Occupational Hazards: Considerations for the Pregnant Anesthesia Provider

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Date of Submission: April 21. 2023

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Abstract

Background: Anesthesia providers are subjected to chemical, biological, physical, ergonomic, and psychosocial risk factors that threaten the individual's health. While pregnancy alone is not considered an independent risk factor for healthcare-associated occupational hazards, the fetus is rapidly developing and thus carries a much lower threshold to hazardous exposure than the adult.

Purpose: To evaluate participants' confidence levels related to their knowledge of environmental considerations for the pregnant anesthetist before and after implementing a self-paced online course presenting the findings from a review of the literature.

Methods: Voluntary participants from a Midwest DNP nurse anesthesia program were invited to partake in a self-paced online course which included a pre- and post-assessment to evaluate confidence level related to the subject matter and its application into practice.

Conclusion: Confidence levels in the participants' knowledge of the environmental risks for anesthesia personnel and pregnant anesthesia providers increased by 36.4% following implementation of literature review findings summarized into self-paced online course.

Keywords: anesthesia, anesthesia care providers, anesthetic gases, anesthesiology, cognitive function impairment, environmental pollutants, exposure controls, fetal development, genomic instability, hospitals, hospital workers, indoor air pollution, inhaled anesthetics, neural cell damage, occupational exposure, occupational health, occupational radiation exposure, occupational risk, occupational safety, precautionary practices, pregnancy, pregnant surgeon, pregnant worker, reproductive health, research, risk management, sevoflurane, staff health, staff safety, surgeons, surgery, volatile anesthetics

Occupational Hazards: Considerations for the Pregnant Anesthesia Provider

Introduction

This project was submitted to the faculty of Marian University Leighton School of Nursing as partial fulfillment of degree requirements for the Doctor of Nursing Practice, Nurse Anesthesia Track. The purpose of this DNP Project was to investigate confidence levels regarding participants' knowledge of occupational hazards for the pregnant anesthesia provider before and after the dissemination of evidence-based safety recommendations from the literature. This study involved certified faculty and trainees of Marian University DNP Nurse Anesthesia Program. The project aimed to share literature review findings with anesthesia providers of all ages and genders as a reminder of standard safety precautions with consideration for the gravid anesthesia provider.

Background

Operating room personnel are at risk of exposure to numerous occupational hazards in their work environment. Anesthesia providers are subjected to chemical, biological, physical, ergonomic, and psychosocial risk factors that threaten the individual's health (Ayoğlu & Ayoğlu, 2021). Such occupational hazards include, but are not limited to, anesthetic gases, bloodborne pathogens, radiation, surgical plume, physical stress, and cytotoxic agents (Landford et al., 2021). Pregnant women working in healthcare should be aware of occupational hazards and precautions for protecting themselves and their unborn babies. While pregnancy alone is not considered an independent risk factor for healthcare-associated occupational hazards, the fetus is rapidly developing and thus carries a much lower threshold to hazardous exposure than the adult. Adverse outcomes associated with the female provider performing surgical activities include infertility, miscarriage, premature birth, intrauterine growth restriction of the fetus, hypertensive disorders of the mother, and placental abruption (Szczesna et al., 2019).

Problem Statement

This DNP project intended to investigate the confidence level of current practice guidelines and recommendations for the expectant practicing anesthesia by answering the following question: Among anesthesia learners and certified providers (P), will the delivery of summarized evidence-based practice recommendations for pregnant anesthesia providers in the operating room (I) improve confidence level toward one's knowledge of the information (O) compared to baseline understanding (C) upon completion of self-guided online course (T)?

Needs Assessment & Gap Analysis

The American Association of Nurse Anesthesiology (AANA) provides publicly accessible resources for nurse anesthesiology. A few examples of these resources include AANA definitions and policies, the code of ethics, the scope of practice, standards, guidelines, position statements, and practice considerations. Each webpage contains references and links to internal and external websites with additional information. A designated page of resources for health and wellness and peer assistance among nurse anesthetists covers topics such as burnout, stress, bullying, grief, suicide, physical well-being, substance abuse, and coping. Despite the depth of information provided in these sources, there are no statements made by the AANA regarding recommendations for the pregnant provider.

In the didactic setting for the anesthesia learner, lessons on the topics related to safety for expecting anesthesia providers are not included in standard learning objectives. APEX Anesthesia Review, a resource for SRNA board review and CRNA continuing education, briefly outlines environmental concerns in the anesthesia setting, including the effect of anesthetic waste gases, allergic reactions in the provider, radiation exposure, excessive noise, and the "second victim" effect. None of the listed subsections specifically mention pregnancy or related considerations among providers.

Anesthesia textbooks generally weave safety considerations for the anesthesia provider throughout the main text without a designated chapter heading for these evidence findings, if mentioned at all.

Review of Literature

Methodology

The database Pubmed hosted by the National Library of Medicine (NIH), was used to search the Boolean phrase *pregnant anesthesia provider safety* limited to full-text English publications between 2016-2022. Translations included pregnant: "gravidity"[MeSH Terms] OR "gravidity"[All Fields] OR "pregnant"[All Fields] OR "pregnants"[All Fields]
anesthesia: "anaesthesia"[All Fields] OR "anesthesia"[MeSH Terms] OR "anesthesia"[All Fields] OR "anaesthesias"[All Fields] OR "anesthesias"[All Fields], provider: "provide"[All Fields] OR "provided"[All Fields] OR "provider"[All Fields] OR "provider's"[All Fields] OR "providers"[All Fields] OR "provides"[All Fields] OR "providing"[All Fields], safety: "safety"[MeSH Terms] OR "safety"[All Fields] OR "safeties"[All Fields]. The yielded results were filtered to eliminate articles that were not directed at the specific target. The keywords identified for this search included anesthesia, anesthesia care providers, anesthetic gases, anesthesiology, cognitive function impairment, environmental pollutants, exposure controls, fetal development, genomic instability, hospitals, hospital workers, indoor air pollution, inhaled anesthetics, neural cell damage, occupational exposure, occupational health, occupational radiation exposure, occupational risk, occupational safety, precautionary practices, pregnancy, pregnant surgeon, pregnant worker, reproductive health, research, risk management, sevoflurane, staff health, staff safety, surgeons, surgery, volatile anesthetics.

Anesthetic Gases

The impact of anesthetics on fetal development was first studied in the 1960s and continues to prove worthy of further research. The first report of adverse effects related to chronic exposure to anesthetic waste gases (WAGs) came from a Russian scientist in 1967, which unveiled an increased prevalence of abortions among female anesthetists. Following this report, three extensive studies from the United Kingdom and the United States during the 1970s and 1980s confirmed the prevalence of

spontaneous abortions among female anesthesiologists was significantly higher than among female physicians working in areas other than the operating room. Research from this period also determined an increased prevalence of congenital anomalies in children from female and male anesthesiologists compared to the control group of physician parents (Gropper et al., 2020). Additional survey-based studies from this era revealed associated health concerns, including renal and liver disease, cancer, miscarriage, and congenital defects (Varughese et al., 2021). Since then, copious studies have evaluated the consequences of exposure to inhalational anesthetics, but the conclusions are yet to provide definitive answers. In 2002, the American Society of Anesthesiologists (ASA) Committee on Occupational Health of Operating Room Personnel convened with The Task Force on Trace Anesthetic Gases to analyze the available research on the issue. The analysis could not systematically dissect the available data given the extraordinary number of variables and research approaches. The report from the ASA stated the incidence of children with congenital anomalies, spontaneous abortion, and rate of infertility among female anesthesiologists was equal to that of physicians in other specialties (Gropper et al., 2020). The ASA states, "there is no evidence that trace concentrations of waste anesthetic gases cause adverse health effects of personnel working in locations where scavenging of waste anesthetic gases is carried out" and "the general conclusion… is that currently used anesthetics… have no mutagenic potential." (Gropper et al., 2020). This statement lacks reassurance to the reproductive female considering previous findings. The document from the task force also provided summarized recommendations from the Occupational Safety and Health Administration's (OSHA) Workers' Rights to Information stating there are "potential adverse effects of exposure to waste anesthetic gases such as spontaneous abortions, and congenital abnormalities in children." (Gropper et al., 2020). The US National Institute for Occupational Safety and Health (NIOSH) recommends a maximal exposure level of 2ppm or less of halogenated anesthetic gases and 25ppm or less of nitrous oxide (N20) within one hour (Varughese et al., 2021). Additionally, NIOSH states that all T-tube devices, nonrebreathing systems, and

anesthetic gas machines must have appropriate scavenging equipment to remove all WAGs (Varughese et al., 2021). Research shows these limits are often exceeded in daily practice (Gropper et al., 2020). If the volatile agent can be smelled, the concentration of exposure has significantly surpassed the recommended limit (Gropper et al., 2020). Considering the average daily exposure to WAGs by anesthesia personnel exceeds NIOSH recommended safe limits and the limitations of the study by the ASA in 2002, it can be implied that exposure to WAGs is an occupational hazard for the anesthesia provider (Gropper et al., 2020).

Physical Stressors

Szczesna et al. (2019) looked at the occupational hazards of the pregnant surgeon and the risk factors associated with her role in the operating room. Physical stress endured by the pregnant surgeon contributes to increased rates of high-risk pregnancies as compared to the general female population (Szczesna et al., 2019). Additionally, it has been shown that female physicians have longer time-to-pregnancy intervals and are more likely to receive infertility treatment than non-physicians (Szczesna et al., 2019). Occupational hazards, including the use of sharp instruments, surgical cases requiring attention overnight or at durations exceeding four hours, and the internal stress response elicited from emergencies are contributing factors to adverse outcomes in the pregnant surgeon (Szczesna et al., 2019). More specifically, in a study evaluating physician residents, females working more than six-night shifts per month and those with increased duration of operating hours were shown to have a higher risk of obstetric complications. Female residents were also at increased risk for hypertensive disorders, placental abruption, intrauterine growth restriction of the fetus, and miscarriage than general population females of similar age (Szczesna et al., 2019).

Radiation

Among operating room personnel, anesthesia providers are routinely exposed to both ionizing and non-ionizing electromagnetic radiation (Gropper et al., 2020). Ionizing electromagnetic radiation

exposure includes radiation from intraoperative ultraviolet radiation rays, gamma rays, or less commonly, radioactive isotopes of gamma emissions, alpha, and beta rays (Landford et al., 2021). Within human tissue, ionizing radiation forces electrons out of a molecule's stabile orbit, generating ionized molecules and free radicals (Gropper et al., 2020). Severe exposure to this form of radiation can stimulate chromosomal abnormalities resulting in malignant tissue growth or destroying the tissue altogether (Gropper et al., 2020). Non-ionizing radiation results in an excitable movement of electrons within a molecule's orbit, creating heat that can ultimately cause damage to human tissue (Gropper et al., 2020). The proximity in which an individual is positioned to the radiation source exponentially increases the risk of exposure. Other variables contributing to radiation exposure include age, sex, and region of the body exposed. During neurointerventional angiographic procedures, the anesthesiologist is exposed to six times more radiation than other operating room personnel (Ayoğlu & Ayoğlu, 2020). Radiation exposure is measured by either Sievert (Sv) or rem, where one Sievert (Sv) equals 100 rem. This unit of measurement defines the biological damage from radiation adjusted to all tissues. OHSA has defined a set of guidelines for maximum radiation exposure by region of the body. For example, the hands can withstand greater exposure to radiation than the head, gonads, or eyes (Gropper et al., 2020). The annual radiation exposure limit is recommended to be less than 15mSv/year (Ayoğlu & Ayoğlu, 2020) with no more than 1.25 rem (12.5 mSv) per calendar quarter (Gropper et al., 2020). In 2007, the International Commission on Radiological Protection published stricter guidelines for the exposure limitations to radiation with maximum doses of 100 mRem/week and 5 Rem/year and relevant exposure limits defined by a specific region of the body (Gropper et al., 2020). Both OHSA and the International Commission on Radiological Protection concluded the limits for radiation exposure should be lower for women that are pregnant (Gropper et al., 2020). According to the National Council on Radiation Protection and Measurements, exposure exceeding 50mSv in pregnant females is associated with teratogenic effects. Thus, the recommended maximum dose of ionizing radiation should not exceed 50

mRem/month during gestation (Ayoğlu & Ayoğlu, 2020). Surgeries utilizing intraoperative imaging or fluoroscopy expose providers to an average range of radiation from 5 to 50 mRem/case, which equates to an average of 10 to 350 mRem/month, depending on the caseload. Other data findings suggest prenatal exposure limits of 50 mSv, with associations of childhood cancer, growth restriction, congenital anomalies, and spontaneous pregnancy termination when exposure exceeds 50 mSv (Landford et al., 2021). Despite the risk of radiation exposure, there are no regulations for monitoring occupational exposure in anesthesia providers, and many organizations fail to offer anesthesia providers the right to radiographic leave despite the elevated risk of occupational exposure (Ayoğlu & Ayoğlu, 2020).

Reducing radiation exposure is dependent on three factors: distance, time, and shielding. Distance to radiation exposure follows the inverse square law, where the amount of x-ray exposure is inversely proportional to the square of the distance of the source. The impact of radiation exposure can be attributed to the accumulation of radiation over time. It is recommended that the radiation used during diagnostic procedures be limited to the least amount possible. Shielding devices such as lead aprons, thyroid protectors, glasses, caps, and radiation-reducing gloves can be used as an additional layer of protection when undergoing x-ray-guided procedures (Kim, 2018).

Surgical Plume

One form of biological occupational exposure in the operating room is the smoke from surgical cauterization from electrocautery, ultrasonic scalpel dissection, and lasers (Gropper et al., 2020). Data shows this byproduct, often referred to as surgical plume, contains aerosolized biological components including infectious bacteria and viruses, malignant cancer cells, and up to 150 chemical pollutants proving mutagenic and carcinogenic in nature (Landford et al., 2021). While many biological exposures are classified as bloodborne pathogens, some infectious materials, such as human papillomavirus, are transmitted via smoke plumes created by electrocautery and laser devices intraoperatively (Szczesna et al., 2019). The amount of surgical smoke emitted while using electrocautery on 1g of tissue equates to

the carcinogens of six unfiltered cigarettes and three unfiltered cigarettes using carbon dioxide lasers. Mitigating exposure to the harmful elements of smoke plume should be a concern for operating room personnel. Standard surgical masks filter particles 5 µm or greater, but 77% of particles are less than 1.1 µm in diameter (Landford et al., 2021) with some as small as 0.31 µm (Ayoğlu & Ayoğlu, 2020). These harmful fragments can enter the respiratory tract and permeate the endothelial lining of the alveolus (Landford et al., 2021). In the pregnant provider, exposure to surgical plume is associated with an increased risk of neural tube defects, restriction of growth development, preterm birth, stillbirth, and spontaneous abortion (Landford et al., 2021).

The Occupational Safety and Health Administration (OSHA) recognizes the chemical components of surgical smoke and recommends the use of proper masks and evacuators to limit the risk of infectious material spread. When evaluating the effectiveness of smoke evacuation, the National Institute for Occupational Safety & Health (NIOSH) looks at capture velocity or the speed of inward airflow at the inlet of the collection tip. The NIOSH recommends the use of evacuation systems with a capture velocity of 30.5-47.5 m/min and the collection nozzle tip should be within 5.1cm of the site of cautery (Georgesen & Lipner, 2018).

Bone Cement

Methyl methacrylate (MMA) is a colorless, volatile liquid often used in orthopedic procedures, neurosurgery, and plastic surgery for cement on bone, metal, or other forms of synthetic implants. When the surgeon is ready to set the bone or prosthesis, the liquid methyl methacrylate is mixed with polymethylmethacrylate, a powder, to create a concrete mixture. This exothermic process creates a toxic emission of free radicals into the environment (Landford et al., 2021). Methyl methacrylate is converted into methacrylic acid within the body, which has proven to be toxic to numerous human tissues (Downes et al., 2014). For this reason, the US Environmental Protection Agency has declared the permissible exposure limit of MMA in the air to be 100 ppm over eight hours (Downes et al., 2014). In

one study examining the exposure to MMA during several points throughout total hip arthroplasty procedures, the air concentration of MMA reached 280 ppm, well above the permissible ceiling vapor pressure (Downes et al., 2014). Exposure to MMA vapor can impact the human nervous system beginning with symptoms resembling that of intoxication (Kakazu et al., 2015). Individuals exposed to this fumigated toxin may experience headaches, dizziness, irritability, loss of appetite, nausea, and lethargy (Kakazu et al., 2015). If the vapor level of MMA reaches 125 ppm, exposed individuals may experience coughing, sore throat, teary eyes, and nasal irritation (Kakazu et al., 2015). Prolonged MMA exposure at 400 ppm resulted in tracheal damage in animal studies, but it is unknown whether this finding is consistent in humans (Kakazu et al., 2015). Direct contact of MMA with the skin can cause redness, burning, swelling, and itching that can lead to severe dermatitis or allergic reaction in some people (Kakazu et al., 2015). Concerns for exposure to MMA in pregnant women began in the 1960s with the discovery of teratogenic effects in rodents (Downes et al., 2014). Potential adverse effects of MMA toxicity in the parturient include increased fetal resorption, skeletal anomalies, and growth impedance (Downes et al., 2014).

Theoretical Framework

The framework for this project was based on the conceptual model designed by the Agency for Healthcare Research and Quality (AHRQ). Based on a patient safety initiative, the AHRQ created a knowledge transfer model that focuses on the transmission of research into practice. The AHRQ model describes the process of knowledge transfer into practice in three phases: 1. *Knowledge creation and distillation*, 2. *Diffusion and dissemination,* 3. *Translation of research into practice* (White et al., 2016).

Framework Identification

This DNP Project used the AHRQ model to assess the need for knowledge transfer related to occupational hazards for the pregnant anesthesia provider.

Framework Explained

Phase 1: Knowledge creation and distillation

The first phase involved collecting research and devising information that may be meaningful and applicable to anesthesia providers. During the distillation process, it was crucial to consider the factors that may enhance or hinder the ability to transfer and generalize the research findings into current-day healthcare. A literature review concerning occupational hazards for the pregnant anesthesia provider was synthesized and categorically outlined according to current guidelines and considerations.

Phase 2: Diffusion and dissemination

The next phase of the AHRQ model for knowledge transfer emphasizes raising awareness of the research findings. This phase aimed to market the information, foster interest in enactment, and encourage mass diffusion efforts among organizations (White et al., 2016). Dissemination of the literature findings concerning pregnant anesthesia providers can be propagated through numerous forms of media.

Phase 3: End-user adoption, implementation, and institutionalization

The third and final phase concentrates on application. This last phase of the model acted on implementing the research, assessing the success within an organization, and investing in creative measures to encourage end-user adoption. This phase may take time and persistence while a group adapts to the change, but the goal is for the implemented knowledge to become a standard of care (White et al., 2016). While the time frame to institutionalize the recommendations from the literature exceeds the allotted time for this project, the author's focus is on end-user adoption. This information could trigger thoughtful consideration towards general safety practice standards in anesthesia and encourage reverence of pregnant providers by all who work in the specialty. A questionnaire survey was conducted to assess the interest in concept adoption and facility implementation.

Framework Application

The AHRQ model was implemented in three phases, as shown in *Appendix B*. The model allows for dynamic movement between objectives within each stage, depicted in corresponding boxes. The variability of the AHRQ model offers versatility in applying this framework.

Goals, Objectives, and Expected Outcomes

Project Aim

This project aimed to investigate confidence levels before and after presenting the occupational hazards and safety considerations for the pregnant anesthesia provider. The comprehensive literature review aims to bridge the gap in practice guidelines related to the pregnant anesthesia provider. Participants will complete a survey to measure confidence levels related to the information distilled and the likelihood of translation into practice.

Objectives

1. Identify a gap in the literature related to safety and practice considerations for the pregnant anesthesia provider through a preliminary literature search
2. Synthesize literature review from published research studies related to pregnant personnel in anesthesia or the operating room setting within the last ten years
3. Articulate the information to anesthesia providers and trainees
4. Evaluate understanding of the knowledge distillation and assess the motivation to apply the knowledge in practice using a voluntary survey questionnaire
5. Devise the data results and illustrate relevant responses related to the information surveys

Expected Outcomes

- Determine baseline familiarity with material among a sample population of anesthesia practitioners and trainees

- Improve knowledge and confidence related to safety recommendations for the pregnant anesthesia provider

SWOT

A strengths, weaknesses, opportunities, and threats (SWOT) analysis was a beneficial component of the project development stage. This tool was helpful to direct the project toward a particular area of need or interest based on an assessment of a phenomenon. The SWOT analysis evaluated internal and external traits of the project, both positive and negative, that could affect the results. Intrinsic attributes involved aspects of the project that innately help, or hurt, the project's aim. Conversely, extrinsic factors included environmental elements or situations that may have impacted the targeted objectives. The SWOT analysis optimized the project design by detecting external sources for threats, minimizing internal weakness, and ascertaining areas of internal and external strength (Moran et al., 2019). The matrix visual for this tool is provided in *Appendix C*.

Intrinsic Strengths & Weaknesses

Though subjective, the SWOT analysis provided perspective of the project proposal for the creator and affiliated committee members. Internal strengths of the project design included its unique content and accessible approach, which may have enticed more voluntary participants. Dissemination of the information in the form of an online self-paced course was both modern and attractive to many different styles of learners. Additionally, there was a need for a comprehensive literature review on the topic, and there was a notable gap in the standard practice guidelines for pregnant anesthesia providers. The basis of the information was founded on universal safety standards in the anesthesia setting and thus indirectly benefited all anesthesia providers. The opportunity to use technology for engagement, surveying, and analysis is an internal factor that could have functioned as a strength or a weakness. Technology provides innovative and efficient results, but the project would have suffered in the event of a technological failure. Other internal weaknesses included the project's dependence on voluntary

participation, and the subject matter may not have attracted the greater anesthesia provider population outside of female providers of childbearing age. The final internal threat was that the online course formatting and design were limited to the skillset of the author.

External Threats

The most significant external threat to this DNP Project was the limited number of voluntary participants. This project lacked outreach potential which significantly restricted the sample size for data analysis. Additionally, the project committee members were geographically located across three U.S. time zones which posed limitations in meeting times and the ability to connect face-to-face. Delayed initiation of the implementation phase while awaiting faculty feedback on drafted proposals and institution IRB approval was an external factor that altered the targeted project timeline.

External Opportunities

In the spirit of optimism, this SWOT analysis concluded with a list of hypothetical opportunities. This endeavor had the potential to motivate leaders in advanced practice roles to standardize safety guidelines and publish facility protocols according to the recommendations in the literature.

Project Design

This project design aims to evaluate participants' confidence levels in their knowledge of occupational considerations for the pregnant anesthetist. A pre-assessment survey, presentation of course material, and post-assessment will be accessible through a self-paced online course through Marian University Canvas, an educational platform for online learning modules. Once published, the course will be distributed to the student registered nurse anesthetists and certified anesthesia faculty of Marian University Leighton School of Nursing DNP Nurse Anesthesia program. Participation is voluntary and there will be no monetary cost associated with the course. The virtual course allows the participants convenient access to the information without the scheduling constraints of attending a live lecture. The course can be accomplished in one sitting or in divided segments at the participants' discretion to allow

for flexible completion. Course content will include individual modules with subsections of the literature review findings with visual reinforcements such as photos and videos.

Project Site and Population

The target population for this project included enrolled students and certified anesthesia faculty of the Marian University Leighton School of Nursing DNP Nurse Anesthesia Program, which comprised 91 students and 5 faculty members. These individuals received an email explaining the project's aim and what is asked of the participants if willing to partake. The email included a link to enroll in the online course titled Occupational Hazards for the Pregnant Anesthesia Provider through the Marian University Canvas platform. The Marian University Canvas portal could only be accessed by individuals actively enrolled with Marian University. Once enrolled, the course would appear on the individual's Canvas Dashboard and participants could access the content at any time. Enrollment provided access to the course content but did not automatically involve individuals in the study. Surveys for data collection were embedded into the course modules with electronic informed consent.

Measurement Instruments and Data Collection

The Occupational Hazards course began with the Pre-Assessment, as shown in *Appendix D*, to survey participant demographics, confidence in participant's knowledge of the subject matter, and confidence in translating the information to the workplace. Following the presentation of course material was the Post-Assessment survey asking the same questions as the Pre-Assessment with one additional free-text response related to the topic reception. The survey tools were developed by the course author using Qualtrics and implemented following approval from the project committee. Data collected from the evaluations on Qualtrics was processed using Microsoft Excel for statistical analysis.

Ethical Considerations/ Protection of Human Subjects

Subjects invited to partake in the study consented electronically before the initial assessment, informing participants of anonymity protection and lack of personal identifiers linked to the surveys.

Individuals involved in the project had the right to abort the study at any time with no penalty or impact on their standing in the academic institution. Individuals enrolled in the Occupational Hazards course had access to the course content regardless of their participation in the surveys. The course modules and information will be accessible to enrollees for three years following the published date of February 26, 2023.

Data Analysis and Results

The target subjects were invited to take part in the course through an introduction email explaining the project aim and what is being asked of willing participants. This email was sent to enrolled students and certified faculty of Marian University Leighton School of Nursing DNP Nurse Anesthesia program, which included 91 students and 5 faculty members. Within the email was a link to the composed course on the Marian Canvas platform. Once enrolled in the course, participants could access and complete the surveys from February 26, 2023, to March 13, 2023. The yielded data from this study was collected from anonymous surveys conducted through Qualtrics.

Pre-Assessment

The Pre-Assessment survey was comprised of 8 multiple-choice questions. The first question served the purpose of electronic informed consent, which detailed the purpose of the survey as it relates to the study. This was the only question that required a response, in which the respondent needed to agree to the terms of the study to proceed with the survey. The following questions included three demographic questions about age, gender, and years of anesthesia experience. The final four questions asked participants to select the response that best correlates with how they relate to the question. A visual representation of the Pre-Assessment Survey, minus the informed consent page, can be found in *Appendix D*. The Pre-Assessment survey was completed by 35 participants. The demographics of this sample included 8 individuals 22-29 years of age comprising 22.8% of the responses. Most of the responses came from individuals aged 30-39, which included 24 of the 35

participants or 68.57%. There were 3 participants aged 40-49, totaling 8.57% of the partakers. Participants were asked to select the gender in which they most identify which unveiled 65.71% female participants and 34.29% males, or 23 and 12 of 35 respectively. Other selections provided when asked about gender included non-binary, non-conforming, and other genders not listed or prefer not to say. None of these gender selections were chosen. Next, participants were asked to disclose the amount of time in which they had been learning and/or practicing anesthesia. 8 of the 35 individuals, or 22.86%, reported less than one year. There were 17, which is 48.57%, who stated 2 years, and 10 of the 35, or 28.57%, had 3 years of anesthesia training. Other categories included 5 or more years and 10 or more years, but there were no participants who reported this amount of anesthesia experience.

The next portion of the Pre-Assessment survey asked participants to rank their confidence level as it relates to occupational hazards in anesthesia and for the parturient working in anesthesia. The response choices were based on a Likert scale which included *extremely confident* (5), *somewhat confident* (4), *neither confident nor unconfident* (3), *somewhat unconfident* (2) and *extremely unconfident* (1). The first question in this series asked about the participant's confidence in their knowledge of the environmental risks of delivering anesthesia. Of the 35 participants, none of them reported feeling extremely confident in their knowledge of the environmental risks of delivering anesthesia. There were 15 individuals, 42.86%, that reported feeling somewhat confident. 9 respondents reported indifference, and 9 others felt somewhat unconfident. This comprised 25.71% for each respective category. There were 2 people, accounting for 5.71%, who felt extremely unconfident in knowing the risks of delivering anesthesia. The next question asked about the participants' confidence level in their knowledge of the occupational risks for a pregnant anesthesia provider. A nearly identical question, but the focus was shifted from the generalized anesthesia provider to a pregnant anesthesia provider. The mean confidence level in this scenario decreased by 12.6% from the previous question. There were no respondents to this question that felt extremely confident, and only 4 of 35, 11.34%, felt

somewhat confident. There were 12, or 34.29% of the sample, who felt neither confident nor unconfident in this question. The most common response was somewhat unconfident, which 40% of the participants reported. There were 5 who stated feeling extremely unconfident, which accounted for 14.29% of the group.

The following question in the Pre-Assessment survey presented an application scenario and asked participants to rate their confidence level in providing safety recommendations to a pregnant anesthesia provider. Interestingly, the confidence level decreased from the previous question by 4.6%. 9 individuals reported feeling extremely unconfident in providing safety recommendations to the parturient as opposed to the 5 individuals in the previous question who stated feeling extremely unconfident in their knowledge of occupational concerns for the expecting anesthesia provider.

The final question in the Pre-Assessment survey asked respondents to rank the topic of occupational considerations for the pregnant anesthesia provider in terms of its usefulness in their role as a DNP-prepared Certified Registered Nurse Anesthetist. There were 11 of the 35 respondents, 31.43%, who reported feeling this information was extremely applicable. The majority felt this content was very applicable to their practice, which accounted for 48.57% of the responses. 6 individuals, 17.14%, selected moderately applicable and 1 person felt it was slightly applicable to their practice. There were no respondents who reported this material as not at all applicable to their practice.

Post-Assessment

The Post-Assessment survey posed identical questions in the same order as the Pre-Assessment, with one additional question at the end of the questionnaire. This final question was an optional free-text response asking participants to share what they found most beneficial from the corresponding online course titled Occupational Hazards for the Pregnant Anesthesia Provider. The Post-Assessment was completed by 29 participants: 7 reported 20-29 years of age, there were 20 between ages 30-39 and 2 participants between the ages of 40-49. There were no participants 50 years or older. Among the

respondents, there were 11 males and 18 females, 37.4% and 62.1% respectively. No other genders were reported. 8 of the survey participants, 27.59%, have less than one year of anesthesia training, 14 of the 29, 48.28%, reported two years, and 7 reported three years which accounted for 24.24% of the sample. There were no participants with greater than 5 years of anesthesia training.

When asked about the participant's knowledge of the environmental risks of delivering anesthesia, the respondents reported an overall 23.6% increase in confidence level. There were 8 individuals, 27.59%, who stated feeling extremely confident in the Post-Assessment survey compared to 0 in the Pre-Assessment. Most Post-Assessment participants, 68.97%, stated feeling somewhat confident in their knowledge of environmental risk. There was 1 report of feeling neither confident nor unconfident on this question, but no participants reported feeling somewhat or extremely unconfident. Regarding the participants' knowledge of environmental risks for the pregnant anesthesia provider, all the respondents reported feeling somewhat, 72.41%, or extremely, 27.59%, confident in the Post-Assessment. This totaled 8 and 21 participants respectively. Similarly, 8 of the 29 Post-Assessment participants felt extremely confident providing safety recommendations to the pregnant anesthesia provider, 20, or 68.97%, reported feeling somewhat confident, and 1 respondent was neither confident nor unconfident toward this question.

When asked how applicable the participants felt this information was in their practice as DNP-prepared Certified Registered Nurse Anesthetists, over 72% reported extremely useful. There were 7 individuals comprising 24.14% of the Post-Assessment participants who selected very useful, and 1 participant selected slightly useful. The final question of the Post-Assessment survey was an optional free-text response asking participants what they felt was most beneficial from the course. The responses to the free-text question can be found in *Appendix E*.

Analysis

The investigative surveys consisted of three core questions about the participant's confidence level in their knowledge of environmental risks for anesthesia personnel, including the parturient. Response choices were coded according to confidence level as follows: *extremely confident* (5), *somewhat confident* (4), *neither confident nor unconfident* (3), *somewhat unconfident* (2), and *extremely unconfident* (1). The first core question asked participants to select the confidence level that correlates with their knowledge of the environmental risks for anesthesia personnel. The Pre-Assessment confidence level averaged 3.06, whereas the Post-Assessment mean was 4.24. Next, participants were asked the same question but regarding pregnant anesthesia personnel. These scores for the Pre-Assessment and Post-Assessment were 2.43 and 4.28 respectively. The final core question asked participants to rank their level of confidence if asked to provide safety recommendations for a pregnant anesthesia colleague. These scores averaged 1.81 on the Pre-Assessment and 4.24 on the Post-Assessment. The mean response scores on these core questions increased by 36.4% in the Post-Assessment following the implementation of literature review findings summarized into a self-paced online course.

A paired *t*-test was performed to compare the mean scores of the core survey questions from the Pre-Assessment and Post-Assessment. The null hypothesis states that the mean values of the Pre-Assessment are equal to the mean values of the Post-Assessment. The alternative hypothesis states that the mean scores for the surveys are not equal. For this analysis, we fail to reject the null hypothesis in which $p = 0.0857$ and the test statistic was -7.379 with 1 degree of freedom, where $\alpha = 0.05$. A visual representation of the mean response scores from the Pre-Assessment and Post-Assessment surveys can be found in *Appendix F*. The bar graph includes the final common question of the survey which asked respondents to select the answer choice that best correlates with how applicable they feel this information pertains to their career as a DNP-prepared Certified Registered Nurse Anesthetist. The response choices were coded as follows: *extremely useful* (5), *very useful* (4), *moderately useful* (3),

slightly useful (2), and *not at all useful* (1). After participants were subjected to the course information, the respondents reported an 11.4% increase in the usefulness of the topic as it relates to their anesthesia practice.

Discussion

A significant limitation of this investigative study was the small sample size and narrow target population. The course invitation was sent to 91 enrolled student registered nurse anesthetists and 5 certified anesthesia faculty of Marian University Leighton School of Nursing DNP Nurse Anesthesia Program. Of the 96 invited, there were 38 individuals enrolled in the online course titled Occupational Hazards for the Pregnant Anesthesia Provider. Participants were invited to join the course regardless of whether they chose to partake in the surveys for data collection. This allowed individuals access to the content without feeling pressured to participate in the study. The questionnaires utilized for data collection were embedded into the course curriculum, thus it was necessary to accept the invitation to the course to take the survey. There were 35 respondents in the Pre-Assessment and 29 participants in the Post-Assessment. This accounted for 36.4% and 30.2% respectively. While these surveys were designed to be anonymous, there were zero participants reporting anesthesia experience exceeding 5 years, and there were no participants 50 years of age or older. Based on this information we can infer zero faculty members participated in the project. This implication limited the population to student registered nurse anesthetists from Marian University DNP Nurse Anesthesia Program. While the result analysis from this study revealed no statistical significance, there was limited data collection given the approximate 33% participation. The mean confidence level values present a clear positive trend from the Pre-Assessment to the Post-Assessment. Further research involving a larger and more diverse target population is recommended.

There is a blatant gap in the literature as evidenced by the literature review for this project. A significant portion of the supportive data for this research comes from studies involving the resident,

physician, or surgeon of specialties other than anesthesia. The anesthesia provider is often exposed to similar levels of occupational risk given their proximity to the procedure and obligation to tend to the patient with every heartbeat. Additional research related to environmental exposures of anesthesia personnel is recommended for the health and safety of future anesthesia providers.

Conclusion

In conclusion, this investigative study demonstrated a gap in the literature related to occupational hazards for the pregnant anesthesia provider and the need for further research on the topic. The findings of this study suggest increased confidence levels related to knowledge of the environmental risks of anesthesia and recommended occupational considerations for anesthesia personnel and pregnant anesthesia providers following the dissemination of the literature. Due to its limited sample size and narrow target population, the results of this study were not statistically significant to be conclusive with the proposed hypothesis. Additional research and translation of the findings into practice are vital to the future health and safety of anesthesia personnel.

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Appendix A

Literature Review Matrix

Reference	Source/ Type	Purpose / Aim	Population / Sample n=x	Variables	Instruments / Data collection	Results	Implications for future research	Implications for future practice
Al-Rasheedi, K. A., Alqasoumi, A. A., & Emara, A. M. (2021). Effect of inhaled anesthetics gases on cytokines and oxidative stress alterations for the staff health status in hospitals. International archives of occupational and environmental health, 94(8), 1953–1962. https://doi.org/10.1007/s00420-021-01705-y	Comparative cross-sectional study; Level II	… to evaluate the effects of waste anesthetic gases on cytokines and oxidative stress of hospital health team members following exposure to waste anesthetic gases (WAGs)	n=180	catalase (CAT), glutathione peroxidase (GSHpx) and superoxide dismutase (SOD) activities, plasma fluoride, serum interferon gamma (IFN-γ), serum interleukin 2 (IL2), serum interleukin 4 (IL4) and plasma thiobarbituric acid reactive substances (TBARS)	Venous blood samples [plasma fluoride levels, enzymatic and non-enzymatic antioxidant assays, and cytokine assay]; statistical analysis via SPSS	Anesthesiologists and their assistants exhibited the highest levels of plasma fluoride, serum IFN-γ and IL 2, exceeding the levels in detected in all the other occupational subgroups. Furthermore, the serum levels of IL4 were significantly raised in anesthesiologists and the difference between this group and other groups was statistically significant. elevated plasma TBARS and reduced CAT, GSHpx and SOD; these variances were also statistically significant.	Further research that builds on the findings presented here is required to investigate in more detail the health effects of occupational exposure to WAGs	Educate healthcare staff to reduce their risks of immunotoxicity by managing these gases. Furthermore, safety protocols for using anesthesia should be re-assessed frequently and improvements be implemented where possible.
Ayoğlu, H., & Ayoğlu, F. N. (2021). Occupational risks for anaesthesiologists and precautions. Turkish Journal of Anaesthesiology	Descriptive Study; Level VI	…to raise awareness about the occupational risks, hazards, and precautions in	n/a	Occupational hazards are classified as physical, chemical,	Review derived from a composition of 27 medical literature pieces	Anaesthesiologists are exposed to numerous potential risks that	These risks are the major mortality and morbidity factors in	There is a need for structured national occupational safety laws and procedures for job

Reference	Source/ Type	Purpose / Aim	Population / Sample n=x	Variables	Instruments / Data collection	Results	Implications for future research	Implications for future practice
and Reanimation, 49(2), 93–99. https://doi.org/10.5152/TJAR.2020.219		anesthesiology practice		biological, ergonomic and psychosocial factors		can harm their general health.	anaesthesiologists. Various preventive measures to be taken to ensure occupational safety in anaesthesia practices are extremely important for employee health	safety in anaesthesiology
Boiano, J. M., & Steege, A. L. (2016). Precautionary practices for administering anesthetic gases: A survey of physician anesthesiologists, nurse anesthetists and anesthesiologist assistants. Journal of Occupational and Environmental Hygiene, 13(10), 782–793. https://doi.org/10.1080/15459624.2016.1177650	Descriptive study; Level VI	…to describe work practices including use of exposure controls and barriers to using scavenging systems by anesthesia care providers who administer general anesthesia to patients	n=2,987 anesthesia care providers (including 1,783 nurse anesthetists, 1,104 physician anesthesiologists, and 100 anesthesiologist assistants)	Training, employer procedures, administration practices, engineering controls, work practice controls, precautionary work practices, post-administration practices, filling anesthetic gas vaporizers, spills of liquid anesthetic agents, personal and environmental monitoring practices for anesthetic gases	Web survey which included a screening module, core module, and seven hazard modules. Data were analyzed using SAS 9.3	Successful management of waste anesthetic gases should include scavenging systems, hazard awareness training, availability of standard procedures to minimize exposure, regular inspection of anesthesia delivery equipment for leaks, periodic air and exposure monitoring, prompt elimination of spills and leaks, and medical surveillance.	Information on the effectiveness of waste gas scavenging systems, types of PPE used during spill cleanup and filling/draining vaporizers, and availability of and participation in a medical surveillance program, was not collected in this study and should be evaluated in future studies.	Nearly one of every five respondents had not received training addressing safe handling of anesthetic agents, including more than a quarter of physician anesthesiologists.

Reference	Source/ Type	Purpose / Aim	Population / Sample n=x	Variables	Instruments / Data collection	Results	Implications for future research	Implications for future practice
Cui, F. H., Li, J., Li, K. Z., Xie, Y. G., & Zhao, X. L. (2021). Effects of sevoflurane exposure during different stages of pregnancy on the brain development of rat offspring. Journal of anesthesia, 35(5), 654–662. https://doi.org/10.1007/s00540-021-02972-2	Randomized control; Level II	… to explore the effects of sevoflurane exposure during different stages of pregnancy on the brain development of offspring	n=72 rat pups	sevoflurane exposure in early (S1) pregnancy, sevoflurane exposure in middle (S2) pregnancy, and sevoflurane exposure in late (S3) pregnancy, interleukin (IL)-1β, IL-6, and tumor necrosis factor (TNF)-α, Nissl body formation, BDNF and CPEB	Morris water maze experiment to measure learning and memory capacity of subjects prior to experiment; Hippocampus tissue sample [levels of interleukin (IL)-1β, IL-6, and tumor necrosis factor (TNF)-α in the hippocampus measured by ELISA. Nissl bodies in the hippocampus were analyzed using Nissl staining. Immunohistochemistry was used to examine the expression of BDNF and CPEB], Statistical analysis via SPSS	Memory and learning capacity significantly reduced in the S1 and S2 groups compared to the control group (p0.05). The level of IL-1β significantly increased ($p<0.05$) in the S1 group compared with the control group. Sevoflurane in early and middle pregnancy affect the formation of Nissl bodies. Expression of BDNF and CPEB2 in hippocampi of S1 offspring rats grealy decreased compared to control group ($p<0.05$). Expression of NR4A1 in hippocampi of rat offspring was signifcantly decreased in the S1 and S2 groups compared with the control group ($p<0.05$). The expression of proteins related to NF-κB pathway increased in S1 group compared to control group ($p<0.05$).	Additional experimental and mechanistic studies required to identify expression of memory-related genes during learning and memory formation, as well as involvement in memory impairment induced by maternal sevoflurane exposure during pregnancy	The neurotoxic effect of maternal sevoflurane anesthesia on the brain development of offspring is higher when the exposure occurs in early pregnancy than in late pregnancy, and its mechanism might involve the NR4A1/NF-κB pathway to increase the secretion of inflammatory cytokines.

Reference	Source/ Type	Purpose / Aim	Population / Sample n=x	Variables	Instruments / Data collection	Results	Implications for future research	Implications for future practice
Downes, J., Rauk, P. N., & Vanheest, A. E. (2014). Occupational hazards for pregnant or lactating women in the orthopaedic operating room. The Journal of the American Academy of Orthopaedic Surgeons, 22(5), 326–332. https://doi.org/10.5435/JAAOS-22-05-326	Descriptive Review; Level IV	… examine the potential occupational hazards present in the orthopaedic OR, including bloodbornerne pathogens, anesthetic gases, methylmethacrylate (MMA), physical stress, and radiation, and the risks that they pose to pregnant and lactating OR staff	n/a	blood-borne pathogens, harmful chemicals, physical stress, and radiation	Review of 48 studies; references 27, 28, and 38 are level II studies. References 23, 24, and 39 are level III studies	Pregnant and lactating women who work in the orthopedic OR are exposed to several potential occupational hazards, including blood-borne pathogens, harmful chemicals, physical stress, and radiation	Effectiveness of preventative measures for occupational hazards in anesthesia	Implementation of recommended prevention techniques to reduce the risk of workplace related perinatal complications
Gaya da Costa, M., Kalmar, A. F., & Struys, M. (2021). Inhaled Anesthetics: Environmental Role, Occupational Risk, and Clinical Use. Journal of clinical medicine, 10(6), 1306. https://doi.org/10.3390/jcm10061306	Systematic Review; Level III	To recount the results of available scientific literature and interpretation of data related to inhaled anesthetics from three perspectives including environmental effects, occupational hazards* and the benefits or potential risks of clinical application	n/a Cited 169 reference sources	*Threshold of anesthetics in the workplace, prevention of exposure to WAGs, health risks related to inhaled anesthetics,	n/a	Although the most important health risks such as abortion were associated with inhaled anesthetics no longer in use, the concern related to long-term exposure is ongoing and warrants more regulatory involvement. The available data on occupational exposure to inhaled anesthetics are still controversial, but potential genotoxic and carcinogenic effects	An inclusive study reporting the (dis) advantages for the patient versus occupational risks and environmental effects is warranted to have a well-considered analysis of the possible clinical impacts of any changes in anesthesia practices	Workplace conditions should be adequate and healthcare professionals should avoid exposure

Reference	Source/ Type	Purpose / Aim	Population / Sample n=x	Variables	Instruments / Data collection	Results	Implications for future research	Implications for future practice
						cannot be excluded. WAG control measures should be implemented as a precaution.		
Harnsberger, C. R., & Davids, J. S. (2019). The pregnant surgeon. Clinics in Colon and Rectal Surgery, 32(6), 450–456. https://doi.org/10.1055/s-0039-1693012	Systematic Review; Level III	… to review the data while providing some practical advice for pregnant surgeons and those considering pregnancy	n/a	physical, logistical, and financial challenges facing the pregnant surgeon	31 referenced literature articles	There are significant challenges faced by the pregnant and postpartum surgeon, as well as her colleagues and administrators, but with awareness, planning, and a supportive environment, there are sustainable solutions. By raising awareness of the specific physical, logistical, and financial challenges facing the pregnant surgeon, we hope to prepare pregnant surgeons, their colleagues, mentors, and administrators.	Sustainable solutions for the challenges faced by pregnant and postpartum surgeons	The commitment to a healthy and sustainable pregnancy and maternity leave for surgeons is a worthy investment to sustain a full and productive career thereafter
Kakazu, C., Lippmann, M., & Karnwal, A. (2015). Hazards of bone cement: for patient and operating theatre personnel. British Journal of Anaesthesia, 114(1), 168–169. https://doi.org/10.1093/bja/aeu433	Descriptive Review; Level VI	… to highlight several dangerous hazards of bone cement to the patient and operating room personnel	n/a	MMA, patient, operating room personnel	3 research studies	MMA inhaled by a pregnant woman can reach the fetus and women who may be pregnant should avoid overexposure to MMA.	Effect of MMA on pregnancy in humans has not been studied, but birth defects were observed in high dose exposure among animals	Operating theatres should be well ventilated with a laminar flow system to take care of the cement odor and fumes

Reference	Source/ Type	Purpose / Aim	Population / Sample n=x	Variables	Instruments / Data collection	Results	Implications for future research	Implications for future practice
						Operating theatres should be well ventilated with a laminar flow system to take care of the cement odor and fumes		
Landford, W. N., Stewart, T., Abousy, M., Ngaage, L. M., Kambouris, A., & Slezak, S. (2021). A Roadmap for Navigating Occupational Exposures for Surgeons: A Special Consideration for the Pregnant Surgeon. Plastic and reconstructive surgery, 147(2), 513–523. https://doi.org/10.1097/PRS.0000000000007581	Retrospective Study; Level III	…to provide current evidence and guidance to aid women in making an informed decision about their perinatal exposures, while maintaining their privacy during the early weeks of pregnancy.	n/a Evidence from 71 cited references	Formaldehyde, methylmethacrylate, anesthetic gases, antineoplastic drugs, poividone-iodone surgical hand scrub, laser/surgical plume, radiation, workplace demands, acoutstics/ vibration, bloodborne pathogens	Comprehensive summarization from 71 referenced sources	Empirical evidence from animal and human studies shows a strong association between these hazards and reproductive outcomes.	Current data for exposure limits by expert agencies is outdated; further research needed to establish reliable exposure limits to occupational hazards	Although pregnant surgeons cannot avoid all occupational exposures, knowledge regarding the risks and ways to mitigate these risks will improve the health of both women surgeons and their unborn children.
Landford, W. N., Ngaage, L. M., Lee, E., Rasko, Y., Yang, R., Slezak, S., & Redett, R. (2021). Occupational exposures in the operating room: Are surgeons well-equipped?. PloS One, 16(7), e0253785. https://doi.org/10.1371/journal.pone.0253785	Cross-sectional survey; Level VI	…to elucidate the extent to which surgeons are trained in OR hazards and assess the self-reported exposure rate across surgical specialties and academic level	n= 183	13 occupational hazards: bloodborne pathogens, surgical smoke, ergonomics, radiation, sharp injuries, inhalation exposure to MMA,	A cross-sectional electronic questionnaire, Qualtrics, online survey and research tool	The results highlight gaps between training, perceived importance and actual practice of occupational risk management among surgeons.	Future studies investigating surgeon knowledge of hazards are warranted.	The data supports the need for medical institutions and surgical specialties to educate the next generation of surgeons on occupational hazards and ensure their protection during training for the sake of surgeon safety.

Reference	Source/ Type	Purpose / Aim	Population / Sample n=x	Variables	Instruments / Data collection	Results	Implications for future research	Implications for future practice
				cytotoxic drugs, formaldehyde, patient lifting, prolonged standing (greater than 3 hours), surgical hand scrub, surgical noise (anesthesia machines, monitors, vibratory devices, suctioning, music), and anesthetic gases				
Marx M. V. (2018). Baby on Board: Managing Occupational Radiation Exposure During Pregnancy. Techniques in vascular and interventional radiology, 21(1), 32–36. https://doi.org/10.1053/j.tvir.2017.12.007	Descriptive Study; Level VI	This article reviews the issue of occupational radiation exposure as a deterrent to recruitment of women into the field of interventional radiology and provides the reader with three strategies to optimize radiation protection during fluoroscopically guided procedures	n/a	Personal protective shielding, use of ancillary shielding, and techniques that limit fluoroscopy x-ray tube output	19 referenced literature citations	With the implementation of optimal radiation safety practices in the interventional radiation suite,	To date, no study has stated in its conclusion that all fetal ill effects of radiation have a distinct threshold dose.	To provide education and work strategies to support safe practice for the healthcare providers in the interventional radiology suite

Reference	Source/ Type	Purpose / Aim	Population / Sample n=x	Variables	Instruments / Data collection	Results	Implications for future research	Implications for future practice
Souza, K. M., Braz, L. G., Nogueira, F. R., Souza, M. B., Bincoleto, L. F., Aun, A. G., Corrente, J. E., Carvalho, L. R., Braz, J., & Braz, M. G. (2016). Occupational exposure to anesthetics leads to genomic instability, cytotoxicity and proliferative changes. Mutation Research, 791-792, 42–48. https://doi.org/10.1016/j.mrfmmm.2016.09.002	Randomized controlled trial; Level III	… this study investigates for the first time whether occupational exposure to WAGs is associated with oxidative stress, DNA damage, inflammation, and transcriptional modulation in university hospital anesthesia providers as a means of achieving a better understanding of these events	n= 60 [30 controlled, 30 exposed]	Workplace air/ scavenging, lipid peroxidation, nitric oxide metabolites, lipophilic antioxidants, antioxidant status, DNA damage, relative telomere length, inflammatory markers, gene expression,	Venous blood samples were collected and assessed using Shapiro-Wilk test; *t* test analysis and categorical variable chi-square test, gene expression analysis via Mann-Whitney; correlation analysis using Pearson or Spearman	No significant differences ($p > .0025$) between the groups were observed for any parameter evaluated. Under the conditions of the study, the findings suggest that occupational exposure to WAGs is not associated with oxidative stress or inflammation when evaluated in serum/plasma, with DNA damage evaluated in lymphocytes and leucocytes or with molecular modulation assessed in peripheral blood cells in university anesthesia providers.	Continued efforts to investigate the biological effects and health outcomes of exposure to WAGs are warranted to better understand the possible toxic mechanisms associated with WAG exposure, including those related to genetic susceptibility and epigenetic patterns.	Reductions in WAGs exposure and increased biomonitoring should be considered for all occupationally exposed professionals.
Sun, M., Xie, Z., Zhang, J., & Leng, Y. (2021). Mechanistic insight into sevoflurane-associated developmental neurotoxicity. Cell biology and toxicology, 10.1007/s10565-021-09677-y. Advance online publication.	Systematic Review; Level IV	.. to discuss mechanisms by which sevofurane exposure during development may induce long-lasting undesirable effects on the brain	n/a	Sevoflurane exposure, neural cell death, neural cell damage, assembly and plasticity of the neural circuit, tau	Review of 142 referenced citations	The developing brain may be uniquely vulnerable to anesthesia, pending further investigation	More research is needed to further reveal the underlying mechanisms by which sevoflurane and other anesthetics can	More advanced technologies and methods should be applied to determine the underlying mechanism(s) and guide prevention and treatment of sevoflurane induced neurotoxicity.

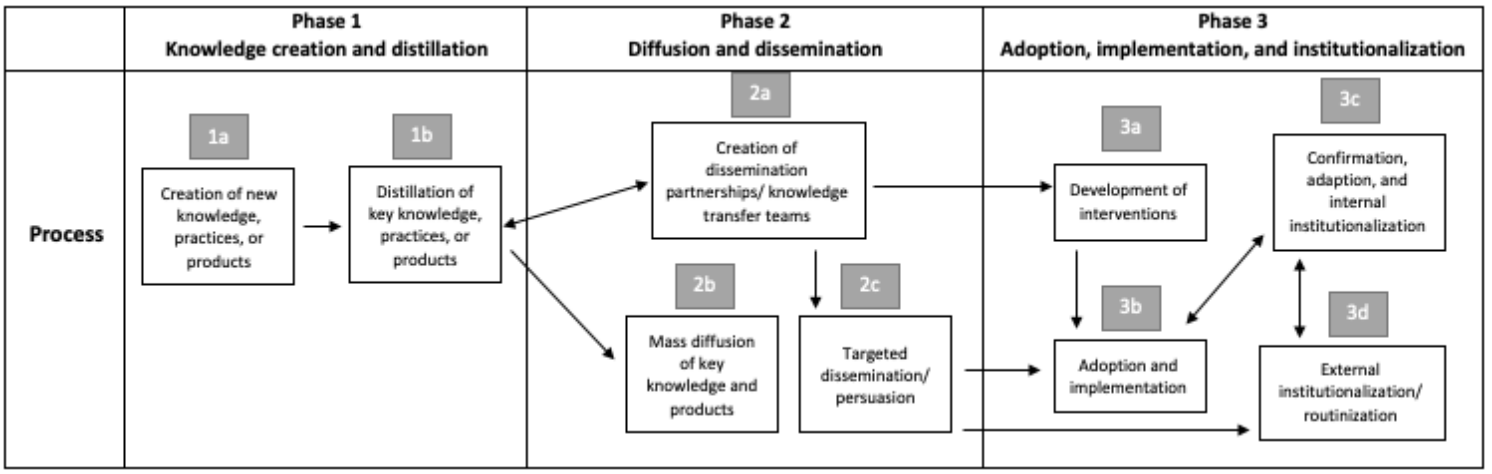
Reference	Source/ Type	Purpose / Aim	Population / Sample n=x	Variables	Instruments / Data collection	Results	Implications for future research	Implications for future practice
https://doi.org/10.1007/s10565-021-09677-y				phosphorylation, and neuroendocrine effects			induce developmental neurotoxicity.	
Szczesna, A., Grzelak, K., Bieniasz, M., Kacperczyk-Bartnik, J., Dobrowolska-Redo, A., Bartnik, P., Zareba-Szczudlik, J., & Romejko-Wolniewicz, E. (2019). Pregnant surgeon - assessment of potential harm to the woman and her unborn child. *Ginekologia Polska*, *90*(8), 470–474. https://doi.org/10.5603/GP.2019.0081	Descriptive Study; VI	… to analyze the risks and consequences of working in the operating theatre during pregnancy	n/a	Laws and regulations, risk factors for gravid or lactating women, consequences of occupational exposure, prevention or lack thereof	Review of 33 referenced citations	The unpredictability of this occupation, prolonged hours and stress associated with work can all affect the future mother and her child. The available research on potential risks for pregnant women performing surgical activities named such consequences as premature birth, miscarriage, fetal growth retardation, hypertensive disorders and infertility.	Further research is needed for evidence-based guidelines for pregnant surgeons on how long and to which extent they should work to minimize risk of pregnancy complications	The key is to maintain balance between limiting the likelihood of pregnancy complications and respecting women's voluntary wish to continue professional development
Varughese, S., & Ahmed, R. (2021). Environmental and occupational considerations of anesthesia: A narrative review and update. Anesthesia and Analgesia, 133(4), 826–835. https://doi.org/10.1213/ANE.0000000000005504	Narrative Review; Level VI	… to summarize the current understand of the environmental and occupational exposure aspects of volatile anesthetic gases	n/a Evidence from 13 referenced articles, with 80 referenced citations	Environmental release and potential impact of volatile anesthetics, occupational exposure and potential impact of VAs, governmental exposure limits, impact	PubMed literature search	Inhaled anesthetics contribute to GHG emissions, although their contributions are lower than those of other human produced substances. Volatile agents may pose a potential health risk	Further research needed to understand long-term impacts and occupational exposure risk and outcomes associated with such exposure, and an increased focus on education and awareness	Measures to reduce occupational exposure and environmental impact of inhaled anesthetics include efficient ventilation and scavenging system, monitoring airborne concentrations of waste gases to maintain below recommended

Reference	Source/ Type	Purpose / Aim	Population / Sample n=x	Variables	Instruments / Data collection	Results	Implications for future research	Implications for future practice
				of Waste Anesthesia Gas regulations, total intravenous anesthesia		to operating-room personnel if not properly managed and scavenged	among individuals, institutions, and governments to mitigate environmental and occupational health footprint associated with global use of volatile anesthetics.	limits, ensuring anesthesia equipment is maintained without leaks, avoiding desflurane and N2O if possible and using appropriate FGF rates. TIVA may be an alternative to inhaled anesthetics due to decreased risks from occupational exposure, but agents such as propofol must be disposed of appropriately.
Wang, R. R., Kumar, A. H., Tanaka, P., & Macario, A. (2017). Occupational Radiation Exposure of Anesthesia Providers: A Summary of Key Learning Points and Resident-Led Radiation Safety Projects. Seminars in cardiothoracic and vascular anesthesia, 21(2), 165–171. https://doi.org/10.1177/1089253217692110	Descriptive Review; Level VI	…to summarize the key learning points for radiation safety related to basic physical principles, effects of ionizing radiation, radiation exposure measurement, occupational dose limits, radiation and pregnancy, sources of radiation exposure, factors affecting occupational exposure such as positioning and	n= 57	key learning points: basic physical principles, effects of ionizing radiation, radiation exposure measurement, occupational dose limits, considerations during pregnancy, sources of exposure, factors affecting	Review of 26 literature references; opt-in dosimeter study n=41 anesthesia residents	Anesthesia providers are frequently exposed to radiation during routine patient care in the operating room and remote anesthetizing locations. Our quality improvement project involving resident exposure and published studies suggest that occupational radiation doses are generally well below the recommended threshold.	Further dosimeter studies that meet the federal regulatory definition of research should be conducted	Continued education and awareness of the risks, improvements in radiation shielding, and increasing distance from the source of ionizing radiation will reduce exposure and potential for associated sequelae

Reference	Source/ Type	Purpose / Aim	Population / Sample n=x	Variables	Instruments / Data collection	Results	Implications for future research	Implications for future practice
		shielding, and monitoring		occupational exposure such as positioning and shielding, and monitoring.				

Appendix B

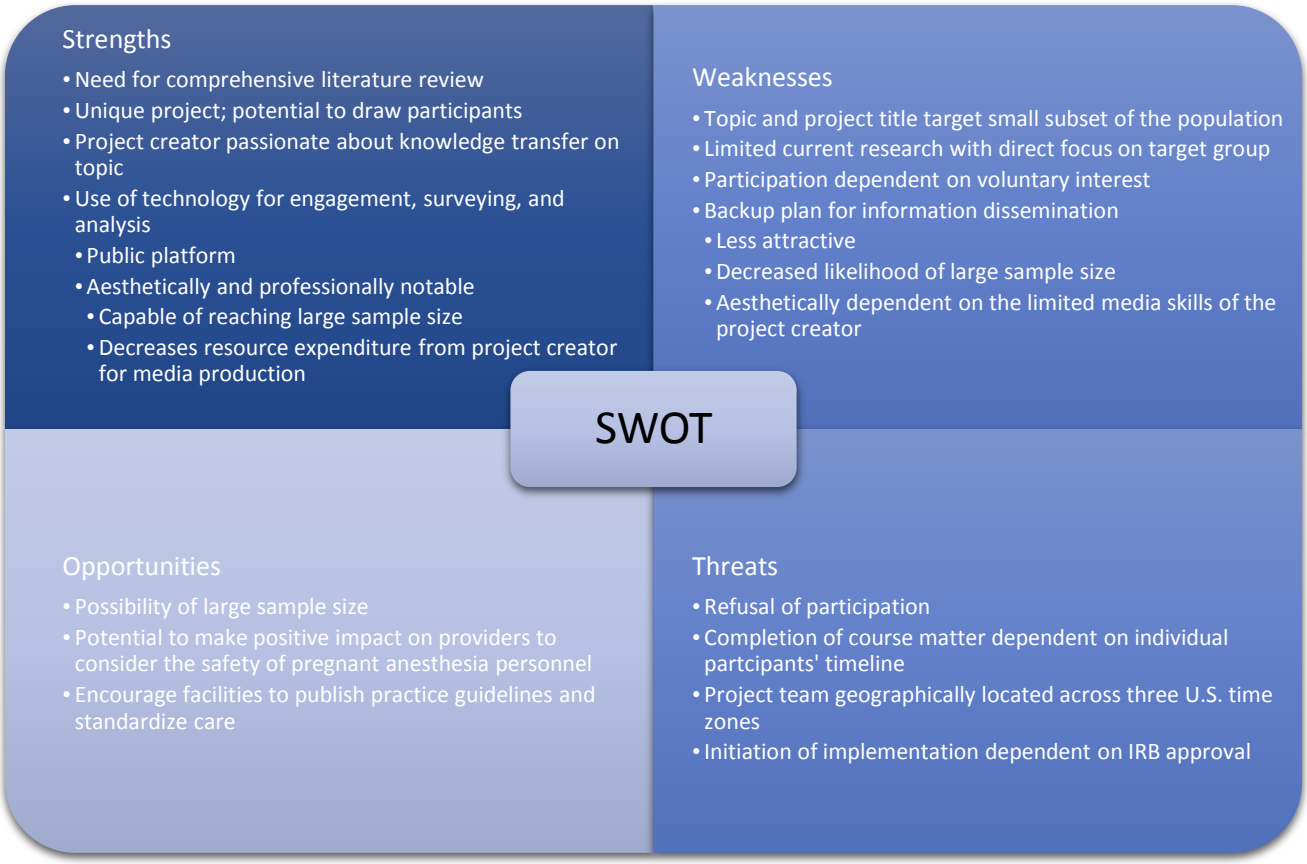
AHRQ Knowledge Transfer Framework



(White et al., 2016)

Appendix C

Strengths, Weaknesses, Opportunities, & Threats



Appendix D

Pre-Assessment Survey

Pre-Assessment

Please select your age bracket:

- 20-29
- 30-39
- 40-49
- > 50

Please select the gender in which you most identify:

- Male
- Female
- Non-binary / non-conforming
- Prefer not to say
- Other gender not listed

How many years have you been learning and/or practicing anesthesia:

- 1
- 2
- 3
- 5 or more
- 10 or more

How confident are you in your knowledge of the environmental risks of delivering anesthesia?

- Extremely confident
- Somewhat confident
- Neither confident nor unconfident
- Somewhat unconfident
- Extremely unconfident

How confident are you in your knowledge of the occupational risks for a pregnant anesthesia provider?

- Extremely confident
- Somewhat confident
- Neither confident nor unconfident
- Somewhat unconfident
- Extremely unconfident

An anesthesia colleague confides in you that she is newly pregnant. How confident would you feel providing her with some recommended safety considerations for her day-to-day in the workplace?

- Extremely confident
- Somewhat confident
- Neither confident nor unconfident
- Somewhat unconfident
- Extremely unconfident

How applicable do you feel this information regarding occupational considerations for the pregnant anesthesia provider is for your role as a Doctor of Nursing Practice in Nurse Anesthesia?

- Extremely useful
- Very useful
- Moderately useful
- Slightly useful
- Not at all useful

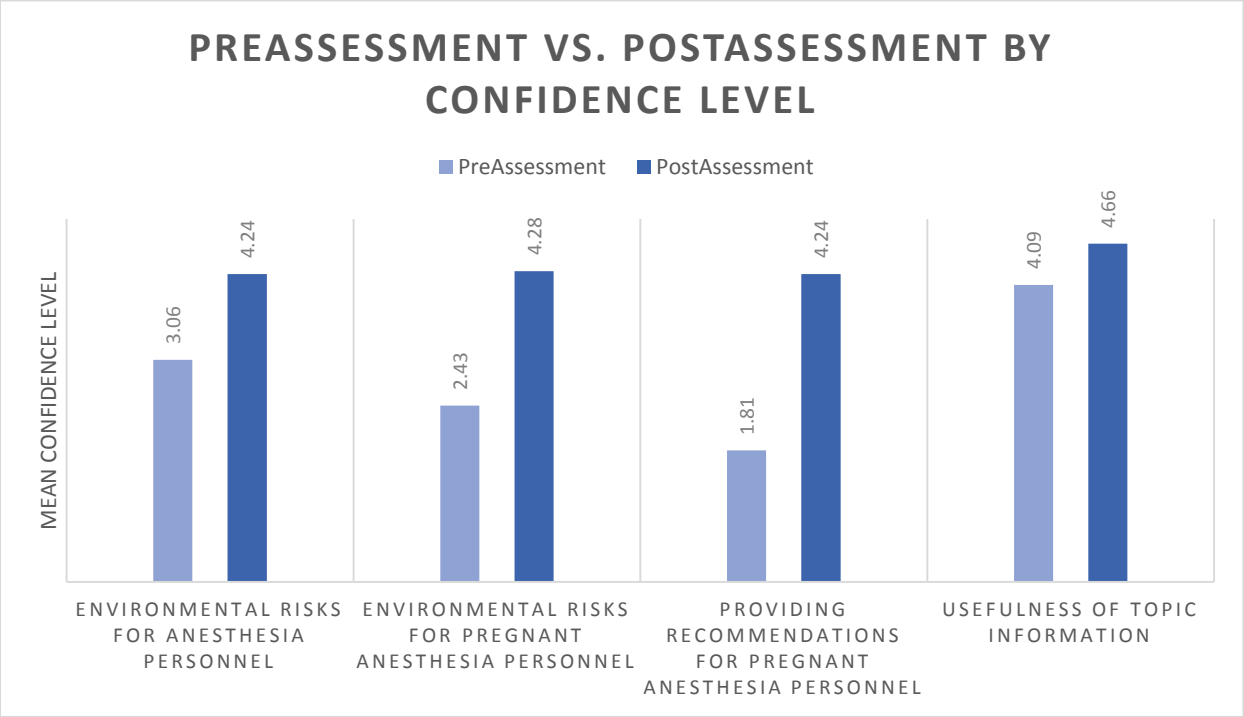
Appendix E

Post-Assessment Free-Text Responses

Post-Assessment: What did you find most beneficial from this course?
"I used to think only volatiles where hazardous to the fetus, I didn't realize how many elements exist in the OR that threaten fetal and parturient health"
"Learning that even outside of anesthesia that there are many hazards in the OR environment and how to mitigate those hazards for myself and all the OR staff"
"Interesting and succinct data for all providers, including parturients"
"Turning down FGF instead of turning off vaporizer before intubating"
"There were a couple of different exposure risks I hadn't considered prior to the course such as the MMA amount within the OR air. This was a good review and reminder of many of the exposures and risks we face as anesthesia providers."
"Learning how to properly fill vaporizers"
"The actual ppm of MMA that can be released into the OR during a hip case was alarming. measures we can take to protect ourselves or others from various hazards in the OR"
"All the data in this module was extremely beneficial"
"I appreciated the review of environment exposures. Cement and gas is often discussed, but I had no idea about the cautery!"

Appendix F

Graph Depicting Mean Confidence Levels of Pre-Assessment vs. Post-Assessment



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