THE SENSITIVITY AND SPECIFICITY OF TRANSCRICOHYRID ULTRASONOGRAPHY TO CONFIRM ENDOTRACHEAL TUBE PLACEMENT IN A CADAVER MODEL

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Abstract—Confirmation of endotracheal (ET) tube placement is critical when performing emergency airway management. No single confirmation strategy has emerged as ideal in all circumstances. Our objective in this study was to assess the sensitivity and specificity of a novel approach to verify endotracheal intubation using transcricothyroid ultrasonography (US). We performed a prospective, randomized double-blinded trial in a human cadaver model. A 7.5-MHz curvilinear probe was placed longitudinally over the cricothyroid membrane as cadavers were randomly intubated in either the trachea or esophagus in two phases: 1) as the intubation was being performed (dynamic) and, 2) after intubation had been completed (static). Volunteer emergency medicine (EM) residents, blinded to tube placement, assessed for esophageal vs. tracheal ET placement using dynamic and static US views. Sensitivity, specificity, positive predictive value, and negative predictive value for detecting esophageal ET placement with 95% confidence intervals were calculated. Seven EM residents made a total of 70 dynamic and 70 static assessments of ET position using transcricothyroid US. Dynamic assessment resulted in 97% sensitivity and 100% specificity for detecting esophageal ET placement. Static assessment resulted in only 51% sensitivity and 91% specificity. This pilot study suggests that dynamic transcricothyroid US is a potentially accurate method of confirming ET placement during the intubation process. Further investigation in live humans is warranted to validate these data. © 2007 Elsevier Inc.

Keywords—ultrasound; endotracheal intubation; tube confirmation; esophageal intubation

INTRODUCTION

Unrecognized esophageal intubation is a relatively infrequent but potentially devastating complication of emergency airway management (1,2). Although many strategies for endotracheal (ET) tube confirmation have been proposed, none has emerged as ideal in all situations (3). Chaters and Wilkinson suggest that the ET tube confirmatory technique fulfill the following criteria: 1) it should work for different intubations; 2) results should be unequivocal; 3) sensitivity for detecting esophageal intubation should be 100%; and 4) it should be easily understandable to physicians (4). Although fiber-optic laryngoscopy may best approximate these qualifications, secretions limit its effectiveness and the technique is highly operator dependent (5). As a result, capnometry has become the standard of care due to its ease of use and reliability (6–8). However, its accuracy in cardiac arrest is unclear, and some data exist to suggest that up to six breaths may be required before the stomach is completely cleared of CO2, especially after prolonged bag-valve-mask ventilation (9).
Ultrasonography (US) is rapidly becoming an indispensable and commonplace tool in the Emergency Department (ED). Although the ability to directly visualize laryngeal structures in real time makes it potentially useful for ET confirmation, its use in this arena has yet to be explored. This pilot study was designed to explore the use of transcricothyroid US in confirming ET position.

**MATERIALS AND METHODS**

This was a prospective, randomized trial using a human cadaver model. Emergency Medicine resident volunteers were recruited for participation in the study. Subjects were given a 5-min briefing on how to identify the larynx on US by visualizing two hyperechoic laryngeal lines in a longitudinal (sagittal) plane (Figure 1). Residents attempted to ultrasonographically visualize the “snow-storm” appearance between the two lines to signify an endotracheal intubation (9). The lack of this “snow-storm” through the double lines and the appearance of movement posterior to the two laryngeal lines served as evidence of an esophageal intubation. A Siemens 7.5-MHz curvilinear US probe was placed longitudinally over the larynx at the cricothyroid membrane to acquire the images. An 8.0 ET tube was used for all intubations. Half were assessed dynamically, during ET tube placement, whereas the other half were assessed statically, after ET tube placement. The order of tracheal vs. esophageal and dynamic vs. static assessments was randomized, with all subjects blinded to these assignments. Intubations were performed by a faculty emergency physician (EP) and confirmed by a second faculty EP. Sensitivity, specificity, and positive and negative predictive values and their 95% confidence intervals (CI) were calculated for both dynamic and static determination of ET placement. Statistical analysis was performed using StatsDirect™ (StatsDirect Software Inc., Ashwell, UK). The project was approved by our institutional Human Research Protection Program.

**RESULTS**

A total of 7 Emergency Medicine (EM) residents participated in this study. Each completed 10 dynamic and 10 static assessments of ET placement, with half being esophageal and half tracheal; this resulted in a total of 140 assessments. Subjects reported being able to easily and rapidly identify the two hyperechoic laryngeal lines. During the dynamic assessment phase, correct identification of ET tube position was achieved in 35/35 tracheal placements and in 34/35 esophageal placements. This yielded a sensitivity of 97.1% (95% CI 85.1–99.9%) and a specificity of 100.0% (95% CI 90.0–100.0%) for detecting esophageal intubation. Positive predictive value was 97.2% (95% CI 85.5–99.9%), with a negative predictive value of 100% (95% CI 89.7–100.0%).

For the static confirmation phase, subjects correctly identified 32/35 endotracheal intubations and 18/35 esophageal intubations. This resulted in a sensitivity of 51.4% (95% CI 34.0–68.6%) and a specificity of 91.4% (95% CI 76.9–98.2%). Positive predictive value was 85.7% (95% CI 63.7–97.0%), with a negative predictive value of 65.3% (95% CI 50.4–78.3%). These values are displayed in Table 1.

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<tr>
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<th>Dynamic</th>
<th>Static</th>
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<tbody>
<tr>
<td>Sensitivity</td>
<td>97.1 (85.1–99.9)</td>
<td>51.4 (34.0–68.6)</td>
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<tr>
<td>Specificity</td>
<td>100.0 (90.0–100.0)</td>
<td>91.4 (76.9–98.2)</td>
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<td>PPV</td>
<td>97.2 (85.5–99.9)</td>
<td>85.7 (63.7–97.0)</td>
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<tr>
<td>NPV</td>
<td>100.0 (89.7–100.0)</td>
<td>65.3 (50.4–78.3)</td>
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**DISCUSSION**

In this pilot study, we observed excellent sensitivity, specificity, positive predictive value, and negative predictive value for predicting both esophageal and tracheal...
ET placement with use of dynamic transcricothyroid US in a group of EM residents. This suggests that this technique may be a rapid and accurate method of confirming ET placement when used during the intubation process. Accuracy was substantially lower with static assessments. Although this technique may not be able to replace other confirmatory techniques, it does provide a rapid, cost-free adjunct to other techniques of verifying ET placement. In addition, the instantaneous data provided by this technique may preclude unnecessary inflation of the stomach with use of capnometry, potentially decreasing the risk of aspiration. The method described here is easily reproduced in any ED with ultrasonography. Additional investigation is needed before this strategy can be employed with confidence in other EDs.

It is possible that this technique could be employed by the individual performing Sellick’s maneuver. At our institution, intubations are generally performed by Emergency Medicine residents, making this technique ideal for the supervising attending to assure prevention of passive regurgitation and aspiration and to provide immediate confirmation of proper ET placement. The US machine is stored in our main resuscitation room for use with advanced procedures, such as US-guided central venous catheter placement, and to assess for intra-peritoneal or pericardial fluid and cardiac activity after arrest.

It is possible that “static” confirmation can be converted into dynamic confirmation with post-intubation manipulation of the ET tube 1–2 cm in a caudad-cephalad fashion. Anecdotally, this seemed to be true in our study, although no data were collected in this regard. Future studies should explore this strategy, which may give transcricothyroid US more versatility in its application. In addition, the dynamic movement of the vocal cords has previously been identified as a potential target for US imaging but was not possible to study using a cadaver model (10). Finally, the use of various contrast agents, potentially injectable into the balloon cuff, may improve the accuracy of this technique, even with static assessments.

The main limitations of this study include its small size and the use of a cadaver model. Thus, this should be considered a pilot study and should not initiate widespread use of the technique. On the other hand, it may be reasonable to employ it as an adjunct to other confirmatory techniques as discussed above. There should be no increased risk to the patient with use of transcricothyroid US, even when dynamic assessments are made. With regard to the fresh-frozen cadaver model, we have no reason to believe that a significant difference in the anatomy exits that would alter results in any way as compared to a live human model. Anecdotally, the same US probe was placed over the cricothyroid window of many of the participating physicians in this study, with a similar appearance to the structures identified in the cadaver model. Nonetheless, this method will need to be verified in an ED setting to confirm its applicability and accuracy.

CONCLUSIONS

Transcricothyroid US seems to be an extremely accurate method of instantaneously identifying esophageal ET placement during the dynamic phase of intubation. Sensitivity and specificity values with static assessment of ET placement were not appropriate for clinical use. Additional studies in the clinical arena are needed before this technique can be recommended for routine use.

REFERENCES