four sonographers (100%) stated that they preferred the linear transducer over the curvilinear transducer.

4. Discussion

Ultrasound has been increasingly studied for the evaluation of ETT location after intubation. Given the limitations of capnography, especially during cardiac arrest, ultrasound may be particularly valuable in this application, with the American Heart Association suggesting its use as an alternate diagnostic test for ETT identification. [12] However, studies have varied with respect to the type of transducer used for the examination. While a linear transducer can provide enhanced resolution of the superficial structures, the curvilinear transducer has a wider breadth of view, facilitating identification of both the esophagus and trachea in a single view with minimal transducer movement. To the best of our knowledge, this is the first study to directly compare the linear transducer with the curvilinear transducer to determine which was most accurate for ETT identification.

Overall, this study found that the curvilinear transducer was associated with a trend toward lower accuracy than the linear transducer, but this was not statistically significant. A recent systematic review and meta-analysis of 1595 patients demonstrated that ultrasound was 98.7% sensitive and 97.1% specific. [11] A subgroup analysis was performed comparing different transducer types and the authors identified a non-statistically significant trend toward improved specificity with the linear transducer. Our study aligns with that data but may be underpowered to identify a statistically significant difference.

Our study also found that the curvilinear transducer was associated with a longer time to ETT location confirmation. The mean time to confirmation was 4 s greater with the curvilinear than the linear. This study also found that provider confidence was lower when using the curvilinear transducer. This may have been due to the decreased resolution in the proximal field with the lower frequency curvilinear transducer. Importantly, all four sonographers preferred using the linear transducer.

5. Limitations

It is important to consider several potential limitations with respect to the current study. First, this study was performed in a cadaver model. Consequently, it may not fully reflect the characteristics of live patients. However, cadaver models have been used extensively in prior studies 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 that this may not completely reflect the broader population. However, we intentionally utilized cadavers with variations in neck sizes to best reflect the differences found in the larger population. Additionally, this study was performed by four sonographers with prior experience using ultrasound for ETT confirmation and it is possible that the results may be different if less-experienced sonographers were utilized. Further studies are recommended to determine whether the accuracy of linear *versus* curvilinear transducers differs with less-experienced providers.

6. Conclusion

The diagnostic accuracy of ultrasound for ETT confirmation did not significantly differ between ultrasound transducer types, but the curvilinear transducer was associated with a longer time to confirmation and lower operator confidence. Further studies are needed to determine if the accuracy would change with novice sonographers or in specific patient populations.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ajem.2019.03.016.

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Meetings

None.

IRB

Approved.

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