Spring 4-18-2023

Final Scholarly Project: Evidence-based Practice Guidelines for the Optimal Assessment of the Airway in Predicting Difficult Intubation

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2023

In Partial Fulfillment of the Requirements for the Degree Doctor of Nursing Practice

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Abstract

Adverse respiratory events are the most common injuries in anesthesia; difficult intubation and ventilation contribute to most cases. Injuries following inadequate airway management include cerebral hypoxia, aspiration, and cardiac arrest. Despite the risk and consequences following inadequate airway management, most medical facilities lack standardized airway assessments for anesthesia providers. Current evidence implicates that ultrasound measurement of the hyomental distance demonstrates the highest specificity and accuracy in predicting difficult intubation. The traditional approach to conducting airway assessments includes Mallampati classification, which shows high specificity for predicting difficult airways only when combined with other airway assessments. The purpose of this evidence-based project is to recommend clinical guidelines for standardized airway assessments with the combined use of ultrasound and Mallampati classifications. The Johns Hopkins Nursing Evidence-based Model will guide the project team through project planning, development, completion, and dissemination. A literature review, analysis, and critical appraisal of available evidence will be conducted to support recommendations regarding clinical practice protocols for airway assessments utilizing ultrasonography and Mallampati classifications. Project facilitators will engage with anesthesia providers using pre and post-implementation surveys and provide formal ultrasound training. Ultrasound evaluation for airway management is a new addition to preoperative airway assessments that will allow anesthesia providers to revolutionize patient care and reduce perioperative morbidity and mortality. Guidelines for standardized airway assessments have been established and will be recommended to the hospital of interest for review, discussion, and determination regarding the potential for implementation.

Key words: airway, difficult, intubation, ultrasound, laryngoscopy, preoperative, adult

Evidence-based Practice Guidelines for the Optimal Assessment of the Airway in Predicting Difficult Intubation

Introduction

Clinical Problem

The Texas Society of Anesthesiologists states that forty million anesthetics are performed in the United States each year; anesthesia providers are uniquely responsible for the medical and anesthetic management of the patient throughout said procedures. With every anesthetic performed, there is a degree of risk for injury that varies from patient to patient. Information from the American Society of Anesthesiologists (ASA) Closed Claims Study reveals that adverse respiratory events are the most common type of injury, with difficult intubation and ventilation contributing to most cases (Fayed et al., 2022). Despite this claim, many medical facilities lack a standardized airway assessment for anesthesia providers to perform in the preoperative setting.

One responsibility of anesthesia providers is to maintain control of the patient's airway during the preoperative, intraoperative, and postoperative environments; because of such responsibility, CRNAs and anesthesiologists endure extensive training and clinical experience to become proficient in airway management. Effective airway management requires the provider to exhibit adequate assessment skills. Additionally, appropriate airway management includes developing a plan of action to predict and manage difficult airways safely; one major component of developing airway management plans is understanding how to safely proceed when the initial plan fails (Nagelhout & Elisha, 2018). Algorithms set in place by the ASA using evidence-based research determine how to safely proceed in airway emergencies, such as "can't intubate, can't ventilate" scenarios. Anesthesia providers are trained to be proficient in such algorithms.

The ASA defines a *difficult airway* as a scenario in which a trained anesthesiologist

experiences difficulty with mask ventilation or tracheal intubation (Workeneh et al., 2017). Factors that contribute to the likelihood of difficult intubation include comorbidities, body habitus, airway anatomy, and patient history; gender, BMI, age, neck mobility, inter-incisor gap, facial structure, Mallampati classification III and IV, decreased hyomental distance, and decreased thyromental distance also precede difficult intubation (Dabija et al., 2019). Conclusively, difficult airways can be both predictive and unexpected.

Problem Statement

Although encountering difficult intubations is less common than other surgical complications, the consequences of an unsecured airway or inability to ventilate are detrimental. Various studies claim that the incidence of difficult intubation ranges from 9% to 16% in the perioperative setting and 20% in intensive care units and emergency departments (Harjai et al., 2021). Conclusively, up to 36% of difficult airway incidents occur in a hospital setting, yet protocols for standardizing airway assessments are not in place. Various mechanisms of injury follow inadequate airway management, including cerebral hypoxia, aspiration, inadequate ventilation, airway trauma, and endotracheal tube complications; additionally, patients who are not adequately ventilated can suffer from hypoxic brain injury, multisystem organ failure, and cardiac arrest (Nagelhout & Elisha, 2018). Current literature recommends that it is imperative to identify appropriate patients at risk, have a plan of action, and perform relevant patient physical exams to optimize outcomes for safe airway management (Dabija et al., 2019). In addition to the recommendations from the literature, standardized airway assessments should be performed by anesthesia providers in the preoperative setting.

Relevance to Anesthesia

Failure of airway management in anesthesia is a significant contributor to patient

morbidity and mortality. Preventable adverse outcomes including airway trauma, brain damage, and death follow inadequate airway management. The ASA Closed Claims Study found that three specific mechanisms of injury accounted for three-fourths of the adverse respiratory events: inadequate ventilation (196 patients; 38%), esophageal intubation (94 patients; 18%), and difficult tracheal intubation (87 patients; 17%); death or brain damage occurred in 85% of cases (Fayed et al., 2022). Of the adverse respiratory events documented, the most common include inadequate oxygenation or ventilation, difficult intubation, and aspiration. Lawsuits filed for adverse respiratory events typically result in high payouts, with one article noting that 85% of airway management claims settle at high values (Schulz et al., 2018). Anesthesia is directly responsible for airway management and may be held accountable in such high-value claims.

Another study conducted by Joffe et al., 2020 evaluated difficult intubation claims from 2000 to 2012 for adequate airway management and preoperative indicators of difficult laryngoscopy. Of the 97 claims filed, inappropriate airway management occurred in 76% of the cases. Prospectively, patient outcomes in recent malpractice claims were poor, and inadequate airway planning and judgment errors contributed to patient harm. Poor clinical judgment, suboptimal preparation, diminished situational awareness, and incompleteness of utilizing the ASA Airway Algorithm directly correlate to adverse outcomes, with death and hypoxic injury occurring once in 22,000 cases in a database of 2.9 million general anesthetics (Traylor & McCutchan, 2021). Notably, most of these adverse outcomes are preventable with adequate preparation and patient assessment.

Anesthesia providers engage in bedside physical examinations in the preoperative area to formulate a strategic anesthetic plan; however, even anatomically normal patients continue to pose the risk of an unanticipated difficult airway. Therefore, an airway evaluation and

assessment should be a standardized and systematic approach performed on all patients to ensure minimal risk in the perioperative setting (Nagelhout & Elisha, 2018). Reducing the morbidity and mortality experienced by surgical patients starts with the implementation of evidence-based, standardized airway assessments for all surgical patients.

Project Objectives

Standardizing an airway assessment enables providers to promote patient safety, therefore, creating positive patient outcomes; implementation of such standards takes time, appropriate planning, financial considerations, and adjustment of guidelines in the absence of success. Nevertheless, the evidence clearly demonstrates the need for standardizing preoperative airway assessments. The significance of reducing adverse patient outcomes will ultimately lower the claims made against anesthesia providers for adverse respiratory events.

The overall goal of the DNP (Doctor of Nursing Practice) project is to provide recommendations for standardized preoperative airway assessments for anesthesia providers constructed through evidence-based guidelines of ultrasound use in airway evaluation. Enacting evidence-based guidelines includes identifying objective clinical evidence that ultimately reforms standards of practice (Moran et al., 2020). Additionally, the DNP project will analyze the effectiveness of basic compared to advanced preoperative airway assessments and determine their clinical value. The objectives of the doctoral project are as follows:

1. Identify evidence-based practice guidelines from the literature for advanced ultrasound airway assessment use in the preoperative setting.
2. Develop a comprehensive plan to implement advanced ultrasound airway assessment in the preoperative setting.
3. Develop a comprehensive plan to monitor and measure ultrasound assessment use.

4. Develop a comprehensive plan to adjust the guidelines as needed.

Research analysis will aid in developing evidence-based guidelines for advanced airway assessments, including reliable ultrasound parameters, difficult airway anatomy, and difficult airway risk factors. Financial impact, patient billing, ethical considerations, limitations, and project feasibility will be extensively explored with the implementation of standardizing advanced airway assessment in the preoperative area. Additionally, a survey will be utilized to gauge the current level of ultrasound experience and provide meaningful feedback from the anesthesia providers (Appendix A). Finally, a post-implementation survey will reflect on efficacy, efficiency, and overall project concerns (Appendix B).

Background

Difficult Airway Significance

Understanding the significance of difficult airways in anesthesia is imperative because airway management is a fundamental skill of advanced providers. Anesthesia providers experience extensive clinical training to build skills that promote airway management competency. According to the ASA, *a difficult airway* is when an appropriately trained CRNA, anesthesia provider, or anesthesiologist experiences difficulty with intubation, mask ventilation, or both (Workeneh et al., 2017). Because all patient airways are anatomically different, even seemingly easy airways can be difficult to manage by experienced providers.

There are various terms used by anesthesia providers to describe a challenging airway. Nagelhout & Elisha, 2018, synonymously refer to a difficult airway as an *unexpected failed airway*. An unexpected failed airway is an airway previously evaluated with no external identifiers indicating difficulty; there is no anticipation of inability to mask ventilate, perform laryngoscopy, or endotracheal intubation, yet difficulty occurs after the patient is anesthetized

(Nagelhout & Elisha, 2018, p. 410). The two definitions of difficult airways are similar in that the provider experiences issues with adequate airway management, which can lead to death, brain damage, ICU admission, prolonged recovery, emergency surgical airway, and trauma to the airway and teeth (Workeneh et al., 2017). These complications require high levels of care and additional costs, affecting both the patients and healthcare facilities.

The responsibility of anesthesia providers to manage airways in various scenarios led to the development of airway management guidelines. The ASA provides standard recommendations supported by synthesis and analysis of current literature, expert opinion, open forum commentary, and clinical feasibility data referred to as the "ASA Practice Guidelines for Difficult Airway Management" (Apfelbaum et al., 2022). These guidelines direct the management of patients with difficult airways, optimize first-attempt success of airway management, improve patient safety during airway management, and minimize adverse outcomes (Apfelbaum et al., 2022). The most updated ASA guidelines are displayed in Appendix D; however, the goal of integrating ultrasound into preoperative airway assessments is to identify difficult airways early and prepare for them appropriately ahead of time.

Difficult Airway Risk Factors

The ASA recommends three approaches in the evaluation of an airway: evaluation of the airway history, physical examination, and additional evaluation in patients with anticipated airway difficulty. The patient's history and physical exam can help reveal risk factors for a difficult airway, including age, obesity, obstructive sleep apnea (OSA), and snoring. Difficult intubation can also occur in patients with mediastinal masses and congenital disease states, including ankylosing spondylitis, degenerative osteoarthritis, subglottic stenosis, tonsillar hypertrophy, Treacher Collins Syndrome, Pierre Robin Syndrome, or Down Syndromes (Dabija

et al., 2019). Historically, increased fat distribution in the anterior neck, elevated BMIs, and Mallampati grades (MPG) III and IV are statistically significant difficult airway risk factors; Harjai et al., 2021, also found that patients with an inter incisor gap of less than 4 cm are associated with difficult laryngoscopy. These examples are common assessment findings that anesthesia providers often note during preoperative airway evaluations.

Special patient populations can also present with seemingly difficult airway assessments. Patients with tumors, obstructing lesions, patients who are post-radiotherapic, obese patients, and patients with OSA are at an increased risk for difficult laryngoscopy (Abraham et al., 2018). Radiation therapy causes fibrosis and edema of the airway, resulting in decreased mouth opening, increased oropharyngeal bleeding, and increased tissue friability (Abraham et al., 2018). Ultimately, repeated radiation therapy induces numerous changes to the airway, often leading to difficult intubation.

Understanding Ultrasound

Ultrasound (US) uses the transmission and reflection of mechanical energy to generate electrical energy in the form of an image. The US uses piezoelectric crystals inside the head of a transducer that travels through tissues at a certain speed; these crystals generate vibrations, or mechanical energy, that echo back at the boundaries of the tissue and convert to electrical energy, which can be viewed as an image of the tissue or visible structure (Carmody et al., 2017). Ultrasound frequency refers to the number of wavelengths per second; the standard medical ultrasound applications utilize frequencies of 2-20 megahertz (Carmody et al., 2017). Understanding frequency is imperative to using ultrasound to accurately assess different anatomical structures. Ultrasound technology has grossly developed over the years, increasing in accuracy and ability to visualize deep anatomical structures.

Different US transducers are used for viewing various structures within the body; for example, the transducer that views vasculature compared to the one that views a fetus are different. The orientation of the piezoelectric crystals within the head of the transducer differentiates them, which is useful for generating frequencies necessary for deep versus superficial structures, structures within an endocavity, and structures that are moving (Carmody et al., 2017). Most medical US machines have three transducers, also referred to as *probes*; a straight linear array probe, used for superficial structures, vascular imaging, and ultrasound-guided vascular techniques; a curvilinear array probe, used for deep structures within the abdominal wall or pelvic apparatus; a phased array probe, used for cardiac imaging, imaging between the ribs, and some fetal monitoring (Carmody et al., 2017). Choosing the appropriate probe for the appropriate anatomical structure is imperative to obtain an accurate US image. The straight linear probe is the most appropriate probe to use for airway assessments because the landmarks to measure hyomental distance are grossly superficial.

With the accessibility and affordability of ultrasound equipment, many providers utilize Point-of-Care ultrasound (POCUS), which refers to ultrasound in aid of diagnostics and treating patients. POCUS enhances assessment of endotracheal tube placement, cardiac function, pulmonary function and anatomy, aspiration risk, and hemodynamics (Naji et al., 2021). Ultrasound technology offers many benefits, as it is a low-cost, easily portable device that can extend advanced practice providers' physical assessments for numerous clinical settings. Because of the ultrasound's ease of use, portability, and affordability, many medical facilities own multiple devices for provider use, and some own their own personal ultrasound apparatus.

Basic Airway Assessment

Current literature states that typical preoperative airway assessments include the modified

Mallampati grading (MPG), mouth opening, thyromental distance assessment, atlanto-occipital extension, jaw protrusion, and the upper lip bite test. However, these clinical assessments have low predictive value for correlating with the Cormack-Lehane (CL) grade observed during direct laryngoscopy (Rana et al., 2019). For reference, the CL grading system is an objective assessment that describes what structures are visible during laryngoscopy, including the glottis, vocal cords, arytenoids, epiglottis, and soft palate (Nagelhout & Elisha, 2018). Patients are given a CL score of one through four based on the structures visibly noted.

Despite low predictability, many providers continue to use the MPG as it is one of the most used tools in pre-anesthetic assessments (Yadav et al., 2020). The Mallampati grading scale compares the size and position of the tongue relative to the size of the patient's oral cavity (Nagelhout & Elisha, 2018). The patient receives a score, I-IV, based on the pharyngeal appearance relative to internal structures; in patients with a Mallampati I, the soft palate, anterior and posterior tonsillar pillars, and uvula are visualized; in Mallampati II patients, the soft palate and uvula are visualized; in Mallampati III patients, the soft palate and base of the uvula are visualized; in Mallampati IV patients, only the hard palate can be visualized (Yadav et al., 2020). To summarize, the more structures visible within the patient’s mouth, the easier the intubation should be due to an increased ability to displace the tongue and lift the epiglottis for vocal cord visualization.

There are many limitations to using the MPG, as the grading depends heavily on patient compliance and body position during the assessment. In a prospective study on patients undergoing endotracheal intubation, MPG was inadequate as a single test to predict difficult tracheal intubation but may be part of a combined model of clinical tests in the prediction of a difficult airway (Yadav et al., 2020). Additionally, a 2013 systematic review and meta-analysis

reported that Mallampati tests have limited accuracy for predicting the difficult airway and thus are not useful screening tests (Roth et al., 2019). The limitations of using Mallampati classifications as a sole assessment tool contribute to the increased likelihood of adverse respiratory events in the perioperative setting and, therefore, should not be used in determining the potential for difficult laryngoscopy.

Conclusively, adequate management of difficult airways is imperative in promoting safety and reducing adverse outcomes; traditional airway assessments used by anesthesia providers demonstrate poor sensitivity and specificity with low predictive values. Although anesthesia providers commonly use standard assessment methods like the Mallampati classifications, they are inefficient assessment tools and do not promote patient safety. Therefore, standardization of an appropriate and accurate preoperative airway assessment is necessary. Ultrasound proposes promising results in the preoperative prediction of difficult laryngoscopy.

Literature Review

PICO Question

Evidence-based questions use the PICO format as a framework to effectively answer a clinical question. The components of a PICO question include a population, intervention, comparison, and outcome (Moran et al., 2020). The population includes adult surgical patients who will need endotracheal intubation for an elective surgical procedure. The intervention pertains to using an ultrasound assessment of the airway, compared to performing a Mallampati assessment. Finally, the outcomes seek to predict the incidence of difficult intubation in the operating room. This doctoral project will address the following PICO question: In adult, elective surgical patients requiring endotracheal intubation **(P)**, does a preoperative ultrasound

airway assessment **(I)** compared to a Mallampati assessment **(C)** predict the difficulty of intubation in the operating room **(O)**.

Databases

Literary evidence relevant to the PICO question was found using Otterbein University's OneSearch through the Courtright Memorial Library; OneSearch is a compilation of scholarly journals, textbooks, and articles that provide literature reviews, randomized controlled trials, meta-analyses, and systematic reviews with other search engines. OneSearch enables searches through multiple databases, including Cumulative Index to Nursing and Allied Health Literature (CINAHL), PUBMED, and Cochrane Library. Additionally, utilizing Boolean Operators allows for the combination or elimination of terms to narrow relevant results. A literature review regarding basic and ultrasound airway assessments was conducted to analyze and identify the most evidence-based clinical guidelines for each respective airway assessment. The search terms and analysis summary are included and extensively synthesized below; ultimately, the data either supports, opposes, or renders inconclusive to the PICO question.

Literature Search Terms

The initial search using the key terms and Boolean operators "airway AND anesthesia AND ultrasound" yielded 40,316 results. The search was modified to scholarly, peer-reviewed articles from 2017- now; this yielded 9,538 results. The phrase "AND difficult" was added to the search, yielding 5,412 results. Again, the search was minimized by adding "AND prediction," resulting in 1,372 articles. Furthermore, the search "airway AND anesthesia AND ultrasound AND difficult AND prediction AND adult AND endotracheal tube AND intubation AND management" yields 265 results. Search terms "AND adult" was modified to "adult patients" due to the high volumes of articles, including pediatric studies; this change rendered 184 results. The

final search utilized the following phrases: "preoperative AND assessment AND laryngoscopy AND view," which conclusively produced 67 results.

Of the 67 total articles found from the literature search, six were disregarded because they were pediatric cases; five articles were eliminated due to exclusively including obese patient populations; nine articles were eliminated as their subjective matter was unrelated to the use of preoperative ultrasound airway assessments and only covered emergent airway management; one article was eliminated because it evaluated three-dimensional printing of airways using ultrasound measurements; one article discussed the use of ultrasound with laryngeal-mask airway (LMA) placement. Several results of the search included meeting abstracts that were determined invalid for use as they were non-specific, non-scholarly reports from anesthesiology departments across the United States; three articles were eliminated because their patient population was only specific to trauma patients; similarly, seven articles were impractical as they considered specific patient populations including cardiac procedures, endoscopic procedures, patients in the intensive care unit (ICU), thyroid-specific cases, and patients in acute respiratory distress syndrome (ARDS). After a review of the 67 articles resulting from the search, 16 articles were extensively analyzed in the evidence of ultrasound use in preoperative airway assessments.

Summary of Analysis

Unanticipated difficult endotracheal intubations are the most common cause of anesthesia-related morbidity and mortality claims. To prevent adverse outcomes for patients, various preoperative airway examinations evaluate for potentially difficult intubation prior to the surgical procedure (El-Radaideh et al., 2020). However, no single test best determines difficult airway predictability. Based on the literature, advanced preoperative airway assessments, compared to basic preoperative airway assessments, more accurately predict the likelihood of

encountering an unexpected~~ly~~ difficult airway during laryngoscopy.

The literature review compares advanced airway assessment techniques (ultrasound) to basic airway assessment techniques (Mallampati grading scale) in predicting difficult intubation. Substantial analysis concurs that the Mallampati scale is grossly non-specific in predicting difficult airways, while ultrasound is a highly specific, noninvasive tool for the preoperative evaluation of difficult airways (Daggupati et al., 2020). Preoperative airway assessment tests should be quick, cost-effective, and easy to perform at the bedside with high sensitivity, specificity, and positive predictive value.

Unfortunately, clinical assessments currently utilized by anesthesia providers are non-specific and often do not accurately predict difficult laryngoscopy. Common assessment techniques utilized by providers include the Mallampati grading scale, thyromental distance, upper lip bite test, and range of motion of the jaw and cervical spine (Abraham et al., 2018). Ultrasound is a safe, non-invasive, imaging modality used in the perioperative setting with high predictive value for difficult laryngoscopy.

Systematic Reviews & Meta-analysis

A systematic review and meta-analysis performed by Gomes et al., 2021., synthesized evidence from the existing literature to determine ultrasonographic predictors of difficult laryngoscopy and difficult tracheal intubation in anesthetized adult patients undergoing elective surgery. The review aimed to establish a standardized ultrasound protocol through summarized current knowledge and applicability of the sonographic measurements previously trialed. Gomes et al., 2021, used databases including PubMed, Web of Science, and Embase, utilizing Boolean operators and organizing the search results into a Microsoft Excel datasheet.

The review determined several parameters are significant in predicting difficult

laryngoscopy, including distance from skin to the hyoid bone, distance from skin to the epiglottis, distance from skin to vocal cords, distance from skin to the anterior aspect of the trachea at the level of suprasternal notch, condylar translation, hyomental distance (HMD), tongue cross-sectional area and volume, thickness and ratio of tongue thickness, pre-epiglottic area, and visualization of hyoid bone with sublingual US approach (Gomes et al., 2021). For reference, the HMD is the distance from the hyoid bone to the mentum. Results proved that hyomental distance is the best indicator for clinical practice, and ultrasonography is a useful tool for predicting difficult laryngoscopy.

Sotoodehnia et al., 2021 conducted a systematic review and meta-analysis to review studies that had compared US indicators for difficult intubation; a comprehensive search PubMed, ISI's Web of Science, SCOPUS, and Embase examined 45 ultrasound indicators for predicting difficult intubation. The results dictate that HMD, HMDR (hyomental distance in ramped to neutral position ratio), and the skin thickness at the epiglottis and hyoid levels correlate with difficult laryngoscopy. The authors also note the availability, applicability, and ease in which ultrasound can be learned and applied to imaging in predicting difficult airways. Therefore, ultrasound measurements of the HMD are feasible for the application of standardized airway assessment guidelines.

Prospective Double-blinded Study

In a prospective, double-blinded study conducted by Parameswari et al., 2017, preoperative ultrasound assessments of the airways were performed on 130 patients undergoing general anesthesia and endotracheal intubation to predict difficult intubation and identify correlations with the CL grade observed during laryngoscopy. The patients ranged in age from 18-60 years old, and Mallampati classifications and CL gradings were recorded for each patient.

The patients were classified as anticipated easy or difficult laryngoscopy based on the Mallampati and ultrasound parameters. The study's results showed the Mallampati classification was most sensitive of the clinical predictors in anticipating difficult laryngoscopy; of the ultrasonographic predictors, skin to epiglottis distance was most sensitive and most specific in predicting difficult laryngoscopy. Therefore, the study concludes that ultrasound can be used to predict difficult airways preoperatively, in addition to the Mallampati classification.

Prospective Clinical Studies

In a prospective clinical study conducted by Abraham et al., 2018, 137 patients undergoing surgery requiring endotracheal intubation were evaluated using US to determine the predictability of difficult laryngoscopy. Anatomical structures including visualization of the hyoid bone, visualization of vocal cords through thyroid cartilage, visualization of the epiglottis, distance from the base of the tongue to the hyoid bone, the distance of hyomental region distance of thyrohyoid region, distance between skin and fat pad thickness to the thyroid cartilage, the thickness of submental region, distance from the epiglottis to the skin, and visualization of the cricothyroid membrane, were viewed in all patients (Abraham et al., 2018). Conclusively, 127 patients did not have difficult airways per the US airway scans and directly correlated to the CL grading with easy laryngoscopy; the other ten patients were expected to be difficult intubations according to their ultrasound assessments and had grade II-IV views observed during laryngoscopy (Abraham et al., 2018).

The results of the clinical study support the use of ultrasound of the airway preoperatively as it accurately predicts the incidence of difficult intubation and suggests that ultrasonography is a safe, non-invasive tool well tolerated by the patients without risk of radiation (Abraham et al., 2018). The study also demonstrates that ultrasound accurately correlates with CL grading

obtained during laryngoscopy.

Daggupati et al., 2020, conducted a prospective observational study with 310 patients between the ages of 18 and 65 years old undergoing surgery with general anesthesia and tracheal intubation using direct laryngoscopy. The study utilized US measurements including mentohyoid distance, mandibular subluxation grade, head extension grade, and mean skin to epiglottis distance (Daggupati et al., 2020). Conclusively, difficult intubation was observed in 62 of the 310 patients (20%) that accurately aligned with a CL grade of III and IV. The study's results helped to determine that the combined use of ultrasound measurements and clinical predictors are helpful in the prediction of difficult intubation.

A prospective and randomized study conducted by Sabaa et al., 2019, evaluated ultrasound to visualize the hyoid bone, measure the HMD in the extended position, measure the distance from the epiglottis to the midpoint of the distance between the vocal cords, and assess gas exchange during positive pressure ventilation after induction of anesthesia and muscle relaxation. The results showed a statistically high correlation between the HMD and the CL grade with difficult laryngoscopy, as well as the measurement of the thyromental distance. Sabaa et al., 2019, declared that airway ultrasound measurements of HMD should be performed on all surgical cases, and argue ultrasound is superior to standard airway assessments. The statistical analysis resulting from the study supports the statement that ultrasound is a sensitive and specific tool for prediction of difficult airway.

Yadav et al., 2020, conducted a prospective and observational study of 200 patients categorized based on CL grading observed during laryngoscopy. Ultrasound parameters including the anterior neck soft-tissue thickness at the level of vocal cord (ANS-VC), ANS tissue thickness at the level of the hyoid, and the ratio of the depth of pre-epiglottic space to distance

from epiglottis to midpoint of the distance between vocal cords, in addition to the modified Mallampati class, thyromental distance, and HMDR were analyzed in the participating patients (Yadav et al., 2020). Of the ultrasound parameters tested, ANS-VC was determined a better predictor for difficult airways than clinical parameters like MPG; the study also notes that using ultrasound to measure HMDR has a high specificity and accuracy, which allows anesthesia providers to be adequately prepared for difficult airways in patients exhibiting decreased HMDR values.

A prospective observational study conducted by Gupta et al., 2022, included 120 patients undergoing endotracheal intubation and general anesthesia to evaluate ultrasound parameters in predicting difficult laryngoscopy in adult patients. The ultrasound parameters utilized included pre-epiglottic space (PES), HMD, distance from skin to the hyoid bone-skin (DSHB), and distance from skin-to-epiglottis midway between the hyoid bone and thyroid cartilage distance from skin to epiglottis midway (DSEM). CL grading was used for describing laryngoscopy, with grades I and II correlated with easy intubation, and grades III and IV with difficult intubation (Gupta et al., 2022). The study found that difficult laryngoscopy occurred in 22.5% of patients, and HMD showed the highest predictability of difficult airway of the ultrasound parameters (Gupta et al., 2022). Using ultrasound to identify patients at risk for difficult intubation, measuring soft-tissue thickness of the anterior neck, and measuring HMD prove essential for accurate prediction of difficult intubation.

Unanticipated difficult endotracheal intubations are the most common cause of anesthesia-related morbidity and mortality. Therefore, it is imperative to identify clinical assessments that are efficient and non-invasive to perform during a preoperative evaluation to accurately predict difficult laryngoscopy with high sensitivity and specificity. The literature

analysis demonstrates that a combination of clinical assessments and ultrasound measurement of the HMD is the most valuable for identifying unanticipated difficult airways.

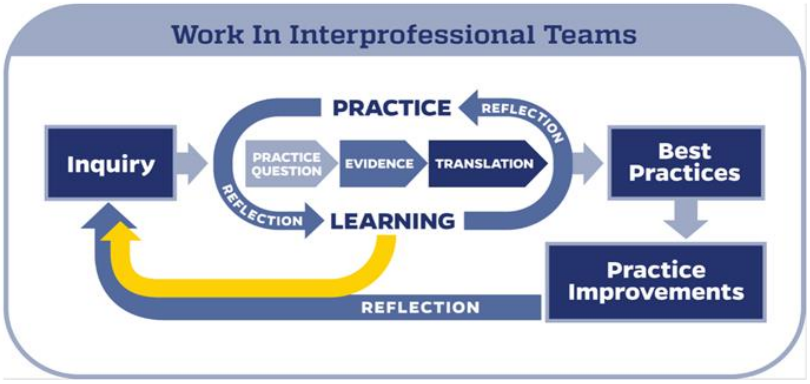
Evidence-based Practice Model

Johns Hopkins Evidence-Based Practice Model for Nurses and Healthcare Professionals

The Johns Hopkins Evidence-Based Practice for Nurses and Healthcare Professionals (JHNEBP) Model is a clinical decision-making tool for clinical and academic uses to enhance team coordination and incorporate evidence-based data to reform standard clinical practices (Dang et al., 2022). Permission to utilize the JHNEBP model was obtained on June 26, 2022, through electronic submission to the Johns Hopkins University Hospital. ~~Figure 2 depicts~~ the 2022 JHNEBP model and the corresponding steps to develop this doctoral project; the model begins with asking a clinical question, exploring appropriate evidence, and translating obtained evidence into clinical practice (Dang et al., 2022). Additionally, the most updated JHNEBP model incorporates reflection into each step of the process, as seen in Figure 2.

Figure 1

The Johns Hopkins Evidence-Based Practice Model for Nursing and Healthcare Professional



Evidence-based Practice Model Rationale

The JHNEBP Model is a reliable framework for developing evidence-based practice guidelines as the model includes inquiry about a clinical dilemma, addressed in the clinical problem and relevance to anesthesia sections, followed by presenting a practice question, evidence, and translating evidence into clinical practice. Integrating evidence-based practice into the clinical setting enables health-care personnel to explore relevant clinical problems and conduct database searches to acquire current, reliable evidence for appraisal to determine applicability to a clinical context (Horntvedt et al., 2018). The JHNEBP Model guides the project team through project planning, development, completion, and dissemination, including conduction of a literature review, analysis, and critical appraisal of available evidence.

Practice Question

The JHNEBP Model directly correlates with the original framework of the PICO question: In adult elective surgical patients requiring endotracheal intubation (P), does a preoperative ultrasound airway assessment (I) compared to a Mallampati assessment (C) predict the difficulty of intubation in the operating room (O)? The population includes adult surgical patients who will need endotracheal intubation for a surgical procedure. The intervention refers to the use of an ultrasound assessment of the airway, compared to performing a Mallampati assessment. Finally, the outcomes seek to predict the incidence of difficult intubation in the operating room.

Evidence

A literature review has been performed to identify relevant, evidence-based clinical data that explores the use of ultrasound in a preoperative assessment to determine difficulty of intubation. Ultrasound parameters including the hyomental distance ratio, anterior neck soft

tissue thickness at the level of anterior commissure of vocal cords, pre-epiglottic space (Pre-E), and distance from the epiglottis to the midpoint between vocal cords (E-VC) have shown to successfully predict difficult intubation. The evidence is extensively synthesized in the "Literature Review" and "Synthesis of Evidence" sections within the project.

Translation

Evidence regarding the use of ultrasound in airway assessments will be evaluated for reliability, validity, and applicability. Following a systematic synthesis of evidence, a standardized preoperative airway assessment using ultrasound will be presented as an evidence-based intervention to limit adverse patient outcomes regarding failed airway management. Additionally, financial considerations, closed claims analysis, ethical considerations, and project limitations will be included to support the project's feasibility and appropriateness for clinical implementation.

Methodology & Project Design

Using the JHNEBP Model to analyze and critically appraise current literature, recommendations regarding evidence-based clinical guidelines for ultrasound use in preoperative airway assessments are acquired. Current evidence substantiates that measurement of the hyomental distance demonstrates the highest specificity and accuracy in the prediction of difficult intubation, with a sensitivity of 75% and a specificity of 85.3% (Rana et al., 2018). Additionally, the Mallampati classification shows high specificity for predicting difficult airways (Parameswari et al., 2017). Therefore, the project will refer to quantitative and qualitative data to implement airway assessment guidelines using hyomental distance ultrasound measurements and Mallampati classifications in preoperative patient assessments, which will be correlated with the Cormack- Lehane (CL) grade observed during laryngoscopy.

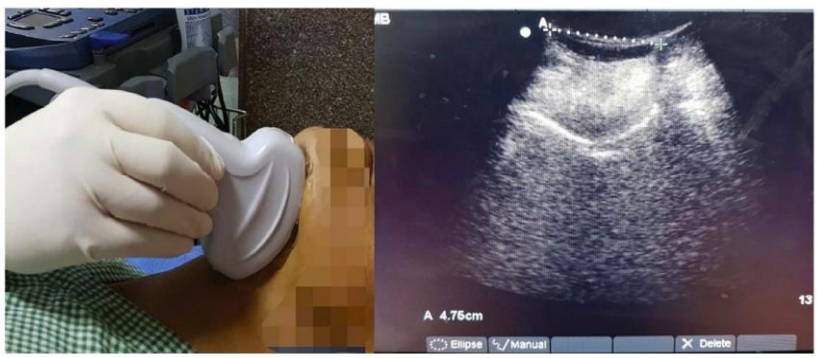
Quantitative Data

Quantitative data includes the measurement of HMD in operative patients, recorded in centimeters in the electronic medical record (EMR). Hyomental distance (HMD) is the measurement of the distance between the upper border of the hyoid bone and the lower border of the mentum; the hyomental distance ratio (HMDR) is a comparison of the hyomental distance when the head is in a neutral position compared to the head in an extended position (Abraham et al., 2018). HMD is measurable in two ways: one with the patient's head in a neutral position and one with the patient's head extended (Singh et al., 2021). Both measurement positions show high specificity for predicting difficult intubation.

HMD is useful in estimating the mandibular space available to displace the tongue and the ability to directly visualize the larynx, as described by Cormack-Lehane grading. Figure 3 demonstrates measurement of hyomental distance using ultrasound in the parasagittal plane. Shorter hyomental distances increase the incidence of difficult intubation (Abraham et al., 2018). More specifically, patients with a HMD of greater than 5.5 cm with the head in a neutral position are easier to intubate, while patients with a HMD of less than 5.5 cm are considered difficult; patients with the head in an extended position exhibit difficulty of intubation with a HMD of less than 5.3 cm (Kalezić et al., 2016). Abraham et al., 2018, conclude that a HMDR less than 1.1 also indicates difficult laryngoscopy.

Figure 2

Ultrasound measurement of HMD. The ultrasound probe is in the parasagittal position. The distance is measured in neutral and extended neck positions (Singh et al., 2021).



Qualitative Data

For all operative patients, qualitative data regarding Mallampati classification and CL grading will be noted in the postoperative note of the EMR annotated by the anesthesia provider who performed the laryngoscopy. The Mallampati classification compares the size and position of the tongue relative to the size of the patient's oral cavity; scores I-IV are given based on pharyngeal appearance relative to internal structures, noting visualization of the soft palate, anterior and posterior tonsillar pillars, and uvula (Yadav et al., 2020). CL grading system is an objective assessment that describes what structures are visible during laryngoscopy; there are four grades with two modifications that anesthesia providers frequently refer to (Nagelout & Elisha, 2018). Grade I refers to a complete view of the glottis opening; Grade IIa refers to a partial view of the vocal cords; Grade IIB describes visualizations of the arytenoids and epiglottis only; Grade III includes visualization of the epiglottis only; Grade IV is a visualization of only the soft palate (Nagelout & Elisha, 2018). Typically, grades III and IV indicate difficulty for laryngoscopy.

Plan for Implementation

Phase 1

The implementation of the project is divided into three different phases. The project's first phase includes a survey that will be presented to anesthesia providers in the hospital of interest to gauge the level of experience of providers with ultrasound use in airway assessments. The survey includes acquisition regarding previous anesthesia experience, ultrasound experience, preferential management of difficult airways, and proposed use of ultrasound in preoperative airway assessments (Appendix A). In addition, evidence shows that the anesthesia provider's comfort level in managing difficult airways is directly related to experience, practice, and

knowledge, which is accounted for in the provider survey (Kuzmanovska et al., 2019). Statistical analysis of the survey will include the utilization of a Chi-square test.

Following analysis of the survey, a department meeting with anesthesia providers and preoperative nursing staff will introduce the guidelines and present the rationale for ultrasound use in preoperative assessments; changing the culture of conducting airway assessments takes time and cooperation from staff. Once staff members have been notified of the upcoming change in preoperative management, formal ultrasound training for both CRNAs and anesthesiologists will be conducted. Ultrasound training will require anesthesia providers to accurately identify the hyoid bone, the border of the mentum, and measure the distance between the two points (HMD).

Phase 2

Phase 2 includes implementing standardized airway assessments following the completeness of ultrasound training. The guidelines indicate that an anesthesia provider will evaluate patients in the preoperative setting using Mallampati grading and measurement of the HMD in the extended and neutral positions. Figure 4 illustrates positioning for HMD ultrasound assessments. Assessment findings will be recorded in the preoperative note found in the EMR, then later correlated to the CL grading observed during laryngoscopy in the postoperative note.

Figure 3

Ultrasound measurement of HMD. Positioning for ultrasound of HMD in neutral and extended positions (Bhosle et al., 2015)

Patients with a HMD of greater than 5.5 cm with the head in a neutral position are easier to intubate, and the choice for laryngoscopy can be provider dependent. In patients with a HMD of less than 5.5 cm, intubation is more difficult, and laryngoscopy will be performed using a video laryngoscope or awake fiberoptic intubation. The following guidelines are synonymous for patients with a HMD of less than 5.3 cm with the head in the extended position or a HMDR of less than 1.1.

Phase 3

The final implementation phase includes a post-intervention survey completed after 90 days by the anesthesia providers and preoperative nursing staff; the survey includes eight questions that offer engaging conversation and critique of the guidelines (Appendix B). Statistical analysis of the survey will include utilization of a Chi-square test, comparable to analysis of the primary survey exercised in Phase 1. The results of the survey will be discussed in a collaborative meeting with the project team leader and department heads from the anesthesia and preoperative nursing departments.

A meeting between departments allows for project modification and collaboration; based on the recommendations from the project facilitators and the qualitative data collected from the post-intervention surveys, adjustments to the guidelines will be made where implicated. Following guideline changes, the project will continue for a 30-day trial, and the same post-intervention survey will be re-issued. If the guidelines continue to fall below the expectations of the anesthesia providers or patient care standards, the guidelines will be voided until the project facilitators and department teams can develop a further action plan.

Data Collection & Analysis

Following 90 days of project implementation, a retrospective analysis of 100 EMR charts

will be randomly selected to evaluate compliance in recording HMD, Mallampati classifications, and corresponding CL grading in the postoperative anesthesia note. Additionally, data will be collected and analyzed to determine if providers recorded appropriate methods for laryngoscopy (video, direct, or awake fiberoptic) based on the HMD charted in the EMR. All patients with a HMD of less than 5.5 cm with the head in a neutral position, a HMD of less than 5.3 cm with the head in the extended position, or a HMDR of less than 1.1 will be evaluated to assess if the anesthesia provider utilized awake fiberoptic intubation or video laryngoscopy (Kalezić et al., 2016). Compliance with the appropriate method for laryngoscopy will be imputed into a Microsoft Excel sheet and presented at the first post-intervention collaboration meeting. Compliance will continue consecutively every 120 days for the first year of implementation.

Sample Setting & Target Population

The hospital of interest includes an academic, level-one trauma hospital in the Midwest region. This facility utilizes both CRNAs and anesthesiologists in the perioperative setting to provide various types of anesthetics for surgical patients. Ultrasound measurements of the HMD will be performed on all surgical patients in the preoperative phase of care requiring endotracheal intubation.

Project Facilitators

This future project requires the cooperation of anesthesia providers, who will be utilizing ultrasound in preoperative assessments, and the preoperative nursing staff, as the initial rollout of ultrasound use will increase the time patients spend in preop, affecting workflow for staff nurses. Ultimately, ultrasound is a fast method for assessing anatomical structures, but the initial use of ultrasound will temporarily increase the amount of time patients spend in the preoperative area. Anesthesia providers must record the patients' HMD in centimeters, Mallampati classification,

and CL grading observed during laryngoscopy within the EMR. Charting within the EMR will require the information technology (IT) department to be involved with the project to develop a method for documenting the HMD in centimeters and corresponding CL grading.

Timeline for Implementation

The project timeline is grossly dependent upon the level of ultrasound training that the anesthesia providers require at the clinical site of interest. Ultrasound classes will occur over two to three weeks, with the ability of providers to schedule a time before, during, or after their shifts. Because ultrasound skill is heavily dependent upon the user, providers will be required to measure hyomental distance and identify airway anatomy accurately before they can be signed off to conduct ultrasound assessments. After roughly three months of implementing the proposed guidelines, the post-intervention survey will identify the guideline's strengths, weaknesses, and areas of improvement.

Product Selection & Financial Considerations

One of the appeals of ultrasound pertains to its portability; currently on the market, the most portable ultrasound with the highest quality is the Butterfly iQ+ unit. The Butterfly iQ+ is a small, water and dust-resistant ultrasound probe that interface with an application compatible with smartphone technology and tablets (Butterfly Network, n.d). The ultrasound probe provides use for various specialties, including anesthesia, critical care, emergency medicine, and cardiology, aiming to make medical imaging more accessible. The Butterfly iQ+ also has unique needle visualization technology for peripheral nerve blocks and in-plane guided procedures, views for focused assessments and scans for trauma patients (FAST), POCUS, and rapid ultrasound scans of the lungs and heart functionality (Butterfly Network, n.d). While the

ultrasound unit is useful for a variety of medical procedures, the Butterfly iQ+ will specifically serve the project in the preoperative setting.

The cost of one Butterfly iQ+ unit is $2,399, although bulk purchases for medical facilities are available at a reduced rate (Butterfly Network, n.d). According to a well-versed equipment company owned by Fujifilm known as Sonosite, a medical-grade ultrasound can range anywhere from $16,000 - 50,000 in price without the additional cost of the transducers (Fujifilm Sonosite, n.d). The Butterfly iQ+ is cost-efficient and easy to store, as the entire device is hand-held. To effectively scan all preoperative patients, the ultrasound probe-to-patient ratio should be 1:3, requiring the facility of interest to purchase upwards of 30 individual ultrasound probes. The total cost of the ultrasounds would equate to roughly $70,000, which is almost equivalent to purchasing one Sonosite ultrasound machine. Additionally, the device needs to be cleaned between patient use and can be sanitized with the Super Sani-Cloth® Germicidal Disposable Wipes; most hospital facilities already use these wipes to clean patient equipment and would not pose an additional cost to the project.

Ethical Considerations

This project will not request, collect, or store names, unique patient or staff identifiers, or protected health information; only de-identifiable data will be shared between the project facilitators regarding HMD, Mallampati classifications, and CL grading. Although ultrasound is a safe, noninvasive method for anatomical identification and measurement collection, all ultrasound assessments will only be done after verbal patient consent is verified. Ultrasound is traditionally well tolerated and poses no risk of radiation to patients (Carmody et al., 2017). Additionally, the Butterfly iQ+ unit does not store patient data and has no memory-saving capabilities; only real-time ultrasound images would be available on the probe (Butterfly

Network, n.d). The Butterfly iQ+ poses no threat to violating patient confidentiality or personal health information.

Project Limitations

A few limitations to the implementation of ultrasound in preoperative assessments require analysis. For example, obtaining accurate airway ultrasound measurements requires technical skills and adequate training because ultrasound is more user dependent than other critical care imaging modalities (Agunbiade & Crimi, 2017). This limitation is resolvable by requiring anesthesia providers to obtain formal ultrasound training to achieve proficiency. Furthermore, the ability to delineate acoustic artifacts of airway structures, ultimately enabling accurate interpretation of the patient's anatomy, is imperative for providers to master the ultrasound machine (Yadav et al., 2020). Using an ultrasound is generally an easily learnable skill that requires practice and training to gain proficiency.

The project must consider that specific subject matters, including trauma patients, obese patients, thyroid patients, patients requiring emergency surgery, pregnant patients, patients using LMAs, patients undergoing endoscopic procedures, critical care patients, and patients with airway and physical abnormalities, were excluded from much of the research appraised. The project aims to evaluate how ultrasound can predict the difficulty of intubation in a seemingly normal airway assessment; the specific patient considerations listed above would likely be easily predictable for difficult laryngoscopy without an ultrasound assessment (Daggupati et al., 2020). Therefore, ultrasound assessments are unnecessary in such patient populations, and those airways should already be considered difficult. Lastly, the project must consider the limitation of patient consent; verbal consent and patient cooperation is required for ultrasound measurements of anatomical landmarks to be successfully obtained.

Conclusions

Unanticipated difficult intubations are a significant concern for anesthesia providers due to the severe consequences of failed endotracheal intubations. Complications related to poor airway management include ICU admission, prolonged recovery, emergency surgical airways, trauma to the oropharynx and dentition, permanent brain damage, and even death (Workeneh et al., 2017). The key to resolving unanticipated difficult intubations and reducing the risk of perioperative morbidity and mortality is identifying a clinical assessment parameter that is accurate and easy to perform during the preoperative assessment. The utilization of ultrasound in airway assessments shows high specificity and sensitivity in the prediction of difficult intubation. With the standardization of preoperative airway assessments, anesthesia providers will promote patient safety and reduce perioperative morbidity and mortality related to inadequate airway management. The project utilizes the Johns Hopkins Evidence-based Model to incorporate the most updated, evidence-based practice into new standards of care, enabling project facilitators to promote the highest levels of patient care and safety. Enacting the guidelines recommended by the project facilitators will allow anesthesia providers to implement best-practice guidelines in airway assessment techniques and management. Using ultrasound and Mallampati classifications as a combined airway assessment is a new addition to anesthesia providers that will revolutionize perioperative patient care. The hospital of interest will be recommended to implement standardized airway assessments.

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Appendix A

Ultrasound Questionnaire for Anesthesia Providers

1. Age:

a) 20-30 yrs

b) 30-40 yrs

c) 40-50 yrs

d) >50 yrs

2. Anesthesia Experience:

a) CRNA

b) SRNA

c) Resident

i) 0-4 yrs experience

ii) 5-10 yrs experience

iii) > 10 yrs experience

3. Which of the following is your preferred test for predicting difficult intubation?

a) Mallampati score

b) Thyromental distance

c) 3-3-2-test

d) Upper lip bite test (if applicable)

e) Other _____

4. Are you comfortable with using ultrasound to identify significant airway structures?

a) Yes

b) No

5. Have you ever seen a colleague or personally use ultrasound as a method for predicting difficult intubation?

a) Yes

b) No

6. Do you think current practice regarding airway assessments in preop is adequate to predict difficult intubations?

a) Yes

b) No

7. Did you receive professional training in ultrasound of the upper airway during school, residency, fellowship, or orientation?

a) Yes

b) No

8. What apprehensions do you have regarding integrating ultrasound in all preoperative airway assessments?

a) Not enough time in preop

b) Too expensive

c) Unnecessary addition to an airway assessment

d) Potential for inaccuracy

e) Other _____

f) None

Survey adapted from Kuzmanovska et al., 2019, *Survey of Current Difficult Airway Management Practice*

Appendix B

Post-intervention Questionnaire for Anesthesia Providers & Nursing Staff

1. **Did you consistently use ultrasound to measure HMD in your anesthetic preoperative airway assessment?**

    a)Yes

    b) No

    c) N/A

2. **Did you find that the standardized airway guidelines accurately correlated with CL grading and predictability of difficult intubation?**

    a) Yes

    b) No

    c) N/A

3. **Did you find that using ultrasound on all preoperative patients delayed patient care or prolonged total preoperative management time?**

    a) Yes, it delayed patient care

    b) Yes, it prolonged total preoperative time but did not delay patient care

    c) No, it did not delay patient care or preoperative time

    d) Other: _____

4. **Were there any barriers to using ultrasound that were not addressed in the guidelines?**

    a) No

    b) If yes, please explain: _____

5. **Were any of these limitations to the guidelines noted during your practice?**

    a) There was not enough time in preop to use ultrasound effectively

    b) Ultrasound measurements were found to be inaccurate

    c) Patients were apprehensive to ultrasound assessments

    d) Previous ultrasound training was inadequate for expected use

    d) Other: _____

6. **Is there anything you would change about the current standardized airway assessment guidelines?**

    _____

7. **What did you like about the standardized airway assessment guidelines?**

    _____

8. **What feedback can you provide regarding the ultrasound training you were provided? Did you feel that the training was appropriate for your expected role in measuring HMD? Did you find any patients HMD were exceptionally difficult or even unable to measure? If so, please explain:**

    _____

    _____

    _____

Survey adapted from Agency for Healthcare Research and Quality, 2016, *Post Intervention Practice Survey*

Appendix C

Standardized Airway Assessment Guidelines

1

Standardized Airway Assessment Guidelines 2022	
Issue Date: 9/4/2022	**Effective Date:**
Developed By: Meredith Louden, SRNA	**Review Date:**
Reviewed By: Dr. Kacy Ballard	**Approved By:** Dr. Kacy Ballard

SCOPE- This guideline is in effect for the hospital of interest for the DNP project setting.

STATEMENT OF PURPOSE:

The purpose of this guideline is to provide evidence-based practice recommendations regarding perioperative airway assessments. Unanticipated difficult intubations are a major concern for anesthesia providers due to the serious consequences of failed endotracheal intubations. Anesthesia providers engage in bedside physical examinations in the preoperative area to formulate a strategic anesthetic plan, but even anatomically normal patients continue to pose the risk for an unanticipated difficult airway. Current practice includes Mallampati classifications to determine difficulty of laryngoscopy, but such clinical assessments show poor predictability for difficult intubation. Ultrasound demonstrates high specificity and sensitivity for accurately predicting difficult intubation in airway assessments. Standardizing preoperative airway assessments will allow anesthesia providers to promote patient safety and reduce perioperative morbidity and mortality related to inadequate airway management.

DEFINITIONS:

- **Endotracheal intubation:** passage of a tube through the mouth or nose into the trachea for airway maintenance during anesthesia or requirement of ventilatory support.
- **Mallampati classification:** grading scale commonly used by anesthesia providers to compare the size and position of the tongue relative to the size of the patient's oral cavity. Scores I-IV reflect the pharyngeal appearance relative to internal structures.
- **Laryngoscopy:** procedure to view inside of the larynx (vocal cords) for intubation or diagnostic evaluation.

POLICY:

The guideline applies to the performance of ultrasound airway assessments in the preoperative phase of care for patients undergoing surgery requiring endotracheal intubation. This guideline assists anesthesia providers in the determine of airway management based on clinical presentation, including ultrasound measurement of hyomental distance (HMD) in the neutral and extended positions. This guideline is intended to incorporate the most updated, evidence-based clinical recommendations into new standards of care. Anesthesia providers will promote the highest levels of patient care and safety for airway assessment techniques and management. This guideline is not a substitute for clinical judgment, and it does not establish legally enforceable requirements or responsibilities.

Standardized Airway Assessment Guidelines

GUIDELINE:

I. Airway Assessment:

a. All surgical patients requiring endotracheal intubation will have a standardized airway assessment performed in preop by an anesthesia provider

b. Airway assessment includes:

i. Mallampati classification

ii. Ultrasound measurement of HMD in neutral position

iii. Ultrasound measurement of HMD in extended position

Figure 1. HMD in neutral and maximal head extension

NEUTRAL POSITION EXTREME OF HEAD EXTENSION

II. Airway Management

a. HMD > 5.5 cm in the **neutral** position is considered *easy laryngoscopy* and method of intubation is at providers' discretion- direct laryngoscopy, video laryngoscopy, etc.

b. HMD < 5.5 cm in the **neutral** position is considered *difficult laryngoscopy* and method for intubation should utilize video laryngoscopy or awake fiberoptic.

c. HMD > 5.3 cm in the **extended** position is considered *easy laryngoscopy* and method of intubation is at providers' discretion- direct laryngoscopy, video laryngoscopy, etc.

d. HMD < 5.3 cm in the **extended** position is considered *difficult laryngoscopy* and method for intubation should utilize video laryngoscopy or awake fiberoptic.

e. HMDR < 1.1 (**ratio** of HMD neutral compared to HMD extended) is considered *difficult laryngoscopy* and method for intubation should utilize video laryngoscopy or awake fiberoptic.

III. Documentation

a. All preoperative assessment findings (Mallampati, HMD neutral, HMD extended) will be documented in preoperative provider note

b. CL grading observed during laryngoscopy will be compared to preoperative assessment findings and documented in the postoperative provider note

c. Methodology for laryngoscopy will be documented in postoperative provider note

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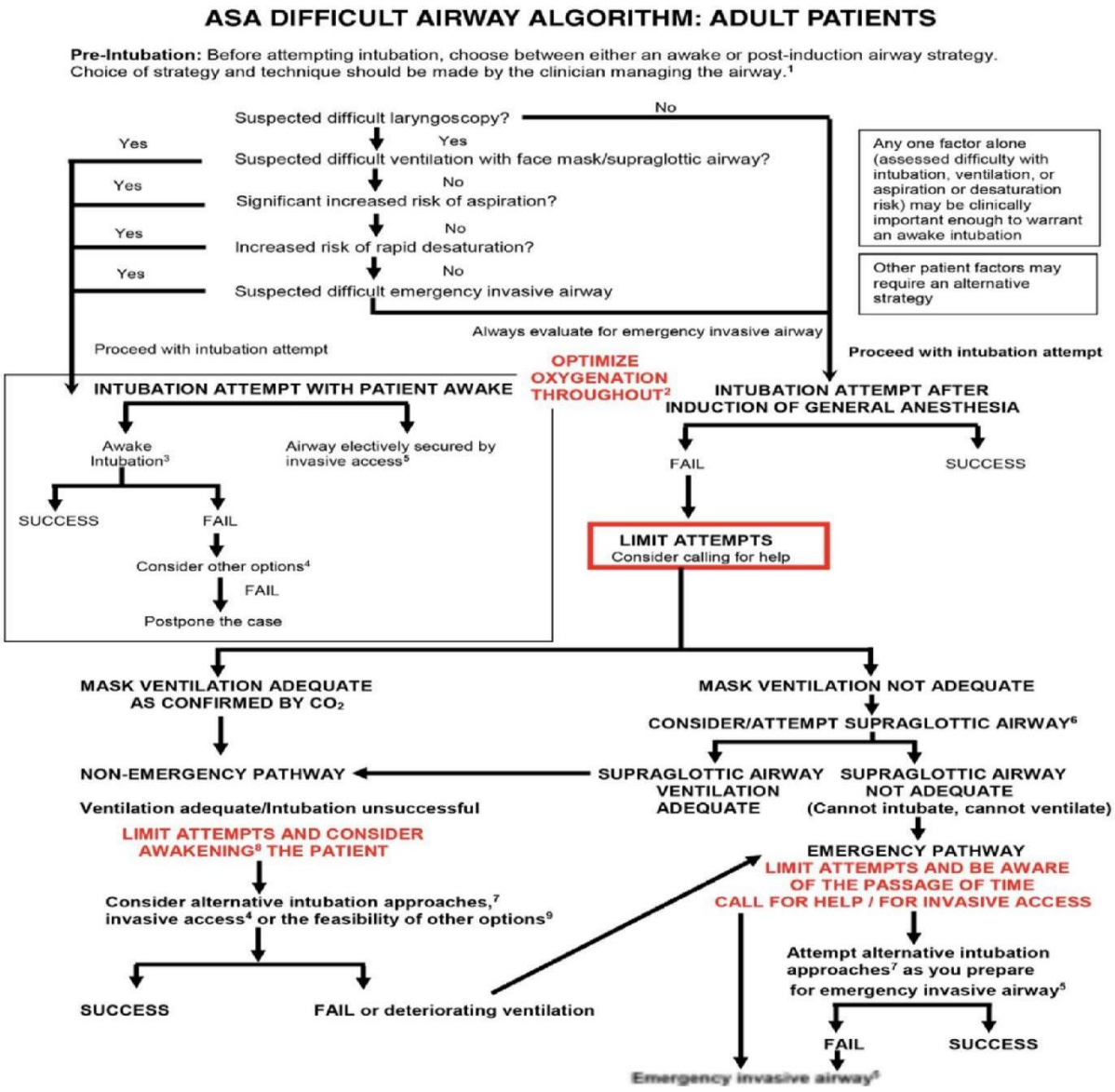
Appendix D

ASA Difficult Airway Algorithm: Adult Patients



Appendix E

Literature Synthesis Table

Citation **(Author, Year, Title, etc…)**	**Conceptual Framework** **(Theoretical Basis for Study)**	**Design/ Method**	**Sample/ Setting** **(Number, Characteristics, Exclusions, Criteria, Attrition, etc.)**	**Major Variables; definitions** **(Independent variables; dependent variables)**	**Outcome Measurement** **(What scales used- reliability information- alphas)**	**Data Analysis** **(What stats used?)**	**Findings** **(Statistical findings or qualitative findings)**	**Level of Evidence** **Level =**
Article 1: Ultrasound as an Assessment Method in Predicting Difficult Intubation: A Prospective Clinical Study								
Abraham, S., Himarani, J., Mary Nancy, S., Shanmugasundaram, S., & Krishnakumar Raja, V. B. (2018). Ultrasound as an assessment method in predicting difficult intubation: A prospective clinical study. *Journal of Maxillofacial and Oral Surgery, 17*(4), 563–569. https://doi.org/10.1007/s12663-018-1088-1	N/A	Prospective clinical study to predict difficult intubation preoperatively using ultrasound. Patients not undergoing surgery were excluded from the study. Ultrasound and laryngoscopy was performed by the same anesthesia provider.	Study included 137 patients requiring general anesthesia and endotracheal intubation	Independent variables: age, thickness of submental region, epiglottis to hyoid bone distances, thyrohyoid distance, skin pad thickness to thyroid cartilage, and hyomental distance. Dependent variables: patient ultrasound exams.	P values used. significance level is fixed as 1% (a = 0.01). ROC curve analysis performed to find cutoff values to classify difficult intubation for hyomental distance; sensitivity and specificity measured.	Airway parameters used included: visualization of hyoid bone, visualization of vocal cords through thyroid, visualization of epiglottis, distance from base of tongue to hyoid bone, distance of hyomental region distance of thyrohyoid region, distance between skin and fat pad thickness to thyroid	All relevant anatomical structures were visualized in participants using ultrasound, and HMD <1.09 is predictive of difficult intubation.	II

						cartilage, thickness of submental region, distance from epiglottis to skin, visualization of cricothyroid membrane.		
Article 2: Perioperative ultrasound: time to move forward!								
Agunbiade, S., & Crimi, E. (2018). Perioperative ultrasound: Time to move forward! ***Minerva Anestesiologica, 84*****(1).** **https://doi.org/10.23736/s0375-9393.17.12515-0**	N/A	Editorial	N/A	N/A	N/A	N/A	Editorial discusses a systematic review conducted by Ferreira et al., to evaluate the impact of perioperative ultrasound and found POCUS led to a 31% change in perioperative management.	V
Article 3: Development of a scoring system for predicting difficult intubation using ultrasonography								
Daggupati, H., Maurya, I., Singh, R., & Ravishankar, M. (2020). Development of a scoring system for predicting difficult intubation using ultrasonography. ***Indian Journal of Anesthesia, 64*****(3).**	N/A	Prospective observational study conducted between May 2018 and November 2018 to develop an airway scoring system using ultrasound and determine its accuracy in prediction of difficult intubation.	310 patients between ages 18-65 yrs old with ASA of 1-3 for elective surgery requiring endotracheal intubation. Anatomical abnormalities, mouth opening <3 cm, and emergency procedures were excluded from the study.	Independent variables: age, BMI, gender, ASA, mentohyoid distance, mandibular subluxation grade, neck extension grade, skin to epiglottis distance, and CL grading. Dependent variables: predictability of ultrasound parameters for difficult laryngoscopy.	Power and Sample Size Calculation Software used for statistical analysis. Student's t-test or Mann-Whitney U test used and for categorical variables, Chi-square test or Fisher exact test used. ROC analysis utilized. Specificity, positive predictive value and	Study incorporated ultrasound measurements of skin to epiglottis distance and clinical screening tests including mentohyoid distance, mandibular subluxation, and head extension.	Developing an airway scoring system using ultrasound measurements of the SED in addition to clinical parameters is helpful in the prediction of difficult intubation.	II

					negative predictive value calculated for both scoring systems. P <0.05 considered significant.			
Article 4: Evaluation of two neck ultrasound measurements as predictors of difficult direct laryngoscopy								
Falcetta, S., Cavallo, S., Gabbanelli, V., Pelaia, P., Sorbello, M., Zdravkovic, I., & Donati, A. (2018). Evaluation of two neck ultrasound measurements as predictors of difficult direct laryngoscopy. ***European Journal of Anesthesiology*****,** ***35*****(8), 605–612. https://doi.org/10.1097/eja.0000000000000832**	N/A	Prospective, single blinded, observational study to determine correlation between ultrasound of anterior cervical soft tissue thickness and CL grading during direct laryngoscopy.	301 patients at least 18 yrs old from May 2017 to September 2017 on patients undergoing elective surgery with general anesthesia and endotracheal tinaubtion. Exclusion criteria included: RSI, pregnancy, history of difficult intubation, c-spine immobility, anatomical abnormalities, thyromental distance <6 cm.	Independent variables: age, sex, VMI and CL grading. Dependent variables: ultrasound view of anterior cervical soft tissue thickness.	Statistical analysis performed using Medcalc 7.3.0.1 statistical program. Kolmogorov–Smirnov's test used to test the normality of distribution. ROC used to determine the difficulty prediction capability of each sonographic measurement and to assess the optimal cut-off scores. Values of P less than 0.05 were considered as statistically significant.	Study measured pre-epiglottic space thickness' at the level of thyrohyoid membrane as the median distance from skin to epiglottis (mDSE) and the pre-epiglottic area was calculated.	Ultrasound assessment of pre-epiglottic tissue thickness at the level of the thyrohyoid membrane may predict difficult laryngoscopy and difficulty with intubation.	I I
Article 5: Useful Ultrasonographic Parameters to Predict Difficult Laryngoscopy and Difficult Tracheal Intubation- A System and Meta-Analysis								
Gomes, S. H., Simões, A. M., Nunes, A. M., Pereira, M. V., Teoh, W. H., Costa, P. S., Kristensen, M. S., Teixeira, P. M., & Pêgo, J. M. (2021). Useful	N/A	Systematic review and meta-analysis to determine the use of ultrasonography in the prediction of difficult laryngoscop	Inclusion criteria: use of ultrasound, prediction of difficult laryngoscopy or tracheal intubation; humans; primary studies; english	Independent variables: different ultrasound measurements for use. Dependent variables: predictive value of difficult laryngoscopy.	Analysis of the obtained data presented in forest plots developed using Review Manager 5.3 software.	Analysis included eleven ultrasound measurements, seven of which had significant overall effect: HMD in extended	Study concludes that ultrasound is useful for prediction of difficult laryngoscopy; the best candidate to implement in	I

ultrasonographic parameters to predict difficult laryngoscopy and difficult tracheal intubation- a systematic review and meta-analysis. *Frontiers in Medicine, 8*. https://doi.org/10.3389/fmed.2021.671658		y or tracheal intubation. Literature search performed on PubMED, Web of Science and Embase, using 19 articles (4,570 patients) analyzed for the systematic review and 12 articles (1,141 patients) for the meta-analysis.	language. Exclusion criteria: obstetric specialty; pediatric population; emergency context; laryngeal mask ventilation; gray literature. Reviews, editorials, conference abstracts and case reports also excluded.			position, HMDR2, Pre-E/E-mVC, distance from skin to hyoid bone, skin to epiglottis, and skin to the anterior commissure of vocal cords.	clinical practice is HMD with head and neck in neutral position.	
Article 6: An Observational Study to Evaluate the Role of Ultrasound in the Prediction of Difficult Laryngoscopy								
Gupta M, Sharma S, Katoch S. An observational study to evaluate the role of ultrasound in the prediction of difficult laryngoscopy. Bali J Anesthesiology. 2020;4:172-7.	N/A	Prospective observational study to evaluate effectiveness of ultrasound in the prediction of difficult laryngoscopy.	120 patients undergoing elective surgery requiring general anesthesia and endotracheal intubation. Inclusion criteria: patients 18–70 yrs old with ASA I–III. Exclusion criteria: head and neck anatomical pathology, edentulous patients, small mouth opening, limitation in head and neck flexion or extension, previous history of difficult intubation, pregnancy,	Independent variables: age, sex, CL grading, weight, BMI. Dependent variables: predictability of ultrasound parameters for difficult laryngoscopy.	Data analysis used Statistical Package for Social Sciences. Categorical variables presented in number and percentage, and continuous variables presented as mean ± standard deviation and median. P values used.	Analysis included preepiglottic space (PES), HMD, distance from skin to the hyoid bone-skin (DSHB), distance from skin-to-epiglottis midway between the hyoid bone and thyroid cartilage, and distance from skin to epiglottis midway (DSEM).	Using ultrasound to measure HMD is predictive of difficult laryngoscopy; US measurements of soft-tissue thickness of anterior neck and tongue thickness in addition to clinical assessment of airway is helpful in predicting difficult intubation.	II

			BMI >34.9 kg/m2 .					
Article 7: Ultrasound measurement of laryngeal structures in the parasagittal plane for the prediction of difficult laryngoscop Chinese adults								
Ni, H., Guan, C., He, G., Bao, Y., Shi, D., & Zhu, Y. (2019). Ultrasound measurement of laryngeal structures in the parasagittal plane for the prediction of difficult laryngoscopies in Chinese adults. https://doi.org/10.21203/rs.2.15933/	N/A	Prospective observational study conducted between May 2018 to October 2018 to explore value of laryngeal structure measurements for predicting difficult laryngoscopy.	Inclusion criteria: elective surgery patients undergoing endotracheal intubation over 18 yrs old. Exclusion criteria: anatomical abnormalities of head and neck, fractures of maxillofacial or cervical bones, airway trauma.	Independent variables: sex, age, weight, height, BMI, TMD <4 cm, CM < 80*, MMT > III, DSE (cm), DTE (cm), DST (cm). Dependent variables: ability to visualize airway structures and compare them to CL grading.	Stata 15.0 software package used for all statistical analyses. Variables in percent compared to the differences in values between groups used a chi-square test. P values utilized.	Analysis included the distance between the skin and thyroid cartilage (DST), the distance between the thyroid cartilage and epiglottis (DTE), and the distance between the skin and epiglottis (DSE) in the parasagittal plane.	Using ultrasound to identify laryngeal structure measurements in the parasagittal plane is valuable for predicting a difficult laryngoscopy, with distance between skin and epiglottis (DSE) as the most accurate predictive value.	I I
Article 8: Radiological evaluation of airway – What an anesthesiologist needs to know!								
Jain K, Gupta N, Yadav M, Thulkar S, Bhatnagar S. Radiological evaluation of airway – What an anesthesiologist needs to know!. Indian J Anaesth 2019;63:257-64.	N/A	Prospective observational study aimed to evaluate usefulness of sonographic airway parameters in predicting DL in adults.	Study includes 120 patients undergoing elective surgery. Inclusion criteria: 18–70 years with ASA I–III undergoing elective surgery requiring general anesthesia with direct laryngoscopy (Macintosh blade) and endotracheal intubation. Exclusion criteria: head and neck anatomical pathology, edentulous patients,	Independent variables: age, sex, BMI, CL-grading, skin-to-epiglottis distance, HMD, distance between hyoid bone and skin (DSHB), distance from skin to epiglottis midway (DSEM) between the hyoid bone and thyroid cartilage (DSEM). Dependent variables: predictability of ultrasound parameters for difficult laryngoscopy.	P values used for statistical analysis. ROC curve plotted, showing performance of all USG parameters at various thresholds to determine true positive rate and false positive rate for DL.	Analysis includes ultrasound parameters: skin-to-epiglottis distance, HMD, distance between hyoid bone and skin (DSHB), distance from skin to epiglottis midway (DSEM) between the hyoid bone and thyroid cartilage (DSEM).	Study concludes US is a novel modality for predicting difficult laryngoscopy. HMD showed highest AUC among DSHB, DSEM, and PES. US measurements of soft-tissue thickness of the anterior neck and tongue thickness along with the clinical assessment of airway can also be useful	I I

			smallmouth opening, limitation in head and neck flexion or extension, previous history of difficult intubation, pregnancy, BMI >34.9 kg/m2.				in predicting DL.	
Article 9: Perioperative Point-of-Care Ultrasound Use by Anesthesiologists								
Naji, A., Chappidi, M., Ahmed, A., Monga, A., & Sanders, J. (2021). Perioperative Point-of-care ultrasound use by anesthesiologists. *Cureus*. https://doi.org/10.7759/cureus.15217	N/A	Academic review aimed at presenting current anesthesiologists with a broad discussion regarding the diverse utility and importance of POCUS in perioperative settings.	Review POCUS for airway assessments, cardiac function, pulmonary function, aspiration risk, hemodynamics, vascular and regional access.	N/A	N/A	Authors reference POCUS in clinical decision-making for variety of perioperative situations due to ability to assess endotracheal tube placement, cardiac function, pulmonary function, aspiration risk, hemodynamics, vascular access, and nerve visualization for regional procedures.	Authors conclude application of POCUS to different organ systems and to variety of perioperative contexts offers unique advantages to enhance clinical perioperative decision-making. POCUS can be utilized to confirm correct endotracheal tube placement and utilized in complex airway situations.	IV
Article 10: Correlation between preoperative ultrasonographic airway assessment and laryngoscopic view in adult patients: A study								
Parameswari, A., Govind, M., & Vakamudi, M. (2017). Correlation between preoperative ultrasonographic airway	N/A	Prospective, double-blinded study conducted to identify correlation between preoperative	Study includes 130 patients undergoing elective surgery under general anesthesia. Inclusion criteria: 18 to 60 years of age	Independent variables: age, sex, BMI, width of tongue, CS area of tongue, CS area of floor of mouth, AP thickness of	Statistical analysis done using SPSS software version 17. Sensitivity, specificity, positive predictive	Analysis of ultrasound parameters includes width of tongue, CS area of tongue, CS area of floor	Study concludes of clinical predictors, modified Mallampati exhibits maximum sensitivity	I

assessment and laryngoscopic view in adult patients: A prospective study. *Journal of Anesthesiology Clinical Pharmacology*, *33*(3), 353. https://doi.org/10.4103/joacp.joacp_166_17		sonographic airway assessment parameters and the Cormack–Lehane (CL) grade at laryngoscopic view in adult patients.	requiring general anesthesia with endotracheal intubation for elective procedures. Exclusion criteria: patients with any feature of difficult airway such as maxillofacial anomalies, restricted neck movements, BMI >40 kg/m2, and limited mouth opening.	geniohyoid, skin to hyoid, skin to epiglottis. Dependent variables: predictability of ultrasound parameters for difficult laryngoscopy.	value, and negative predictive value calculated for all measured parameters. Association between different predictors and difficult laryngoscopy evaluated with Chi-square test and Fisher's exact test. A P < 0.05 was considered to be significant.	of mouth, AP thickness of geniohyoid, skin to hyoid, skin to epiglottis. Mallampati class, mouth opening, mentohyoid distance, TMD, and neck circumference were recorded for all patients in study.	and specificity; of the sonographic parameters, skin to epiglottis distance exhibits maximum sensitivity and specificity to predict difficult laryngoscopy. Combining these two tests improved the sensitivity in predicting difficult laryngoscopy.	
Article 11: Preoperative difficult airway prediction using suprahyoid and infrahyoid ultrasonography derived measurements anesthesiology								
Petrisor, C., Dîrzu, D., Trancă, S., Hagău, N., & Bodolea, C. (2019). Preoperative difficult airway prediction using suprahyoid and infrahyoid ultrasonography derived measurements in anesthesiology. *Medical Ultrasonography*, *21*(1), 83. https://doi.org/10.11152/mu-1764	N/A	Educational paper to describe suprahyoid and infrahyoid US measurements investigated and summarize current knowledge regarding their diagnostic performance for difficult airway detection.	Inclusion criteria: adult patients undergoing elective surgery requiring general anesthesia Exclusion criteria: pregnant patients, patients with airway tumors, distorted airways, external laryngeal manipulation and laryngeal mask insertion.	Independent variables: ANS at different levels, tongue thickness and tongue-to-oral cavity ratio, hyomental distances. Dependent variables: ability to visualize airway structures and predict difficulty of intubation	Educational paper refers to the statistical analysis of recent results from a meta-analysis based on eight original studies that pooled characteristics of US-derived measurements to predict difficult airway.	Authors evaluated US measurements including ANS at different levels, tongue thickness and tongue-to-oral cavity ratio, hyomental distances with derived ratios and composite scores.	Many available US-derived parameters are accessible to provide additional information regarding airway anatomy during the preoperative airway evaluation, which could serve as potential screening parameters for a difficult laryngoscopy /difficult airway.	I V
Article 12: Point-of-care ultrasound in the airway assessment: A correlation of ultrasonography-guided parameters to the Co Lehane Classification								

Rana, S., Koundal, V., Thakur, R., Chauhan, V., Ekke, S., & Kumar, M. (2019). The usefulness of point of care ultrasound (Pocus) in pre anesthetic airway assessment. ***Indian Journal of Anesthesia,*** **63(12), 1022. https://doi.org/10.4103/ija.ija_492_19**	N/A	Prospective, observational study conducted to determine ultrasound assessments in the prediction of difficult laryngoscopy.	120 patients scheduled for elective surgery requiring general anesthesia and tracheal intubation analyzed. Inclusion criteria: ASA I/II patients 20-60 yrs old. Exclusion criteria: interincisor < 3 cm, edentulous, head and neck pathologies, altered level of consciousness, inability to follow commands.	Independent variables: age, gender, BMI. Dependent variables: ability to correspond anatomical structures with CL grading.	MS Excel® and SPSS® 19 software packages used for data entry and analysis. Results averaged (mean ± standard deviation [SD]) for each parameter. Chi-square test used to determine the statistical difference between the easy and difficult laryngoscopies. P values utilized.	Analysis included depth of the pre-epiglottic space (Pre-E), distance from the epiglottis to midpoint of distance between vocal cords (E-VC), and hyomental distance ratio (HMDR) with head in neutral and extended positions.	US measurement of Pre E/E-VC has high predictability for predicting difficult laryngoscopy, and measurement of HMDR is a potential predictor of difficult laryngoscopy.	I I
Article 13: Comparative study between El-Ganzouri airway risk index alone and in combination with upper airway ultrasoun preoperative airway assessment								
Abo Sabaa, M. A., Amer, G. F., Saleh, A. E., & Elbakery, M. A. (2019). Comparative study between El-Ganzouri Airway Risk Index alone and in combination with upper airway ultrasound in preoperative airway assessment. ***The Egyptian Journal of Hospital Medicine, 77*****(5), 5621–5632. https://doi.org/**	N/A	Prospective and randomized study to evaluate combination of El-Ganzouri airway risk index (EGRI) with ultrasound of the airway in the prediction of difficult airway.	60 patients undergoing general anesthesia and endotracheal intubation. Inclusion criteria: ASA I/II scheduled for elective surgery requiring endotracheal intubation for general anesthesia. Exclusion criteria: < 18 yrs old, cervical spine fractures, tracheostomy tube, inability to consent,	Control group: patients assessed with the EGRI index for difficult intubation. Study group: patients assessed with EGRI and upper airway ultrasound.	Statistical analysis using the mean, standard deviation, unpaired student test, analysis of variance [ANOVA] test, Chi-square, Linear Correlation Coefficient [r] and ROC-curve tests by IBM SPSS Statistics. P values utilized.	Analysis includes EGRI with CL grading; ultrasound analysis includes visualizing hyoid bone, measurement of hyomental distance in neck extended position, measurement of distance from the epiglottis to midpoint of distance between vocal cords,	Using ultrasound in the prediction of difficult intubation is reliable in combination of EGRI with epiglottis to vocal cord distance and hyomental distance.	I

10.21608/ejhm.2019.62144			abnormalities of airway including facial fractures, tumors, etc.			and assessment of ease of gas exchange during positive pressure ventilation via face mask after induction of anesthesia and muscle relaxation.		
Article 14: Comparison of Different Ultrasound Parameters for Airway Assessment in Patients Undergoing Surgery under Ge Anesthesia								
Singh, S., Ohri, R., Singh, K., Singh, M., & Bansal, P. (2021). Comparison of different ultraso und parameters for airway assessment in patients undergoing surgery under general anesthesia. ***Turkish Journal of Anesthesiology and Reanimation,*** ***49*****(5), 394–399. https://doi.org/**	N/A	Prospective observationa l study to evaluate and correlate ultrasound measuremen t of airway parameters with CL grading for prediction of difficult airway.	Study includes 96 patients scheduled for elective surgery under general anesthesia and endotracheal intubation. Inclusion criteria: patients between 18-70 yrs old with ASA I/II scheduled for elective surgery. Exclusion criteria: pregnant women, history of airway pathology, history of	Independent variables: age, BMI, ANS-VC, HMDr, tongue volume Dependent variables: ability to identify airway measurements with ultrasound compared to CL grading.	Statistical analysis includes use of SPSS 21 for quantification data mean SD calculated and for qualitative data percentage and proportion calculated. Categorical variables analyzed using Chi-square test, Fisher exact test, and independent t-test. P values used.	Analysis includes anterior neck soft tissue thickness at vocal cord level (ANS-VC), hyomental distance ratio (HMDr), and tongue volume (TV). Parameters were compared and correlated with CL grading.	Study showed ANS-VC was most significant parameter as a predictor of difficult intubation. Combined parameters (ANS-VC, HMDr, and TV) are better predictors of difficult intubation.	I I

10.5152/tjar.2021.1370			arthritis, history of cervical spine injury, history of previous head and neck injury, patient refusals.					
Article 15: Ultrasonography indicators for predicting difficult intubation: a systematic review and meta-analysis								
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). https://doi.org/10.1186/s12873-021-00472-w	N/A	Systematic review and meta-analysis conducted to review the performance of ultrasound in difficult airway assessment.	Comprehensive search performed in international bibliometric databases including PubMed, ISI's Web of Science, SCOPUS, and EMbase. Inclusion criteria: having performed difficult airway assessment based on ultrasound, indicators, having compared the indicators in difficult and easy groups, and English publication. Exclusion criteria: data from another included study or if full text could not be accessed.	Independent variables: ultrasound measurements for use based on the literature reviewed. Dependent variables: predictive value of difficult laryngoscopy based on the literature reviewed.	Meta-analysis conducted based on the random-effects model. Forest plot and pooled mean difference presented for all the US indicators with at least two studies. The heterogeneity of preliminary studies were evaluated using the I-squared, Tau squared statistics, and Cochran's Q test. Meta-analysis performed in STATA statistical software, version 16.	Analysis includes a total of 45 ultrasound indicators for predicting difficult intubation examined in the 26 reviewed studies.	Study results show the use of ultrasound in airway assessments is effective for prediction of difficult laryngoscopy.	I
Article 16: Comparative Study of Preoperative Airway Assessment by Conventional Clinical Predictors and Ultrasound-Assis Predictors								
Yadav U, Singh RB, Chaudhari S, Srivastava S. Comparative study of preoperative airway	N/A	Prospective, observational study to evaluate effectiveness of ultrasound	Study includes 200 patients older than 18 years undergoing elective surgery under general	Independent variables: age, BMI, sex, ASA grade, ANS-VC, ANS-HYOID, ration of PES/ EVC.	Sensitivity and specificity values for calculation based on a previous study. Target	Analysis includes measurements of anterior neck soft-tissue thickness at	Study concludes ANS-VC is a good predictor of difficult laryngoscopy	I I

assessment by conventional clinical predictors and ultrasound-assisted predictors. Anesth Essays Res 2020;14:213-8.		airway parameters as predictors of difficult laryngoscopy and evaluate the validity of combined sonographic and clinical tests.	anesthesia with endotracheal intubation. Exclusion criteria: patients who require rapid sequence intubation, with cervical spine pathology, scheduled for fiber-optic tracheal intubation, uncooperative patients, and pregnant.	Dependent variables: ability to identify airway measurements with ultrasound compared to CL grading, Mallampati scoring, TMD, and HMDR.	significance level is 0.05. MS Excel and Epi Info software packages used for the data entry and analysis. In comparing continuous variables, Student's t-test was used, and results were presented as mean ± standard deviation. Comparison of variables between groups was assessed using Chi-square test.	the level of vocal cord, ANS tissue thickness at the level of hyoid, and ratio of pre-epiglottic space to distance from epiglottis to midpoint of the distance between vocal cords, also including clinical parameters such as modified Mallampati class, thyromental distance, and hyomental distance ratio (HMDR).	; ANS-VC is a better predictor for difficult airway than clinical parameters such as MMP and TMD. HMDR has high specificity and accuracy for difficult intubation. Combined models of sonographic and physical tests further improve diagnostic value to identify the cases of difficult intubation.	