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Guidelines for Non-Anesthesia Providers Performing Point of Care Ultrasound (POCUS) for Airway Assessment in the Emergency Room

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Abstract

Effective airway management is critical for nurse anesthetists, encompassing tasks such as anesthesia administration, airway establishment, and patient safety, particularly in challenging cases where airway difficulties may arise. The subjectivity in airway assessments poses challenges for clinicians when accurately predicting difficult cases. Point-of-care ultrasound (POCUS) has emerged as a valuable tool for quantifying airway parameters, providing objective data to guide decision-making. This project aims to establish evidence-based guidelines for managing the airway in unconscious trauma patients requiring intubation using POCUS. By quantifying parameters such as PEP/E-VC ratios, hyomental distance, thyrohyoid membrane thickness, and anterior neck thickness, healthcare providers can make more informed decisions and potentially reduce malpractice settlements associated with anesthesia-related complications. The project follows the John Hopkins Evidence-Based Practice (JHEBP) Model, a systematic approach for incorporating research findings into patient care. Data collection will involve retrospective chart analysis to assess compliance in documenting airway parameters and using POCUS in difficult cases. The project will monitor CL grade III or IV classifications in patient records to identify trends and evaluate the application of POCUS in managing difficult airways. The timeline spans seven months, including planning, education, training, and data analysis. The ER staff will use a portable handheld ultrasound device, Vscan Air, to efficiently perform scans on all ER patients. This project seeks to enhance airway management in unconscious trauma patients, improve clinical outcomes, and reduce the risk of adverse events, ultimately benefiting anesthesia and emergency room providers and patients.

Key words: difficult airway, assessment, emergency, trauma, ultrasound, POCUS, adult

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Introduction

Clinical Problem

The preoperative setting typically involves an anesthesia provider, usually an anesthesiologist or a certified registered nurse anesthetist (CRNA), who conducts a comprehensive airway assessment using conventional techniques, formulating a plan of care to prevent patient injury. These methods typically rely on subjective information and involve evaluating the patient's Mallampati score, thyromental distance, and other physical characteristics (Sotoodehnia et al., 2021). However, airway management in a trauma patient is an urgent situation in the emergency room (ER), requiring quick, life-dependent decision-making skills. Practitioners with limited knowledge of a patient's medical comorbidities and evolving physiologic derangements often perform the airway assessment. These providers rely on traditional examinations and assessments to predict airway difficulty and provide specialized care using the equipment and tools. However, because the exam requires patient cooperation, it may not accurately reflect the challenges faced in a trauma setting with unresponsive patients.

Patients who need to be intubated, such as those who are obtunded, unconscious, or have impaired cognition and cannot follow to perform commands, still need to be screened for a difficult airway to ensure an appropriate airway management plan. However, assessing the airway in unresponsive patients presents an issue due to the inability to obtain direct patient feedback and therefore rely solely on physical examination. This limitation can lead to a suboptimal prediction of a difficult airway and increases the potential for complications during a traumatic airway case. The incidence of difficult airway and difficult intubation ranges from 5-

22%, resulting in poor patient outcomes such as hypoxic brain injury due to misplaced tracheal tubes (11.9%) and death (2%) (Carsetti et al., 2022; Özkurtul et al., 2019). Patients who cannot provide feedback or partake in the physical airway examination are at higher risk of worse outcomes unless there is a method or device to compensate for the limited amount of information the physician receives.

By utilizing point of care ultrasound (POCUS), ER physicians, physician assistants (PAs), nurse practitioners (NPs), and residents can quickly evaluate a patient's trachea and surrounding structures, accurately determining the level of airway difficulty. Performing several crucial airway assessments on a patient will help guide the decision-making in airway management. For example, knowing the intactness of anterior soft neck tissue, the distance from the hyoid to mandible bone (HMD), or the peri-epiglottic space to epiglottis to vocal cord ratio (PEP/E. VC), the provider will be able to reduce complications and risks (Koundal et al., 2019; Fulkerson et al., 2017). For example, according to Sotoodehnia et al., a PEP/E-VC value of 0.88 or less correlates to a LEMON score, (look externally, evaluate 3-3-2- rule, Mallampati, obesity/obstruction, neck circumference), of 2-3, corresponding to a difficult airway (2023). ER physicians, PAs, NPs, and residents, can better prevent delays in obtaining an airway by quickly identifying a misplaced endotracheal tube (ETT) or promptly opting to perform a tracheostomy. While anesthesia care providers typically determine these needs with the help of an awake and cooperative patient, POCUS can provide the necessary information to ER providers in cases where the patient is unresponsive.

The identification of the issue arises from several factors. First, research and literature reviews highlight the concerns associated with traditional airway examination techniques, including the inability to accurately predict difficult airways and complications. Second, POCUS has emerged as a promising technology in various medical specialties, providing real-time imaging capabilities at the bedside. Recent studies have shown that implementing POCUS improves airway assessment accuracy by identifying misplaced ETTs, locating the cricoid membrane, and measuring the thyromental distance (Gottlieb et al., 2020; Mishra et al., 2018). In light of these factors, undertaking this project is important, as it enables healthcare providers to adapt to evolving technology and ultimately enhance patient safety and clinical outcomes.

Developing a project to address the issue is significant as technology is rapidly changing, and healthcare providers must be able to adapt to keep patients as safe as possible. By investigating the effectiveness of implementing POCUS for rapidly assessing the airway of an unresponsive adult, one can enhance clinical outcomes and minimize patient injury. Since POCUS is easy to apply and positively impacts airway management in trauma patients, this project aims to implement guidelines for POCUS in a level two rural trauma center.

The gaps observed in our practice include the limitations of physical examination alone in accurately predicting a difficult airway, which may contribute to complications in unresponsive patients. Additionally, the lack of evidence-based practice guidelines for incorporating POCUS into emergency airway management further emphasizes the need for a comprehensive study. Addressing these gaps can enhance clinical decision-making, reduce adverse events, and improve patient outcomes in a critical and time-sensitive setting.

By exploring the benefits of POCUS as an adjunctive tool for assessment, we can address the limitations of traditional airway examination techniques and enhance airway assessments while reducing complications. This project aims to develop and implement guidelines for POCUS in a small rural ER by using evidence-based practices and ultimately improve the safety of trauma patients during airway management.

Background

Because the patient loses the ability to breathe under anesthesia, a laryngoscope, a small stiff device used to help identify the vocal cords of the larynx, is used as an aid for endotracheal intubation. An endotracheal tube (ETT) is placed in between the vocal cords within the trachea to allow for ventilation or gas exchange. Intubating a patient is preferred in prolonged cases, with high aspiration risk, those requiring paralysis throughout the procedure, or in patients suffering from a critical illness such as sepsis or acute respiratory distress syndrome (ARDS). Although there are many benefits to using an invasive airway, unfortunate events, such as a misplaced tube, prolonged airway attainment, and difficult laryngoscopy can occur.

Prior to the ultrasound, an airway assessment consisted of using multiple forms of evaluation. The anesthetist must look for and anticipate a difficult intubation, mask, or airway management, in every case in order to be prepared for anything unexpected. They consider difficult intubation criteria such as: <3cm for the length of the patient’s incisors, <6cm or 3 fingerbreadth distance of the thyromental distance, class 3 or 4 Mallampati (visualization only the base of the uvula or only the hard palate), Cormack-Lehane (CL) grade 3 or 4 (epiglottis or soft palate only visible), <23 degrees signifies limited atlantooccipital joint mobility, and class C of mandibular protrusion test (lower incisors cannot be brought to the edge of the upper incisors) (Nagelhout & Elisha, 2018). A comprehensive airway assessment is crucial for an anesthetist to anticipate and address potential challenges during intubation or airway management.

Additionally, healthcare providers must consider aspiration risk factors, certain disease process that can affect joint manipulation like ankylosing spondylitis or Downs syndrome, or disease that affect lung compliance like chronic bronchitis, emphysema, or acute respiratory distress syndrome (Nagelhout & Elisha, 2018). They must also consider their baseline vitals, pulse oximetry, assess their pulmonary functions, and assess for sleep apnea. This process and these questions are still used today, but poor outcomes associated with airway injuries still occur, costing the patient their livelihood and costing the hospital millions of dollars.

Ultrasound (US) is a noninvasive imaging test that allows for visualization of structures inside the body using high-intensity sound waves. Marty Wilcox designed the first portable ultrasound, which was commercially available in 1975, weighing 25 pounds (*Portable Ultrasound*, n.d.) Ultrasound. Through technologic advancements and easy accessibility and movability, POCUS was created (You-Ten et al., 2018). Instead of bringing the patient to the ultrasound machine, the device can now scan a patient wherever they are being treated, whether it is in an urgent care, an ambulance, or a remote city. The portability is especially beneficial to the weak, non-ambulatory, or critical patient as they are not inconvenienced by the need to physically move to the radiology department to be scanned, therefore also decreasing the workload on those departments. Appropriately trained healthcare providers can utilize the ultrasound to differentiate tracheal, esophageal, and endobronchial intubation and can accurately locate the cricothyroid membrane and tracheal rings for emergency airway access. While US can identify various pathology like vocal cord dysfunction prior to anesthesia induction, limitations include lack of screening protocols and limited training. However, literature shows evidence of ultrasonography that is used in conjunction with physical management of the airway may benefit patient care (Koundal et al., 2019; Fulkerson et al., 2017). POCUS utilizes a safe, quick, and inexpensive diagnostic tool to visualize internal anatomical structures that are to palpate.

Significance to the Profession

Airway management is a vital skill for nurse anesthetists, who constantly assess ventilation, oxygenation, and perfusion regardless of the patient's case. The anesthesia provider's role involves administering anesthesia during surgical procedures, establishing an artificial airway, and prioritizing patient safety, especially in trauma patients who require intubation but cannot actively participate in the anesthetic plan. A critical challenge anesthesia providers face daily is determining whether an airway will pose difficulties or be straightforward. An anesthesia provider deems an airway straightforward when they plan to proceed without anticipated complications. Conversely, according to the American Society of Anesthesiologists (ASA), an airway is difficult when an anesthesia professional encounters problems with facemask ventilation, tracheal intubation, or both (Apfelbaum, 2022). The ability to effectively manage an airway is a crucial aspect of a nurse anesthetist's role involving the administration of anesthesia, establishing airways, and prioritizing patient safety, particularly in challenging cases where airway difficulties may arise.

Traditionally in the preoperative assessment, the patient will undergo a series of assessments to help the anesthesia provider gauge how difficult obtaining an airway will be. These evaluations include the Mallampati exam, atlantooccipital joint mobility, and thyromental distance. Additionally, a thorough review of the patient's chart, including allergies, medical and surgical history, prior anesthesia experiences, current condition, and plan of airway maintenance, is necessary to minimize the risk of patient injury.

Subjectivity in airway assessments poses challenges for clinicians when accurately predicting difficult cases. POCUS provides a solution by measuring tracheal size, hyoid distance, and neck thickness, providing objective information to guide decision-making. This quantifiable data assists ER clinicians in making more educated decisions and formulating precise anesthetic plans, especially when dealing with unconscious patients. While less than three percent of anesthesia-related deaths contribute to difficult intubation, failed intubation, and misplaced tracheal tubes, a single anesthesia malpractice lawsuit can have significant financial implications for a facility. A study analyzing anesthesia malpractice cases between 1959 and 2018 concluded that the average settlement was $1,140,544 (Kang et al., 2020). If complications occurred post-procedure, the average settlement was approximately $3 million higher. (Kang et al., 2020). The implementation of POCUS in airway assessments not only enhances the accuracy of predicting difficult cases but also aids in reducing the risk of costly anesthesia malpractice lawsuits.

The following study sheds light on the implications of airway management-related injuries over a 15-year period, revealing substantial findings regarding compensation and the severity of outcomes among claimants. A Norwegian group analyzing 400 claims related to airway management found that 20% of the claims resulted in compensation (Fornebo et al., 2017). Patients with difficult airways were 20 times more likely to experience dental trauma due to limited mouth opening and neck mobility, poor visibility in the oral cavity, and narrow thyromental distance. Dental claims, one of the most commonly reported injuries, comprised only 1.3% of the total amount paid (Fornebo et al., 2017). However, among the claimants, sixteen patients who died due to failed intubation or a misplaced ETT received significant compensation. Although this group constituted only 4% of the claimants, they accounted for 60% of the total sum paid for injuries associated with airway management. (Fornebo et al., 2017). The Norwegian study emphasizes the substantial impact of airway management-related injuries, particularly highlighting the significant compensation awarded to a small percentage of claimants who experienced fatal outcomes.

Trauma patients may exhibit normal anatomical body habitus yet experience internal tracheal and tissue damage. When dealing with patients who cannot actively participate in their anesthetic care plan due to impaired consciousness, using an advanced airway by healthcare providers may pose obstacles. These obstacles encompass the requirement for infrequently-utilized techniques, access to specialized devices, and a team with unique expertise. Consequently, these factors can hinder the formulation of an optimal anesthetic plan for intubation.

These evaluations heavily rely on the patient's cooperation, and severe complications like failed intubations or misplaced ETTs can occur without the ability to conduct a thorough airway exam. Anesthesia malpractice cases often report injuries such as asphyxia, spinal cord injuries, brain damage, or tracheal damage. The ASA Closed Claims Study revealed that adverse respiratory events are the most common type of injury (34%), with difficult intubation and ventilation contributing to most cases (Harjai et al., 2021). Inadequate ventilation (38%), esophageal intubation (18%), and difficult tracheal intubation (17%) account for almost 75% of these adverse respiratory events alone (Harjai et al., 2021). High risks and potential complications in anesthesia procedures highlight the critical importance of patient cooperation and thorough airway examinations to prevent severe adverse respiratory events and anesthesia malpractice cases.

Implementing POCUS in traumatic airway assessment is justified due to the favorable balance between its advantages and the potential reduction in malpractice settlements, despite the investments required for staff training, equipment, and resources. POCUS provides valuable information that was previously unknown or presumed, allowing healthcare professionals to make more informed decisions regarding the safest and most effective approach to intubation and other airway management techniques.

Integrating guidelines for POCUS in airway management can have significant implications for nurse anesthetists in improving clinical outcomes. By reducing the risk of failed intubation, difficult tracheal intubation, and difficult laryngoscopy, POCUS enables ED healthcare professionals to make more informed decisions, improve patient safety, and potentially reduce malpractice settlements associated with anesthesia-related complications. These outcomes not only affect the nurse anesthetists' but also the nurses who encounter the patient after leaving the operating room.

PICO

Developing a focused question allows for an easier and more efficient method to research and identify appropriate resources for relevant evidence. The PICO format provides a method for posing clinical questions and facilitating literature searches. The acronym stands for [P] patient problem or population, [I] interventions being considered, [C] comparison or control, and [O] outcome desired or unanticipated (Melnyk & Fineout-Overholt, 2019). This project utilizes the PICO framework to assist in deliberate search terminology and provide the best level of evidence. Based on current policy and practice with anesthesia and non-anesthesia healthcare providers at a small rural level two trauma center, the PICO question is as follows: [P] In unconscious trauma patients requiring endotracheal intubation in the ER, would the [I] development and implementation of guidelines for POCUS compared to [C] traditional airway examination affect the [O] incidence of first-time success rate, esophageal intubation, and difficult tracheal intubation?

Clinical Immersion Site

The clinical immersion site occurs in an rural community containing a level two trauma center ER that has not currently adopted ultrasound for preoperative airway assessment.

Project Objectives

The primary objective of this project is to synthesize existing evidence and outcomes regarding the utilization of POCUS during emergency airway management compared to traditional assessment methods. The following three objectives were framed using the Johns Hopkins Model for evidence-based practice (EBP) and designed to guide the direction of the project (Dang et al., 2022):

1. Synthesize guidelines using the evidence and outcomes around the use of POCUS during emergency airway management compared to the traditional assessment
2. Develop EBP recommendation for implementing POCUS in the emergency airway assessment of the unconscious patient
3. Develop a comprehensive plan to enact and monitor recommendations for optimal effectiveness

Overall, the project aims to advance the understanding of POCUS in emergency airway management by critically analyzing and consolidating evidence, providing evidence-based recommendations, and constructing a comprehensive implementation and monitoring plan. Achieving these objectives will enhance the quality and safety of emergency airway assessment, ultimately leading to improved patient outcomes and optimized clinical practices.

Literature Search

Conducting a thorough literature search is a fundamental step in any research process. In this literature search, the academic scholarly databases, Academic Search Complete and PubMed, were utilized to meticulously identify relevant literature pertaining to the central theme of airway management and POCUS utilization. The intricate process involved reiterative adjustments of search terms, filters, and publication dates to yield a refined collection of scholarly articles. For the Academic Search Complete database, the advanced search bar was utilized, with the Boolean/phrase "airway" and "point-of-care-ultrasound" or "POCUS" entered. This initial search yielded 51 results, which were then reduced to 46 by applying a publication date filter of 2017 and beyond.

Within the narrowed EBSCO database, the root term "airway*" was entered to encompass outcomes related to airway management or assessment. Additionally, "POCUS" or "point-of-care ultrasound" and “emergency” was included, resulting in 209 outcomes. To further refine the selection, "preop*" was added to encompass terms like "preoperative" or "preoperatively," yielding 59 outcomes. These results were automatically sorted by best match based on the search criteria. The outcomes were then limited to 46 by selecting categories such as meta-analysis, randomized controlled trial, and systematic review. Finally, after resetting the publication year to 2011 and then reverting to a minimum year of 2017, the outcomes were narrowed down to 11.

In the case of PubMed, an advanced search was immediately chosen. Keywords like "Pocus" or "point of care ultrasound" or "point-of-care ultrasound" were entered, resulting in 424 outcomes. Upon adding "airway" to the search, the outcomes were reduced to 220. By utilizing filters to specify article types, "meta-analysis," "randomized controlled trial," and "systematic review" were selected, leading to 15 outcomes. Adjusting the publication date to five years further reduced the outcomes to nine.

The use of targeted phrases and filters effectively streamlined the literature search to align with the requirements of the PICOT question. It is worth noting that each database had its unique setup: PubMed's filter proved user-friendly and rapidly narrowed down the outcomes, while EBSCO offered an array of options, requiring careful scrolling within each category to confine the results to randomized controlled trials or meta-analyses. Interestingly, if one were to input "systematic review" or "meta-analysis" directly into EBSCO's advanced search bar, no outcomes would be generated, whereas five such outcomes would emerge in PubMed.

Literature Synthesis

Ultrasound Parameters for Difficult Laryngoscopy

Several studies focus on using ultrasound measurements to predict difficult airway management. Specifically, the Pre-E/E-VC ratio emerged as a significant factor in predicting difficult intubation in Sotoodehnia et al. (2023), Koundal et al. (2019), and Carsetti et al. (2022). Anterior neck soft tissue thickness at the level of the hyoid bone also emerged as a potential predictor for difficult intubation, with varying measurements reported by Sotoodehnia et al. (2021), Srinivasarangan et al. (2021), and Fulkerson et al. (2017). In contrast, Fulkerson et al. (2017) cautioned against relying solely on thyromental distance for predicting difficult intubation and proposed using the distance from the skin to the thyrohyoid membrane, an idea that Gottlieb et al. (2020) reinforced. These studies provide valuable insights into the potential of ultrasound indicators for anticipating challenges during airway management procedures. Refer to Appendix J for an evidence review table.

In comparing the data between Sotoodehnia et al. (2023) and Carsetti et al. (2022), there is a common theme of assessing the Pre-E/E-VC ratio as an ultrasound indicator for predicting difficult airway management. Sotoodehnia et al. (2023) found that the Pre-E/E-VC ratio showed a significantly higher mean value in the difficult intubation group than in the easy intubation group. The study demonstrated a pooled mean difference of 0.73 cm higher in the difficult group (Sotoodehnia et al., 2023). Researchers proposed that the optimal cutoff point for this ratio was 1.77, with reported sensitivities of 82.0% and specificities of 80.0% (Sotoodehnia et al., 2023).

Similarly, Koundal et al. (2019) found the cutoff value for Pre-E/E-VC ≥1.785, with a sensitivity and specificity being 82.8% and 83.8%, demonstrating a reliable predictor of difficult laryngoscopy.

Carsetti et al. (2022) also assessed the Pre-E/E-VC ratio as an extensively reported index test. They found that a higher value of DSE (distance from skin to epiglottis), DSHB (distance from skin to hyoid bone), DSVC (distance from skin to vocal cords), and Pre-E/E-VC were associated with difficult laryngoscopy (Carsetti et al., 2022). However, due to the few studies included, the 95% prediction regions for each index test were broad, and researchers could not draw a definitive conclusion about the superiority of one index test over others (Carsetti et al., 2022). Both studies highlight the Pre-E/E-VC ratio as a potential indicator for predicting difficult airway management. Sotoodehnia et al. (2023) provide specific results for this ratio, including the mean difference and cutoff values, while Carsetti et al. (2022) include the Pre-E/E-VC ratio as one of the extensively reported index tests without providing specific values.

In comparing the data between Sotoodehnia et al. (2021), Srinivasarangan et al. (2021), and Fulkerson et al. (2017), there are similarities in the assessment of anterior neck soft tissue thickness at the level of the hyoid bone as a potential indicator for difficult intubation. However, there are also some differences in the specific measurements and findings.

Sotoodehnia et al. (2021) assessed the anterior neck soft tissue thickness at the hyoid bone level in relation to difficult intubation. Researchers found that the mean thickness of the anterior neck soft tissue at the hyoid bone was significantly higher in the difficult intubation group than in the easy intubation group (Sotoodehnia et al., 2021). The pooled mean difference based on the research was 0.20 cm higher in the difficult group, and the area under the curve (AUC) for this index ranged from 0.559 to 0.92 in different studies (Sotoodehnia et al., 2021).

Optimal cutoff points varied between studies, with values of 0.66 and 0.99 reported (Sotoodehnia et al., 2021).

Similarly, using ultrasound, Srinivasarangan et al. (2021) measured the anterior neck soft tissue thickness at the hyoid bone level. They found that the anterior neck soft tissue thickness at the hyoid bone was significantly greater in the difficult intubation group than in the easy intubation group (Srinivasarangan et al., 2021). They reported an optimal cutoff point of 0.58 cm at the hyoid bone level, with a sensitivity of 87% and specificity of 87.5%. The AUC was 0.92 for this measurement (Srinivasarangan et al., 2021).

Fulkerson et al. (2017) also examined the anterior tissue thickness at the hyoid bone. They found that the measurements of anterior tissue thickness at the hyoid bone were more significant in the difficult laryngoscopy group (16.9 mm (95% CI 11.9–21.9)) compared to the easy laryngoscopy group (15.9 ± 2.7 mm) (Fulkerson et al., 2017). The difference in anterior tissue thickness between the difficult and easy groups was statistically significant ($p < 0.0001$) (Fulkerson et al., 2017).

In the study by Srinivasarangan et al. (2021), the thickness of soft tissue anterior to the neck at the thyrohyoid membrane level varied from 1.19 to 2.0 cm. They found that the anterior neck soft tissue at the level of the thyrohyoid membrane was significantly greater in difficult intubation cases compared to easy intubation cases (Srinivasarangan et al., 2021). The mean thickness in difficult patients was 1.83 cm (95% CI: 1.7–1.89), while in easy patients, it was 1.46 cm (95% CI: 1.41–1.51) (Srinivasarangan et al., 2021). The AUC for the thyrohyoid membrane level was 0.99, indicating accurate predictability of a difficult airway (Srinivasarangan et al., 2021). They determined an optimal cutoff value of 1.59 cm for thyrohyoid membrane thickness, which yielded a sensitivity of 100% and specificity of 91.9% (Srinivasarangan et al., 2021).

The study performed by Fulkerson et al. (2017) found that thyromental distance alone, measured by ruler or fingerbreadth, had limited sensitivity for predicting difficult intubation. A thyromental distance of less than 6.5 cm measured by ruler had a sensitivity of 48%, while the method of less than three fingerbreadths had a sensitivity of 16% (Fulkerson et al., 2017). They concluded that thyromental distance alone is unreliable for detecting a difficult airway.

Gottlieb et al. (2020) also highlighted the predictive value of the thyrohyoid membrane distance. They found that the distance from the skin to the thyrohyoid membrane was a significant predictor of difficult intubations. They recommended a threshold greater than 2.8 cm for this distance to identify difficult intubations (Gottlieb et al., 2020).

Overall, the studies show that the thickness of soft tissue at the thyrohyoid membrane level can indicate a difficult airway. Srinivasarangan et al. (2021) provided specific anterior neck soft tissue thickness measurements at the thyrohyoid membrane level in difficult and easy intubation cases. Fulkerson et al. (2017) cautioned against relying solely on thyromental distance for predicting difficult intubation. Gottlieb et al. (2020) emphasized the usefulness of the distance from the skin to the thyrohyoid membrane as a predictor of difficult intubations.

POCUS in Endotracheal Tube Confirmation

Data from three articles demonstrate that ultrasonography (US) is an effective tool for confirming ETT placement and predicting difficult airways. The studies included different patient populations and settings, but they collectively demonstrate the utility and accuracy of the US.

You-Ten et al. (2017) assess the diagnostic accuracy of tracheal ultrasound in examining ETT placement during emergency intubations. The study indirectly excluded esophageal intubations by focusing on tracheal ultrasound. The pooled sensitivity of tracheal ultrasound for detecting esophageal intubation was 0.93, indicating that it correctly identified esophageal intubations 93% of the time. The pooled specificity was 0.97, suggesting that POCUS accurately ruled out esophageal intubations 97% of the time. Additionally, You-Ten et al. (2017) referenced another study involving 969 intubations performed in both emergency and elective situations. The study analyzed the sensitivity and specificity of transtracheal ultrasound in confirming proper ETT in the trachea. The pooled sensitivity of transtracheal ultrasound for identifying tracheal intubation was 0.98, and the pooled specificity was also 0.98.

Mishra et al. (2018) evaluated the utility of POCUS, specifically in rapid sequence intubation (RSI) for trauma patients in the emergency department (ED). The study included 100 trauma patients requiring emergent airway management. The study used POCUS to confirm ETT placement and compared its efficacy with conventional methods like auscultation and capnography (Mishra et al., 2018). POCUS detected esophageal intubations and confirmed proper tube position in less time (18.25 seconds) than standard techniques (177.5 seconds) (Mishra et al., 2018). The mean time taken for ETT placement was significantly less in the POCUS group compared to the conventional examination group (45 seconds vs. 91.36 seconds) (Mishra et al., 2018). Other recent studies mentioned in the research indicated that using POCUS to confirm ETT placement took anywhere from 5 to 45 seconds (Mishra et al., 2018). The results demonstrated that POCUS is a beneficial adjunct for emergency physicians to improve the quality of care in trauma patients.

Lastly, Sahu et al. (2020) assessed the diagnostic accuracy of ultrasonography in confirming ETT placement compared to standard confirmatory methods. Ultrasonography demonstrated an overall sensitivity of 0.982 and a specificity of 0.957 for detecting the correct

ETT position (Sahu et al., 2020). The results showed that POCUS is a valuable and reliable adjunct for ETT confirmation.

These three studies highlight the importance of accurate ETT placement in emergency settings and the potential benefits of using POCUS as an adjunct to traditional confirmation methods. They demonstrate that POCUS can rapidly detect tube malposition, improving patient outcomes and reducing complications. However, some limitations of POCUS include operator dependence and certain anatomical constraints when integrating it into clinical practice. Further research is warranted to better understand its optimal use and implementation in various clinical scenarios.

Identification of Cricothyrotomy

Both Siddiqui et al. (2018) and Gottlieb et al. (2020) investigated ultrasound's benefits for first-time success in cricothyrotomy. Siddiqui et al. (2018) conducted a randomized clinical trial comparing the accuracy of ultrasonography versus external palpation in localizing the cricothyroid membrane in subjects with abnormal neck anatomy. They found that ultrasound was significantly more accurate than external palpation in localizing the cricothyroid membrane, with a success rate of 81% in the ultrasound group compared to only 8% in the external-palpation group (Siddiqui et al., 2018). The risk ratio of inaccurate localization was 9.14-fold greater with external palpation than with ultrasound (Siddiqui et al., 2018). These results highlight the potential benefits of ultrasound in accurately identifying the cricothyroid membrane in patients with poorly defined neck landmarks.

Similarly, Gottlieb et al. (2020) reviewed the current literature on POCUS for airway assessment, including cricothyrotomy. Ultrasound accurately confirmed ETT placement in both adult and pediatric patients. Regarding cricothyrotomy, they reported that landmark guidance alone is inadequate and that ultrasound has been superior for identifying the cricothyroid membrane (Gottlieb et al., 2020). Studies illustrate a five-fold improvement in correct tube placement when using ultrasound guidance in patients with difficult-to-palpate anatomy (Gottlieb et al., 2020). Emergency medicine physicians could reliably identify the cricothyroid membrane with ultrasound in 24 seconds (Gottlieb et al., 2020). Gottlieb et al. (2020) also suggested that marking the cricothyroid membrane prior to intubation in patients with anticipated difficult airways can facilitate a prompt surgical cricothyroidotomy if endotracheal intubation fails.

Both studies concluded that ultrasound provides superior accuracy in localizing the cricothyroid membrane compared to traditional external palpation techniques, especially in patients with neck pathology or poorly defined neck landmarks. Using ultrasound in such cases may improve first-time success rates in cricothyrotomy and minimize complications associated with the misplacement of the tube.

Evidence-Based Practice Framework

Model Used for Project Framework

The John Hopkins Evidence-Based Practice (JHEBP) Model is a method that begins with a three-step process of making clinical decisions and problem-solving to ensure the successful implementation of the latest research findings and best practices are quickly and appropriately incorporated into patient care (Dang et al., 2022). Permission to use this model was obtained electronically on June 30, 2023, from the Johns Hopkins University School of Nursing. Appendix A includes proof of permission for use. This approach reevaluates the initial PICO question and utilizes the PET process guide (practice question, evidence, translation) to transition evidence-based practice from various literary works to the clinical setting that nurses and clinicians can use (Dang et al., 2022). The JHEBP Model will guide healthcare professionals through their inquiry, research, and development, ultimately translating the supported evidence into practice and patient care (Dang et al., 2022). The model was selected as the framework of the project as it guides the process of formulating a practice question, gathering evidence, and effectively applying that evidence to clinical practice. By incorporating evidence-based practice into healthcare settings, professionals can investigate pertinent clinical issues, conduct comprehensive database searches to access current evidence and evaluate its suitability within the clinical setting. Appendix B includes Figure 1 which illustrates each step of the JHEBP Model through a cyclic process.

PET

The JHEBP model begins with an inquiry since the foundation of nursing is derived from systematically questioning, analyzing, and collecting data and information on an issue or clinical concern (Dang et al., 2022). An inquiry aims to understand the extent of the problem and identify opportunities for improvement or solutions to the issue. In evidence-based practice, inquiry involves understanding existing practices, identifying areas of concern, and collecting evidence to address these concerns.

Practice Question

While trained and experienced ER physicians, physician assistants, nurse practitioners, and residents are involved in intubating traumatic patients, misplaced ETT still occur, and clinicians do not know how to consistently and accurately assess a difficult airway in an unresponsive trauma patient. Consequently, patients may suffer from anoxic brain injury due to hypoxia, airway trauma, esophageal intubations, or other airway complications. The JHEBP Model correlates to the PICO question: In unconscious trauma patients requiring endotracheal intubation in the ER, would the development and implementation of guidelines for POCUS compared to traditional airway examination affect the incidence of first-time success rate, failed intubation, correct ETT, size, and difficult tracheal intubation? The main goal was to develop an evidence-based guideline for managing the airway in unconscious trauma patients outside the operating room. The collaborative process involves key stakeholders such as ER nurses and physicians, PAs, NPs, presenting an opportunity to enhance patient care and minimize variations in practice through interprofessional relationships.

Evidence

The project team conducted a comprehensive literature review in the second phase of the JHEBP Model (Dang et al., 2022). The project team searched for various types of evidence, including research studies, EBP practice guidelines, quality improvement data, expert opinions, and patient survey data. The review primarily focused on examining the sensitivity, specificity, confidence interval, and area under the curve to analyze the findings. Within the ultrasound assessments, the team measured specific parameters such as the peri-epiglottis space to epiglottis to vocal cord ratio (PEP/E.VC), the hyomental distance (HMD), the thyrohyoid membrane, and anterior neck soft tissue thickness. Several studies of high-level evidence have consistently confirmed that these parameters effectively predict difficult intubation. The literature review findings and the evidence synthesis are discussed in depth in the “Literature Review” and “Synthesis of Evidence” sections of the project.

Translation

In the third step of the JHEBP Model, the project team evaluates the feasibility of implementing changes and develops a comprehensive action plan (Dang et al., 2022). The main objective was to establish guidelines for intubating trauma patients at a level-two trauma center, prioritizing the continuous monitoring of their effectiveness and making appropriate adjustments if the desired outcomes were unmet. The team condensed the evidence and guidelines and presented them in an engaging PowerPoint or poster to allow key stakeholders to review and provide feedback.

The subsequent step of the JHEBP Model entails disseminating the findings internally and externally through various networks such as publications, meetings, or newsletters (Dang et al., 2022). Sharing these findings aims to distribute the best practices and practice improvements identified, ultimately enhancing patient outcomes. Lastly, during the reflection phase, the level-two hospital holds the authority to implement changes and make additions, or deletions, to the trauma airway management practices outside of the operating room (Dang et al., 2022). The focus of these changes is specifically on integrating POCUS for use during emergent intubations.

Methodology & Project Design

The JHEBP Model played a crucial role in examining and evaluating current research for the project. Evidence-based guidelines and recommendations have demonstrated the effectiveness of incorporating ultrasound in pre-operative airway assessment for trauma patients. The available evidence supports the use of measuring the PEP/E-VC distances as a highly specific and accurate predictor of difficult intubation, with a sensitivity of 82% and specificity of 80% (Sotoodehnia et al., 2021). Additionally, factors such as HMD, thyrohyoid membrane, and anterior neck thickness, have emerged as significant predictors when assessing the difficulty of laryngoscopies using the Cormack-Lehane (CL) grading system. Given these findings, the project will utilize quantitative and qualitative data to establish airway assessment guidelines tailored to unresponsive trauma patients.

Qualitative Data

In the case of unresponsive trauma patients, assessing the Mallampati classification or mouth opening may not be possible. Therefore, the remaining components of the LEMON score and the CL grading will be documented in the electronic medical records (EMR) by the healthcare provider who performed the laryngoscopy. Although the LEMON score itself may not possess inherent qualitative characteristics, the subjectivity lies in the documentation within the EMR.

The LEMON assessment variables such as external observation for facial and neck features, evaluation of the 3-3-2 rule to assess mouth opening and mandibular mobility, Mallampati score to assess the visibility of oropharyngeal structures, assessment for clinical signs of airway obstruction, and evaluation of neck mobility. In a study by Sotoodehnia et al. (2023), participants were classified into a difficult airway group if they had a LEMON score of 2 or higher. The CL classification is a grading system that clinical practitioners use to describe their view of the vocal cords during laryngoscopy. The grading system encompasses four grades and includes two variations within Grade II. Grade I signifies a clear view of the glottis opening, Grade IIa indicates a partial view of the vocal cords, Grade IIb describes the visualization of the arytenoids and epiglottis only, Grade III involves the visualization of the epiglottis alone, and Grade IV is limited to the visualization of the soft palate. Difficult encountered during laryngoscopy are typically associated with Grades III and IV.

Quantitative Data

Informational technology (IT) will ensure that providers in the ER have the same airway documentation that anesthesia providers have in the OR. After performing the ultrasound and securing an airway for the unconscious trauma patient, the provider must chart their findings in the EMR. The number of attempts, the size and blade used, the depth inserted, ETT confirmation, and any specialty equipment will be documented. According to Sakles et al., (2013) adverse effects occurred in 14.2% of patients with successful first pass intubation versus 47.2% in failed first pass attempts (increases to 63.6% and 70.6% in third and fourth attempt), and therefore the number of attempts will be a trigger for the EMR to provide more airway analysis once those options are created by IT.

Upon successful obtainment of an artificial airway after multiple attempts, or upon documenting a CL grade III or IV in the patient’s chart, IT will create a drop-down option that populates in the EMR that will collect additional quantitative data: PEP/E-VC distances, HMD, thyrohyoid membrane anterior tissue, and anterior neck thickness. These values are useful when monitoring the incidence of adverse outcomes retrospectively. Difficult airways have successful first pass intubation only 82.2% of the time compared to 92.4% for non-difficult airways and first pass success in rural hospitals are 69% versus 95% at trauma centers (Pacheco et al., 2021 Ehrlich et al., 2004).

The PEP/E-VC is the distance between the pre-epiglottic space to the epiglottis to the vocal cords. The researchers achieved a view that crossed the epiglottis and the posterior region of the vocal folds by angling the ultrasound probe midline and downwards below the mandible. The view obtained determines the Pre-E and E-VC ratios. Sotodehnia et al. (2023) found that a 1.77 cut-off value provided a reasonably accurate prediction, resulting in significant distinctions between the difficult and easy intubation groups.

The hyomental distance with neck extension refers to measuring the distance between the superior border of the hyoid bone and the inferior border of the mentum when the patient’s head is extended back rather than in a neutral position. Fulkerson et al. (2017) reported that their difficult laryngoscopy group had an average measurement of 52.6 ± 5.8 mm. In comparison, the easy intubation group measured 65.5 ± 4.1 mm, demonstrating a significant association with intubation difficulty. Figure 2 in Appendix B illustrates an ultrasound user measuring the hyomental distance.

The thyrohyoid membrane connects the thyroid cartilage's upper border to the hyoid bone's lower border. In individuals classified as CL Grade III/IV, the measurement of this tissue was found to be 34.7 mm, while in those classified as CL Grade I/II, it measured 23.7 mm. Wu's study also reported a correlation between this measurement and difficult laryngoscopy, with the easy group measuring 14.9 ± 3.9 mm, and the difficult group measuring 23.9 ± 3.4 mm (Fulkerson et al., 2017). Figure 3 in Appendix B demonstrates the measurement of the thyrohyoid membrane via ultrasound.

Anterior neck thickness refers to the soft tissue located at the level of the hyoid bone. Ezri's study revealed that individuals with difficult laryngoscopies had a neck thickness of 28 ± 2.7 mm, whereas those with easy laryngoscopies had a neck thickness of 17.5 ± 1.8 mm. Wu's findings supported the research, which showed that individuals with CL Grades III/IV had a neck thickness of 13.0 ± 3.1 mm, whereas those with easy grades had a neck thickness of 9.2 ± 2.0 mm (Fulkerson et al., 2017). Srinivasaragan et al. (2021) found slightly different but still significant values, as the thickness of anterior neck soft tissues at the level of the hyoid bone in difficult patients was 0.73 cm compared to 0.47 cm in easy patients. Appendix B includes Figure 4, which shows an ultrasound operator measuring the anterior soft tissue thickness at the level of the hyoid bone.

The project follows the JHEBP Model which involves a three-step process for making clinical decisions and implementing research findings into patient care. The model guides formulating a practice question, gathering evidence, and applying evidence in clinical practice.

The project focuses on establishing evidence-based guidelines for managing the airway in unconscious trauma patients. Researchers obtained evidence through a comprehensive literature review, which highlights the effectiveness of ultrasound measurements, such as PEP/E-VC distances, HMD, thyrohyoid membrane thickness, and anterior neck thickness, in predicting difficult intubation. The project utilizes qualitative and quantitative data and will incorporate the findings into guidelines for airway assessment in trauma patients.

Plan for Implementation

Phase 1

In order to initiate the project, an approval from the institutional review board (IRB) and Quality Improvement Hospital Committee must be obtain. See Appendix C for the institutional review board form. The initial implementation phase involves two CRNAs assessing the existing knowledge and growth areas among ER clinicians. In the context of the small rural facility where the project is set to take place, the ER staff consists of fewer than 10 members, and the trauma center currently performs roughly 50 intubations per month. Over 30 days, one CRNA will administer a quiz containing ultrasound (US) images and measurements to allow time for those currently unavailable to participate. This quiz serves the dual purpose of evaluating the level of experience of ER providers in the US for airway assessment and identifying areas for improvement (see Appendix D for a sample quiz). Statistical analysis of the quiz results will be performed by a CRNA using the Chi-squared test.

Following the analysis of the quiz results, a virtual meeting held by one of the CRNAs and one anesthesiologist will be scheduled a week later with ER providers and nursing staff. This meeting will include a brief PowerPoint presentation introducing the guidelines and presenting relevant literature on POCUS in unconscious trauma patients. See Appendix E for the guidelines.

Subsequently, two CRNAs and an anesthesiologist will provide formal training provided to ER providers. The anesthesia team may need to come in during a few off days to assist in training, but compensation will be assured. The training of the ER clinicians will be mandatory but will only last for a maximum of 30 minutes on their assigned shifts over 15 days. An instructor-to-learner ratio of 1:2 will help maximize hands-on instruction and demonstration time. The CRNAs and the anesthesiologist will be encouraged to customize their bedside teaching, expanding or collapsing the time for specific indicators better to meet the specific needs of each ER clinician.

The goal is to ensure that the CRNAs and anesthesiologist adequately train ER physicians, PAs, NPs, and residents and can confidently and accurately perform various measurements and assessments using POCUS, including the PEP/E-VC ratio, HMD, thyrohyoid membrane thickness, anterior neck thickness, ETT placement verification, and identification of the cricothyroid membrane. These ER providers will perform a skill check-off by the CRNAs and an anesthesiologist at the end of their 15 days and obtain 20 hours of ultrasound utilization after that in 3 months.

Phase 2

After completing the training in Phase 1, Phase 2 involves a CRNA or anesthesiologist implementing POCUS in the ER setting. The guidelines dictate that unconscious trauma patients requiring intubation should follow the difficult airway algorithm but should be screened with ultrasound prior to intubation attempt, remembering to take a mental note of four structures that aid in difficult airway identification: HMD, thyrohyoid membrane, anterior neck thickness, and cricothyroid membrane. The ER provider will continue the difficult airway algorithm if multiple intubation attempts are needed. The American Society of Anesthesiologists set forth the evidence-based algorithm; refer to Appendix F for information on how to proceed. These assessments will be documented in the EMR under the ER airway assessment note, being sure to select the number of attempts and the equipment used. This information will subsequently link to the Cormack-Lehane (CL) grading documented after laryngoscopy. A CL grade of III or IV should correspond to US measurements, such as a PEP/E-VC ratio < 0.88, HMD < 53mm, thyrohyoid membrane thickness > 35mm, or anterior neck thickness > 13mm. In cases where a provider is uncertain about tracheal or esophageal intubation, the provider will be able to select "verified by ultrasound" as one of the options once modified by IT. Similarly, if working through the difficult airway algorithm leads to an emergency cricothyrotomy, the option to select "cricothyroid membrane was identified via ultrasound" will be available for clinicians to select.

Phase 3

The final phase involves the two CRNAs administering a post-intervention quiz to the ER providers three months after the training (see Appendix G for a sample quiz). The clinicians will submit the quiz along with their logged hours no longer than 15 days after the three months. These questions seek feedback on the training experience and the effectiveness of implementing POCUS for unconscious trauma patients requiring intubation. The anesthesia team will perform and analyze a Chi-square test and compare the data to the Phase 1 quiz results.

Furthermore, the anesthesiologist and two CRNAs will organize a virtual interdisciplinary meeting, bringing together the nursing manager, project team leader, ER department chair, and an IT representative. This meeting aims to discuss the results and consider any necessary adjustments to the project based on the qualitative data gathered during the implementation phases.

If any adjustments to the guidelines are deemed necessary, they will be put into effect as required. Following the guideline modifications, the anesthesiology team will initiate a trial period of 30 days, during which they will issue a post-intervention survey. If the guidelines do not align with the expectations of anesthesia providers or meet patient care standards, the anesthesia team will temporarily stop the implementation. This suspension will continue until the anesthesia and department teams collaboratively develop a comprehensive action plan to resolve the underlying issues.

Project Facilitators

Collaborating with anesthesia providers, including CRNAs and anesthesiologists, is essential to initiate the project. This collaborative effort will also involve active participation from ER physicians and nurse practitioners. While initial ultrasound assessments may marginally extend the duration of airway evaluation, ultrasound can expedite the measurement and analysis of anatomical structures compared to traditional methods. Proper documentation of intubation attempts, CL grade, and possible parameters, including the PEP/E-VC ratio, HMD, thyrohyoid membrane thickness, or anterior neck thickness, will require collaboration with the IT department to ensure documentation of pertinent POCUS data. Overall efficiency can be enhanced with a compatible POCUS device that communicates with the EMR, streamlining the workflow, and ensuring seamless integration.

Timeline for Implementation

The project's timeline spans approximately seven months, encompassing planning, education, training, and a post-intervention quiz, excluding the potential design or methodology reevaluation in case of unmet outcomes; see Appendix H for timeline figure. During the initial month, the anesthesia team will administer a quiz to ER providers. Subsequently, the anesthesia team will dedicate 15 days to delivering 30-minute POCUS education and training to ER clinicians during their shifts. Following their training, CRNAs and an anesthesiologist will conduct a competency check to ensure the providers' proficiency in airway POCUS. The last three months involve ER physicians, NPs, PAs, and residents using ultrasound for at least 20 hours in trauma patients requiring an artificial airway. Within 15 days, the anesthesia team will collect post-intervention quizzes and logged hours. Data analysis will occur over a month, and the anesthesia team will hold a post-intervention meeting afterward. Chart evaluations and feedback will be ongoing every four months throughout the first year of project implementation to identify areas of strength and areas needing improvement.

Product Selection & Budget

Clinicians should consider factors such as image quality, ease of use, portability, total costs, and probe availability based on their specific clinical needs when selecting a handheld ultrasound device. A study involving 24 experienced POCUS experts from various medical specialties compared four popular devices: Butterfly iQ, Kosmos, Vscan Air, and Lumify. The experts evaluated these devices using standardized Likert scale ratings, with the Vscan Air being rated highest for ease of use, especially regarding physical characteristics and maneuverability, and the Butterfly iQ+ excelling in software navigability (Le et al., 2022).

Lumify received the highest overall image quality rating, particularly for detail resolution, contrast resolution, and clutter, while Kosmos performed well in penetration (Le et al., 2022). Regarding overall satisfaction, Lumify was the top-rated device among experts, followed by the Vscan Air. However, when asked which device the experts would purchase and carry in their coat pocket, the Vscan Air was the most frequently chosen option. The study stressed that no single device emerged as the best choice, highlighting the complexity of handheld ultrasound device purchasing decisions.

Given the previous reviews and ratings, the Vscan Air will be the project's portable handheld ultrasound. Vscan Air's frequency ranges from 3-12 MHz, obtains a depth of 8 cm, has a weight of 205g, and has a scan time of approximately 50 minutes with a recharge time of 75 minutes. Vscan Air has a three-year warranty and costs $4,855 for a linear and curved array in one probe (the curved array probe has a depth of 24 cm using 2-5 MHz frequencies). Because of the dual-headed transducer, providers can be the probe to perform specific examinations on obstetric and pediatric patients and even accomplish focused exams such as abdominal, vascular, thoracic, lung, and nerve blocks.

Medical-grade ultrasounds typically range from $20,000 to $75,000, even extending up to $200,000 for high-end machines. The Vscan Air connects to an app compatible with Android and iOS devices. To efficiently perform scans on all ER patients, the project facilitators recommend maintaining a ratio of one ultrasound probe for every three patients. The rural level two trauma center would need to acquire more than ten individual ultrasound probes. The total cost for these ultrasounds is approximately $50,000, equivalent to purchasing a single ultrasound machine. Additionally, the device requires regular cleaning between patient uses with Sani Cloth Prime, which most hospital facilities already use. Acquiring over ten individual ultrasound probes for efficient ER patient scans represents a cost-effective approach compared to investing in a single high-end ultrasound machine.

To establish a solid foundation for budget planning, project facilitators will analyze the costs for services from the anesthesiology department, IT, and data analysts. The fee for an anesthesiologist providing services for seven hours amounts to $1344, calculated at $192 per hour (*Anesthesiologists*, 2023). In contrast, the combined cost of two CRNAs delivering services for 10 hours is $1980, computed at $99 per hour (*Nurse anesthetist*, 2023). The IT services expenses cost approximately $50 per hour, approximately $200 for four hours (*Information Security Analysts: Occupational Outlook Handbook: U.S. Bureau of Labor Statistics*, 2023). If the team enlist the services of two data analysts for two hours, the total cost would be $200, at a rate of $50 per hour (*Data Scientists: Occupational Outlook Handbook: U.S. Bureau of Labor Statistics*, 2023). Since the anesthesia team will conduct the training sessions for ER physicians and residents within their regular work hours, the project facilitators will not factor the ER clinician's service costs into the financial considerations. Listed in Appendix I is the cost breakdown, providing a clear understanding of the financial aspects associated with various services and equipment, facilitating comprehensive budget planning for the project.

The SCCM-Weil Research Trust generously provides a $50,000 grant, which will cover 95% of the total project expenses, including the acquisition of handheld ultrasounds. Our proposed project aligns seamlessly with the grant research requirements outlined by SCCM-Weil Research Trust, encompassing clinical aspects such as airway management, patient and family involvement in survivorship and recovery, and the education of healthcare providers (SCCM, 2023). Furthermore, our project is fully compliant with the grant's stipulations, as it is designed to be completed within 12 months at a single site, specifically our rural Level Two trauma center. Should the team secure this grant, the hospital's financial commitment would only be the operational costs, a mere $2,272.

Outcomes & Analysis

Upon the completion of the project, data analysis will occur over one month through retrospective evaluation. The two data analysts will randomly analyze and assess thirty EMR charts belonging to unresponsive trauma patients. This selection aims to assess compliance in accurately documenting intubation attempts and the possible documentation of parameters, such as the PEP/E-VC ratio, HMD, thyrohyoid membrane thickness, and anterior neck thickness within the emergency clinician's airway notes. Additionally, alternative approaches/equipment providers use when faced with airway difficulties identified by the US will be documented.

The following steps involve monitoring for the incidence of CL Grade III or IV classifications within patients' EMRs. This aspect is crucial as it signifies instances where utilizing POCUS becomes particularly relevant. The degree of compliance regarding the application of POCUS in such cases will be systematically recorded in an Excel sheet by the data analysis team. The results will then be presented and discussed with the project facilitators during the first post-intervention meeting.

Monitoring for the incidence of CL grade III or IV classifications in patients' EMRs will continue consistently every four months throughout the first year of project implementation. This tracking will allow for identifying trends or patterns, facilitating a thorough examination of potential improvements or challenges encountered when managing cases involving difficult airways in unconscious patients.

The project sets out to achieve several important outcomes. First and foremost, it aims to reduce the occurrence of difficult airway situations and difficult intubations, currently ranging from 5% to 22%, to a range of 3% to 15%. Simultaneously, the project seeks to decrease the incidence of hypoxic brain injury stemming from misplaced tracheal tubes from its current rate of 12% to 8%, enhancing patient safety. Furthermore, the project aims to lower mortality rates from 2% to less than 1%, ensuring a more favorable patient outcome.

In addition to these primary objectives, the project strives to enhance the success rate of cricothyroid membrane location through the use of ultrasound. Currently, this success rate stands at 8% when relying on external palpation. The project aims to significantly improve this rate, setting a target of 85% accuracy through the implementation of ultrasound technology.

Limitations, Barriers, and Future Direction

Implementing POCUS for airway assessment can offer significant benefits in clinical practice, but it also comes with its own set of limitations and barriers. One of the primary barriers is the need for adequate training and education for healthcare providers. Not all clinicians may be proficient in ultrasound, and specialized training is required to accurately interpret ultrasound images for airway assessment. The lack of skills in the facility would also be a limitation because the facility has only some, not all, providers that regularly intubate and maintain that skill. Additionally, if the grant is not obtained or is no longer available, acquiring enough POCUS probes may pose a financial challenge for healthcare facilities, especially those with limited budgets. Another challenge to overcome would be integrating ultrasound into existing clinical workflows, as it may require changes in protocols and routines, which could disrupt processes and workflows that are already proven successful. Engaging stakeholders, such as hospital administrators, ER managers, medical staff, and anesthesiologists, can also be a barrier, as buy-in and support are needed to make informed decisions. Workflow can be impaired if communication with ER medical staff and stakeholders is neglected. Lastly, ensuring the quality and accuracy of ultrasound examinations is crucial. Quality assurance is needed to monitor and maintain the competency of healthcare providers performing ultrasound scans. If documentation is inaccurate or ignored, assessing the success or failure of the project would be futile.

Today, many locum CRNAs or 1099 CRNAs have purchased their own POCUS probe mainly for vascular access. The future direction of POCUS for airway assessment specifically involves developments aimed at improving its efficacy, addressing the knowledge deficit, accessibility, and integration into clinical practice. Incorporation of ultrasound education and training into medical and advanced healthcare providers' curriculum will help ensure that future generations of medical staff are proficient in utilizing ultrasound for airway assessment. More importantly, the development of standardized protocols and guidelines for performing and interpreting ultrasound scans will help ensure consistency, variability, and quality across different healthcare settings and specialties.

Conclusion & Recommendations

The project highlights the critical need for improving airway assessments in unresponsive trauma patients requiring intubation, particularly in emergency room settings. The limitations of traditional methods and the potential for adverse outcomes emphasize the importance of incorporating POCUS as an adjunctive tool. POCUS offers objective and quantifiable data that can enhance the accuracy of airway assessments, ultimately improving patient safety and reducing the risk of complications such as anoxic brain injury due to hypoxia from esophageal intubations or failed intubations.

The project aims to bridge the gap between research and clinical practice by following the John Hopkins Evidence-Based Practice Model. Furthermore, the project emphasizes the significance of evidence-based guidelines for POCUS in airway assessment and management. Through active engagement with healthcare providers and structured training, the project seeks to promote the adoption of POCUS in ER settings.

Incorporating POCUS into airway assessments is pivotal to ensuring unresponsive trauma patients receive the best possible care. Using ultrasound in airway assessments shows high specificity and sensitivity in predicting difficult intubation and misplaced ETTs. Enacting the guidelines recommended by the project facilitators will allow anesthesia providers to educate other healthcare professionals in making more informed decisions, reducing complications, and enhancing patient outcomes in critical and time-sensitive situations. This project is a valuable contribution to improving the safety and efficacy of airway management in trauma patients.

Summary

This project aims to improve airway management in unconscious trauma patients using POCUS to provide objective data for decision-making. The process seeks to establish evidence-based guidelines by quantifying key airway parameters and assessing their impact on patient outcomes. Following the JHEBP Model, the project involves retrospective chart analysis to evaluate compliance and monitor trends in difficult airway cases. By assessing specific airway parameters, healthcare providers can potentially reduce malpractice settlements associated with anesthesia-related complications, but more importantly, enhance clinical practice and improve patient safety by reducing the risk of respiratory adverse events.

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Srinivasarangan M, Akkamahadevi P, Balkal VC, Javali RH. (2021). Diagnostic accuracy of ultrasound measurements of anterior neck soft tissue in determining a difficult airway. *J emerg trauma shock*. *14*, 33-7. doi: 10.4103/JETS.JETS_12_20

Stopar-Pintaric, T., Vlassakov, K., Azman, J., & Cvetko, E. (2015). The thyrohyoid membrane as a target for ultrasonography-guided block of the internal branch of the superior laryngeal nerve. *Journal of clinical anesthesia, 27 (7),* 548-52.

Appendix A

JOHNS HOPKINS NURSING

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Home

JOHNS HOPKINS EBP MODEL AND TOOLS- PERMISSION

Johns Hopkins Nursing Center for Evidence-Based Practice

Thank you for your submission.
We are happy to give you permission to use the Johns Hopkins Evidence-Based Practice model and tools to adhere to our legal terms noted below.
No further permission for use is necessary.

You may not modify the model or the tools without written approval from Johns Hopkins.
All references to source forms should include "© 2022 Johns Hopkins Health System/Johns Hopkins School of Nursing."
The tools may not be used for commercial purposes without special permission.
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Available Downloads:

2022 JHEBP Tools- English version

2022 JHEBP Tools- Spanish version

2022 JHEBP Tools- Chinese version

2022 JHEBP Tools- Portuguese version

Would you like to join us? *Group rates are available, email ijhn@jhmi.edu to inquire.*

EBP Boot Camp: We are offering a 5-day intensive Boot Camp where you will learn and master the entire EBP process from beginning to end. Take advantage of our retreat-type setting to focus on your project, collaborate with peers, and get expertise and assistance from our faculty. *COMING in 2024!*

EBP Skill Build: This 3-day virtual workshop gives you a front-row seat to our EBP training and provides every participant with the guidance and support they need to get their EBP projects started.

Appendix B

Figure 1

The Johns Hopkins Evidence-Based Practice Model PET Process

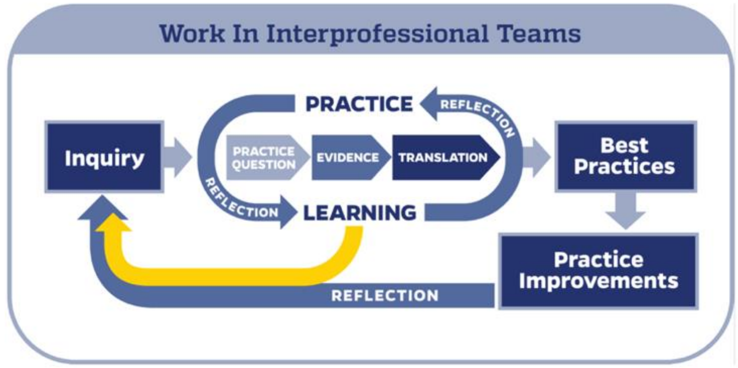


Figure 2

Ultrasound measurement of HMD with the neck extended (Andruszkiewicz et al., 2016).

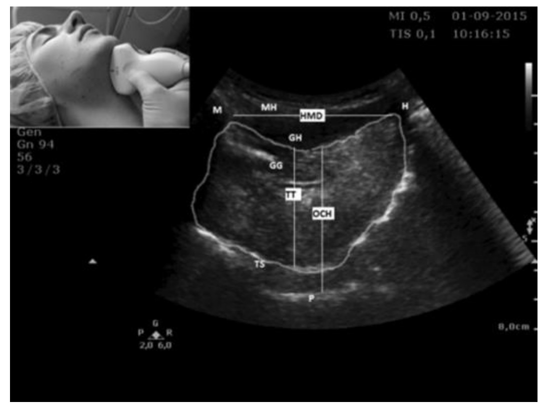


Figure 3

Ultrasound measurement of the thyrohyoid membrane (Stopar-Pintaric et al., 2015).

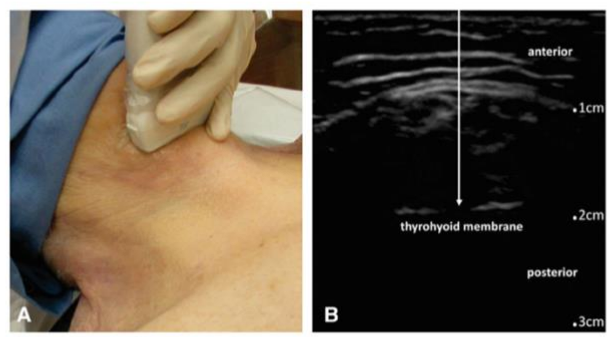
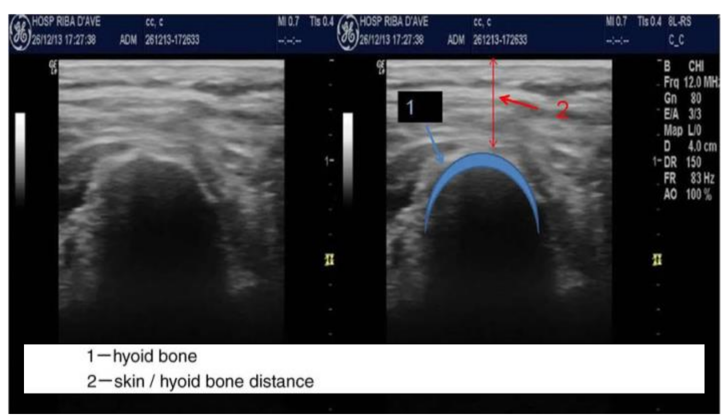


Figure 4

Ultrasound measurement of the anterior soft tissue thickness at the level of the hyoid bone (Lages et al., 2018).



Appendix C

OTTERBEIN UNIVERSITY

INSTITUTIONAL REVIEW BOARD
Application Forms

Please read the Guidelines for Submission of Protocols carefully prior to completing the attached materials. Per the Guidelines, determine if your submission is for expedited or complete committee review. Requests for both full and expedited review must follow the same procedures, with the exception that a request for expedited review must be indicated on the "Cover Page of Summary Sheets."

The following materials are required to support the review process of the IRB Committee. **Please type.**

1. **SUMMARY SHEETS:**

   a. Cover Page for Summary Sheets must include original signatures of the principal and co-investigators. (If student, advisor must be listed as principal investigator.)

   b. The Summary Sheets include 17 questions regarding subject population, consent procedures, risks and benefits. Complete each section. Do not leave any question unanswered. Attach all questionnaires and describe all materials and procedure fully.

2. **ORAL AND/OR WRITTEN INSTRUCTIONS TO SUBJECTS.** Please provide an outline or script of the information which will be provided to subjects prior to their volunteering to participate. (Please note: Subjects must be informed about the nature of what is involved as a participant, including a description of anything they might consider to be unpleasant or a risk.) Include a copy of the written solicitation and an outline of the oral solicitation when applicable. If you are recruiting by means of a "sign-up sheet," please attach a copy of that sheet.

3. **CONSENT FORM, IF REQUIRED, SHOULD BE INCLUDED.** Example consent forms can be found in the guidelines. Please note that the person obtaining consent shall sign a copy of the cover sheet for the summary sheets.

4. **ALL SUPPLEMENTARY MATERIALS (SOLICITATION, INSTRUCTIONS, CONSENT, QUESTIONNAIRES/ SURVEYS/TESTS/ETC.) MUST BE SUBMITTED AS HARD COPY, EMAIL ATTACHMENT, OR LINK TO SHARED FOLDER IN ORDER FOR THE PROPOSAL TO BE EVALUATED.**

Only protocols that are complete as defined below will be scheduled for review. Incomplete protocols will be returned to the principal investigator.

FOR EXPEDITED REVIEW, SUBMIT A DIGITAL OR HARD COPY OF THE COMPLETE PROTOCOL – (Summary Sheets including original signatures, oral/written instructions to subjects, questionnaires-instruments, and consent form) as defined above to:

FOR FULL COMMITTEE REVIEW SUBMIT A DIGITAL COPY OF THE COMPLETE PROTOCOL – (Summary Sheets including original signatures, oral/written instructions to subjects, questionnaires-instruments, and consent form) as defined above to:

Noam Shpancer, TRB Chair
Psychology Department
TRB@Otterbein.edu

(Updated June 2021)

Otterbein University
Institutional Review Board

Office Use:
Protocol No.
Date Received:

Cover Page for
SUMMARY SHEETS

Investigator(s): **A student may not be PI; if this is a student project, list the research advisor's name first.**	Regina Prusinski Principal Tnvestigator (PT) Name	Signature
	Shannen Steinbrunner Co-Tnvestigator Name	Shannen Steinbrunner Signature
	Shannen Steinbrunner Co-Tnvestigator Name	Shannen Steinbrunner Signature
	List additional investigators (if applicable)	
PI Academic Title:	DNP, APRN, FNP-BC, CPN	PT email: rprusinski@otterbein.edu
Department :	Nursing	PT phone: 614-823-1388
Campus Address:	1 S Grove St. Westerville, OH 43081 (Faculty Member's Campus Address)	
PROPOSAL TITLE:	Guidelines for Non-Anesthesia Providers Performing Point-of-Care Ultrasound (POCUS) for Airway Assessment in the Emergency Room	

Are you applying for limited review? If so, indicate, the category in the drop down menu which best describes your project.

(•) Yes ( ) No   Collection of data through non-invasive procedures routinely involv

Is there outside funding for the proposed research? If so, please indicate the source:

( ) Yes (•) No

When do you plan to begin collecting data? 3/1/24

When do you plan to finish collecting data? 9/1/24

OTTERBEIN UNIVERSITY INSTITUTIONAL REVIEW BOARD

RESEARCH SUMMARY SHEETS

Be specific about exactly what subjects will experience when they participate in your research, and about the protections that have been included to safeguard them. Careful attention to the following may help facilitate the review process.

1. In a sentence or two, describe the background and purpose of the research.

   The purpose of the study is to enhance airway management in unconscious trauma patients, improve clinical outcomes, and reduce the risk of adverse events, ultimately benefiting anesthesia and emergency room providers and patients.

2. Briefly describe each procedure or manipulation to be implemented that will impact subjects included within the study.

   Once the patient arrives unresponsive and requiring an endotracheal tube (ETT), the portable ultrasound will be used to determine any underlying airway trauma or even to identify their cricothyroid membrane for a can't intubate or can't ventilate situation. The ultrasound can also be used to identify correct placement of the ETT. This can expedite the difficult airway

3. What measures or observations will be taken in the study? If any questionnaires, tests, or other instruments are used, provide a brief description and include a copy for review.

   The patient themselves will be observed via anesthesia team and followed by their primary team, but monitoring for adverse effect of the point of care ultrasound will not occur due to minimal or no residual effects.

4. Who will be the subjects in this study? How will they be solicited or contacted?

   The participants will be age >18 and chosen at random (those who qualify and meet the parameters). Family or next of kin will be contacted if the patient is unconscious and requires intubation. The point of care ultrasound will be useful on those particular patients.

5. What steps will be taken to insure that each subject's participation is voluntary? What, if any inducements will be offered to the subjects for their participation?

   Informed consent will be mandatory by the next of kin to educate the participants of what to expect and the possible risks. The consent is the medical informed consent form. This is assuming the patient is full code providing that the patient arrives to the emergency room unresponsive and requiring an airway.

6. If there are any risks involved in the study, are there any offsetting benefits that might accrue to either the subject or society?

   Similar risk to ultrasound during pregnancy: no active infections or rask over airway will be examined, will avoid scanning pacemaker patients. Ultrasound is considered safe, non-invasive, and quick.

Appendix D

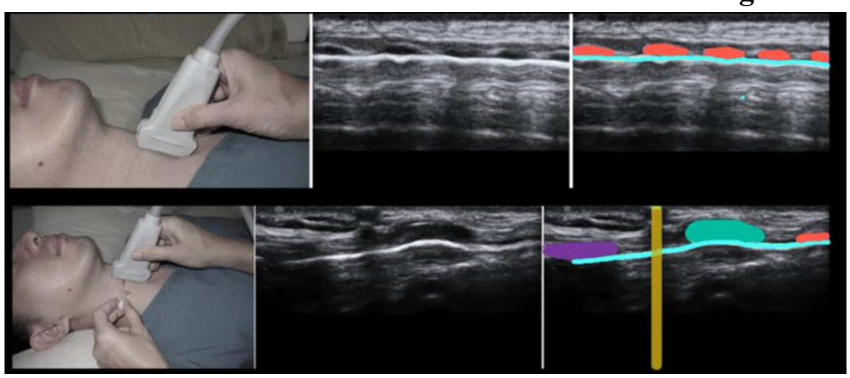
POCUS Airway Quiz for ER Providers

1. **ER Role/Experience:**
    a. Emergency physician
    b. PA
    c. NP
    d. Resident
        i. 0-4 years experience
        ii. 5-10 years experience
        iii. >10 years experience
2. **What is the PEP/E-VC measuring on ultrasound?**
    a. Skin to epiglottis distance
    b. Peri-epiglottis space to epiglottis to vocal cords ratio
    c. The depth of the pre-epiglottic space
    d. The distance from the epiglottis to the midpoint of the distance between the vocal cords
3. **At what measurement does the HMD in the extended neck position indicate difficult airway?**
    a. > 5.5 cm
    b. < 5.5 cm
    c. > 5.3 cm
    d. < 5.3 cm
4. **A thyrohyoid membrane thickness of <35mm indicates easy or difficult airway?**

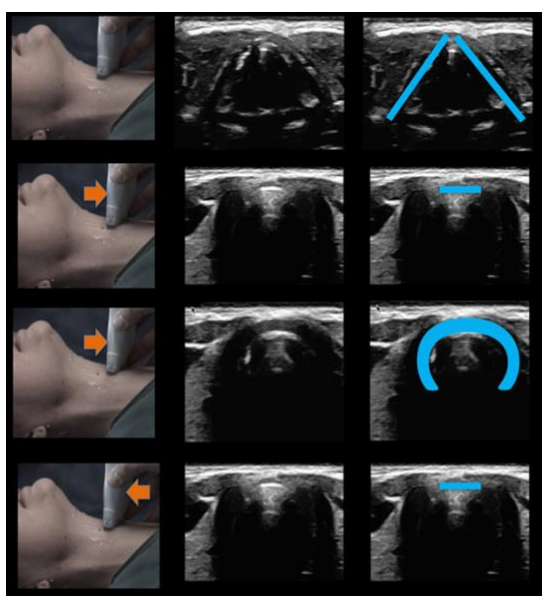
5. **An anterior neck thickness of >13mm indicates easy or difficult airway?**

6. **T/F: The image below shows an ETT in the trachea**

7. **The following image shows the string of pearls (SOP) technique for identifying the cricothyroid membrane. What color indicates the cricoid cartilage?**



8. **The follow image depicts the TACA technique for identifying the cricothyroid membrane. What does the A mean in the acronym?**



9. Do you feel comfortable using ultrasound as a method of predicting difficult airway?

a. Yes

b. No

10. What is your preferred test for predicting difficult airway in the trauma patient?

a. Mallampati

b. LEMON

c. 3-3-2 test

d. Thyromental distance

e. Mandibular protrusion test

f. Other ________________________________

11. What apprehensions do you have implementing POCUS in an airway assessment in the unconscious trauma patient?

a. Expensive

b. Current assessment is working

c. Inaccurate/subjective

d. Not enough time

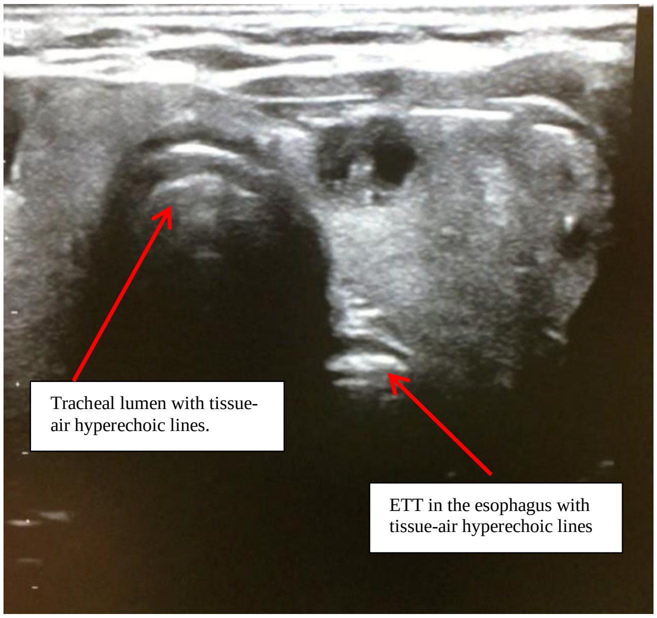
e. It is a great idea

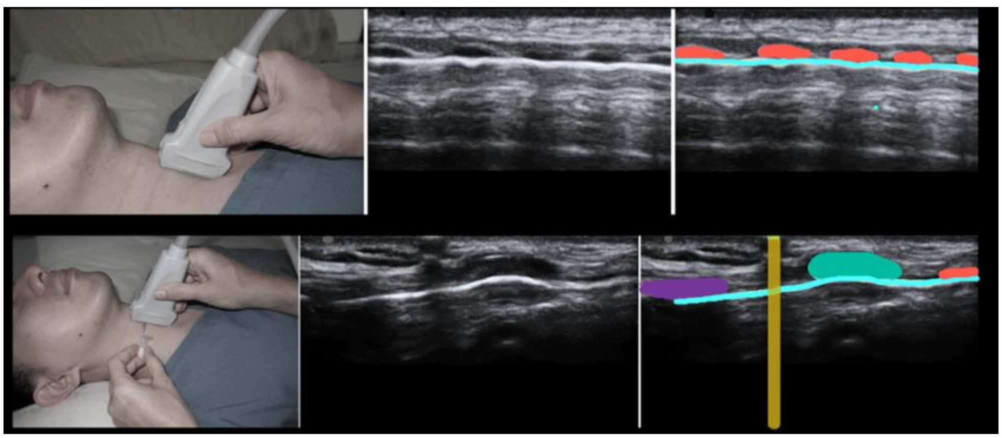
f. Other ________________________________

Appendix E

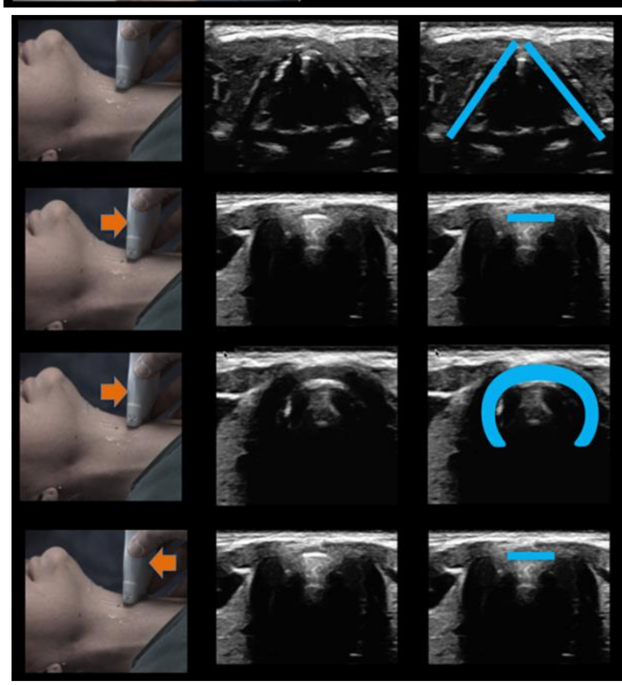
GUIDELINE:

1. **Airway Assessment:**
   a. All unconscious trauma patients requiring emergency intubation will have a POCUS airway assessment performed in the emergency room by ER clinicians (physicians, nurse practitioners, etc.)
   b. In addition to performing the limited LEMON assessment, the POCUS airway assessment includes:
      i. PEP/E-VC
      ii. HMD in extended position
      iii. Thyrohyoid membrane thickness
      iv. Anterior neck thickness
      v. ETT Confirmation
      vi. Cricothyrotomy Identification
2. **Airway management**
   a. The following four parameters are considered a difficult airway and method of intubation/securing an airway should follow the difficult airway algorithm (fiberoptic, glidescope, cricothyrotomy, etc.)
      i. PEP/E-VC <0.88
      ii. HMD <53 mm in the extended neck position
      iii. Thyrohyoid membrane thickness >35 mm
      iv. Anterior neck thickness >13 mm
      v. ETT Confirmation can be determined by the absence of adjacent hyperechoic structure with shadowing posterolateral to the trachea, consistent with the ETT location within the esophagus. This is also known as the “double tract sign.”
      vi. Cricothyrotomy Identification: String of pearls technique (SOP) or Thyroid-Airline-Cricoid-Airline (TACA) technique.
3. **Documentation**
   a. The initial method of intubation and equipment used will be documented in the ER provider notes
   b. The POCUS airway assessment in trauma patients will be documented only if more than one attempt was made by the ER clinician. IT will ensure that the ER airway documentation will be similar to anesthesia’s OR airway documentation on the EMR.
   c. After the patient’s airway is stable and secured, if multiple attempts were made to obtain an airway, the provider can select airway characteristics from a drop-down checklist option in the ER provider note (select all that apply). The chart has the potential to be monitored randomly and will be monitored retrospectively if poor airway situations arise.
   d. CL grading observed during intubation will be compared to ER assessment findings and also documented in the ER provider note





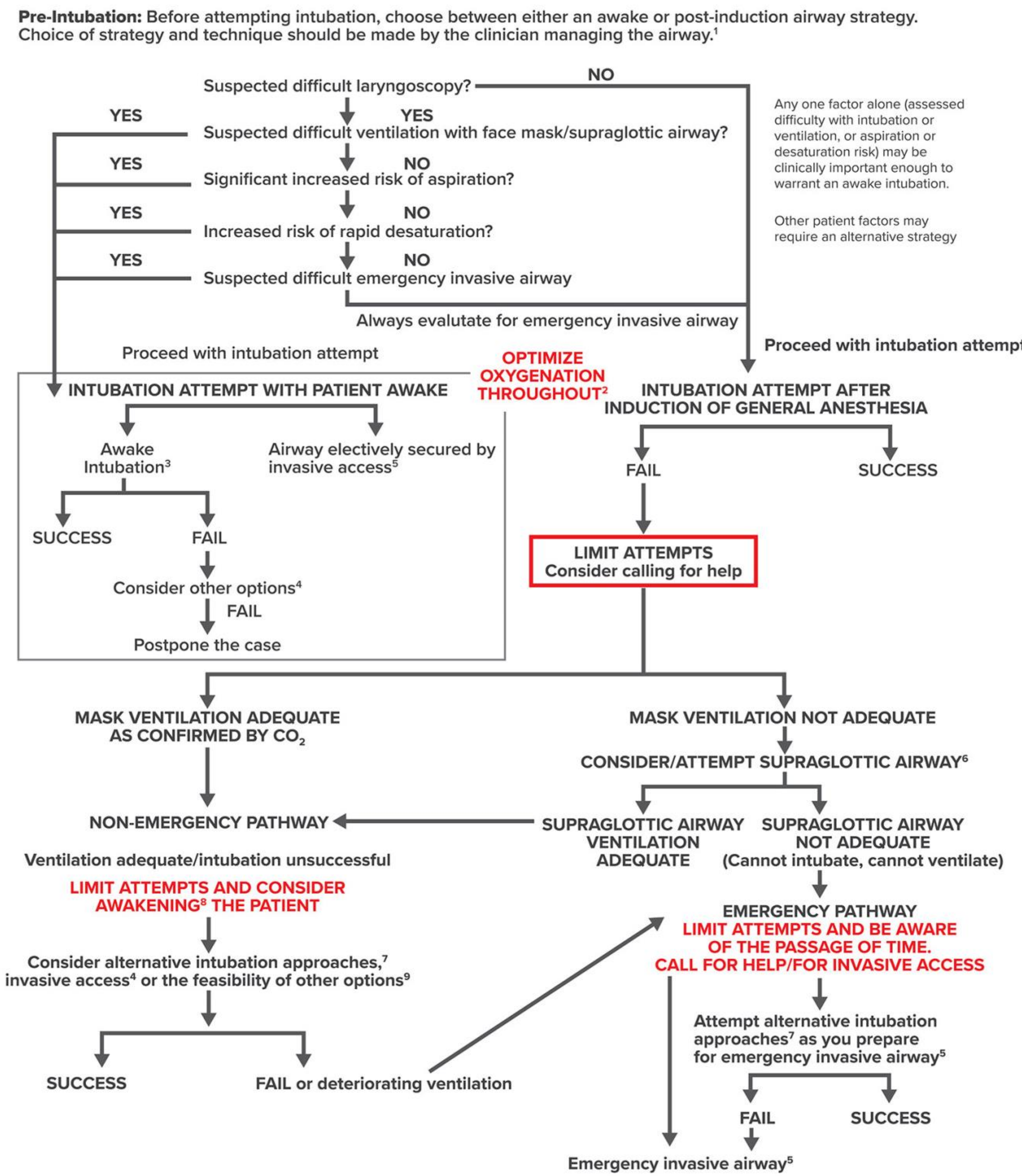
SOP Technique:
Orange-red = tracheal ring
Light blue = the tissue-air border
Green = the cricoid cartilage
Purple = the distal end of the thyroid cartilage
Yellow = the shadow from the needle slid in between the transducer and the skin



TACA Technique:
Blue triangle = thyroid cartilage
Blue horizontal line = the ‘‘airline’’ = the cricothyroid membrane
Blue ‘‘lying C’’ = the anterior part of the cricoid cartilage

Appendix F

Difficult Airway Algorithm for Adult Patients



Appendix G

Post-intervention Quiz for ER Providers

1. **Did you find that using POCUS for the unconscious trauma patient airway assessment correlated with the CL grading?**
   a. Yes
   b. No
   c. Sometimes (provide a rough percent):
2. **Did you feel that the training you were provided was adequate? Did you find one measurement more useful than another? If so, explain:**

   ____

   ____

3. **What would you change about the guidelines, if anything?**

   ____

   ____

4. **Were there limitations to the assessment during clinical practice?**

   ____

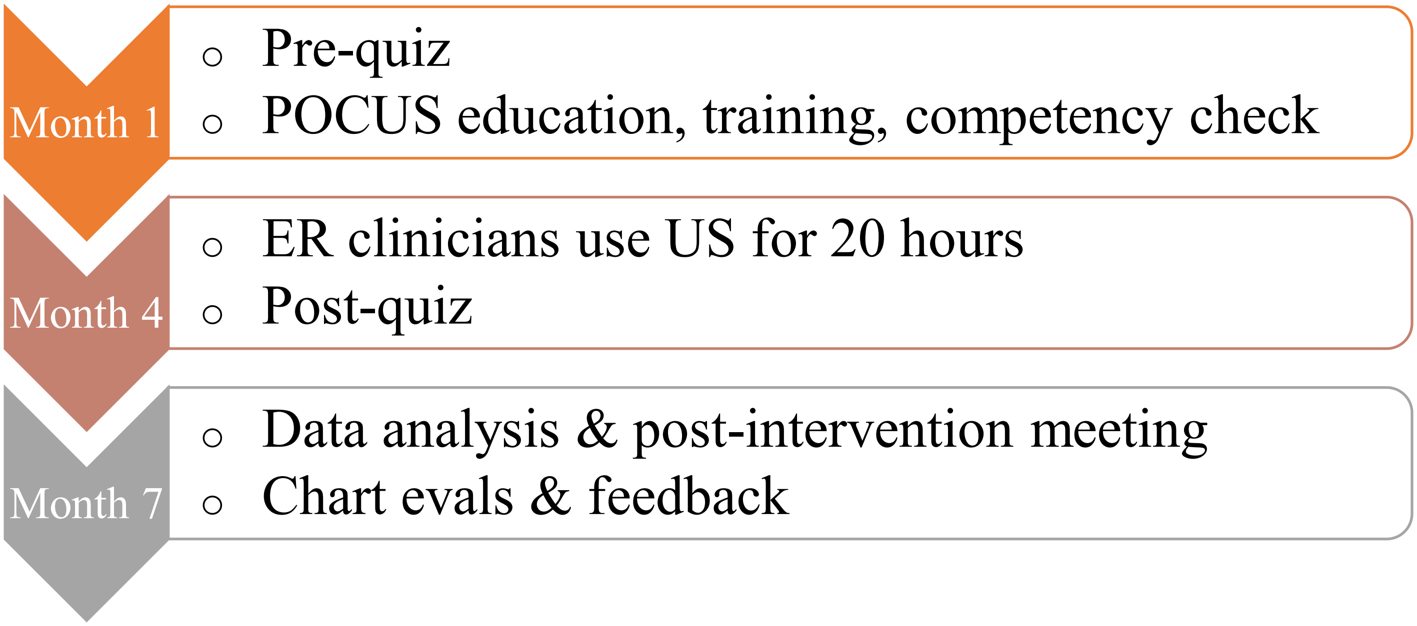
   ____

5. **Circle: Patient care was: *delayed, prolonged, or not affected* during the POCUS airway assessment?**
6. **Are there any other barriers you foresee limiting the implementation of POCUS in the unconscious trauma patient?**

   ____

   ____

Appendix H


Month 1
Pre-quiz
POCUS education, training, competency check
Month 4
ER clinicians use US for 20 hours
Post-quiz
Month 7
Data analysis & post-intervention meeting
Chart evals & feedback

Appendix I

Service/Equipment	**Quantity**	**Hours Utilized**	**Total Cost**
VScan Air	10	n/a	$48,550
Anesthesiologist	1	7	$1,344
Nurse Anesthetist	2	10	$1,980
Informational Technologist	1	4	$200
Data Analyst	2	2	$200
Total	**$52,274**		
SSCM-Weil Research Grant	**$50,000**		
Total with Grant	**$2,274**		

Appendix J

Evidence Review Worksheet

APA Citation:

Carsetti, A., Sorbello, M., Adrario, E., Donati, A., & Falcetta, S. (2022) Airway ultrasound as predictor of difficult direct laryngoscopy: A systematic review and meta-analysis, *Anesthesia & Analgesia*, 134(4), 740-750. doi: 10.1213/ANE.0000000000005839

Conceptual Framework of Model	Design or Method	Sample & Setting	Major Variables Studied & their Definitions, if any	Outcome Measurement(s)	Data Analysis	Findings	Level of Evidence	Quality of Evidence: Critical Worth to Practice
Theoretical basis for the study: The conceptual framework is based on the hypothesis that airway ultrasound can be used as a predictor of difficult direct laryngoscopy (DL). By using ultrasound as a tool, researchers aim to predict the level of	From the beginning to December 2020, Medline, Scopus, and Web of Science databases were searched. The population included adults who required tracheal intubation for elective surgery under general anesthesia	Number of Characteristics: 1064 Exclusion Criteria: 1064 titles were retrieved; Excluded: duplicates, studied that included pregnant women, studies with a different definition of difficult direct laryngoscopy, patients with a history of previous difficult	Independent variables: ultrasound (UA-US) index tests used to assess the airway and predict difficult laryngoscopy: DSE (thickness of the pre-epiglottic space at the midline), DSHB (hyomental distance measured in the extended head position), DSVC (tongue thickness), and Pre-E/E-VC (parameters related to subhyoid soft tissue thickness) Dependent variables: prediction of difficult laryngoscopy: AUC-	Scale(s) used: Reliability information (alphas, if any): n/a The primary outcome was the predictive value of neck US index test to anticipate difficult DL. The secondary outcome was to determine the mean differences of UA-US index test between patients with easy and difficult DL. Area Under the Curve (AUC-SROC): The AUC-SROC is a measure of the overall diagnostic accuracy of the ultrasound (UA-US) index tests in predicting difficult laryngoscopy. The value of 0.87 (with a 95%	Qualitative analysis, if any: n/a Statistical analysis: metandi and midas in STATA (StataCorp 2021; Stata Statistical Software: Release 17; StataCorp LLC) and RevMan version 5.3 (Cochrane Collaboration).	"The sensitivity for (distance from skin to epiglottis. (DSE), distance from skin to hyoid bone (DSHB), and distance from skin to vocal cords (DSVC) was 0.82, 0.71, and 0.75. The specificity for DSE, DSHB, and DSVC were 0.79, 0.71, and 0.72. Patient with difficult direct laryngoscopy	Level I: Systematic review and meta-analysis	Strengths: The article is described as a SR/MA, the article focuses on diagnostic accuracy of ultrasound index tests, the article includes multiple studies that have assessed different UA-US index tests in relation to difficult laryngoscopy. Limitations: The article acknowledges the limitations of the available evidence, including the limited number of studies and the heterogeneity in

difficulty of performing a DL. The framework suggests that the ability to anticipate difficult intubations can aid healthcare providers in implementing appropriate strategies or techniques to optimize patient care and safety.	without clear anatomical abnormalities suggesting difficult DL. Researchers used a bivariate model to assess the accuracy of each ultrasound index test to predict difficult DL.	intubation or expected difficult laryngoscopy, conference proceedings, abstracts, and studies conducted on animals, studies recorded in a non-English language. Attrition: 25 studies Setting: clinical	SROC, PPV, NPV, and cutoff values were used to assess the diagnostic accuracy and predictive values of the UA-US tests in relation to the dependent variable. Airway ultrasound: The use of ultrasound to visualize and assess the anatomical structures of the airway, such as the hyoid bone, thyroid cartilage, epiglottis, and vocal cords. Difficult direct laryngoscopy: Refers to instances where the healthcare provider encounters challenges or obstacles during the procedure of direct laryngoscopy, resulting in a difficult or failed intubation.	confidence interval of 0.84-0.90) indicates the discriminatory power of the tests. Positive Predictive Value (PPV): The PPV represents the probability that a positive result on the UA-US test indicates a difficult laryngoscopy. The range of PPV reported in the considered studies is from 30.26% to 49.4%. Negative Predictive Value (NPV): The NPV represents the probability that a negative result on the UA-US test indicates an easy laryngoscopy. The range of NPV reported in the considered studies is from 94.61% to 97.53%. Cutoff Values: The cutoff values refer to the specific threshold values used for each UA-US index test to distinguish between patients with possible easy and difficult laryngoscopy. Different studies used different cutoff values for the same index test.	The bivariate model proposed by Reitsma et a.l has been used to assess the accuracy of each US index test to predict difficult direct laryngoscop y.	have higher DSE, DSHB, and DSVC than those with easy laryngoscopy (95% confidence interval (CI))...further studies are needed with better standardization of ultrasound assessment to limit all possible sources of heterogeneity" (p. 740)		methods and patient selection. It also highlights the need for further research and standardization in the field. Risk or harm if implemented: 2 studies out of 32 were reported as having an uncertain risk of bias. Feasibility of use in the project practice area: More research needs to be performed with a larger sample

APA Citation:

Fulkerson, J. S., Moore, H. M., Anderson, T. S., & Lowe, R. F., Jr (2017). Ultrasonography in the preoperative difficult airway assessment. *Journal of clinical monitoring and computing*, *31*(3), 513–530. https://doi.org/10.1007/s10877-016-9888-7

Conceptual Framework of Model	Design or Method	Sample & Setting	Major Variables Studied & their Definitions, if any	Outcome Measurement(s)	Data Analysis	Findings	Level of Evidence	Quality of Evidence: Critical Worth to Practice
Theoretical basis for the study: The theoretical basis is to evaluate the utility of ultrasound for detecting difficult intubation in a preoperative setting. The authors aimed to explore the potential of ultrasound as a tool for identifying patients at risk of difficult intubation, which could help improve patient outcomes and	PubMed, Ovid, CINAHL Plus Full Text, and Google Scholar searches were conducted on May 1st, 2016 the PRISMA [28] methodology as indicated in Fig. 1. Keywords and Boolean phrases searched were: [‘‘difficult airway’’ OR ‘‘difficult intubation’’ OR ‘‘difficult laryngoscopy’’ OR ‘‘difficult ventilation’’]	Number of Characteristics: 136 Exclusion Criteria: duplicates, abstracts, case reports, letters, textbooks, foreign language, unrelated studies, unoriginal works, unavailable data, relevance, concerns over data quality Attrition: 10 Setting: clinical	Independent variables: anatomical locations, anterior neck soft tissue thickness, patient demographics. Dependent variables: difficultly of laryngoscopy and predictive values, soft tissue thickness measurements, and time to acquisition The The term "difficult airway" encompasses	Scale(s) used: Reliability information (alphas, if any): n/a Predictive value for difficult laryngoscopy: measurements at different anatomical locations, such as the hyoid bone, thyrohyoid membrane, hyomental distance, and suprasternal notch, have been studied to predict difficult laryngoscopy. The discussion highlights mixed results and	Qualitative analysis, if any: n/a The STARD checklist for diagnostic tools was used to critically appraise the twelve primary research studies that exist in the literature. Bias was assessed by use of this checklist including blinding, incomplete data	“Predictive value for difficult laryngoscopy has been demonstrated at the hyoid bone, thyrohyoid membrane, and hyomental distance in the sniffing position. The results at other locations inferior to the thyrohyoid membrane, however, are mixed” (p. 527). “Hyomental distance with neck extension demonstrates predictive significance in a small sample size of 12 obese adults with 6 difficult laryngoscopies. The difficult laryngoscopy group had a 52.6 ± 5.8 mm measure compared to 65.5 ± 4.1 mm in the easy intubation group (p\0.01)” (p. 523). “At the hyoid bone, Adhikari found measurements of 16.9 mm (95 % CI 11.9–21.9) in	Level 1: Systematic Review	Strengths: Predictive value for difficult laryngoscopy has been demonstrated at the hyoid bone, thyrohyoid membrane, and hyomental distance in the sniffing position. Adhikari suggests that an anterior neck soft tissue thickness of 28 mm at the thyrohyoid membrane can serve as a cut off to detect difficult laryngoscopy. Limitations: Not all studies used Sellick’s

reduce complications. The conceptual framework of this model involves using ultrasound as a tool to assess specific anatomical measurements and determine their predictive value in identifying patients at risk of difficult intubation.	AND [ultrasonograp hy OR sonography OR ultrasound]. Two reviewers manually screened the record titles and abstract and excluded many criterias. Bias was assessed by use of this checklist including blinding, incomplete data reporting, and subject attrition.		various aspects of airway management, including difficult mask or supraglottic airway ventilation, difficult supraglottic airway placement, difficult or failed endotracheal intubation, and difficult laryngoscopy. Difficult laryngoscopy can refer to direct laryngoscopy, indirect laryngoscopy (video), or flexible fiber optic bronchoscopy. There is no widely-accepted standard definition for difficult airway or difficult intubation.	conflicting findings; Anterior neck soft tissue thickness: anterior neck soft tissue thickness of 28 mm at the thyrohyoid membrane has been suggested as a cutoff to detect difficult laryngoscopy. Studies by Adhikari, Wu, and Pinto are referenced, which report different measurements for the easy and difficult laryngoscopy groups; Hyomental distance: Wojtczak's study is mentioned, which examined the hyomental distance. The study found significance with the neck extended, representing the intubating position. This measurement	reporting, and subject attrition. Use of appropriate statistical tests was determined algorithmica lly using graphical flow charts. Those that failed to meet relevance (n = 2) or did not analyze intubation difficulty (n = 1) were rejected, leaving ten studies in this systematic synthesis.	the CLG III/IV group differed significantly from the 13.7 mm (95 % CI (12.7–14.6) in the CLG I/II group. This aligns with Wu's findings, with measurements of 15.9 ± 2.7 mm in the difficult laryngoscopy group, versus 9.8 ± 2.6 mm in the easy laryngoscopy group (p\0.0001) (p. 523). "Adhikari found thyrohyoid membrane anterior tissue as a significant predictor. CLG III/IV have a 34.7 mm (95 % CI 28.8–40.7) versus 23.7 mm (95 % CI 22.9–24.4) in CLG I/II. Wu also found this level to correlate to difficult laryngoscopy of 23.9 ± 3.4 mm versus14.9 ± 3.9 mm (p\0.0001) in the easy group. Similarly, Pinto evaluated only this location and found significance and derived that C27.5 mm denotes a difficult laryngoscopy" (p. 523). "There are conflicting findings at the vocal cords: three authors found significance when measuring the distance from the anterior commissure to the skin. This finding was not supported by Adhikari, who measured from the thyroid cartilage to the skin at the level of the		maneuver and the use of convenience samples. There were also no ultrasound prototcol and variations of US training. Risk or harm if implemented: Some studies had limitations that were risk of bias. Feasibility of use in the project practice area: More studies should address limitations with a larger sample size.

				difference is attributed to the stylohyoid ligament's stationary affixing of the hyoid bone to the occiput.		vocal cords. Ezri found difficult laryngoscopies had neck thickness of 28 ± 2.7 mm compared to 17.5 ± 1.8 mm (p\0.001). Wu's findings support this marker with CLG III/IV having 13.0 ± 3.1 mm compared to easy grades measuring 9.2 ± 2.0 mm (p\0.0001)" (p. 526).		

APA Citation:

Gottlieb, M., Holladay, D., Burns, K. M., Nakitende, D., & Bailitz, J. (2020). Ultrasound for airway management: An evidence-based review for the emergency clinician. *The American journal of emergency medicine*, *38*(5), 1007–1013. https://doi.org/10.1016/j.ajem.2019.12.019

Conceptual Framework of Model	Design or Method	Sample & Setting	Major Variables Studied & their Definitions, if any	Outcome Measurement(s)	Data Analysis	Findings	Level of Evidence	Quality of Evidence: Critical Worth to Practice
Theoretical basis for the study: The basis of the study is to explore the use of point-of-care ultrasound (POCUS) in the	The authors searched PubMed and Google Scholar for articles using a combination of the keywords "ultrasound", "airway", "intubation", "cricothyrotomy", and "cricothyroidotomy". Authors included case reports	Number of Characteristics: n/a Exclusion Criteria: n/a Attrition: n/a	Independent variables: using POCUS for airway management in the ED - identifying difficult airways, confirming endotracheal	Scale(s) used: Reliability information (alphas, if any): Diagnostic accuracy: The accuracy of POCUS in identifying difficult airways can be measured by comparing the ultrasound measurements (e.g., distance from the skin to the thyrohyoid membrane, hyoid bone, or epiglottis) with the actual difficult airway	Statistical tests, if any: Qualitative analysis, if any: The diagnostic accuracy of each technique	Statistical findings, if any: n/a Qualitative findings, if any: n/a POCUS can be a useful tool for identifying difficult airways by measuring the distance from the skin to	Level V – evidence based review	Strengths: The study summarizes current POCUS for airway assessment, intubation confirmation, ETT depth assessment, and performing a cricothyroidoto

assessment and management of the airway in critically ill patients in the Emergency Department (ED). The study acknowledges that airway management is a common procedure in the ED, but it also recognizes that traditional physical examination maneuvers have limitations in evaluating and managing difficult airways.	and series, retrospective and prospective studies, systematic reviews and meta-analyses, clinical guidelines, and other narrative reviews. The literature search was restricted to studies published in English. Emergency Medicine physicians with experience in critical appraisal of the literature reviewed all of the articles and decided which studies to include for the review by consensus, with a focus on EMrelevant articles.When available systematic reviews and meta-analyses were preferentially selected, followed sequentially by randomized controlled trials, prospective studies, retrospective studies, case reports, and other narrative reviews when alternate data were not available.	Setting: ED	tube (ETT) placement, assessing ETT depth, and localizing the cricothyroid membrane. Dependent variables: identificatio n of difficult airways, confirmation of ETT placement, assessment of ETT depth, localization of the cricothyroid membrane	status determined by other means (e.g., direct laryngoscopy, intubation success). Confirmation of endotracheal tube (ETT) placement: The accuracy of POCUS in confirming the proper placement of the endotracheal tube in the trachea can be assessed by comparing the ultrasound findings with a gold standard method (e.g., visualization of ETT passing through vocal cords, end-tidal capnography). Assessment of ETT depth: The effectiveness of POCUS in determining the proper depth of ETT placement can be measured by comparing the ultrasound assessment (e.g., visualization of ETT cuff in the trachea, use of lung sliding and lung pulse sign) with the desired ETT depth based on patient characteristics and guidelines. Localization of the cricothyroid membrane: The accuracy and speed of POCUS in identifying the cricothyroid membrane can be evaluated by comparing the ultrasound localization with the traditional landmark-based approach or other reference methods.	is usually assessed by calculating sensitivity and specificity. Sensitivity measures the proportion of true positives correctly identified by the test (i.e., correctly identifying the correct ETT placement), while specificity measures the proportion of true negatives correctly identified (i.e., correctly identifying the incorrect ETT placement).	the thyrohyoid membrane, hyoid bone, or epiglottis. It can also predict ETT size better than age-based formulae. POCUS is highly accurate for confirming ETT placement in adult and pediatric patients. The typical approach involves transtracheal visualization but can also include lung sliding and diaphragmatic elevation. ETT depth can be assessed by visualizing the ETT cuff in the trachea, as well as using lung sliding and the lung pulse sign. Finally, POCUS can identify the cricothyroid membrane more quickly and accurately than the landmark-based approach.		my. Limitations: the studies used does not specify characteristics, the heterogeneity of the studies might have different populations, ETT sizes, also, there are different variabilities in technique application used. Risk or harm if implemented: n/a Feasibility of use in the project practice area: n/a

APA Citation: Mishra, P. R., Bhoi, S., & Sinha, T. P. (2018). Integration of Point-of-care Ultrasound during Rapid Sequence Intubation in Trauma Resuscitation. *Journal of emergencies, trauma, and shock*, *11*(2), 92–97. https://doi.org/10.4103/JETS.JETS_56_17								
Conceptual Framework of Model	Design or Method	Sample & Setting	Major Variables Studied & their Definitions, if any	Outcome Measurement(s)	Data Analysis	Findings	Level of Evidence	Quality of Evidence: Critical Worth to Practice
Theoretical basis for the study: The basis of the study is the importance of airway management, specifically in the context of trauma resuscitation. The study emphasizes the significance of promptly securing an adequate airway in trauma victims, as the majority of trauma deaths occur within the first hour after the incident, known as the "Golden Hour." The study aims to integrate POCUS into the standard RSI technique to enhance the effectiveness of	A prospective, randomized single-centered study was conducted in 100 trauma patients requiring emergent airway management, presenting to the ED. The time taken and efficacy of confirmation of tube placement is recorded and compared in two arms.	Number of Characteristics: 100 Exclusion Criteria: Patients in cardiac arrest, overt tracheal injury, open thoracic wound, patients requiring surgical airway, transfer-in patients with an existing endotracheal tube, pregnant patient (with	Independent variables: Use of Point of Care Ultrasound (POCUS) during Rapid Sequence Intubation (RSI) and method of confirmation to confirm EET placement through POCUS or examination Dependent variables: time taken to correct oesophageal intubation, the time taken to detect oesophageal intubation, potentially fatal conditions affecting emergency airway management, time taken for correct intubation Definition:	Scale(s) used: Reliability information (alphas, if any): Detection of airway complications: pneumothorax, tracheal tears, neck hematoma, and vascular injuries, time taken for primary survey: The outcomes include the duration of the primary survey and any statistically significant differences between the POCUS and clinical examination arms, tube placement confirmation: The outcomes include	Statistical tests, if any: Qualitative analysis, if any: Data was entered into Microsoft excel data sheet and analyzed using SPSS 22 version software. Categorical data was represented in the form of Frequencies and proportions. Continuous data was represented as mean and standard deviation. • Independent T test was used to	Statistical findings, if any: Qualitative findings, if any: In our study we found the mean procedure time for ETT placement was less in the PA arm compared to the CE arm (45 vs 91.36 seconds, $p<0.0001$). Oesophageal intubations were detected in the PA arm in 22	Level II - prospective, randomized single-centered study	Strengths: The study found that POCUS is useful for detection of Airway and Breathing problems such as neck hematoma and pneumothorax during the primary survey at the time of pre-oxygenation. It shortens the time taken for RSI by more rapid detection of ETT placement, oesophageal intubation and correction of the same if detected. Limitations: There is not a section on biasas or limitations or practical challenges in implementing

trauma resuscitation. By incorporating POCUS, the researchers seek to improve airway management, minimize complications, and ultimately improve patient outcomes in trauma cases.		positive urine on serum b -HCG) Attrition: same number but 2 groups Setting: hospital	Rapid Sequence Intubation (RSI) is identified as the cornerstone of emergency airway management and consists of three phases: preoxygenation, endotracheal tube placement, and confirmation of tube placement. Any delays in the latter two phases can lead to compromised patient outcomes.	the time taken to confirm correct tube placement, including distinguishing between endotracheal and esophageal placement. The study also compares the reintubation time in cases of oesophageal intubation, patient characteristics: gender distribution, age groups, mechanisms of trauma, and indications for RSI.	check for association between the mean values of variables in both groups of the study. Chi square was used to check for association of qualitative data. • Pearson correlation Test was used to analyse the correlation between continuous variables. • Graphical representation of data: MS Excel and MS word was used to obtain various types of graphs such as bar diagram and Scatter diagram.	seconds vs 114 seconds in CE arm with a $p< 0.0001$ and the time taken for effective reintubation was 26.67 vs 55 seconds in the PA and CE arm with a p value < 0.007 respectively.		POCUS during RSI in real-world settings. Risk or harm if implemented: n/a Feasibility of use in the project practice area: POCUS in RSI is noninferior to any of the above methods and suggests that it may even be superior to the conventional techniques as it has a shorter mean time for confirming ETT placement as well as for detecting certain adverse complications of RSI such as Oesophageal Intubations.

APA Citation: Özkurtul, O., Struck, M., Fakler, J., Bernhard, M., Seinen, S., Wrigge, H., Josten, C. (2019). Physician-based on-scene airway management in severely injured patients and in-hospital consequences: is the misplaced intubation an underestimated danger in trauma management? *Trauma surgery & Acute care open* 2019;4:e000271. doi: 10.1136/tsaco-2018-000271								
Conceptual Framework of Model	Design or Method	Sample & Setting	Major Variables Studied & their Definitions , if any	Outcome Measurement(s)	Data Analysis	Findings	Level of Evidenc e	Quality of Evidence: Critical Worth to Practice
Theoretical basis for the study: to evaluate the incidence of unrecognized tube malposition during out-of-hospital endotracheal intubation (ETI) in severely injured patients. The study aims to assess the potential mechanical complications and failures associated with ETI in emergency situations, where	In a retrospective study for all patients who underwent out-of-hospital ETI before admittance to a level 1 trauma center were analyzed consecutively. Patients with supraglottic airways, being under cardiopulmonary resuscitation and interfacility transports were excluded. The main study endpoint was the	Number of Characteristic s: 1176 Exclusion Criteria: Patient <16 years, Patients with supraglottic airways, being under cardiopulmon ary resuscitation and interfacility transports Attrition: 151 Setting: Germany, out-of-hospital emergency	Independent variables: type of tube misplacement , EMS physician training and experience, and use of video laryngoscopy. Dependent variables: Patient outcomes or neurological outcomes and Glasgow Outcome Scale (GOS) scores of the trauma patients. It is	Scale(s) used: Reliability information (alphas, if any): Prevalence of tube malpositions: The study investigates the incidence or prevalence of misplaced endotracheal intubations (ETIs) in major trauma patients admitted to a level I trauma center after out-of-hospital ETI by EMS physicians. The incidence of misplaced ETIs is reported to be 5.9%. Incidence of esophageal misplacements: The text highlights that esophageal misplacements are more likely to cause irreversible neurological sequelae and are often fatal due to inadvertent iatrogenic hypoxemia. The	Statistical tests, if any: Descriptive statistics was performed using numbers (percentage) and mean values (±SD). Computatio ns used SPSS V.20 (SPSS) for Windows using X2 test or Fisher's test for	Statistical findings, if any: Context of injuries were motor vehicle crash in 85.1%, falls from height in 10.4%, and 4.5% other trauma mechanisms. After hospital admission, 139 patients (92.1%) were classified as successfully intubated and in nine patients (5.9%) tube malpositions were recognized. Five	IIA: Retrospec tive cohort studies	Strengths: Approved by the ethics committee of the medical faculty of the university of Leipzig, there. There was no competing interest. Limitations: retrospective design may have caused study bias, small sample size, did not include patients undergoing alternative

time is critical, patient presentation may be poor, and the environment may be hostile. The researchers retrospectively analyzed patients who underwent out-of-hospital ETI before admission to a level 1 trauma center, excluding those with supraglottic airways, patients under cardiopulmonary resuscitation, and interfacility transports.	incidence of unrecognized tube malposition; secondary endpoints were Glasgow Outcome Scale (GOS) and in-hospital mortality adjusted to on-scene Glasgow Coma Scale (GCS), Injury Severity Score (ISS), Abbreviated Injury Scale head (AIS head), and on-scene time. Researchers analyzed all electronic and paper-based medical charts of patients who were admitted to our university emergency department (ED) with trauma team activation between January 1, 2011 and December 31, 2013.		used to assess the impact of tube misplacements on patient outcomes, specifically comparing patients with successful airway management to those with delayed or unrecognized misplacements.	reported incidence of unrecognized esophageal misplacements in out-of-hospital ETI ranges from <1% up to 16.7%. Neurological outcomes: The study compares the outcomes of patients with successful airway management to those with delayed or unrecognized tube misplacement. Patients with unrecognized tube misplacement had more unfavorable Glasgow Outcome Scale (GOS) scores, indicating poorer neurological outcomes. Survival and detection of tube misplacements: The text mentions that esophageal intubation can be survived when spontaneous breathing is warranted, but the use of paralytics and anesthetic drugs may impair or make spontaneous breathing impossible. The risk of tracheobronchial aspiration may also be increased when the tube is removed from the esophagus. The detection of tube misplacements is crucial, and direct laryngoscopy and ETI should be performed before removing an esophageally placed tube.	categorical variables. Normal distribution was tested using Student's t-test or Mann-Whitney test. Differences between the two groups were compared by using X2 test for categorical variables and the t-test for continuous variables. The significance level was set up at $p<0.05$. Multivariate analysis was not performed due to low sample sizes.	patients (3.3%) had esophageal malpositions and four patients (2.7%) had mainstem malpositions (three right side, one left side). Esophageal malpositions were associated with three fatal outcomes (60.0%) and two patients had a GOS score of 3 and 4, respectively). Four esophageal malpositions were detected during primary survey after connecting to capnography and in one patient after a whole-body CT scan.		airway devices or investigated rate of video laryngoscopy. Risk or harm if implemented: n/a Feasibility of use in the project practice area: further studies warranted to develop strategies for an improved endotracheal intubation by EMS providers

APA Citation: Sahu A, Bhoi S, Aggarwal P, Mathew R, Nayer J, T AV, Mishra P, Sinha T. (2020). Endotracheal tube placement confirmation by ultrasonography: A systematic review and meta-analysis of more than 2500 Patients. *Journal of Emergency Medicine*, 59(2):254-264. doi: 10.1016/j.jemermed.2020.04.040.								
Conceptual Framework of Model	Design or Method	Sample & Setting	Major Variables Studied & their Definitions, if any	Outcome Measurement(s)	Data Analysis	Findings	Level of Evidence	Quality of Evidence: Critical Worth to Practice
Theoretical basis for the study: The basis of the study is to evaluate the diagnostic accuracy of ultrasonography in confirming endotracheal intubation (ETI) compared to standard ETI confirmatory methods. The study recognizes that rapid and accurate ETI is crucial in managing	The systematic review was performed according to the Preferred Reporting Items for Systematic review and Meta-analysis for Diagnostic Test Accuracy studies (PRISMA-DTA). Databases including	Number of Characteristics: 8751 Exclusion Criteria: duplicate studies, patients with cardiac arrest, age <18 years, different outcomes, population, study design, or data not available. Attrition: 30 Setting: ED vs non-ED	Independent variables: IV1= accuracy of POCUS IV2= ETT confirmation method (capnography or fiberoptic) Dependent variables: accuracy or performance of ultrasonography (POCUS) in confirming ETT placement	Scale(s) used: Reliability information (alphas, if any): Sensitivity: The sensitivity of ultrasonography (POCUS) in confirming endotracheal tube (ETT) placement is reported as 0.982 (95% CI 0.971-0.988). Sensitivity measures the proportion of true positives correctly identified by the test, indicating how well POCUS can detect correct ETT positioning. Specificity: The specificity of	Statistical tests, if any: Qualitative analysis, if any: One reviewer extracted the data (RM) and a second reviewer (SB) verified the data independently. The methodologic quality of the study was assessed with the Quality Assessment of Diagnostic	Statistical findings, if any: Qualitative findings, if any: Thirty studies involving 2534 patients were selected for this metaanalysis. The estimated pooled sensitivity and specificity for ultrasonography were 0.982 (95% confidence interval [CI] 0.971–0.988) and 0.957 (95% CI 0.901–0.982), respectively. Subgroup analyses did not reveal significant difference	Level I: Systematic Review and Meta Analysis	Strengths: Bias was low for most of the parameters, Integration of POCUS was shown to be useful even in all phases of rapid sequence intubation, ie, the preoxygenation phase, the tracheal intubation phase, and the ETT confirmation phase Limitations: Studies did not mention the level of expertise, variability with training received, one study had publication bias.

critically ill patients, as incorrect intubation can lead to serious complications and even death. The incidence rate of esophageal intubation is significant, and early recognition of misplaced endotracheal tubes (ETTs) is essential.	PubMed, EMBASE, Cochrane Central, and Web of Science were searched from inception to October 2019.			ultrasonography (POCUS) in confirming ETT placement is reported as 0.957 (95% CI 0.901-0.982). Specificity measures the proportion of true negatives correctly identified by the test, indicating how well POCUS can identify incorrect ETT positioning. Accuracy: The accuracy of ultrasonography in detecting esophageal intubation using the double tract sign is reported as 98% sensitivity and 95% specificity. Accuracy refers to the overall correctness of the test results.	Accuracy Studies (QUADAS-2) tool. Two authors (AK and AV) performed the quality assessment separately, and disagreements were resolved by consensus in the presence of a third reviewer	by ultrasonographic sign used, location, the sonographer's specialty, transducer type, or ultrasound technique used. Ultrasound was also found to be a useful adjunct in confirming endotracheal tube position in the subgroup of patients with cardiac arrest, with sensitivity of 0.99 (95% CI 0.98–1.00) and specificity of 0.84 (95% CI 0.67–1.00), respectively.		Risk or harm if implemented: n/a Feasibility of use in the project practice area: future studies will need to clarify the performance of different ultrasonography signs.

APA Citation: Sotoodehnia, M., Abbasi, N., Bahri, R. A., Abdollahi, A., & Baratloo, A. (2023). Accuracy of airway ultrasound parameters to predict difficult airway using the LEMON criteria as a reference: A cross-sectional diagnostic accuracy study. *Turkish journal of emergency medicine*, *23*(1), 38–43. https://doi.org/10.4103/2452-2473.366484								
Conceptual Framework of Model	Design or Method	Sample & Setting	Major Variables Studied & their Definitions, if any	Outcome Measurement(s)	Data Analysis	Findings	Level of Evidence	Quality of Evidence: Critical Worth to Practice
Theoretical basis for the study: The conceptual framework of the study you described is to evaluate the accuracy of certain ultrasound (US) parameters in screening for a difficult airway using the LEMON criteria as a reference. The LEMON criteria is a scoring system used to assess the difficulty of intubation in patients. The	This was a cross-sectional diagnostic accuracy study in which people with at least 18 years old coming to the emergency departments for any reason who had consent for	Number of Characteristics: 299 Exclusion Criteria: Refusing the participation from completing the sonography, presence of unstable vital sign, or interference with other	Independent variables: US airway indexes, specifically hyo-mental distance (HMD), skin to epiglottis distance (EP), and peri-epiglottis space to epiglottis to vocal cord ratio (PEP/E.VC) Dependent variables: identificati	Scale(s) used: Reliability information (alphas, if any): Ultrasound (US) parameters: Hyo-mental distance (HMD): The linear distance measured in the ultrasound image from the hyoid bone to the mental symphysis (chin). Skin to epiglottis distance (EP): The linear distance measured in the ultrasound image from the skin surface to the epiglottis. Peri-epiglottic space to epiglottis to vocal cord ratio (PEP/E. VC): This is a calculated ratio based on measurements of the peri-epiglottic space, epiglottis, and vocal cords in the ultrasound image. LEMON score: The LEMON score variables were assessed	Statistical tests, if any: Qualitative analysis, if any: The researchers used Kolmogorov – Smirnov test and graphical approach, Q-Q plot, to assess the normality assumption of the variables. Qualitative variables were analyzed using the Chi-square test. For considering quantitative variables, independent t-test	Statistical findings, if any: Qualitative findings, if any: Based on LEMON score ≥2, 20 participants (6.7%) were categorized in difficult airway group. Comparison of the PEP/E. VC (P = 0.007) and EP distance (P = 0.049) of the participants based on LEMON score showed a statistically significant difference; but comparison of the means of HMD in the two	IV – prospective diagnostic accuracy cross sectional study	Strengths: the study used all 299 participants. Also, HMD, PEP/E.VC and EP were all measured on patients who went to the ED to measure difficult airway. The study concluded that PEP/E.VC can be used to distinguish difficult airway. Limitations: The study highlights the need for more accurate estimation of difficult airway prevalence in the emergency department (ED) compared to

study aimed to compare the US airway indexes (Hyo-mental distance, skin to epiglottis distance, and peri-epiglottic space to epiglottis to vocal cord ratio) with the LEMON score and determine their effectiveness in identifying difficult airway cases.	participati on, were enrolled with the simple random sampling method.	diagnostic process Attrition: 299 Setting: ED	on of difficult airway with LEMON score	for each participant, which include the following factors: Look externally (assessing for facial and neck features) Evaluate 3-3-2 rule (assessing for mouth opening and mandibular mobility) Mallampati score (assessing the visibility of the oropharyngeal structures) Obstruction (assessing for clinical signs of airway obstruction) Neck mobility Difficult airway classification: Participants were categorized into a difficult airway group based on a LEMON score of 2 or higher. Statistical analysis: Comparison of the US parameters (PEP/E. VC and EP distance) between participants based on LEMON score, assessing for statistically significant differences. Calculation of sensitivity, specificity, accuracy, and the best cutoff points for the US parameters in evaluating a difficult airway.	has been used for comparing the means of two groups and analysis of variance for comparing the means of three groups. Furthermore, the nonnormal distributed variable, we used of Kruskal–Wallis H and Mann–Whitney U test.	groups was not statistically significant (P = 0.144). The median of EP of the participants was 7.70 mm (interquartile range [IQR]: 6.70–9.40). The best cutoff point of EP distance for evaluating a difficult airway was 12.27 mm and more with the sensitivity of 35% and the specificity of 86.96% (accuracy = 0.614; 95% CI: 0.492–0.736). The median of PEP/E. VC was 1.01(IQR: 0.79–1.23). The best cutoff point of PEP/E. VC for evaluating a difficult airway was 0.88 and less with the sensitivity of 70% and the specificity of 67.38% (accuracy = 0.701; 95% CI: 0.583–0.818).		operating room settings. This is important for proper sample size calculation and generalizability of results. The study acknowledges potential selection bias and suggests including patients with truly difficult intubations in future studies. Risk or harm if implemented: Feasibility of use in the project practice area: further studies are needed to use PEP/E. VC and EP distance as a part of reliable indexes. For further studies, it can be underlined that these USG parameters can be used in combination with current criteria to create a novel scoring system to assess patients with difficult airway.

APA Citation: Sotoodehnia, M., Rafiemanesh, H., Mirfazaelian, H., Safaie, A., & Baratloo, A. (2021). Ultrasonography indicators for predicting difficult intubation: a systematic review and meta-analysis. *BMC emergency medicine*, *21*(1), 76. https://doi.org/10.1186/s12873-021-00472-w								
Conceptual Framework of Model	Design or Method	Sample & Setting	Major Variables Studied & their Definitions, if any	Outcome Measurement(s)	Data Analysis	Findings	Level of Evidence	Quality of Evidence: Critical Worth to Practice
Theoretical basis for the study: The basis of the study is the evaluation of ultrasound (US) indicators for the assessment of difficult airways in the context of rapid sequence intubation (RSI) in emergency departments (EDs). The study aims to investigate the performance of US in identifying patients with difficult intubation (endotracheal tube placement) compared to those	The study was conducted to systematically review studies that had assessed and compared US indicators in difficult and easy intubation group patients. The methods adopted for this systematic review and meta-analysis were consistent with the guideline of	Number of Characteristics: 17153 Exclusion Criteria: duplicated, no data or unrelated data, not full abstract, ASA class 1-III scheduled surgical/pregnant & morbid obesity Attrition: 26 Setting: ED	Independent variables: ultrasound indicators for difficult airway assessment during RSI: skin thickness at the epiglottis and hypid levels, the hyomental distance, and hyomental distance ratio Dependent variables: assessment of difficult airways and the performance of US indicators	Scale(s) used: Reliability information (alphas, if any): Skin thickness and soft tissue thickness: The study explores the correlation between increased anterior neck soft tissue thickness and difficult laryngoscopy. Measurements of skin thickness at the epiglottis and hyoid levels, as well as soft tissue thickness at the vocal cords, thyroid isthmus, suprasternal notch, hyoid bone, and epiglottis levels, were assessed to determine their significance in predicting difficult intubation.	Statistical tests, if any: Qualitative analysis, if any: The quality of the studies was assessed using the Quality Assessment of Diagnostic Accuracy Studies, version 2 (QUADAS-2). The meta-analysis was conducted based on the	Statistical findings, if any: Qualitative findings, if any: In three of these studies, the optimal cut-off point calculated was 1.62 (sensitivity = 89.7 and specificity = 64.8), 2.54 (sensitivity = 82.0 and specificity = 91.0) and 3.0 (sensitivity = 56.3 and specificity = 88.2). In the other one, accuracy indicators were reported, but the cut-off point was not. For thickness of the anterior neck soft tissue at the VC level, the AUC was reported as 0.47, 0.54 and	Level 1: Systematic review and Meta-analysis	Strengths: There is no bias noted and the level of evidence is strong. The researchers also narrowed down a large sample. Limitations: The US is operator-dependent and there was some variabilities dur to the level of operator expertise. The Cormack and lehane score is assessed in different conditions like the BURP maneuver and by different assessors.

with easy intubation.	Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) and the Cochrane book.			Hyo-mental distance (HMD) and Hyo-mental distance ratio (HMDR): HMD, which refers to the distance between the hyoid bone and mental symphysis (chin), is considered important for displacing the tongue during laryngoscopy. HMDR, calculated based on the hyomental distance and neck extension, remains constant and affects the line of view of the laryngeal structures. Pre-Epiglottic space (Pre-E) to Vocal Cord (VC) ratio: This ratio is calculated using an oblique view obtained through submandibular ultrasound. It bisects the epiglottis and posterior-most part of the vocal folds, and the ratio is used to predict difficult intubation.	random-effects model. The heterogeneity of the preliminary studies was evaluated using the I-squared, Tau squared statistics, and Cochran's Q test. The meta-analysis was performed in STATA statistical software, version 16.	0.85 in three studies. In one study with an unknown cutoff point, the sensitivity and specificity were reported as 53 and 66%, respectively For the anterior neck soft tissue at the hyoid bone level: the optimal cut-off point was calculated as 0.66 (sensitivity = 68.0 and specificity = 69.0) and 0.99 (sensitivity = 48.0 and specificity = 82.0) For ration of pre-epiglottic space (pre-E) and epiglottis VC (E-VC) distances: The AUC of this index was reported as 0.868 and 0.871 in two studies. In two studies, the optimal cut-off point was 1.77 (sensitivity = 82.0 and specificity = 80.0) and 1.77 (sensitivity = 82.0 and specificity = 80.0)..		Risk or harm if implemented: none Feasibility of use in the project practice area: While the systematic review and meta-analysis can be used to predict difficult airways, the study should be carefully assessed in other settings before making any recommendations. area:

APA Citation:

Srinivasarangan M, Akkamahadevi P, Balkal VC, Javali RH. (2021). Diagnostic accuracy of ultrasound measurements of anterior neck soft tissue in determining a difficult airway. *J Emerg Trauma Shock*.14:33-7. doi: 10.4103/JETS.JETS_12_20								
Conceptual Framework of Model	Design or Method	Sample & Setting	Major Variables Studied & their Definitions, if any	Outcome Measurement(s)	Data Analysis	Findings	Level of Evidence	Quality of Evidence: Critical Worth to Practice
The conceptual framework of the study you described revolves around the use of ultrasound measurements of anterior neck soft tissue to identify a difficult airway in patients requiring intubation in the emergency department. The researchers aimed to examine the association between these ultrasound measurements and the Cormack-Lehane grading, which is a	The researchers conducted a prospective study over a period of 18 months in the emergency medicine department. Patients requiring intubation were included in the study.	Number of Characteristics: unknown Exclusion Criteria: Patients requiring crash intubation, pts having open injuries on the neck, facial fractures, maxillofacial tumors, patients with known airway pathology, uncooperative patients, pregnant patients, abnormal dentition.	Independent variable: Ultrasound measurements of anterior neck soft tissue at three levels: thyrohyoid membrane, hyoid bone, and vocal cords. Dependent variable: Difficulty of airway management as indicated by the Cormack-Lehane grading.	Scale(s) used: Reliability information (alphas, if any): Thickness of anterior neck soft tissues at the level of the hyoid bone: Measured in centimeters (cm). Reported mean thickness for difficult patients. Reported mean thickness for easy patients. Presented with corresponding 95% confidence intervals for both groups. Thickness of anterior neck soft tissues at the level of the thyrohyoid membrane: Measured in centimeters (cm). Reported mean thickness for difficult patients. Reported mean thickness for easy patients. Presented with corresponding 95% confidence intervals for both groups. Thickness of anterior neck soft tissues at the level of the vocal cords:	Descriptive statistics, such as mean, standard deviation, frequency, and percentage, were used to summarize the data. Inferential statistics, including Student's t-test and receiver operating characteristic (ROC) curve analysis, were conducted	Statistical findings, if any: Qualitative findings, if any: The thickness of anterior neck soft tissues at the level of hyoid bone in difficult patients was 0.73 cm (95% confidence interval = 0.65–0.80) compared to easy patients 0.47 cm (95% confidence interval = 0.44–0.51) with a P = 0.001 and at the level of thyrohyoid membrane in difficult patients it was 1.83 cm (95% confidence interval = 1.7–1.89) compared to easy patients 1.46 cm (95% confidence interval = 1.41–1.51) with a P = 0.001. Area under the ROC curve was significant at all the three levels with	V - observational study	Strengths – the topic focuses on ED patients who requires endotracheal intubation. Limitations – the study did not include the original number of characteristics, patients who were uncooperative were excluded. Feasibility of use in the project practice area: This was a single-center study. Larger studies involving populations from different geographical regions will be required to shed light on the appropriate cutoff values of

classification system used to assess the view of the vocal cords during laryngoscopy.		Attrition: 60 Setting: ED		Measured in centimeters (cm). Reported mean thickness for difficult patients. Reported mean thickness for easy patients. Presented with corresponding 95% confidence intervals for both groups.	using SPSS software (version 22).	the highest at the level of thyrohyoid membrane 0.99 and least at the level of vocal cords 0.79, the area under the curve was 0.92 at the level of hyoid bone.		anterior neck soft-tissue thickness by point-of-care ultrasound for the prediction of difficult airway.