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Perioperative Chest X-ray Interpretation for Anesthesia Providers

Kaitlyn Brown

Jessica Parsons

PERIOPERATIVE CHEST X-RAY INTERPRETATION FOR ANESTHESIA PROVIDERS

by

Kaitlyn Brown and Jessica Parsons

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Committee:

Dr. Mary Jane Collins Committee Chair
Dr. Nina McLain

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ABSTRACT

Currently, a knowledge gap exists among anesthesia providers regarding perioperative chest x-ray (CXR) appropriateness and interpretation (Collins, 2022). The Council on Accreditation (COA) requires that students graduating from a nurse anesthesia program (NAP) interpret a minimum of five CXRs before program completion (Council on Accreditation [COA], 2020). This DNP project aimed to address the knowledge gap by offering an easily accessible online forum that guides anesthesia providers on CXR indications in surgical patients, and in identifying pathologies and invasive line and tube placement using CXR.

The authors created four learning modules regarding perioperative CXRs using Microsoft PowerPoint presentations with animation and voiceover. Modules one, two, three, and four covered CXR indications and basic anatomy, endotracheal tube placement (ETT) on CXR, central venous catheters (CVC) and pulmonary artery catheters (PAC) on CXR, and identifying common pathologies respectively. The authors uploaded the presentations to YouTube® and created a post-module assessment using Qualtrics®. An electronic mail invitation which included links to the YouTube® modules and the survey was sent to certified registered nurse anesthetists (CRNA) and student registered nurse anesthetists (SRNA).

The authors evaluated participants' answers to knowledge-based questions on the post-module survey as quantitative data. The qualitative data included participants' feedback regarding the overall experience with the online learning module and participants' preferences regarding educational forums. The quantitative data supported the assertion that an online medium regarding CXR indications and interpretation in

anesthesia is an effective learning tool. Both CRNAs and SRNAs provided positive feedback regarding the educational experience.

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DEDICATION

I would like to dedicate this project to several people. First, I would like to thank my husband, Chris, for pushing me to accomplish my dreams. I am thankful for his unwavering support and love throughout this program and our marriage. Thank you for your understanding and sacrifice over the last three years. I would also like to thank my mother, Patricia Cheek, stepfather, Chris Cheek, my brother, Jonathan, my father, Eddie Thornton, and my mother and father-in-law, Cindy and David Brown for their immense support, encouragement, and love. I would not have made it this far without all of you cheering me on. Lastly, I would like to thank my project partner and friend, Jessica, for her assistance and dedication to this project. I am very grateful that CRNA school brought us together. Without each of you, completion of this doctoral project and earning my doctoral degree would not be possible. – *Kaitlyn Brown*

I would not have been able to complete this project without the continued support of my husband, Matthew Kenney, and my parents, David and Patsy Parsons. Thank you all for helping keep everything together at home while I have been busy working to meet the requirements for this DNP project and the DNP program. I would also like to thank my DNP project partner, classmate, and friend, Kaitlyn Brown for her contribution to the project, and her patience with me throughout this process. We work together well, and I am grateful for her role and continued diligence throughout our project. I am fortunate to have each of you in my life. For the dedication you all have shown me, I am dedicating this project to you. – *Jessica Parsons*

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LIST OF ABBREVIATIONS

AACN	American Association of Colleges of Nursing
AANA	American Association of Nurse Anesthesiologists
ABIM	American Board of Internal Medicine
ACR	American College of Radiology
AP	Anteroposterior
ASA	American Society of Anesthesiology
ASC	Ambulatory surgery center
COA	Council of Accreditation
COPD	Chronic obstructive pulmonary disease
C*RNA*	Certified Registered Nurse Anesthetist
CVC	Central venous catheter
CVP	Central venous pressure
CXR	Chest X-ray
ETT	Endotracheal tube
IHI	Institute for Healthcare Improvement
IJV	Internal jugular vein
IRB	Institutional review board
NAP	Nurse Anesthesia Program
PA	Posteroanterior
PAC	Pulmonary artery catheter
SRNA	Student Registered Nurse Anesthetist
SVC	Superior vena cava

USCMS	U.S. Center for Medicare and Medicaid Services
USFDA	U.S. Food and Drug Administration
USM	The University of Southern Mississippi

CHAPTER I – INTRODUCTION AND BACKGROUND

The American Association of Nurse Anesthesiology (AANA), established in 1931, represents the Certified Registered Nurse Anesthetist (CRNA) profession. Nearly 60,000 CRNAs and Student Registered Nurse Anesthetists (SRNA) are AANA members (American Association of Nurse Anesthesiology [AANA], 2022a). The organization sets forth the expectations, guidelines, and scope of practice for the nurse anesthesia profession (AANA, 2022b).

Included in the nurse anesthesia scope of practice, CRNAs have the authority to order and interpret chest X-rays (CXR) when clinically necessary (AANA, 2022b). Clinical indications for CXRs include verification of invasive access placement, suspected pathological cardiac and pulmonary processes, and preoperative assessment of high-risk patient populations (Jindal et al., 2018). While facility-specific guidelines for perioperative CXR may be in place, the onus is on the anesthesia provider to order CXR on a patient-specific basis. Furthermore, the provider's responsibility is to interpret CXR accurately and understand the clinical implications of image results.

Prior to January 1, 2022, the Council on Accreditation of Nurse Anesthesia Programs (COA) requirements for CXR interpretation included a didactic curriculum covering basic principles of radiology, anatomy, and radiation safety (Council on Accreditation [COA], 2021). Effective January 1, 2022, students matriculating into accredited nurse anesthesia programs (NAP) must also fulfill a clinical experience requirement in CXR interpretation. The standard that COA establishes is five CXR interpretations, with a preference that students perform a total of 10 CXR interpretations before NAP completion. Students may meet COA requirements for CXR interpretation

via online courses, simulations, classroom activities, and clinical settings. The COA (2021) standard states that the SRNA must meet the following requirements when interpreting CXR:

> The student accurately recognizes normal and abnormal findings on [CXR] that may have immediate preanesthetic implications (e.g. pneumothorax, pulmonary edema) along with evaluating proper positioning of various tubes (e.g. endotracheal tubes, chest tubes) and invasive vascular access lines (e.g. central venous catheters) (p. 32).

Problem Description

Statement of the Problem

Based on informal feedback from anesthesia providers in clinical settings and training programs, a knowledge gap exists surrounding CXR indications and interpretation (Collins, 2022). Negative consequences of this knowledge gap include potential adverse patient outcomes and increased patient and facility expenditures. While lecture-format education is in place for students enrolled in the NAP at The University of Southern Mississippi (USM), there is currently no uniform assessment modality available to assess students' proficiency in CXR. Establishing an evidence based CXR education module and uniform method of learning assessment has the potential to better equip anesthesia providers in safely delivering patient care.

Significance of the Problem

Ordering and interpreting CXR falls within the scope of practice of nurse anesthetists (AANA, 2020). SRNAs and CRNAs must be able to discern the indications for ordering perioperative CXRs, recognize major anatomical structures on CXR, identify

pathologies and invasive lines, interpret findings, and adjust medical approaches accordingly. Unrecognized pathologies or improperly placed invasive lines or tubes may potentially harm patients undergoing and recovering from anesthesia (Kellner et al., 2018). An educational module that includes CXR indications and a structured approach to CXR analysis may improve knowledge of CXR assessment and ordering criteria among anesthesia providers. Anesthesia providers may use the educational modules to minimize the current knowledge deficit regarding perioperative CXR and improve patient care.

Available Knowledge

Chest X-rays and Anesthesia Providers

While understanding CXR appropriateness is important, anesthesia providers' competence in CXR interpretation yields safe, independent anesthesia practice. The CRNA's scope of practice includes inserting central venous catheters (CVC) and pulmonary artery catheters (PAC), providing critical care services, and ordering necessary patient care consults (AANA, 2020). Proficiency in CXR interpretation is necessary to confirm proper placement of CVCs and PACs, provide proper pulmonary care to the critically ill, and order pulmonology consults when appropriate. Familiarity with normal and pathological CXRs begins during didactic instruction, but students and practitioners may not achieve proficiency without proper guidance and skill repetition (Barash et al., 2017). Higher levels of experience and practice in CXR interpretation positively correlate with accurate diagnoses and faster interpretation times (Kelly et al., 2016). Exposure to interpreting diagnostic and routine CXRs in anesthesia training is necessary to become a competent provider upon certification receipt.

Chest X-ray Indications

When considering the appropriateness of perioperative CXRs, providers weigh the risks and benefits of such imaging on an individualized basis. Risks of CXRs include radiation exposure and increased cost to the patient and facility (United States Centers for Medicare and Medicaid Services [USCMS], 2019). Radiation exposure due to CXR is low relative to other radiologic procedures (American Board of Internal Medicine [ABIM], 2016). Still, repeated radiation exposure increases patients' risk of cancer in the future (U.S. Food and Drug Administration [USFDA], 2019). Because ordering providers may not know patients' cumulative radiation exposure, providers should utilize CXR imaging judiciously. The relatively low cost of CXR makes for an attractive assessment option; however, if providers cannot adequately justify ordering such imaging, patients may incur the total fee without insurance aid (American Society of Anesthesiologists [ASA], 2012). While perioperative CXR may expose patients to risks, there are benefits that anesthesia providers must consider. Chest X-rays are readily accessible in most facilities offering anesthesia services, and imaging results are quick (Park et al., 2019). Additionally, when practitioners suspect the presence of an undiagnosed cardiac or pulmonary pathology, perioperative CXRs offer diagnostic evidence of a disease process (Jindal et al., 2018). Imaging results may impact anesthetic and surgical approaches and shape patients' health care beyond the perioperative stage.

Several healthcare entities seek to establish recommendations for preoperative CXRs. The Choosing Wisely initiative recommends that providers order preoperative CXRs for patients in the following categories: patients 70 years of age or older without a CXR in the six months before surgery, patients with a known or suspected cardiac or

pulmonary history, and patients undergoing intrathoracic procedures (ABIM, 2016). The USCMS discourage preoperative CXRs for patients in the following populations: patients without known or suspected cardiac or pulmonary disease and patients presenting with minor trauma of the head, lower back, or extremities (USCMS, 2019).

In 2015, the American College of Radiology (ACR) published a rating system for CXR appropriateness. In the publication, ACR assigned patient population scores from one to nine, with higher values corresponding with increased CXR appropriateness. According to this model, patients without a known or suspected clinical diagnosis score three, while patients with known or suspected cardiopulmonary disease score an eight. Patients older than 70 years old, patients scheduled for high-risk procedures, and patients with an unreliable health history have a CXR appropriateness score of seven (American College of Radiology [ACR], 2015). The ACR (2022) set forth practice recommendations for CXR indications, however, these suggestions are not intended to establish a standard of care. Instead, the ACR suggests that providers order CXRs on an individualized basis and consider the circumstances and the patient's health history. The ACR (2022) states that preoperative CXR is appropriate when "cardiac or respiratory symptoms are present and there is a significant potential for thoracic pathology that may influence anesthesia or the surgical result or lead to increased perioperative morbidity or mortality" (ACR, 2022). The group maintains that the practice of performing routine preoperative CXR is not evidence-based.

The American Society of Anesthesiology (ASA) acknowledges that abnormal CXRs are likely in disease processes such as chronic obstructive pulmonary disease (COPD), cardiac disease, and recent respiratory infections, as well as patients of

advanced age and clients who are current or former smokers (ASA, 2012). However, the organization discourages practitioners from viewing these factors as absolute indications for preoperative CXRs. While these recommendations may guide anesthesia providers' decision-making process, there is no formal guideline, and many facilities lack established criteria or protocols concerning perioperative CXRs (USFDA, 2019).

Pathological indications for preoperative CXR include known or suspected pneumonia, pulmonary edema, atelectasis, congestive heart failure, valvular heart disease, aortic aneurysm, mediastinal or pulmonary masses, tracheal deviation, pulmonary hypertension, cardiomegaly, COPD, and pulmonary embolism (Jaffe et al., 2019). While understanding the patient's condition aids providers in anesthetic approaches, it is outside the scope of practice for CRNA and this DNP project to diagnose disease processes. Rather, anesthesia providers may use known or suspected conditions to guide decisions regarding CXR appropriateness and anesthetic approaches.

Chest X-ray Interpretation

Evaluating CXR requires a thorough understanding of chest anatomy, pathophysiology, terminology, and physics. The three common CXR views include posteroanterior (PA), anteroposterior (AP), and lateral views (Pezzotti, 2014). In the PA view, the x-ray beams pass through the patient from posterior to anterior. This approach requires the patient to stand during the procedure. Conversely, in the AP orientation, x-ray beams pass through the patient anteriorly while the patient is in the supine position. Practitioners may request the AP view in portable CXR for patients who are unable to stand. While portability and accessibility are advantages of the AP orientation, clinicians should be aware that this view will magnify anterior thoracic structures, including the

cardiac silhouette. In the lateral view, the x-ray beams project from right to left (Pezzotti, 2014). The lateral orientation allows examiners to view anomalies behind the heart. X-ray technicians achieve the most thorough examinations with both AP and lateral imaging taken during maximal inspiration (ACR, 2022).

X-rays translate into images based on the density of anatomical structures. Understanding opacities of structures, fluid, and air allows for an accurate interpretation of anatomic features and physiologic processes. Bone and metal are dense, resist the passage of X-rays, and appear radiopaque or white on a radiograph. Water and soft tissue appear gray to white and signify fluid-filled organs and soft tissue or fluid-filled lesions (Pezzotti, 2014). Fat is more lucent than bone and soft tissue, but more opaque than gas, and it appears gray. Gas, the least dense state of matter, is the most radiolucent and appears black on a radiograph (Pezzotti, 2014).

Understanding the basic features of a CXR is the foundation for accurate interpretation. When initially viewing a CXR, practitioners may use the mnemonic RIPE to assess CXR quality and features. The R signifies rotation, followed by inspiration, positioning, and finally, exposure (Ozlem, 2023). Examiners may look at the patient's clavicles to assess patient rotation. Ideally, the clavicles will be symmetrical and in-line with each other. Patient rotation alters the shape and size of mediastinal structures, therefore, overlooked patient rotation may result in CXR misinterpretation (Ozlem, 2023). Patient inspiration places the diaphragm at the level of the eighth- 10^{th} posterior rib. While inspiration yields an optimal view of thoracic structures, expiration may be useful in visualizing pneumothoraces (Ozlem, 2023). Positioning refers to the CXR approach: AP, PA, and lateral. A lateral and PA view of each patient needing a CXR is

ideal, however, the patient's physical status may preclude this approach. When examining the lateral view, the right chest is closer to the x-ray machine, and practitioners appreciate larger-appearing ribs on the right side. The lateral view is particularly helpful in patients with a known or suspected pathological condition concerning the posterior heart (Ozlem, 2023). Examiners may note exposure quality by assessing the opacity and brightness of anatomic structures. Anatomy in underexposed images appears bright white, and the examiner is unable to note thoracic vertebrae. Overexposed CXR appears dark where bony structures should be, however, the vertebrae are usually more defined than in images with normal exposure. (Ozlem, 2023).

Examiners may employ a systematic approach to identifying landmarks and physiologic features using the acronyms A, B, C, D, E, and F, denoting airway, bones, circulation, diaphragm, edges, and fields respectively (Pezzotti, 2014). When assessing the airway, practitioners note the positioning of the trachea, which should be midline, but a slight rightward shift may be present around the aortic arch. Generally, a deviated trachea indicates a pathology such as a tension pneumothorax or goiter, that requires follow-up. However, considering patient positioning when a pathology is an unexpected finding is important (Pezzotti, 2014). Inferior to the trachea, the examiner identifies the carina. Normally, the carina lies between the T4 and T6 vertebrae. Providers may confirm the proper placement of an endotracheal tube (ETT) in an intubated patient when the tip of the ETT is three to five centimeters superior to the carina (Pezzotti, 2014). When assessing the bones in a CXR, observe all bony structures for any deformities or fractures (Pezzotti, 2014). Features of optimal positioning include vertebrae centered between the clavicles and scapulae imaging outside of the lung fields (ACR, 2022). With maximal

inspiration on a PA view, the examiner notes nine to ten posterior ribs. Intercostal spaces should be symmetrical (Pezzotti, 2014). Larger intercostal spaces indicate an air-trapping pathology consistent with conditions such as COPD and bronchial obstruction (Hines & Marschall, 2017). Circulatory assessment includes examining cardiac features and vasculature. The cardiac silhouette should be no more than 50% of the width of the thorax. The AP approach to CXR may magnify cardiac imaging, however, cardiomegaly and pericardial effusion are possible etiologies of a large cardiac silhouette (Pezzotti, 2014). In a healthy patient, the mediastinum appears clear with some vasculature noted around the heart. Visible lymph nodes around cardiac structures warrant further investigation (Clarke & Dux, 2017). The diaphragm should curve superiorly in the center, and nine to 10 ribs should be visible (Pezzotti, 2014). In pathologies such as pneumothorax or COPD, the examiner visualizes more than 10 ribs, and in conditions such as abdominal distension and atelectasis, fewer than nine ribs are visible on imaging (Pezzotti, 2014). Examining lung edges and fields includes noting air and fluid collection. Poorly defined, non-acute costophrenic angles appear in patients with a hemithorax, pneumothorax, or pleural effusion (Pezzotti, 2014). Consider patient positioning when noting the presence of fluid or free air in lung fields. Fluid follows gravity, while air moves in the opposite manner (Pezzotti, 2014).

The authors identify four domains regarding CXR that anesthesia providers encounter in practice. These domains include CXR appropriateness, assessing ETT position, evaluating invasive line position, and recognizing pathologic findings on a CXR. The most fundamental of these domains is CXR appropriateness. Before ordering or interpreting a CXR, providers identify CXR indications on an individual basis. While

various groups make recommendations regarding perioperative CXR, the provider may make judgments regarding CXR appropriateness that lie outside of these established parameters. Anesthesia providers must make informed decisions when ordering perioperative CXR.

The examiner notes the proper placement of an ETT when the tip of the tube rests three to five centimeters above the carina (Gropper et al., 2020). The carina is the cartilaginous base of the trachea that separates the openings of the left and right mainstem bronchi and lies at the level of the fourth and fifth thoracic vertebrae (Nagelhout & Elisha, 2018). There may be slight individual variation, meaning the carina may be anatomically located at a vertebral space above or below the fourth and fifth thoracic vertebrae. The examiner may use this vertebral landmark if the carina is not visible on a CXR.

A common complication following ETT placement is inadvertent right mainstem bronchus intubation (Dawson et al., 2019). From the carina, the right bronchus branches off at a 25-degree angle, and the left bronchus branches off at a 45-degree angle (Nagelhout & Elisha, 2018). The more vertical angle of the right bronchus contributes to the right mainstem bronchus intubation. Unrecognized bronchial intubation may lead to atelectasis of the contralateral lung, barotrauma of the ipsilateral lung, and hypoxemia (Cornelius & Sakai, 2015).

A common entry point for CVC is the right internal jugular vein (IJV). Optimal placement of a right-side IJV CVC places the tip of the catheter in the distal one-third of the superior vena cava (SVC), just above the SVC and right atrial junction. Advancing the CVC into the heart chambers may lead to dysrhythmias, cardiac perforation, or

cardiac tamponade (Butterworth et al., 2022). Incorrect positioning of a CVC within the SVC results in peripheral medication administration and inaccurate central venous pressure (CVP) monitoring. Optimally, providers confirm correct CVC placement under fluoroscopy or obtain a CXR post-operatively. Positioning the CVC within the superior vena cava and below the level of the pericardial reflection is ideal. However, examiners may not be able to identify the SVC and pericardial reflection on a CXR. Instead, providers may use the carina as a landmark. The examiner notes ideal CVC positioning when the tip of the catheter projects over the anatomical location of the superior vena cava and at or slightly below the carina on a CXR (Venugopal et al., 2013).

Because the right IJV is a direct route to the right heart chambers, the vessel is a common insertion site for PACs. The practitioner advances the PAC through the SVC, right atrium, right ventricle, and finally in the right or left pulmonary arteries. On chest imaging, the PAC makes a counterclockwise turn within the cardiac silhouette and ends at the level of the hilum. The tip of the PAC should be within two centimeters of the cardiac silhouette on a standard AP CXR. Advancing the PAC too far may result in pulmonary artery rupture and mortality (Gropper et al., 2020).

Anesthesia providers must be well-versed in recognizing pathologic findings on a CXR. Possible pathologic findings anesthesia providers may encounter in practice include a simple pneumothorax, tension pneumothorax, negative pressure pulmonary edema, cardiogenic pulmonary edema, and atelectasis. A simple pneumothorax occurs when air enters the pleural space, separating the visceral pleura from the parietal pleura. Air is visible between the visceral pleural lining and the rib cage. Radiographic features of a simple pneumothorax include a thin, sharp white line that represents the visceral

pleura, no lung markings visible past the white line, no mediastinal shift, and partial or complete collapse of the affected lung. When air enters the pleural space and cannot escape during expiration, intrapleural pressure increases leading to compression of mediastinal structures, a tension pneumothorax. A tension pneumothorax has the same radiographic features as a simple pneumothorax but with a contralateral shift of the mediastinum, contralateral tracheal deviation, and depression of the hemidiaphragm in a caudad direction. Additionally, a deep sulcus sign may be present. The provider notes a deep sulcus sign when an acute, well-defined costophrenic angle is visible on the side ipsilateral to the pneumothorax. This phenomenon occurs secondary to a hyperinflated pleural space (Hines & Marshall, 2017).

Pulmonary edema is a broad term describing an abnormal accumulation of fluid in the lungs. There are various etiologies of pulmonary edema. For this DNP project, the authors will limit the discussion of pulmonary edema to negative pressure pulmonary edema and cardiogenic pulmonary edema.

Negative pressure pulmonary edema is a rare complication that typically transpires immediately following or within a few minutes of tracheal extubation in spontaneously breathing healthy, muscular adolescents and young adults (Barash et al., 2017). The pathophysiology of negative pressure pulmonary edema is related to increased negative intrapleural pressure secondary to robust inspiratory efforts against an obstructed upper airway (Hines & Marshall, 2017). The most common radiographic findings consistent with negative pressure pulmonary edema are diffuse, bilateral hazy infiltrates in the perihilar region (Barash et al., 2017). The fluid pattern is often described

as a “butterfly” due to bilateral, symmetrical opacities on the CXR (Hines & Marshall, 2017).

Cardiogenic pulmonary edema is the result of left-sided heart dysfunction or failure leading to fluid buildup in the lungs. Conditions associated with cardiogenic pulmonary edema include left-sided heart failure, hypertension, ischemic heart disease, coronary artery disease, cardiomyopathies, and fluid overload (Nagelhout & Elisha, 2018). Radiographic features consistent with cardiogenic pulmonary edema are an enlarged cardiac silhouette, interstitial edema, pulmonary vascular congestion, pleural effusions, “whiteout” or “butterfly” fluid pattern, and Kerley B lines (Barash et al., 2017).

Atelectasis, a major cause of perioperative morbidity, describes the incomplete expansion of the lungs. Alveoli are unable to fully inflate and cannot effectively participate in gas exchange. The incidence of atelectasis in surgical patients is 90% (Gropper et al., 2020). Clinicians may observe hypoxemia and decreased lung compliance in patients with atelectasis. Anesthetics, neuromuscular blockers, inadequate pain control, thoracic or cardiopulmonary procedures, aspiration, pneumonia, foreign body aspiration, mucus plug, and intrathoracic tumor increase the risk of developing atelectasis in the perioperative period. Radiographic findings that indicate atelectasis include displacement of lobar fissures on the affected side, opacification in the collapsed segment, slight contralateral mediastinal shift, and elevated ipsilateral hemidiaphragm (Grott et al., 2022).

Adult Education Best Practices

In 1926, Eduard Lindeman introduced the notion that adult learning is an experience distinct from learning that takes place during childhood (Lindeman, 2017).

Lindeman proposed that for education to be meaningful for adults, learners must be able to apply new knowledge to situations and experiences rather than study based solely on observation or via text. He posited that "we learn what we do," and that adults who actively practice and apply newly learned information will retain knowledge better than individuals who learn passively and will achieve a greater sense of fulfillment (Lindeman, 2017). Furthermore, adult learners require a level of autonomy and self-direction that is not necessary in younger learners. Ideally, adult learners will have the freedom to analyze educational experiences and reflect on the learning process (Lindeman, 2017). While Lindeman applied these principles to all adult learners, he acknowledged the significance of the setting in which the learner operates (Lindeman, 2017).

With the technological advancements that have taken place in the last 100 years, current adult learners no longer function in the same environment as the adult learners to which Lindeman referred. However, the increased availability of information affords adult learners with autonomy and freedom that was not possible in the past (May et al., 2009). Students in higher education institutions report that interactive online modules are overall beneficial and foster a positive learning environment that emphasizes autonomy and ease of access (May et al., 2009). More specifically, medical students who participated in online learning for CXR interpretation described the experience as meaningful and stated that they would recommend the forum to peers (Sait & Tombs, 2021). Whether or not the educator enlists the use of current technologies, creating an environment of autonomy and interactive experiences with the freedom to analyze the educational process is paramount in the adult learning experience (May et al., 2009).

Rationale

Theory

Miller (1990) describes the clinical assessment framework hierarchically by illustrating graduated levels of knowledge on a pyramid. The basis of clinical application according to Miller is raw knowledge. Clinicians and students must begin with a basic understanding of the scientific foundations surrounding clinical practices. Next, moving up on the pyramid, learners exhibit competence by translating clinical knowledge to task performance. In the third stage, learners use the knowledge and competence gained in prior levels to perform a skill. The final level of the pyramid requires that learners use all prior knowledge and skills to make sound clinical decisions regarding a given topic (Miller, 1990). Reaching this final tier of Miller's framework requires that the learner can assess patients' condition, plan a course of action, and apply the plan in the clinical setting.

The authors created a learning module that applies the clinical assessment principles of Miller's framework. Participants had the opportunity to follow learning resource modules that outline fundamentals of CXR interpretation applicable to anesthesia. The modules equipped learners with information regarding CXR indications, how to identify physical landmarks, invasive lines and tubes, and pathological processes. Furthermore, the authors will include guidance on indications for ordering perioperative CXRs. The authors used a post-module questionnaire to assess participants' upward mobility on Miller's pyramid.

Quadruple Aim

The Institute for Health Improvement (IHI) (2023) identifies three healthcare objectives aimed at improving health quality. These objectives include patient experience, population health, and cost reduction, and collectively comprise the IHI triple aim initiative. The quadruple aim considers provider wellbeing, yielding a comprehensive approach to quality improvement in health care (Bradshaw & Vitale, 2020). The current DNP project seeks to address each objective of the quadruple aim to encourage evidence-based practices in the clinical setting and facilitate improved patient outcomes.

Patients realize an improved experience when providers are competent in fundamental clinical skills such as CXR interpretation. The current DNP project aims to provide a medium through which anesthesia providers may learn CXR appropriateness and how to recognize common findings. This DNP project focuses on the perioperative patient population.

Chest X-rays are common in the perioperative setting, however, there is limited evidence regarding the direct impact CXR has on patient outcomes. The ASA (2019) guidelines stress the significance of clinical assessment, comprehensive history and physical examination, and evaluation of pertinent risk factors to determine the need for perioperative CXR. While initiatives like the Choosing Wisely campaign (ABIM, 2019) and recommendations set forth by the ACR (2022) and ASA (2012) focus on preoperative testing, the patient experience in this population includes all phases of surgical care. Half of the anesthesia closed claims from 2010 to 2014 that involved patient demise were the result of respiratory complications (Kellner et al., 2018). Among these complications were missed esophageal intubation, pulmonary edema due to fluid

volume overload, and pneumothoraces. One case of pneumothorax involved subclavian CVC malposition in which anesthesia providers cited reliance on the radiology department to report an error (Kellner et al., 2018). These complications are examples of intraoperative and postoperative events that healthcare providers may have identified before the patient's demise had the healthcare team utilized CXR properly. Anesthesia providers may consider the implications of CXR in this patient population, and use CXR results to guide anesthetic management and promote population health.

Surgical patients require preoperative laboratory and diagnostic studies that are consistent with their medical history. In the United States, the cost of preoperative testing is approximately $3 billion annually (Jaffe, 2020). Inapt preoperative testing may lead to superfluous surgical delays, cancelations, and unnecessary follow-up procedures. Potential costs to patients with health insurance coverage include out-of-pocket expenses such as deductibles and co-pays. The total cost a patient is responsible for is variable and depends on the specific insurance plan. Patients with Medicare coverage realize an average cost of $4 and $17 for CXR in outpatient surgery centers and outpatient hospital settings respectively (USCMS, 2022). However, individuals without insurance may be responsible for the entire cost of the CXR. Prospective facility costs include the radiologist’s CXR interpretation service fee and the salaries of radiology technicians who perform the CXR examination. Though CXRs are a relatively cheap procedure, understanding CXR appropriateness aids in keeping patient and facility costs down.

Proficiency in perioperative CXR interpretation among anesthesia providers promotes confidence in clinical skills which may decrease workplace stress and enhance

provider wellbeing. This DNP project aimed to promote confidence in this clinical skill through educational modules and encourage an understanding of CXR appropriateness. The authors' goal was to provide clinicians with a low-stakes, anonymous forum that encourages honest feedback.

DNP Essentials

The American Association of Colleges of Nursing (AACN) establishes eight advanced nursing concepts that DNP programs must emphasize throughout students' educational tenure. The AACN refers to these concepts collectively as DNP Essentials (American Association of Colleges of Nursing [AACN], 2006). The current DNP project employs DNP essentials to guide the research process. Establishing an informatics forum for CXR interpretation and indications involves the following DNP essentials.

Essential I: Scientific Underpinnings for Practice

The AACN requires that doctorate students understand the scientific basis of human processes and can incorporate nursing theories in the treatment of such processes (AACN, 2006). Instruction surrounding CXR includes anatomy and physiology, pathological conditions, and physical principles of radiographs. Examining instruction methods through the lens of Miller's information processing theory further solidifies this DNP project's scientific basis. The results of this study support future DNP students' participation in scientific-based practices regarding perioperative CXR.

Essential II: Organization and Systems Leadership for Quality Improvement and Systems Thinking

Understanding CXR indications and appropriateness as well as the costs and risks associated with CXR will yield more judicious and informed decisions regarding

perioperative radiographs. Students who gain a comprehensive understanding of the patient's condition as it relates to CXR indications will potentially have the skillset and confidence to make clinical judgments that support patients' health. In this way, applying the principles outlined in the CXR educational forums may lead to quality improvement in the clinical setting.

Essential III: Clinical Scholarship and Analytical Methods for Evidence-Based Practice

This DNP project employed clinical research methods to better understand CXR indications and interpretation. The process included analyzing the available information and translating that knowledge into an educational forum. The authors communicated the knowledge gained via educational modules. In accordance with the AACN's Essential III (AACN, 2006), the authors analyzed the efficacy and user satisfaction of each learning modality and disseminated the findings.

Essential IV: Information Systems/Technology and Patient Care Technology for the Improvement and Transformation of Health Care

Essential IV requires that students use and apply information and technology to improve patient care (AACN, 2006). When evaluating educational modalities, the authors will analyze the efficacy of two types of information systems each with differing degrees of technological application. By providing the optimal approach to the students of the USM NAP, this DNP project will provide the resources necessary for clinicians in training to better understand patients' physical processes and provide informed care.

Essential VIII: Advanced Nursing Practice

This DNP project employed the principles of patient assessment, clinical interventions, evidence-based practices, and peer guidance in nursing that the AACN

(2006) outlines in Essential VIII. The authors offered anesthesia providers a learning module that focuses on patient assessment and guides clinical interventions.

Specific Aims

This DNP project aimed to establish a learning modality that aids anesthesia providers in CXR interpretation and CXR indications for surgery patients. The goal was to offer a learning environment through which the anesthesia community may learn and apply CXR interpretation skills. The authors plan to provide access to these modules as instructional tools for students enrolled in the USM NAP and currently practicing anesthesia providers. The authors collected quantitative information via post-module questionnaires and qualitative data via learner feedback. Providing this population with a comprehensive and palatable learning experience regarding CXR interpretation will potentially aid in yielding safe and informed anesthesia providers.

Stakeholders

The authors establish four groups of stakeholders for the current DNP project. The first group includes the panel of experts participating in the DNP project, anesthesia providers. Anesthesia providers include currently practicing CRNA, anesthesiologists, and SRNA. The next group of stakeholders is surgical patients who rely on anesthesia services for perioperative care. Patients presenting to ambulatory surgery centers (ASC) and hospitals depend on anesthesia providers to make decisions regarding medical care. Similarly, healthcare facilities offering surgical services trust that anesthesia providers will order services, including CXR, that are relevant to patients' wellness in the perioperative period. Educational entities teaching anesthesia providers comprise the final group of stakeholders. These schools include NAP and medical schools whose interest is

to provide students with accessible resources relevant to patient care in students' future careers.

Summary

Based on informal feedback from anesthesia providers in clinical settings and training programs, a knowledge gap exists surrounding CXR indications and interpretation (Collins, 2022). Negative consequences of this knowledge gap include potential adverse patient outcomes and increased patient and facility expenditures. While lecture-format education is in place for students enrolled in the NAP at The University of Southern Mississippi (USM), there is currently no uniform assessment modality available to assess students' proficiency in CXR. By employing current evidence regarding perioperative CXRs and adult learning practices (Appendix A) and using the DNP essentials (Appendix B) as guidance, the authors assert that an evidence based CXR education module and uniform method of learning assessment has the potential to better equip anesthesia providers in the delivery of safe and effective patient care.

CHAPTER II – METHODOLOGY

Introduction

A knowledge deficit exists among anesthesia providers surrounding CXR indications and proficiency in interpretation. This DNP project aimed to establish an education modality regarding perioperative CXR indications and interpretation guidelines by creating CXR learning modules. At the time of this study, lecture-format education was in place for students enrolled in the USM NAP, however, no uniform assessment modality was available to assess students' proficiency in CXR. Developing an evidence based CXR educational module with a systematic method of CXR interpretation can increase knowledge among anesthesia providers, improve the quality of patient care, and enhance provider confidence. Upon completing this CXR learning module, anesthesia providers identified normal anatomy on a CXR, recognized pertinent pathologic findings on a CXR that may have immediate anesthetic implications, and confirmed the proper positioning of invasive tubes and lines. The authors created this CXR training module to serve as a learning and evaluation tool for students enrolled in the USM NAP.

Context

Anesthesia providers' scope of practice includes ordering and interpreting CXR findings (AANA, 2022b). Providing quality care to the surgical patient requires proper knowledge and proficiency in CXR indications and interpretation. Effective January 1, 2022, students enrolled in accredited nurse anesthesia programs (NAP) must fulfill a didactic and clinical experience requirement in CXR interpretation (COA, 2021). Four domains were identified in the CXR training modules, including CXR appropriateness, proper positioning of ETT, evaluation of invasive line placement, and recognition of

relevant pathologic findings on a CXR. This DNP project involved the creation of a CXR training module to bridge the gap in knowledge among anesthesia providers.

The execution of this DNP project utilized SRNAs enrolled in the USM NAP, faculty at USM NAP, and CRNAs affiliated with USM NAP clinical sites. The CXR training module may be used by first-, second- or third-year SRNAs to solidify didactic education and to prepare for clinical application. Additionally, actively practicing anesthesia providers may use the CXR training module to review CXR indications and interpretation.

The USM NAP is a three-year DNP degree specializing in anesthetic practice. Each year, 20-25 students matriculate into the program. Currently practicing CRNA comprise the faculty responsible for training USM NAP students. The curriculum consists of a front-loaded didactic portion during the first year, followed by two years of clinical rotations in combination with didactic instruction. The USM NAP has 22 clinical sites with anesthesia providers. The affiliated clinical sites and the USM NAP foster a supportive environment for quality improvement of patient care.

While the USM NAP didactic curriculum does incorporate CXR interpretation and clinical application through a lecture format, there is no formal modality to assess students' learning. The USM NAP faculty confirmed the need for a learning tool to educate and evaluate students' proficiency in CXR understanding (Collins, 2022). The CXR training module was designed for students of any level in the NAP. Specifically, the modules compliment courses NUR 837: Basic Principles of Anesthesia Practice and NUR 855: Clinical Correlation and Facets of Nurse Anesthesia with simulation.

Interventions

The creation of this DNP project involved multiple steps to confirm the accuracy of information required for completion. The authors proposed the DNP project plan to the DNP committee following a methodology process. The DNP project included the following interventions:

1. The authors developed an evidence-based CXR training module from current peer-reviewed evidence-based literature review and anesthesia textbooks. The authors organized the material into four Microsoft PowerPoint presentations and recorded four asynchronous videos with audio. Participants reviewed each video at their leisure. Module content included CXR appropriateness, identifying proper ETT positions, evaluating invasive line placement, and recognizing perioperative pathologic findings that may impact anesthesia care.
2. The authors created a questionnaire to assess learning, perception of learning, and quality of the CXR training module.
3. The authors created an informed consent document.
4. A panel of experts from the USM NAP faculty, SRNAs, and clinical preceptors were identified.
5. The authors developed an invitation email to participate in the CXR training modules.
6. The authors requested DNP project approval from the Institutional Review Board of USM.

7. Following IRB approval, the authors sent an invitation email to participants. The email included a CXR training module link, an informed consent document, and an anonymous Qualtrics® link.
8. Data from the questionnaire was organized into a table. The authors stored the data on personal password-protected computers.
9. The authors reviewed and analyzed feedback from the questionnaire and compared participants' insight with evidence-based practice literature. If any responses aligned with evidence-based practice, the authors consulted with the DNP chair and committee and made the necessary changes.
10. The authors presented an executive summary with a report of findings and a policy proposal for the nurse anesthesia training program and anesthesia administration at clinical sites.
11. The CXR training module and research findings from the questionnaire results were disseminated at the School of Leadership and Advanced Nursing Practice Scholarship Day at USM.
12. The authors destroyed electronic data from secured personal computers by deleting files in the computer trash bin and deleting files in the trash bin.

The panel of experts included all levels of anesthesia providers. Feedback from SRNAs provided the perspective of learning and format. Clinically practicing CRNAs provided the perspective of learning, format, and practical application. Nurse anesthesia educators offered the perspective of curriculum design feedback and teaching methodology. The target participants surveyed were 35 SRNA and 20 CRNA clinical preceptors.

Measures and Instruments used to Study the Intervention

Following completion of the instructional modules, participants received a link to Qualtrics® with a questionnaire that included two questions pertaining to each module. The authors scored participants' answers. Evaluation scores were the basis for the quantitative measurements in this DNP project. The researchers evaluated scores to measure CXR interpretation proficiency and medical management appropriateness. In the later portion of the questionnaire, participants provided feedback through a rating system and free-text comment boxes. This final evaluation was the basis for qualitative research in this DNP project. The authors used participant feedback to better understand participants' learning preferences and guide decisions regarding changes to the learning modules. Participation and participants' performance were anonymous.

Participants who received participation invitations included anesthesia providers with varying levels of experience and educational backgrounds. Anesthesia providers included students currently enrolled in the NAP at USM, NAP faculty at USM, anesthesia preceptors at NAP clinical sites, and other currently practicing anesthesiologists and CRNAs who may not have direct affiliation with the NAP at USM. The authors agreed that the variety of anesthesia providers yielded multiple perspectives on the qualitative portion of the intervention measurements. Furthermore, the varying levels of experience allowed researchers to gauge the quality and clarity of the learning modules. Inviting educators and preceptors to participate yielded insights from individuals familiar with effective teaching methods and strategies.

The following questions were included in the survey:

1. Do you agree with the standard online consent form to participate in this study?
    a. Yes
    b. No
2. Please indicate your current title in anesthesia practice.
    a. Student Registered Nurse Anesthetist
    b. Certified Registered Nurse Anesthetist
3. For which patient is a perioperative CXR most appropriate?
    a. A 30-year-old female with a 12-pack/year smoking history presenting for preoperative testing for a robotic hysterectomy.
    b. 54-year-old male currently taking doxorubicin for the treatment of Hodgkin's lymphoma requiring 4 liters/min per nasal cannula in the post-anesthesia care unit (PACU) after a laparoscopic cholecystectomy
    c. A 68-year-old male with uncontrolled diabetes mellitus type 2 and chronic kidney disease presenting for right great toe amputation.
    d. A 72-year-old male with a history of hypertension and congestive heart failure with preserved ejection fraction presenting to preoperative testing before mitral valve repair

Answer and rationale: D. The ABIM recommends preoperative CXR for patients older than 70 years of age, individuals with known or suspected cardiac disease, and patients undergoing intrathoracic procedures (ABIM, 2016). The ACR preoperative CXR

recommendation guidelines assign this patient a score of 9, which corresponds with the highest level of preoperative CXR appropriateness (ACR, 2015).

4. A post-operative CXR may be beneficial in which of the following cases?
    a. Post-endotracheal extubation of a 65-year-old female on 6 liters/ minute simple facemask with an oxygen saturation of 95%
    b. A 33-year-old female who underwent external fixation of the tibia and fibula following a motor vehicle accident and will be transferred to the intensive care unit mechanically ventilated
    c. An 82-year-old male with chronic obstructive pulmonary disease who received total intravenous anesthesia for a bone marrow biopsy and is in the PACU on 3 liters/ minute nasal cannula with an oxygen saturation of 93%
    d. A 16-year-old male with a history of asthma who received a prophylactic albuterol treatment prior to extubation for a laparoscopic appendectomy

Answer and rationale: B. It is advisable to confirm and record the proper placement of an endotracheal tube that will remain in place outside of the operating suite. Complications regarding endotracheal tube migration and malposition may initially go unnoticed and result in poor patient outcomes (Kellner et al., 2018).

5. Anatomically, where should the tip of the endotracheal tube be located on the CXR for proper ventilation of both lungs?
    a. 1 cm above the carina
    b. 2-3 cm above the carina

c. 3-5 cm above the carina

d. 5-7 cm above the carina

Answer and rationale: C. The tip of the ETT should rest three to five centimeters above the carina or three to five centimeters above the fourth and fifth thoracic vertebrae to ensure adequate ventilation and oxygenation to both lungs.

6. The more _____ angle of the right mainstem bronchus contributes to inadvertent right mainstem bronchus intubation.

    a. Vertical

    b. Horizontal

    c. Obtuse

    d. Caudad

Answer and rationale: A. From the carina, the right bronchus branches off at a more vertical, 25-degree angle. The more vertical angle of the right mainstem bronchus contributes to inadvertent right mainstem bronchus intubation. Consequences of unrecognized right mainstem intubation include atelectasis of the contralateral lung, barotrauma of the ipsilateral lung, and hypoxemia.

7. Anatomically, where should the tip of a central venous catheter be on a chest x-ray?

    a. Proximal 1/3 of superior vena cava, tip of catheter projects over the anatomical location of superior vena cava and below the carina

    b. Distal 1/3 of the superior vena cava, tip of the catheter projects over the anatomical location of the superior vena cava and at or slightly below the carina

c. Right atrium, a tip of the catheter projects over the anatomical location of the right atrium and below the carina

d. Within 2 centimeters of the cardiac silhouette at the level of the hilum

Answer and rationale: B. Optimal placement of a right-side internal jugular vein CVC places the tip of the catheter in the distal one-third of the superior vena cava, just above the superior vena cava and right atrial junction. The examiner notes ideal central venous catheter positioning when the tip of the catheter projects over the anatomical location of the superior vena cava and at or slightly below the carina on a chest x-ray. The catheter in this position on the chest x-ray approximates the tip of the central venous catheter in the distal one-third of the SVC. Placement of the central venous catheter in the distal one-third of the superior vena cava ensures proper delivery of vasoactive medications directly into the central venous system and accurate central venous pressure monitoring.

8. Anatomically, where should the tip of a pulmonary artery catheter be located on a chest x-ray?

    a. Pulmonary artery, within 2 centimeters of the cardiac silhouette ending at the level of the hilum

    b. Pulmonary artery, within 4 centimeters of the cardiac silhouette and endings below the level of the hilum

    c. Right middle lobe, 4 centimeters outside of the cardiac silhouette and ending below the level of the hilum

    d. Right middle lobe, 2 centimeters outside of the cardiac silhouette and ending above the level of the hilum

Answer and rationale: A. Correct positioning of a PAC places the tip of the catheter in the left or right pulmonary artery. On a chest x-ray, the pulmonary artery makes a counter-clockwise turn within the cardiac silhouette and ends at the level of the hilum. The tip of the PAC should be within two centimeters of the cardiac silhouette on a standard anteroposterior chest x-ray. Proper placement of a PAC in the pulmonary arteries ensures accurate pulmonary artery pressure monitoring and pulmonary capillary wedge pressure measurements.

9. Chest x-ray findings consistent with a tension pneumothorax include:
    a. Enlarged cardiac silhouette, sharp white line denoting visceral pleura of unaffected side, and pulmonary vascular engorgement
    b. Absence of lung markings past the visceral pleura, contralateral mediastinal and tracheal shift, and deep sulcus sign
    c. Visible lung markings past the visceral pleura, ipsilateral mediastinal and tracheal shift, and shallow sulcus sign
    d. Lung markings are visible only on the unaffected side, the midline cardiac silhouette on the right side is affected

Answer and rationale: B. Hyperinflation in the pleural space results in contralateral shifting of mediastinal structures and caudal displacement of the hemidiaphragm (Hines & Marshall, 2017).

10. The pattern of fluid opacities in a patient with negative pressure pulmonary edema seen on a chest x-ray is described as the shape of a:
    a. Donut
    b. Crescent moon

c. Butterfly or batwing

d. Semi-circle

Answer and rationale: C. The pattern of fluid opacities in a patient with negative pressure pulmonary edema seen on a chest x-ray is described as the shape of a butterfly or batwing. Pulmonary congestion resulting from negative pressure pulmonary edema collects in the central thoracic vasculature (Barash et al., 2017).

11. Please indicate the degree to which you agree with the following statements:

    a. The learning modules were easy to understand.

        i. Strongly agree

        ii. Agree

        iii. Somewhat agree

        iv. Neutral

        v. Disagree

        vi. Somewhat disagree

        vii. Strongly disagree

    b. The learning modules included information that is relevant to my current or future anesthesia practice.

        i. Strongly agree

        ii. Agree

        iii. Somewhat agree

        iv. Neutral

        v. Disagree

        vi. Somewhat disagree

vii. Strongly disagree

c. It was easy to access the learning modules.

i. Strongly agree

ii. Agree

iii. Somewhat agree

iv. Neutral

v. Disagree

vi. Somewhat disagree

vii. Strongly disagree

12. Which learning approach do you prefer?

a. Traditional, in-person lecture

b. Remote, self-directed instruction

13. Please provide any recommendations or comments that would make this CXR training module easier to understand.

14. Are there any other comments you care to make?

Analysis

Data for this DNP project was collected using quantitative and qualitative methods. The responses gathered from the questionnaire were organized into a table. The researchers averaged the scores from the post-module questionnaire to measure how well the modules met the educational goals this DNP project established. The authors read and evaluated feedback from the questionnaire to determine participant satisfaction. This qualitative portion included a Likert scale rating of aspects of the modules, including clarity, clinical relevance, instruction preference, and ease of access. Also included in this

portion was free-text feedback that aided in understanding participants and participants' backgrounds.

Ethical Considerations

Ethical considerations regarding this study included participant misguidance regarding the aim of the educational modules. The authors informed participants that diagnosing pathological conditions was not the aim of the study. Participants received instructions regarding information application, and the authors provided sources for the information covered in the modules. The authors also considered that rejecting the information covered in the modules may result in furthering the knowledge gap that exists among anesthesia providers regarding CXR interpretation. The authors met the standards the IRB at USM sets forth for instructional modalities.

Summary

The purpose of this DNP project was to develop a learning module to improve CXR interpretation skills, which will help strengthen the didactic curriculum of the NAP, clinical preparedness, and anesthesia provider confidence. This DNP project comprised of four chest x-ray modules in the form of YouTube® videos, varying in length from four minutes and 45 seconds to ten minutes and 45 seconds. After participants viewed all of the CXR modules, they were asked to complete a post-module Qualtrics® survey with questions relevant to the material covered in the learning modules. The survey also included questions pertaining to learning style preference, participant satisfaction, and free text comment boxes. The authors reviewed and analyzed feedback from the questionnaire and compared participants' insight with evidence-based practice literature.

If any responses aligned with evidence-based practice, the authors consulted with the DNP chair and committee and made the necessary changes.

CHAPTER III – RESULTS

Introduction

The current DNP project aims to provide a clear, relevant, and accessible medium for anesthesia providers to learn about CXR interpretation and appropriateness. The authors created an online forum for CRNAs and SRNAs to view instructions regarding CXRs and to apply CXR interpretation to current anesthesia practice. A panel of experts received invitations to participate in the online forum and to complete a post-participation survey. The authors reviewed the results of the survey and organized the data into charts and tables for ease of presentation and analysis.

Steps of Intervention

The authors proposed the current DNP project to the DNP chair and committee. The DNP chair and committee reviewed plans regarding CXR module creation and disbursement as well as the proposed strategies to evaluate participants' knowledge retention and overall experience. Following the proposal and review, the DNP chair and committee approved the DNP project.

Upon DNP project approval, the authors began the process of IRB approval at USM. The IRB received drafts of participant recruitment e-mails, an informed consent document, and an outline of DNP project aims and data collection methods. Drafts of participant recruitment e-mails and the informed consent document are available in Appendices A and B respectively. The USM IRB approved the current DNP project (Appendix C) and the authors began CXR module creation and subsequent data collection without edits or deviation to the IRB- approved DNP project.

A review of the literature and current anesthesia CXR utility guided the content for the CXR modules. The authors used Microsoft PowerPoint with animation and voice-over narration to create four progressive, informational modules regarding CXR interpretation. The modules covered the basics of CXR interpretation and indications, ETT placement on CXR, invasive line placement and identification on CXR, and identifying pathologies and complications on CXRs. The presentations varied in length from four minutes and 45 seconds to ten minutes and 45 seconds. The authors uploaded the modules to YouTube® to facilitate ease of access.

To measure knowledge retention and assess participants' experience, the authors created a survey using Qualtrics®. The knowledge-retention portion of the survey included two questions per video. To assess participants' experience, the authors included statements regarding accessibility, clarity, and overall opinion on the modules. The survey prompted participants to rank their level of agreement with these statements ranging from strongly agree to strongly disagree. The authors also included a question regarding participants' preferred learning style: traditional, in-person lecture or remote, self-directed instruction. The final portion of the survey included free-text boxes in which participants could offer feedback regarding the CXR modules and suggest improvements to the learning forum.

The participant pool included 69 practicing CRNAs from 22 clinical sites across Mississippi and 66 SRNAs enrolled in the NAP at USM. Participants received the invitation e-mail (Appendix A) and hyperlinks to the CXR modules and the Qualtrics® survey. The survey remained active for three weeks and the participant pool received an

additional invitation e-mail in that time. Upon survey closure, eight SRNAs and six CRNAs participated in the CXR forum and completed the Qualtrics® survey.

The authors reviewed participants' responses and organized the information into graphs and tables. The quantitative data consisted of results from the knowledge-retention portion of the survey. These questions addressed preoperative CXR indications, postoperative CXR indications, ETT placement on a CXR, right mainstem bronchus intubation on a CXR, proper CVC placement, proper PAC placement, tension pneumothorax features on a CXR, and negative pressure pulmonary edema on a CXR. Researchers organized the data according to the participants' current level of practice: CRNA or SRNA. The quantitative results are outlined in Figure 1. The SRNAs performed best on the question regarding negative pressure pulmonary edema (100% correct), while the CRNAs performed best on the questions regarding negative pressure pulmonary edema and tension pneumothorax (83% correct). Overall, the SRNAs scored lowest on tension pneumothorax identification (62.5%) while the CRNAs scored lowest overall on preoperative CXR indications and ETT placement (16.7%).

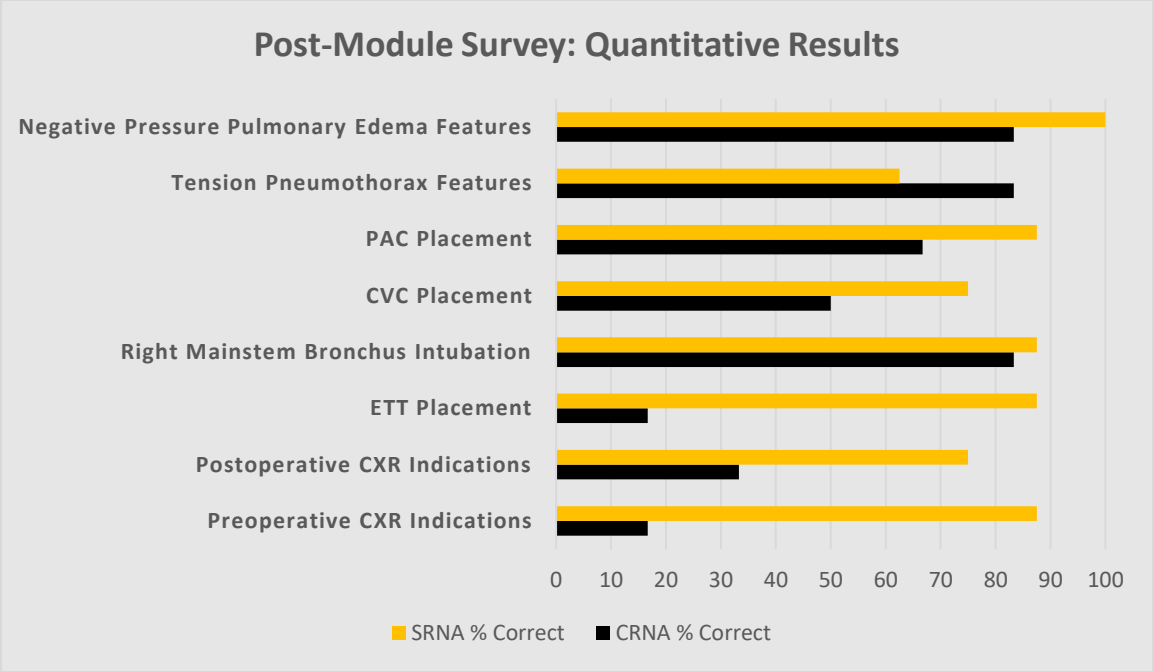

Figure 1. Post-Module Survey Quantitative Results for Knowledge Retention Measurement

The authors organized responses to the Likert scale questions into a table. The survey prompted participants to rank the clarity, relevance, and accessibility of the CXR modules. The panel of experts either strongly agreed, somewhat agreed, or did not respond to all three Likert scale questions, therefore, researchers did not include the other options when presenting the data in Table 1. One participant did not respond to any of the Likert scale questions.

Table 1

Panel of Experts' Responses Regarding CXR Module Experience

	Strongly Agree	Somewhat Agree	No Response
The modules were easy to understand.	12	1	1
The modules are relevant to my current or future anesthesia practice.	13	-	1
The modules were easy to access.	12	-	1

Finally, researchers organized data regarding preferred learning styles into the pie chart in Figure 2 and the bar graph in Figure 3. Most of the panel of experts (64%) preferred traditional, in-person instruction and one participant did not respond to the question regarding learning style preference. Five CRNAs responded to the learning style prompt, and three CRNA respondents preferred remote, self-directed learning while two preferred traditional, in-person instruction. Eight SRNAs responded to the learning style prompt, and seven preferred traditional, self-directed instruction while one preferred remote, self-directed learning.

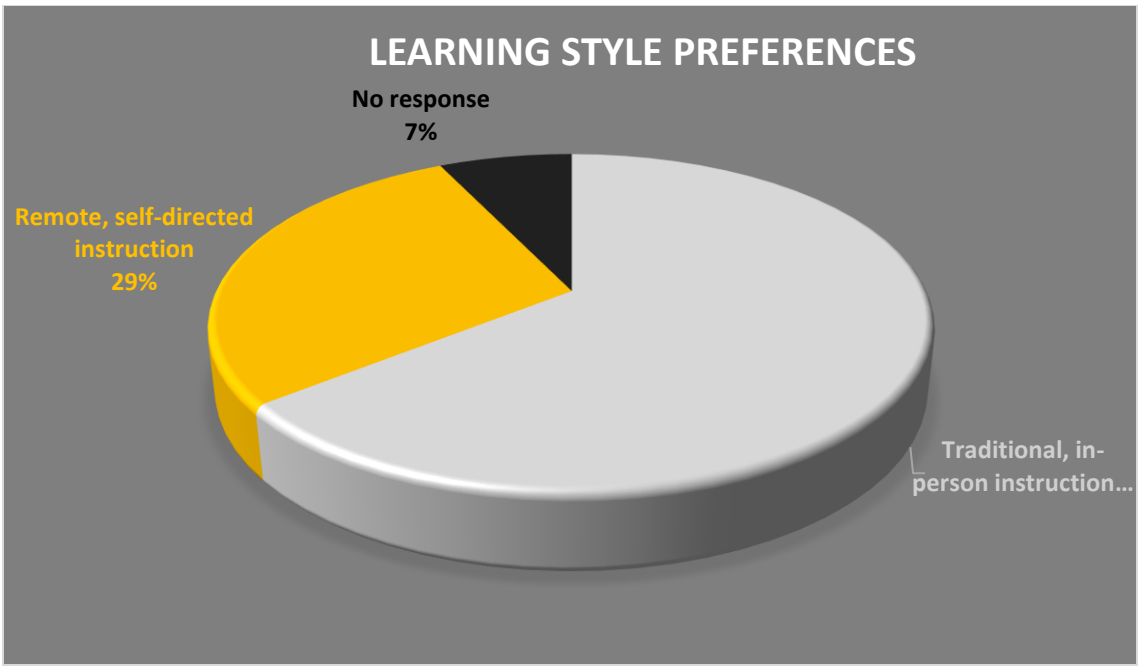

Figure 2. Overall Learning Style Preferences Among CRNAs and SRNAs

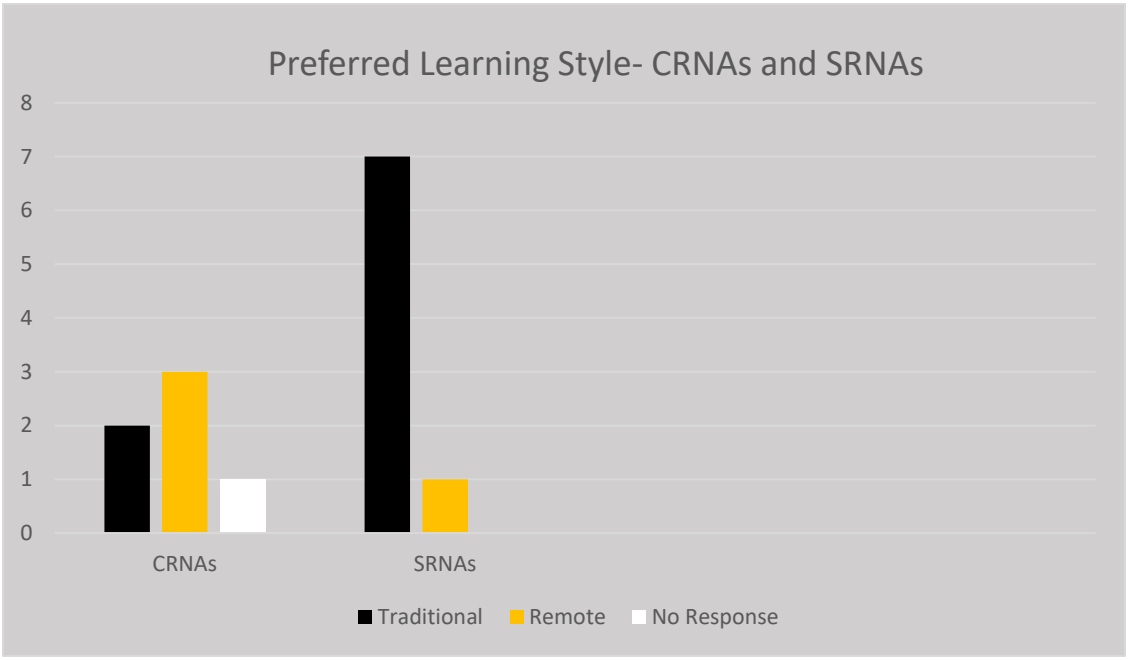

Figure 3. Learning Style Preferences According to Current Anesthesia Team Role

The authors reviewed and organized qualitative data regarding the CXR modules by organizing the free-text portion of the survey into Table 2. Participants offered feedback regarding the overall experience, plans to use the modules in the future, and suggestions that may improve the forum. The researchers separated this data into two overarching categories: commentary and suggestions. The responses in black lettering belong to CRNA participants, while the responses in yellow lettering belong to SRNA participants.

Table 2

Qualitative Data: Panel of Experts Free-Text Feedback

Participant Suggestions	Participant Commentary
More case examples for practice	Like the overlay of anatomical markings
Embed questions into the videos if planning to use them for continuing education	Well organized; liked the division of videos by topic
Shorter videos	Light yellow markings on CXR were sometimes hard to see.
	Will reference it when studying for boards
	Direct and understandable instructional videos

Note. The suggestions and commentary are not direct quotes, instead, they are synopses of feedback regarding the CXR modules.

Details of Process Measures and Outcomes

The Qualtrics® survey served to evaluate anesthesia providers' perspectives on the CXR learning modules that the authors created and to evaluate participants' level of

knowledge retention upon completion of the modules. The authors also sought to evaluate the panel of experts' preferred learning styles to align current education modalities to learners' preferences in the future. The qualitative data supports overall satisfaction with the CXR modules, and the quantitative data supports an understanding of the information presented in the online forum. While most participants preferred traditional lectures, 60% of currently practicing CRNAs who participated in the DNP project preferred remote learning. The SRNAs averaged 82.8% correct on the knowledge- retention questions while the CRNAs averaged 54.2% correct on the knowledge-retention questions. This data suggests that incorporating the CXR learning modules into the curriculum at USM NAP will edify students' understanding of CXR appropriateness and interpretation. The information included in the modules may serve to meet the COA requirements regarding CXR interpretation among SRNAs.

Summary

Proficiency in CXR interpretation and appropriateness is a vital clinical practice skill for anesthesia providers. Inaccurate CXR interpretation may negatively impact patient outcomes. As indicated by the post-module survey results of this study, the data suggests that integrating the CXR learning modules into the curriculum at USM NAP will improve students' understanding of CXR appropriateness and interpretation. The material included in the modules may serve to meet the COA clinical guideline requirements regarding CXR interpretation among SRNAs and offer valuable knowledge for clinical practice.

CHAPTER IV – DISCUSSION

Introduction

The goal of this DNP project was to establish a learning modality that aids anesthesia providers in CXR interpretation and CXR indications for surgery patients. With the integration of a uniform evidence based CXR training module into the USM NAP curriculum, knowledge and confidence regarding CXR interpretation will potentially be increased among anesthesia providers. Increased knowledge and confidence of anesthesia providers transitioning into practice will improve patient outcomes.

Interpretation

The success of the CXR training modules can be measured by evaluating the post-module survey responses by participants to determine if the goals of the DNP project were met. Based upon the results collected through survey responses, all the participants agreed that the learning modules were easy to understand, easily accessible, and included information relevant to current or future anesthesia practice. More than half of the respondents indicated that they prefer traditional face-to-face learning as opposed to virtual learning. The CXR module could be used in conjunction with a traditional lecture format to solidify CXR knowledge. The post-module average score for all participants was 62.3%. The mean post-module survey score for SRNAs was 84.4%, and the mean for CRNAs was 67.5%. Questions 3 and 4 received the lowest correct answers. These scores could be due to a poorly written or confusing question.

Feedback from the expert panel indicates that the CXR training modules created during this DNP project have the potential to benefit anesthesia providers. This DNP

project has several strengths. The CXR training modules are easily accessible. Anesthesia providers can access the training modules at their own pace from their cellular phones or computers while in clinical practice or from the comfort of their homes. Furthermore, the training modules are short and concise videos categorized by topic for quick reference. The material is presented in a systematic approach to CXR interpretation with annotated CXR images to facilitate learning through visual aids. The modules are available to anyone at no cost. Moreover, the information covered in the training modules applies to medical professionals across the healthcare spectrum.

Limitations

The small sample size contributed to the limitations of this DNP project. Survey distribution was limited to USM NAP SNRAs, USM NAP faculty, and USM NAP-affiliated clinical site CRNAs. In addition, the survey time period was limited to two weeks, which could have been extended. Out of 135 potential participants, 14 participants completed survey responses, which contributed to a low response rate of approximately ten percent. A reminder email was sent one week after the initial invitation email to encourage participation. The sample size could be increased by inviting other nurse anesthesia programs to participate in the study. Lastly, one-third of the participants were involved in a cyberattack, which hindered computer access and the ability to participate in the DNP project. The authors made efforts to minimize limitations. The survey questions were reviewed, and video presentations were reviewed by graduate educators and subject matter experts. Lastly, the length and number of videos were limited to encourage participation.

Conclusions

The CXR modules have a high potential for sustainability. The modules will be submitted to The University of Southern Mississippi's Nurse Anesthesia program for potential incorporation into the program's curriculum and 22 clinical sites. There are several future research recommendations related to this work. The CXR training modules could be beneficial to many healthcare disciplines. Information covered in the modules is pertinent to SRNAs, CRNAs, anesthesia training programs, nurse practitioners, intensive care unit nurses, and any healthcare provider that places invasive lines or tubes.

Future research on this work could involve evaluating how the CXR modules benefit various healthcare disciplines, assessment of learning outcomes, and impact on clinical practice improvement. Another recommendation is the consideration of the CXR modules as continuing education for healthcare providers. Continuing education would allow healthcare providers to refresh their CXR interpretation skills while also earning continuing education units. Additionally, the CXR modules could be disseminated into healthcare facilities and training programs. Future studies could assess the efficacy of the CXR modules and knowledge gaps among healthcare providers and trainees. Implementation of the CXR modules into training programs and hospital systems could potentially increase knowledge and confidence in CXR interpretation, improve patient outcomes, limit unnecessary testing, and affect the fiscal systems of hospitals and insurance providers.

APPENDIX A – Literature Matrix

Authors	Date	Purpose	Conclusion	Evaluation
Clarke, C & Dux, A.	2017	Provide resources for students learning CXR.	CXRs are an essential part of medical practice. Providers need guidance in CXR interpretation methodology that is clear and concise.	A knowledge gap exists in the medical community regarding CXR interpretation proficiency. Making learning resources clear and accessible may aid in closing the knowledge gap.
Jindal, S. , Gombar, S. , & Jain, K.	2018	Assess the level of CXR appropriateness in the preoperative stage of patient care	Routine preoperative CXR in this patient resulted in incidental identification of a 5cm x 3.5 cm thymoma.	While routine preoperative CXRs are not necessary, incidental findings of pathologies that require medical attention do occur.
Kellnre, D. B., Urman, R. D., Greenberg, P., & Brovman, E. Y.	2018	Evaluate closed claims regarding adverse anesthesia-related events that occurred in the PACU between 2010 and 2014	Anesthesia complications resulted in varying degrees of complications ranging from temporary/ reversible conditions to death. Most of the deaths reported were respiratory-related.	Proper application and interpretation of CXR in patients experiencing postoperative complications may prevent serious patient injury and mortality.
May, L., Acquaviva,	2009	Evaluate medical	All participants reported an overall	Adult learners prefer flexibility

K. D., Dorfman, A., & Posey, L.		students' attitudes regarding online self-paced learning modality	positive experience with the online modules. Flexibility and independence were common themes of the positive feedback.	in education forums versus structured instruction.
Pezzotti, W.	2014	Inform readers regarding CXR interpretation and patient management related to CXR findings	Medical professionals may use CXR interpretation skills to affirm patient assessment findings.	The goal of CXR interpretation among healthcare professionals is not limited to making diagnoses.

APPENDIX B – DNP Essentials

Doctorate of Nursing Practice Essentials	**Method of Meeting Essential**
I: Scientific Underpinnings for Practice	The authors provided guidance surrounding anatomy, physiology, and pathophysiology regarding CXR imaging. Furthermore, the authors employed knowledge related to radiology in the learning platform.
II: Organization and Systems Leadership for Quality Improvement and Systems Thinking	Understanding perioperative CXR appropriateness encourages judicious and informed clinical decisions that may mitigate unnecessary healthcare costs and improve patient outcomes.
III: Clinical Scholarship and Analytical Methods for Evidence-Based Practice	The authors employed clinical research methods to better understand CXR indications and interpretation. The process included analyzing the available information and translating that knowledge into an educational forum. The authors communicated the knowledge gained via educational modules.
IV: Information Systems/ Technology and Patient Care Technology for the Improvement and Transformation of Health Care	When evaluating educational modalities, the authors analyzed the efficacy of two types of information systems each with differing degrees of technological application. By providing the optimal approach to the students of the USM NAP, this DNP project provided the resources necessary for clinicians in training to better understand patients' physical processes and provide informed care.
VIII: Advanced Nursing Practice	This DNP project employed the principles of patient assessment, clinical interventions, evidence-based practices, and peer guidance in nursing. The authors offered anesthesia providers a learning module that focuses on patient assessment and guides clinical interventions.

APPENDIX C – Recruitment Email

Dear Participant,

We are Kaitlyn Brown and Jessica Parsons, Nurse Anesthesia students at the University of Southern Mississippi. We invite you to participate in our Doctor of Nursing Practice (DNP) project. Participation in the project includes viewing four modules regarding chest x-ray interpretation and answering two to three questions following each module. After completion of all four modules, you will be asked to complete a short survey regarding your experience. Each module is 10 minutes or shorter, and the single post-module survey will take less than five minutes to complete.

Participation in this project is voluntary and responses are anonymous. You may choose to exit modules or surveys at any time without consequence. Within the survey, you will be prompted to consent to participation. The reference document is attached for your review.

This project and the informed consent form have been reviewed and approved by the University of Southern Mississippi Institutional Review Board #23-0587.

The survey will close September 4, 2023. Please contact us if you have any questions regarding this project or project participation. We appreciate your time and feedback.

Thank you,

Kaitlyn Brown
kaitlyn.a.brown@usm.edu

Jessica Parsons
jessica.a.parsons@usm.edu

APPENDIX D – Informed Consent

ORI | Office of Research Integrity

INSTITUTIONAL REVIEW BOARD
STANDARD (ONLINE) INFORMED CONSENT

STANDARD (ONLINE) INFORMED CONSENT PROCEDURES
☐ ***Use of this template is optional.*** However, by federal regulations (45 CFR 46.116), all consent documentation must address each of the required elements listed below (purpose, procedures, duration, benefits, risks, alternative procedures, confidentiality, whom to contact in case of injury, and a statement that participation is voluntary). Last Edited March 13th, 2023

Today's date:06/22/2023		
PROJECT INFORMATION		
Project Title: Perioperative Chest X-ray Interpretation for Anesthesia Providers		
Protocol Number: 23-0587		
Principal Investigator: Kaitlyn Brown	Phone: [redacted]	Email: Kaitlyn.a.brown@usm.edu
College: Nursing and Health Professions	School and Program: School of Leadership and Advanced Nursing Practice	
RESEARCH DESCRIPTION		

1. **Purpose**:
The goal of this project is to offer a learning environment through which current nurse anesthesia students at the University of Southern Mississippi (USM) and currently practicing anesthesia providers may learn and apply chest x-ray (CXR) interpretation skills. While lecture-format education is in place for students enrolled in the NAP at USM, there is currently no uniform assessment modality available to assess students' proficiency in CXR. Establishing an evidence-based CXR education module and uniform method of learning assessment has the potential to better equip anesthesia providers in the delivery of safe and effective patient care, increase knowledge among anesthesia providers, and enhance provider confidence in CXR interpretation. This study will also assess student learning and perception of learning.

2. **Description of Study:**
Participants will watch four CXR learning module. After completion of the learning modules participants will be asked to complete a voluntary and anonymous questionnaire. Feedback will be obtained through an anonymous online questionnaire from volunteers. The questionnaire will take approximately 10-15 minutes to complete. The feedback will be evaluated and improvements to the CXR learning modules will be implemented. After

completion, the CXR learning modules will be used as an evaluation tool for nurse anesthesia students.

3. **Benefits:**
Participating in the online questionnaire is completely voluntary, and there are no benefits or incentives offered to participants.

4. **Risks:**
Participation in this study carries no risk, however, the only inconvenience is that of time. The estimated time to complete the four learnings module is approximately 10 minutes per module and the anonymous, voluntary questionnaire is approximately 5-10 minutes.

5. **Confidentiality:**
The survey presents no more than minimal risk of harm to subjects and involves no procedures for patients or participants. Data being collected is confidential, anonymous, and 100% voluntary with no repercussions for non-participation. Email addresses for the participants are available through public information or have been volunteered by the participant. Anonymous surveys will be administered using Qualtrics, USM's survey platform software. The link will be supplied in a recruitment email. The questionnaire data will be evaluated and combined. All paper data collection sheets including any identifying information will be completely shredded and disposed of on-site in the secure shred box of the College of Nursing and Health Professions work room. All electronic files will be deleted from a password protected computer and the trash emptied. No identifying information will be solicited.

6. **Alternative Procedures:**
N/A

7. **Participant's Assurance:**
This project and this consent form have been approved by the Institutional Review Board, which ensures that research projects involving human subjects follow federal regulations. Any questions or concerns about rights as a research participant should be directed to the Chair of the Institutional Review Board, The University of Southern Mississippi, 118 College Drive #5125, Hattiesburg, MS 39406-0001, 601-266-5997.

Any questions about this research project should be directed to the Principal Investigator using the contact information provided above.

CONSENT TO PARTICIPATE IN RESEARCH

I understand that participation in this project is completely voluntary, and I may withdraw at any time without penalty, prejudice, or loss of benefits. Unless described above, all personal information will be kept strictly confidential, including my name and other identifying information. All procedures to be followed and their purposes were explained to me.

Information was given about all benefits, risks, inconveniences, or discomforts that might be expected. Any new information that develops during the project will be provided to me if that information may affect my willingness to continue participation in the project.

(Include the following information only if applicable. Otherwise delete this entire paragraph before submitting for IRB approval:) The University of Southern Mississippi has no mechanism to provide compensation for participants who may incur injuries as a result of participation in research projects. However, efforts will be made to make available the facilities and professional skills at the University. Participants may incur charges as a result of treatment related to research injuries. Information regarding treatment or the absence of treatment has been given above.

CONSENT TO PARTICIPATE IN RESEARCH

By clicking the box below, I give my consent to participate in this research project. ***If you do not wish to participate in this study, please close your browser now.***

☐ Yes, I consent to participate.

APPENDIX E – IRB Approval Letter

Office of Research Integrity
THE UNIVERSITY OF SOUTHERN MISSISSIPPI
118 COLLEGE DRIVE #5116 • HATTIESBURG, MS | 601.266.6756 | WWW.USM.EDU/ORI

NOTICE OF INSTITUTIONAL REVIEW BOARD ACTION

The project below has been reviewed by The University of Southern Mississippi Institutional Review Board in accordance with Federal Drug Administration regulations (21 CFR 26, 111), Department of Health and Human Services regulations (45 CFR Part 46), and University Policy to ensure:

- The risks to subjects are minimized and reasonable in relation to the anticipated benefits.
- The selection of subjects is equitable.
- Informed consent is adequate and appropriately documented.
- Where appropriate, the research plan makes adequate provisions for monitoring the data collected to ensure the safety of the subjects.
- Where appropriate, there are adequate provisions to protect the privacy of subjects and to maintain the confidentiality of all data.
- Appropriate additional safeguards have been included to protect vulnerable subjects.
- Any unanticipated, serious, or continuing problems encountered involving risks to subjects must be reported immediately. Problems should be reported to ORI using the Incident form available in InfoEd.
- The period of approval is twelve months. If a project will exceed twelve months, a request should be submitted to ORI using the Renewal form available in InfoEd prior to the expiration date.

PROTOCOL NUMBER:	23-0587
PROJECT TITLE:	Perioperative Chest X-ray Interpretation for Anesthesia Providers
SCHOOL/PROGRAM	Leadership & Advanced Nursing
RESEARCHERS:	PI: Kaitlyn Brown Investigators: Brown, Kaitlyn~Collins, Mary Jane~Parsons, Jessica~
IRB COMMITTEE ACTION:	Approved
CATEGORY:	Expedited Category
PERIOD OF APPROVAL:	14-Jul-2023 to 13-Jul-2024

Lisa Wright

Lisa Wright, Ph.D., MPH
Senior Institutional Review Board Analyst

APPENDIX F – Survey

1. Do you agree with the standard online consent form to participate in this study?
    a. Yes
    b. No

2. Please indicate your current title in anesthesia practice.
    a. Student Registered Nurse Anesthetist
    b. Certified Registered Nurse Anesthetist

3. For which patient is a perioperative CXR most appropriate?
    a. 30-year old female with a 12 pack/year smoking history presenting for preoperative testing for a robotic hysterectomy
    b. 54-year old male currently taking doxorubicin for treatment of Hodgkin's lymphoma requiring 4 liters/ minute per nasal cannula in the post anesthesia care unit (PACU) after a laparoscopic cholecystectomy
    c. 68-year old male with uncontrolled diabetes mellitus type 2 and chronic kidney disease presenting for right great toe amputation
    d. 72-year old male with a history of hypertension and congestive heart failure with preserved ejection fraction presenting to preoperative testing prior to mitral valve repair

4. A post- operative CXR may be beneficial in which of the following cases?
    a. Post- endotracheal extubation of a 65-year-old female on 6 liters/ minute simple facemask with an oxygen saturation of 95%
    b. A 33- year old female that underwent external fixation of the tibia and fibula following a motor vehicle accident and will be transferred to the intensive care unit mechanically ventilated
    c. An 82-year old male with chronic obstructive pulmonary disease who received total intravenous anesthesia for a bone marrow biopsy and is in the PACU on 3 liters/ minute nasal cannula with an oxygen saturation of 93%
    d. A 16-year-old male with a history of asthma who received a prophylactic albuterol treatment prior to extubation for a laparoscopic appendectomy

5. Anatomically, where should the tip of the endotracheal tube be located on the CXR for proper ventilation of both lungs?
    a. 1 cm above the carina
    b. 2-3 cm above the carina
    c. 3-5 cm above the carina
    d. 5-7 cm above the carina

6. The more _____ angle of the right mainstem bronchus contributes to inadvertent right mainstem bronchus intubation.

a. Vertical
b. Horizontal
c. Obtuse
d. Caudad

7. Anatomically, where should the tip of a central venous catheter be on a chest x-ray?
    a. Proximal 1/3 of superior vena cava, tip of catheter projects over anatomical location of superior vena cava and below carina
    b. Distal 1/3 of superior vena cava, tip of catheter projects over anatomical location of superior vena cava and at the level or slightly below the carina
    c. Right atrium, tip of the catheter projects over the anatomical location of the right atrium and below the carina
    d. Within 2 centimeters of the cardiac silhouette at the level of the hilum

8. Anatomically, where should the tip of a pulmonary artery catheter be located on a chest x-ray?
    a. Pulmonary artery, within 2 centimeters of the cardiac silhouette ending at the level of the hilum
    b. Pulmonary artery, within 4 centimeters of the cardiac silhouette and endings below the level of the hilum
    c. Right middle lobe, 4 centimeters outside of the cardiac silhouette and ending below the level of the hilum
    d. Right middle lobe, 2 centimeters outside of the cardiac silhouette and ending above the level of the hilum

9. Chest x-ray findings consistent with a tension pneumothorax include:
    a. Enlarged cardiac silhouette, sharp white line denoting visceral pleura of unaffected side, and pulmonary vascular engorgement
    b. Absence of lung markings past the visceral pleura, contralateral mediastinal and tracheal shift, and deep sulcus sign
    c. Visible lung markings past the visceral pleura, ipsilateral mediastinal and tracheal shift, and shallow sulcus sign
    d. Lung markings visible only on unaffected side, midline cardiac silhoutte the right side is affected

10. The pattern of fluid opacities in a patient with negative pressure pulmonary edema seen on a chest x-ray is described as the shape of a:
    a. Donut
    b. Cresent moon
    c. Butterfly or batwing

a. Semi-circle

11. Please indicate the degree to which you agree with the following statements:
    a. The learning modules were easy to understand.
        i. Strongly agree
        ii. Agree
        iii. Somewhat agree
        iv. Neutral
        v. Disagree
        vi. Somewhat disagree
        vii. Strongly disagree
    b. The learning modules included information that is relevant to my current or future anesthesia practice.
        i. Strongly agree
        ii. Agree
        iii. Somewhat agree
        iv. Neutral
        v. Disagree
        vi. Somewhat disagree
        vii. Strongly disagree
    c. It was easy to access the learning modules.
        i. Strongly agree
        ii. Agree
        iii. Somewhat agree
        iv. Neutral
        v. Disagree
        vi. Somewhat disagree
        vii. Strongly disagree

12. Which learning approach do you prefer?
    a. Traditional, in-person lecture
    b. Remote, self-directed instruction

13. Please provide any recommendations or comments that would make this CXR training module easier to understand.

14. Are there any other comments you care to make?

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