Pilot Study to Determine the Utility of Point-of-care Ultrasound in the Assessment of Difficult Laryngoscopy

Srikar Adhikari, MD, MS, RDMS, Wes Zeger, DO, Charles Schmier, MD, Todd Crum, MD, Andy Craven, MD, Ilir Frrokaj, MD, Huiling Pang, MD, and Valerie Shostrom, MS

Abstract

Objectives: Prediction of difficult laryngoscopy in emergency care settings is challenging. The preintubation clinical screening tests may not be applied in a large number of emergency intubations due to the patient's clinical condition. The objectives of this study were 1) to determine the utility of sonographic measurements of thickness of the tongue, anterior neck soft tissue at the level of the hyoid bone, and thyrohyoid membrane in distinguishing difficult and easy laryngoscopies and 2) to examine the association between sonographic measurements (thickness of tongue and anterior neck soft tissue) and difficult airway clinical screening tests (modified Mallampati score, thyromental distance, and interincisor gap).

Methods: This was a prospective observational study at an academic medical center. Adult patients undergoing endotracheal intubation for an elective surgical procedure were included. The investigators involved in data collection were blinded to each other's assessments. Demographic variables were collected preoperatively. The clinical screening tests to predict a difficult airway were performed. The ultrasound (US) measurements of tongue and anterior neck soft tissue were obtained. The laryngoscopic view was graded using Cormack and Lehane classification by anesthesia providers on the day of surgery. To allow for comparisons between difficult airway and easy airway groups, a two-sided Student's t-test and Fisher's exact test were employed as appropriate. Spearman's rank correlation coefficients were used to examine the association between screening tests and sonographic measurements.

Results: The mean (±standard deviation [SD]) age of 51 eligible patients (32 female, 19 male) was 53.1 (±13.2) years. Six of the 51 patients (12%, 95% confidence interval [CI] = 3% to 20%) were classified as having difficult laryngoscopy by anesthesia providers. The distribution of laryngoscopy grades for all subjects was 63, 25, 4, and 8% for grades 1, 2, 3, and 4, respectively. In this study, 83% of subjects with difficult airways were males. No other significant differences were noted in the demographic variables and difficult airway clinical screening tests between the two groups. The sonographic measurements of anterior neck soft tissue were greater in the difficult laryngoscopy group compared to the easy laryngoscopy group at the level of the hyoid bone (1.69, 95% CI = 1.19 to 2.19 vs. 1.37, 95% CI = 1.27 to 1.46) and thyrohyoid membrane (3.47, 95% CI = 2.88 to 4.07 vs. 2.37, 95% CI = 2.29 to 2.44). No significant correlation was found between sonographic measurements and clinical screening tests.

Conclusions: This pilot study demonstrated that sonographic measurements of anterior neck soft tissue thickness at the level of hyoid bone and thyrohyoid membrane can be used to distinguish difficult and easy laryngoscopies. Clinical screening tests did not correlate with US measurements, and US was able to detect difficult laryngoscopy, indicating the limitations of the conventional screening tests for predicting difficult laryngoscopy.

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From the Department of Emergency Medicine, University of Arizona Health Sciences Center (SA), Tucson, AZ; and the Department of Emergency Medicine (WZ, CS, TC, AC, IF), the Department of Anesthesiology (HP), and the Department of Biostatistics (VS), University of Nebraska Medical Center, Omaha, NE.

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Address for correspondence and reprints: Srikar Adhikari, MD, MS, RDMS; e-mail: sriadhikari@aol.com.

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Emergency physicians are confronted with the challenge of managing a difficult airway. The preintubation clinical screening tests (Mallampati classification, interincisor gap, thyromental distance, and testing neck mobility) to assess for difficult laryngoscopy have poor to moderate sensitivity.[1] These clinical screening tests are often not applicable in the emergency and critical care settings, because patients are frequently confused, lethargic, uncooperative, and unable to follow directions or appropriately position themselves.[2,3]

There is limited evidence from the current literature regarding the potential to use ultrasound (US) in the assessment of difficult laryngoscopy. Two prior studies investigating the use of US in the evaluation of difficult laryngoscopy have produced conflicting results.[4,5] Both studies primarily focused on soft tissue thickness at and below the level of vocal cords and were done in a select group of obese patients. However, the anterior neck soft tissue at the hyoid bone and thyrohyoid membrane levels need to be displaced by the laryngoscopic blade while performing intubation.[5] Additionally, a large tongue has been shown to be associated with difficult intubation.[6] We hypothesized that US measurements of the base of the tongue and anterior neck soft tissue at the level of the hyoid bone and thyrohyoid membrane are better indicators of difficult laryngoscopy than anterior neck soft tissue thickness at and below the level of vocal cords. The primary objective of this study was to determine the utility of sonographic measurements of the thickness of the tongue and anterior neck soft tissue at the level of the hyoid bone and thyrohyoid membrane in distinguishing difficult and easy laryngoscopies. The secondary objective was to examine the association between sonographic measurements (thickness of tongue and anterior neck soft tissue) and difficult airway clinical screening tests (modified Mallampati score, thyromental distance, and interincisor gap).

METHODS

Study Design

This was a prospective observational study. The study was approved by the local university institutional review board and funded through an Endowment for Education and Research grant from the American Institute of Ultrasound in Medicine. Informed consent was obtained from all subjects who participated in the study.

Study Setting and Population

The study took place between June 2009 and September 2009 at an academic tertiary care hospital anesthesia preoperative evaluation unit. Consecutive participants were prospectively recruited during preselected study - days. Patients were eligible for the study if they were at least 19 years of age and required endotracheal intubation for an elective surgical procedure. Patients were excluded if they had any abnormalities preventing the use of clinical screening tests (facial fractures, maxillofacial abnormalities, tumors, and cervical spine fractures), had a tracheostomy tube, or were unable to give consent.

Study Protocol

Prior to data collection, all co-investigators were trained in the proper technique for performing difficult airway clinical screening tests. Our anesthesia department was informed and supportive of the study. The US measurements were only obtained by the primary investigator (PI) who is fellowship-trained in emergency US. Airway US experience was obtained through additional bedside scanning and reviewing journal articles and images. The variables collected in the study are shown in Figure 1.[7–10]

On the study days, all variables were collected preoperatively except grade of laryngoscopy, which was recorded by anesthesia providers on the day of surgery. The investigators involved in data collection were blinded to each other's assessments. Demographic variables were collected and clinical screening tests were performed by the same co-investigator. The examination was performed by the PI with a Sonosite M-turbo (Bothell, WA) US system using a 10–5 MHz, 38-mm broadband linear array transducer. The frequency settings (Pen/Gen/Res) were adjusted as necessary, and SonoMB multibeam imaging technology was used routinely. The US examination was performed with the patient supine and the head and neck in a neutral position without a pillow. The anteroposterior thickness of the hypoechoic geniohyoid muscle of the tongue was measured in the short axis (Figure 2A). The anterior neck soft tissue thickness was measured from the skin at five different levels in short axis (Figures 2B–2D). At each level, three measurements (central axis and approximately 10 mm to the left and right of the central axis) were taken and averaged to obtain the soft tissue thickness. The time required to obtain US images at each level was recorded by the PI and also cross-checked by another investigator by reviewing the time displayed on the images.

On the day of surgery, the grade of laryngoscopy was recorded as part of routine documentation by the anesthesia attending physician, resident, or certified nurse anesthetist who performed the endotracheal intubation (standard practice in our institution). A Cormack-Lehane grade 1 or 2 was categorized as an easy laryngoscopy, and a grade 3 or 4 was categorized as a difficult laryngoscopy (Figure 1). All patients received paralytics prior to intubation.

Data Analysis

SAS version 9.2 was used for all summary statistics and analyses (SAS Institute, Cary, NC). Data normality was examined using the Shapiro-Wilks test. To allow for comparisons between the difficult airway and easy airway groups, a two-sided Student's t-test and Fisher's exact test were employed as appropriate. We did not adjust for multiple comparisons in our analyses. Spearman's rank correlation coefficients were used to examine the association between clinical screening tests and sonographic measurements.

Sample Size. We anticipated that 10% ($n = 5$) of patients would have difficult laryngoscopy and 90% ($n = 45$) would have easy laryngoscopy. A sample size of five patients with difficult laryngoscopy will produce

1) Demographic variables:
- -Age
- -Sex
- -Race

2) Clinical screening tests (to predict difficult airway):
- -History of obstructive sleep apnea-diagnosed with polysomnography or undiagnosed sleep apnea suspected by the presence of snoring and cessation of breathing during sleep
- -Body mass index (BMI)
- -Abnormalities of upper teeth: loose or protruding upper teeth, or partially missing upper teeth
- -Ability to move the lower teeth in front of the upper teeth
- -Interincisor gap (cm): distance between the upper and lower incisors
  - ≥ 4 cm—classified as easy laryngoscopy
  - < 4 cm—classified as difficult laryngoscopy[7]
- -Modified Mallampati score[8]
  - I and II—classified as easy laryngoscopy
  - III and IV—classified as difficult laryngoscopy
- -Thyromental distance (cm): distance from the thyroid cartilage to the mental prominence, measured with the neck extended fully
  - > 6 cm—classified as easy laryngoscopy
  - ≤ 6 cm—classified as difficult laryngoscopy[9]
- -Ability to extend and flex the neck more than 90°

3) Ultrasound measurements:
- -Base of the tongue
- -Thickness of anterior neck soft tissue at five levels:
  - a. Hyoid bone
  - b. Thyrohyoid membrane
  - c. Vocal cords
  - d. Thyroid isthmus
  - e. Suprasternal notch

4) Laryngoscopy grade: (based on the method described by Cormack and Lehane)[10]:
- Grade 1—full view of the glottis
- Grade 2—partial view of the glottis or arytenoids
- Grade 3—only epiglottis seen
- Grade 4—neither glottis nor epiglottis visible

- Grade 1 or 2—categorized as easy laryngoscopy
- Grade 3 or 4—categorized as difficult laryngoscopy

Figure 1. Description of study variables.

a 95% confidence interval (CI) equal to the sample mean, plus or minus 1.24 standard deviations (±SDs), and a sample of 45 patients with easy laryngoscopy will produce a 95% CI equal to the sample mean (SD ± 0.3). Based on these calculations, the estimated sample size for this pilot study was 50. We intentionally enrolled more subjects scheduled for general anesthesia with endotracheal intubation than calculated, anticipating that some would undergo other methods of anesthesia on the day of surgery.

RESULTS

A total of 51 subjects (32 female, 19 male) were included in the analyses after excluding the subjects who underwent regional anesthesia or had surgical procedures done using laryngeal mask airway. The mean (±SD) age of the 51 eligible patients was 53.1 (±13.2) years. The mean time taken to obtain all US measurements was 9.6 (95% CI = 9.06 to 10.2) minutes. Six of the 51 patients (12%, 95% CI = 3% to 20%) were classified as having difficult laryngoscopy. The distribution of laryngoscopy grades for all subjects was 63, 25, 4, and 8% for grades 1, 2, 3, and 4, respectively. Eighty-three percent of subjects with difficult airways were males. No other significant differences were noted in the demographic variables and difficult airway clinical screening tests between the two groups.

The sonographic measurements of anterior neck soft tissue were greater in the difficult laryngoscopy group, compared to the easy laryngoscopy group at the level of the hyoid bone (1.69 [95% CI = 1.19 to 2.19] cm vs. 1.37 [95% CI = 1.27 to 1.46] cm) and the thyrohyoid membrane (3.47 [95% CI = 2.88 to 4.07] cm vs. 2.37 [95% CI = 2.29 to 2.44] cm). A 2.8 cm US measurement at thyrohyoid membrane level completely separated the patients with difficult and easy laryngoscopies. No statistically significant differences were found in the US measurements of the anterior neck soft tissue at other levels or the base of the tongue between the two groups. No significant correlation was found between modified Mallampati score, interincisor gap, and sonographic measurements of the thickness of the tongue. No significant correlation was noted between thyromental distance and sonographic measurements. However, in a post hoc analysis, there was a significant correlation between body mass index (BMI) and US measurements of the anterior neck soft tissue.

DISCUSSION

Our study showed that laryngoscopy was difficult in patients with increased sonographic thickness of the anterior neck soft tissue at the level of the hyoid bone and thyrohyoid membrane. To our knowledge, this is the first study to measure anterior neck soft tissue by US at these levels to determine its relationship to difficult laryngoscopy. Additionally, our study results suggest that anterior neck soft tissue thickness cutoff value of 2.8 cm at the thyrohyoid membrane level can potentially be used to detect difficult laryngoscopy. This cutoff value was derived upon examination of the data;

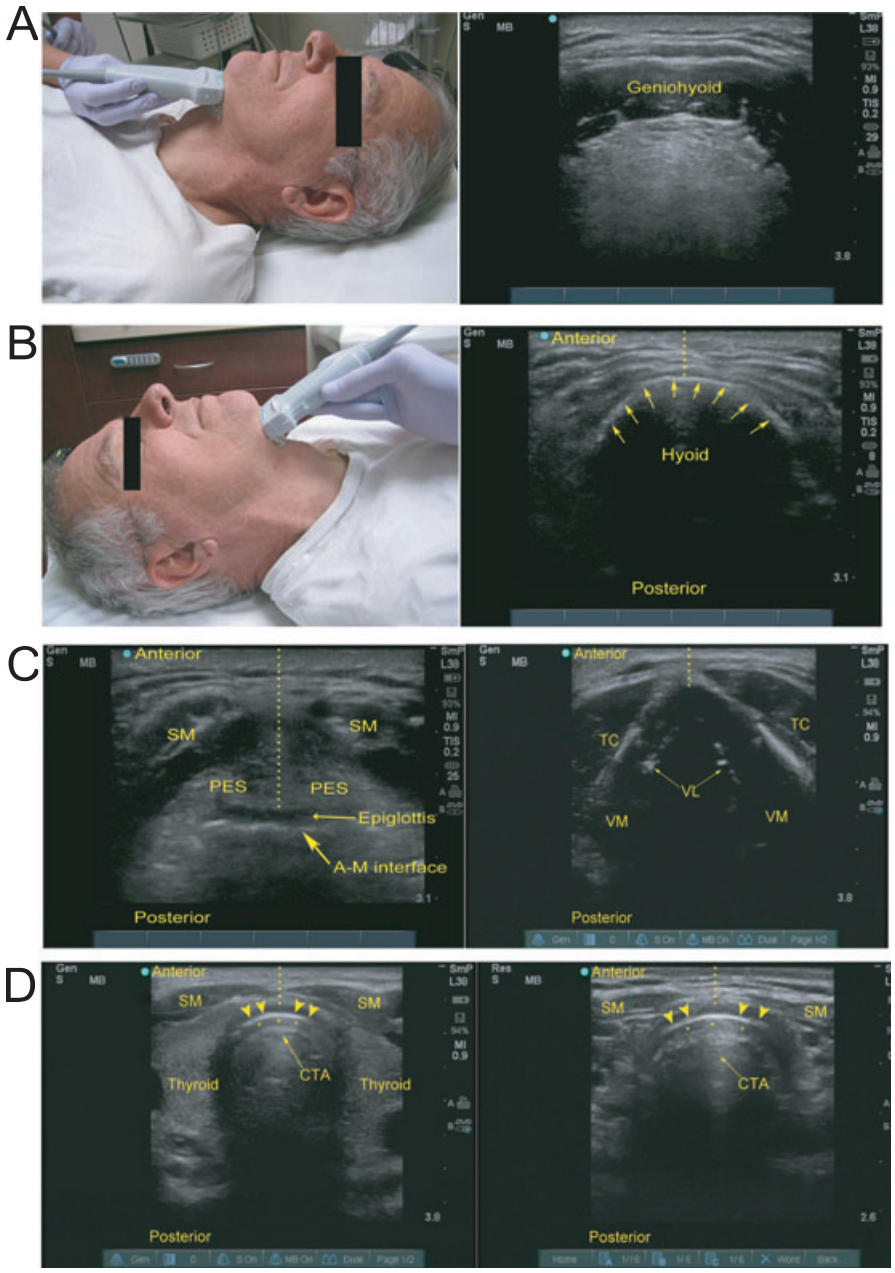

Figure 2. (**A**) Patient positioning and transducer placement for measuring thickness of tongue (*left*) and US image of the tongue (*right*). (**B**) Patient positioning and transducer placement for measuring anterior neck soft tissue thickness (*left*), US image at the level of the hyoid bone, and measurement obtained from skin to hyoid bone (*right*). (**C**) US image at the level of thyrohyoid membrane, measurement obtained from skin to epiglottis midway between the hyoid bone and thyroid cartilage (*left*), and US image at the level of vocal cords (*right*). (**D**) US image at the level of the thyroid isthmus (*left*) and suprasternal notch (*right*); posterior A–M interface (*arrowheads*) and reverberation artifacts (*asterisks*). SM = strap muscles; PES = preepiglottic space; A–M interface = air–mucosa interface; TC = thyroid cartilage; VL = vocal ligaments; VM = vocalis muscle; CTA = comet tail artifacts; US = ultrasound.

however, we are unable to validate this cutoff value since this is a pilot study with only six subjects in the difficult laryngoscopy group.

Ezri et al.[4] found that an abundance of soft tissue anterior to the vocal cords, measured by US, was a good independent predictor of difficult laryngoscopy. In contrast, we did not detect any significant difference between the easy and difficult laryngoscopy groups in the thickness of the anterior neck soft tissue at the level of the vocal cords and suprasternal notch. The reasons for different results between our study and that of Ezri et al. may relate to the US technique, ethnicity, and BMI of subjects. Our study subjects were whites and African Americans; in contrast, Ezri et al. studied Middle Eastern patients. Prior studies have documented differences in neck fat tissue distribution between different ethnic groups.[5] Our subjects mean BMI was 10–20 kg/m^2 lower than the patient populations in these studies.

Based on our study results, we recommend obtaining a central measurement at only two levels (hyoid bone and thyrohyoid membrane), since sonographic

measurements at the other locations have not shown to be predictive of difficult airway. Our data analyses indicate that central measurements at these levels can be obtained in less than 2 minutes, supporting the potential utility of these measurements in the critical or emergency care setting. We also did not encounter any technical difficulties visualizing all relevant anatomic structures regardless of age, sex, race, and BMI. All US measurements were obtained in the neutral position with no cervical extension; however; access to the anterior neck was required. This technique could still be useful in patients with cervical spine stabilization by removing the anterior portion of the collar and holding in-line stabilization. In contrast to prior studies, US measurements in this study were obtained by an emergency physician, indicating that this technique can be performed by clinicians at the bedside. Our study suggests that upper airway US can provide anatomic information that would not be evident on clinical screening indices used in the assessment of a difficult laryngoscopy. US assessment can be used as an adjunct to clinical screening tests and could add incremental diagnostic value when combined with clinical screening tests.

LIMITATIONS

This was a pilot study, so the small sample size may limit the conclusions that can be reached. The easy and difficult laryngoscopy groups were uneven, with only six patients in the difficult laryngoscopy group. The investigators were not blinded to the study hypothesis, which could have introduced some bias with measurements. Even though our study subjects were preoperative patients, based on age, demographics, and BMI distribution of our study population, we anticipate similar results when tested in an emergency care setting. We could not control variables such as experience of anesthesia providers, laryngoscopy equipment used, number of intubation attempts, external laryngeal maneuvers during intubation, and the view of glottis used for Cormack-Lehane grading (the first view or the best view or the view immediately before passing of the endotracheal tube). These factors need to be addressed or standardized in future studies. Our study findings do not apply to patients with distorted airway anatomy from trauma or airway obstruction from secretions, vomitus, blood, or foreign bodies. The PI may have more airway US experience compared to an average emergency physician sonologist. However, with 6 hours of additional training and increasing experience, emergency physician sonologists would be able to obtain the US measurements.

CONCLUSIONS

Our pilot study demonstrated that sonographic measurements of the anterior neck soft tissue thickness at the level of the hyoid bone and thyrohyoid membrane can be used to distinguish difficult and easy laryngoscopies. Clinical screening tests did not correlate with ultrasound measurements. Ultrasound was able to detect difficult laryngoscopy, indicating the limitations of the conventional screening tests for predicting difficult laryngoscopy. A prospective study in an emergency care setting with a larger sample of difficult laryngoscopy patients and more ethnic diversity is needed to clearly define the role and feasibility of bedside ultrasound in the prediction of difficult airways.

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