SCHOLARLY PROJECT: A RADIATION SAFETY EDUCATION INTERVENTION FOR CERTIFIED REGISTERED NURSE ANESTHETISTS

by

Khadija Faulkner

A doctoral scholarly project submitted to the faculty of
The University of North Carolina at Charlotte
in partial fulfillment of the requirements
for the degree of Doctor of Nursing Practice

Charlotte

2023

Approved by:

____
Dr. Stephanie Woods

____
Dr. Katie Shue-McGuffin

____
Dr. Dianne Earnhardt

____
Dr. Jodie Huffstetler

____
Dr. Tricia Turner

ABSTRACT

KHADIJA FAULKNER. A Radiation Safety Education Intervention for Certified Registered Nurse Anesthetists. (Under the Direction of DR. STEPHANIE WOODS, PH.D., RN)

CRNAs provide anesthesia for surgeries that utilize ionizing radiation daily and must possess the knowledge to protect themselves from the adverse biological sequelae that can be caused by ionizing radiation exposure. CRNAs must comply with the Occupational Safety and Health Administration's (OSHA) ionizing radiation standards and not exceed an annual whole-body dose equivalent of 1.25 rem per quarter or 5 rem per year (OSHA, n.d.). This quality improvement (QI) project aimed to assess and enhance Certified Registered Nurse Anesthetists (CRNAs) familiarity with the health hazards associated with exposure to ionizing radiation. This project used a comparative design to determine whether an online voice-over radiation safety educational infographic improved radiation safety knowledge. By increasing awareness of the risks of occupational exposure to ionizing radiation in the anesthesia setting, safer radiation precautions and practices can be promoted to minimize workplace exposure. The PICO question is, "In Certified Registered Nurse Anesthetists, does a radiation safety online educational intervention enhance knowledge of radiation safety measures?"

This project was part of a larger QI group project and was individualized based on the project's setting. The site for this QI project was an inner-city full-service hospital. The intervention contained a pre-test consisting of four demographic and 11 knowledge-based questions, a narrated radiation safety infographic, and a post-test consisting of the same knowledge-based questions as the pre-test. Data analysis revealed that the educational infographic enhanced Certified Registered Nurse Anesthetists (CRNAs) knowledge of radiation safety. CRNAs demonstrated the most improvement in their knowledge of potential health hazards of occupational exposure to ionizing radiation. The QI project recommends increasing

distance from the radiation source, custom fit lead, acknowledgment of ionizing radiation use during the surgical time-out, and for CRNAs to be sent their quarterly dosimeter reports.

ACKNOWLEDGMENT

I am writing to express my immense gratitude to my project chair, Dr. Stephanie Woods, for her guidance and support throughout this quality improvement project. My gratitude also extends to all the quality project committee members. I want to acknowledge Dr. Job Chen, a critical factor in the data analysis portion of the project. I want to thank my classmate Alyssa Oliveri for her contribution to our quality improvement project; I could not have done it without your hard work and support. Not only have I learned so much from you, but I consider you a lifelong friend. Finally, thank you to Zac Simmons, a classmate who contributed to our quality improvement project earlier. The success of this project is a direct result of the support, work, and dedication of my committee members and nurse anesthesia faculty.

DEDICATION

I dedicate this project to my brilliant 6-year-old, Reco III, my supportive husband, Reco Jr., my loving parents and in-laws. Their unwavering support over the years has not gone unnoticed. So many people have made a positive impact during this journey, including my friends, family, program faculty, and my fantastic cohort. To my dad in heaven, you made all of this possible. I love you all deeply.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ALARA	As Low As Reasonably Achievable
ACOG	American College of Obstetricians & Gynecologists
CRNA	Certified Registered Nurse Anesthetist
CT	computed tomography
DNP	Doctor of Nursing Practice
Gy	grays
IR	interventional radiology
ICRP	International Commission on Radiological Protection
mSv	milli sievert
NORA	non-operating room anesthesia
NRC	Nuclear Regulatory Commission
OR	operating room
OSHA	Occupational Safety and Health Administration
PDSA	plan-do-study-act
QI	quality improvement
QR	quick response
RSO	radiation safety officer

SECTION I: INTRODUCTION

Background

Certified Registered Nurse Anesthetists (CRNAs) consistently deliver anesthesia care in environments that utilize ionizing radiation. Ionizing radiation penetrates the human body, is absorbed by tissues and damages living cells (Occupational Safety and Health Administration [OSHA], n.d.). According to Barash et al. (2017), trends have shown that anesthesia providers are increasingly exposed to ionizing radiation. The increased use of ionizing radiation for surgical procedures has tripled the exposure rate to U.S. healthcare workers within the past quarter century (Phillips & Monaghan, 2011). Sources of ionizing radiation in the operating room (OR) and procedure suites are from a primary X-ray beam, computed tomography (CT) scans, scattered X-rays, and leakage (Smith, T., Quencer, K., et al., 2021).

Problem Statement

The surgical visualization of internal vessels, organs, and bones often necessitates the generation of continuous X-ray images, a technique known as fluoroscopy, which employs higher doses of radiation (FDA, 2020). Fluoroscopy is the primary source of radiation exposure to healthcare personnel and CRNAs participate in direct patient care involving fluoroscopy frequently (Smith M., Yanko, et al., 2023). Ionizing radiation exposure from surgeries that require X-ray imaging to non-invasively visualize anatomical structures could lead to multiple health concerns, such as cancer, cataracts, and reproductive implications.

Purpose of the Project

CRNAs are a group of healthcare professionals who require radiation protection education, according to the International Commission on Radiological Protection (ICRP, Publication 113, 2015). Providing an educational online intervention to CRNAs will help mitigate the damaging risks of radiation exposure and bridge radiation safety knowledge gaps in the clinical environment. This quality improvement project aims to promote radiation safety precautions and awareness of the health hazards of ionizing radiation for CRNAs.

Clinical Question

The overarching clinical question and area of interest is, “In Certified Registered Nurse Anesthetists, does a radiation safety online educational intervention enhance knowledge of radiation safety measures?”

SECTION II: LITERATURE REVIEW

A literature review was conducted to evaluate the occupational hazards that ionizing radiation poses to CRNAs and effective means of risk mitigation. The keywords used for the literature search included: anesthesiologists, cancer, cataracts, fluoroscopy, ionizing radiation, nurse anesthetists, pregnancy, occupational risk, and radiation exposure. These words were searched individually, and by using the Boolean phrase “AND” to expand the search. Electronic databases that were employed included PubMed, CINAHL, and ScienceDirect. The United States Department of Labor Occupational Safety and Health Administration (OSHA), the United States Nuclear Regulatory Commission (NRC), and the International Commission on Radiological Protection (ICRP) were webpages that were also utilized. The literature search was narrowed to include the years 2011 to 2023. The initial search was expanded to include healthcare workers other than anesthesia providers for a more expansive review. Appraisal of the literature revealed the biological consequences of exposure to ionizing radiation, annual and organ-specific dose limits, pregnancy implications, and protective measures that prevent negative health sequela caused by ionizing radiation.

Units of Measurement

Ionizing radiation can be measured by radiation absorbed dose by an International System (SI) unit known as the gray (Gy). SI units are recognized by all countries except the United States. One gray (Gy) absorbed dose is measured in joules per kilogram (J/kg) – the amount of radiation necessary to produce one joule of energy into one kilogram of matter. The absorbed dose of ionizing radiation transmitted to the body does not equate to the amount of biological damage (Unit Converter, 2023). Grays are large quantities, and often more than humans absorb. For example, a dose of 10-20 Gy is considered lethal (2023).

Dose equivalent or effective dose are units that delineate biological damage by combining the radiation absorbed with the biological effects of the radiation. The units expressing biological damage are the roentgen equivalent man (rem) and Sievert (Sv). These radiation exposure units can be measured and tracked by dosimeters that are worn by all intraoperative healthcare personnel to track their exposure to ionizing radiation (Akram & Chowdhury, 2021). Sievert (Sv) is also an International System (SI) unit that is recognized by all countries except the United States but is cited often in scientific literature. The United States Nuclear Regulatory Commission (NRC), responsible for regulating radioactive chemicals and materials, states that one rem is equivalent to the dose of one full-body CT scan (2022). For further context, one rem equals 0.01 Sv. Furthermore, one Gy of X-rays has a dose equivalent of one Sv on living tissues (Unit Converter, 2023).

Dose Limits

Biological damage caused by ionizing radiation ensues from the formation of reactive oxygen particles which can lead to irreversible cell damage (Smith et al., 2021). Cellular apoptosis, DNA breakdown, and molecular destruction can harm radiosensitive body tissues and cause oncogenic and teratogenic effects (Akram & Chowdhury, 2021). OSHA is responsible for regulating employee exposure to ionizing radiation from radiation-producing equipment such as X-rays, CT scan, and fluoroscopy. OSHA standards recommend an annual whole-body dose equivalent of five rem per year (OSHA, n.d.). However, every attempt should be made to maintain annual radiation exposure to less than 50% of the annual occupational dose limit (Akram & Chowdhury, 2021).

The International Commission on Radiological Protection (ICRP) requires that a declared pregnant worker who is occupationally exposed to ionizing radiation receive a dose equivalent of no more than 500 mrem (five mSv) throughout the course of the pregnancy (Publication 103, OSHA, n.d.). Fetal exposure to ionizing radiation during the organogenesis period increases the risk for neuropathology, malformations, and intrauterine growth restriction (Mattsson et al., 2021). The susceptibility of the fetus during organogenesis (weeks four through eight of intrauterine development), underscores the impact of gestational age on the risk of teratogenesis.

The maximum dose of ionizing radiation recommended for the lens of the eyes is 20 mSv per year, on average, over the course of five years (ICRP, 2019). This dose limit comes from a 2011 update from the ICRP, which is a notable decrease from the previous ICRP recommendation of 150 mSv per year (ICRP, 2019). This recommendation also stated that annual radiation exposure for the lens of the eyes should remain below a threshold of 50 mSv. However, Ainsbury et al. (2021) stated that the updated dose recommendation was based on past epidemiological data analysis and that there is no consistent link between the dose limit and human cataracts development. For example, Ainsbury et al. found underwhelming evidence of radiation-induced cataracts occurring at doses under 500 mSv and an obvious risk from doses exceeding 1 Sv (2021).

ALARA Principle

The As Low As Reasonably Achievable (ALARA) principle is a proposition that underscores three fundamental concepts to minimize exposure to ionizing radiation: decreasing exposure time, implementing proper shielding, and increasing distance away from the source of ionizing radiation. The goal of the ALARA principle is to keep occupational exposure to ionizing radiation below regulatory and legal limits. Since any dose of ionizing radiation has some degree of risk, it is recommended that all attempts be made to minimize vulnerability (Phillips & Monaghan, 2011).

Fluoroscopy time is a common metric used to quantify radiation dose and ensure the cautious use of exposure time. Ionizing radiation can only be shielded by lead and therefore, leaded aprons should be donned by all susceptible individuals. Further shielding information, specifically related to protecting radiosensitive tissues and mitigating risks to the fetus, is detailed in the *health hazards* section. Additionally, the Inverse-Square Law states that the concentration of radiation exposure is inversely proportional to the square of the distance from the radiation source (Kim, 2018). For example, when the distance from the radiation source is doubled, the concentration of radiation exposure is reduced to one-fourth the initial intensity. When the original distance is tripled, radiation exposure is reduced by one-ninth. This concept underscores how increasing the distance from the ionizing radiation beam by only one meter can substantially reduce exposure.

Health Hazards: Cancer, Teratogenesis, and Cataracts

Cancer

Ionizing radiation is a known carcinogen and has the potential to cause stochastic effects. This term describes an increased probability of harm arising from increased radiation doses, such as with low-dose long-term exposure rather than exceeding a set threshold dose (Akram & Chowdhury, 2021). Cancer is the classic stochastic effect associated with ionizing radiation to which exposure varies between healthcare providers depending on the length of time and proximity they have to the radiation source during a surgery or procedure. Minimally invasive surgeries, such as cystoscopy and catheterization procedures, pose greater ionizing radiation exposure from the use of fluoroscopy than open surgical approaches because they rely on the use of fluoroscopy for a longer period for diagnostic and interventional approaches, instead of the surgeon having direct visualization of the patient's anatomy through an open surgical approach

(Matityahu et al., 2017; Yu & Khan, 2014). The benefits of minimally invasive surgeries that utilize fluoroscopy include less tissue dissection, pain, and blood loss. However, although the growth of minimally invasive surgery is beneficial to patients, it may increase the risk of radiation exposure for healthcare providers (Matityahu et al.,2017). According to Matityahu et al., a radiation exposure dose of “1 Sv represents a 5.5% chance of developing cancer” (2017, p. 1728).

The type of cancers associated with ionizing radiation varies. Li and Athar (2016) associated the pathogenesis of basal cell carcinoma with healthcare providers' exposure to ionizing radiation, while other studies referenced the risk of thyroid cancer (Matityahu et al., 2017). These studies focused on ionizing radiation exposure from fluoroscopy in orthopedic surgeries, and state that cancer prevention is possible by utilizing evidence-based practices to minimize cancer risk (Matityahu et al., 2017; Yu & Khan, 2014). Evidence-based measures that are proven to protect CRNAs and other healthcare personnel in the operating room include: a thorough understanding of the ionizing radiation dose limits, wearing radiation protection shields, increasing distance from radiation sources, and reducing total fluoroscopy exposure time (Matityahu et al., 2017; Yu & Khan, 2014). Limitations of the literature reviews include the variability in the amount of radiation exposure in studies among different providers in the OR, and the need for more high-quality evidence (Yu & Khan, 2014). Matityahu et al. (2017) reviewed radiation exposure to orthopedic surgeons whose proximity to radiation sources in the operating room differs from CRNAs who stand at the head of the bed. Depending on the surgery site, surgeons usually operate next to patients, either on the left or right.

Only a few studies reported on the exact proximity of surgeons from the operating table. (Matityahu et al., 2017). In addition, the literature review included different fluoroscopy systems and dosimeters to measure radiation exposure, which may compromise healthcare providers' radiation exposure results (Matityahu et al., 2017). Yu and Khan (2014) recommended that future cohort studies examine the long-term effects of ionizing radiation exposure and cancer rates in healthcare providers.

Lee et al. (2021) collected data from South Korean diagnostic medical radiation workers enrolled in their national dose registry from 1996 to 2011. They compared cancer and death incidence up to December 2017. Lee et al. (2021) reported differences in cancer incidence compared to the general population depending on sex and site of cancer. Female diagnostic radiation workers in South Korea had a higher risk of solid cancer (tumors) than male coworkers. However, radiation workers who were male had a significantly lower risk of solid cancer than the general population (Lee et al., 2021). They concluded that there were no significant associations between occupational radiation doses received and cancer incidence among South Korean radiation workers (2021). This recent cohort study was limited due to relatively young cohort members; the average employee age in the cohort was 35 years old. Lee et al. also reported that their cohort study had a short follow-up time, and the sample of interventional medical workers who perform fluoroscopy-guided procedures was about seven percent (Lee et al., 2021). Although the study by Lee et al. (2021) did not report significant associations between occupational radiation doses received and cancer, they recommend that future medical practice should employ more efforts to implement protective radiation measures to minimize potential health risks due to the growth of medical imaging use (Lee et al., 2021). Agreeably, Smith, T., Quencer, K., et al. (2021) reported the need for future research to understand the occupational cancer risk from very low-dose radiation due to the limited evidence to associate cancer with occupational radiation exposure from medical procedures.

Teratogenesis

Ionizing radiation exposure may have reproductive implications. It is important to note that there are no studies that exist that have investigated the effects of ionizing radiation in pregnant women and fetal development for obvious ethical reasons. Existing information about in-utero ionizing radiation exposure is based on the atomic bombings of Hiroshima and Nagasaki (Englander & Ghatan, 2020). Studies that occurred following these disasters are largely inconclusive and have many confounding variables such as maternal disease, age, and parity (Neel & Schull, 1956). For example, in 1951, the Atomic Bomb Casualty Commission compiled a list of women who were pregnant on August 9, 1951, and in 1956 a book entitled, *The Effects of Exposure to the Atomic Bombs on Pregnancy Termination in Hiroshima and Nagasaki,* was published (Neel & Schull, 1956). While many chapters detail the incidence of congenital anomalies, malformations, and stillbirths, the data does not show consistent findings of maternal exposure affecting fetal outcomes (1956).

Substantial doses of ionizing radiation that exceed a set threshold are referred to as deterministic effects, and these historical events are examples of such (Akram & Chowdhury, 2021). Deterministic effects are immediately observed, and the probability of occurrence increases as the dose of ionizing radiation increases (Phillips & Monaghan, 2011). Based on studies from Hiroshima and Nagasaki, DeSantis et al. stated this threshold dose was greater than one Gy and that below this dose, teratogenic effects do not occur (2005). In addition, Englander & Ghatan (2020) noted that in women 30 years old and above, infertility will only occur 30% of the time at 4 Gy doses – a dose so high that it is over 80 times greater than the limit recommended by the American College of Obstetricians and Gynecologists (ACOG). Women over 40 years old who receive this same extreme dose of ionizing radiation will experience infertility 100% of the time (2020). While this demonstrates the potential effect that maternal age can have on fetal outcomes when exposed to ionizing radiation, doses of 4 Gy are not used for medical imaging.

Mattsson et al. also pointed out that cases of prenatal death during the first two weeks of pregnancy, the implantation phase, are deterministic in nature (2021). This is an all-or-nothing effect during this timeframe where the embryo either dies or is undamaged. Typically, the first two weeks of pregnancy make the embryo resistant to the effects of potential teratogens (Chestnut, 2019). Weeks four through eight following fertilization is termed the organogenesis period, which is when fetal cells are rapidly proliferating and differentiating (2019). This timeframe poses a heightened risk for the deterministic effects of ionizing radiation and shows that gestational age partly determines the consequences of ionizing radiation (Mattsson et al., 2021). However, developmental or neurocognitive disability, congenital malformations and microcephaly during the organogenesis period occur at high dose rates exceeding 500 mGy (2021). Mattsson et al. noted that fluoroscopic exams and pelvic and abdominal CT scans present the greatest risk to the fetus when pregnant women undergo medical imaging for diagnostic purposes (2021). Englander & Ghatan also noted that an extremely high dose of ionizing radiation is needed to cause sterility – doses which exceed occupational radiation exposure (2020). Occupational ionizing radiation exposure doses are much below the threshold that can cause impotence and there is no current evidence that fluoroscopy has been associated with infertility (2020). Furthermore, several studies specifically noted that after 20 to 25 weeks of gestational age, the fetus is resistant to the teratogenicity of occupational doses of ionizing radiation (Phillips & Monaghan, 2011).

While fetotoxic doses of ionizing radiation are outlined in many articles, several also clarified that no dose is considered a safe dose (Chestnut, 2019). The American Journal of Nursing (AJN) published an article about occupational hazards for pregnant nurses in which they maintained that the stochastic effects of low-dose long-term ionizing radiation are ambiguous (2011). No studies exist that have reported levels in pregnant nurses who are occupationally exposed to ionizing radiation, but available data showed that nurses receive less than or equal to the amount of exposure that physician operators accrue (Ghatan, 2020). To ensure the absorbed dose is below the known threshold dose, declared pregnant healthcare providers are required to wear two dosimeters. One dosimeter is to be worn under the lead (2020). A study by Marx et al. demonstrated that pregnant interventional radiology physicians received an under-lead dose of 1.3 mSv – almost four times less than the ICRP legal limit (2020). Importantly, the under-lead dosimeter is considered to overestimate the fetal dose since it does not compensate for the attenuation or loss of energy as the electromagnetic waves travel through abdominal tissue (2020). Phillips & Monaghan suggested that pregnant anesthesia providers always wear one millimeter of wraparound at the level of the fetus (2011). With proper education and safety precautions, fetal exposure to occupational ionizing radiation is negligible.

Cataracts

Cataracts are another potentially hazardous implication of ionizing radiation. Ainsbury and Barnard (2021) discussed the susceptibility of the lens of the eye to radiation-induced cataracts. The researchers concluded there was no well-understood pathophysiological timeline for the appearance of cataracts following radiation exposure. Furthermore, they agreed there was no known safe limit of radiation exposure (2021). Donning radio-protective glass serves as a specific measure of protection against the acquisition of radiation-induced cataracts. This eyewear contains a protective layer of lead that functions as a shield for the lens of the eyes, preventing direct absorption of radiation. Klingler et al. (2021) performed a clinical trial to determine the most effective way to limit ocular lens exposure to radiation in the OR. In their research article, they discussed testing three different methods: use of leaded eye goggles, application of a shielding wall, and stepping 0.5-3 meters away from the source of ionizing radiation. In their conclusion, they found that up to 91.2% of all radiation to the ocular lens can be blocked – even while in close proximity to the radiation source – solely by donning leaded eye goggles (2021). This study provided evidence that there are benefits to leaded eyewear, which is one of the simplest approaches to overall protection from radiation-induced cataracts in the intraoperative setting.

Several studies centering around interventional radiological procedures found that the most common OR personnel to develop radiation-induced cataracts are Interventional Radiologists (Sun et al., 2013; Wagner, 2020). A limitation of this research is that anesthesia providers in Interventional Radiology (IR) suites typically are not located as close to the source of radiation as the interventional radiologist. The interventional radiologist is positioned directly beside the patient, where the radiation source is more concentrated. A literature review by Wagner (2020) discussed the differences in radiation exposure to the lens of the eyes. It compared OR personnel who were wearing leaded eyeglasses while directly facing the source of radiation to those who were exposed from the side. Wagner found that IR personnel standing at the side of the radiation beam received up to five times more radiation to the eye lens in comparison to those who were directly facing the beam. Lateral exposure to the radiation beam leaves the lateral aspect of the eye unprotected. Thus, Wagner sufficed to say that radiation exposure is strongly correlated not only with leaded eyewear, but also with the orientation of the individual who is exposed (2020).

In another literature review article, Sun et al. (2013) discussed the deterministic nature of radiation-induced cataracts. They described the increasing threat of cataracts development by mentioning an epidemiological trial consisting of 54 IR cardiologists, as well as a single group of 64 Registered Nurses (RNs) and radiation technicians. Half of the IR cardiologists were affected by radiation-induced cataracts, and a combined 41% of the RNs and radiation technicians were affected. Though this study consisted of limited sample sizes, it demonstrated that all IR personnel were affected by radiation-induced cataracts. Additionally, the study did not state whether any of these individuals were wearing leaded eyewear, nor did they mention the orientation of these IR personnel to the source of radiation. Appraisal of the literature did not show any studies that included only CRNAs. However, since they are exposed to ionizing radiation, an educational intervention targeted at this population is necessary.

Conclusion

This literature review emphasized a need for radiation safety awareness amongst CRNAs since they are regularly exposed to ionizing radiation during intraoperative fluoroscopy use. There is also an increased utilization of medical imaging in current medical practice. Radiation safety knowledge in CRNAs is necessary to help prevent the negative health hazards that can ensue from occupational exposure. Incorporating an online educational presentation about the hazards of ionizing radiation can lead to heightened awareness of radiation dose limits and precautions among CRNAs. The maximum radiation exposure dose is regulated nationally and must be understood by CRNAs. The literature regarding ionizing radiation dose limits, biological effects of ionizing radiation, and proper safety measures is well outlined. However, no studies are specific to CRNAs. Critical appraisal of the relevant literature and analysis of similar groups of healthcare workers who work in the same departments as CRNAs leads to the conclusion that the same principles and risks apply to CRNAs.

Conceptual Framework

The radiation safety quality improvement (QI) project will be carried out via the four-step Plan-Do-Study-Act (PDSA) model, which is frequently utilized to effect positive change within a healthcare organization (AHRQ, 2020). The first step in this model was the completion of the literature review. The project members searched for scholarly articles that discussed radiation safety practices in anesthesia environments and literature that suggested a need for improved radiation safety practices within these environments. Using the reviewed literature, the investigators created a 15-question pre-test composed of demographic and knowledge-based questions. The 11-question post-test was comprised of the same knowledge-based questions for the sake of uniformity and to evaluate outcomes accurately. A radiation safety educational infographic was placed in between the assessments. Following the planning step of the QI project’s conceptual framework came the execution of the devised plan. The project members responsible for this project first made the CRNAs at the two participating clinical sites aware of the project's details, instructions, and goals via email. Participation was voluntary. All CRNAs were provided a Survey Monkey link to access the pre-and-post tests and voice-over educational infographic. Quick Response (QR) code flyers to access the survey were placed in multiple areas of the clinical site where CRNAs congregate. The data collection period remained open to participants for seven total weeks. Email reminders were sent at the two-, four-, and six-week marks.

The third step of this QI project's conceptual framework was to study or analyze the data trends. The pre-test and post-test data were analyzed using Survey Monkey and Excel. An Excel spreadsheet captured each participant's demographic information and their pre-and-post test scores from Survey Monkey. The final step, taking action, consisted of statistical analysis of the investigators determining the degree of success of the project's voice-over infographic intervention based on comparing the pre- and post-assessment scores. Additionally, in the Act stage, recommendations for change were made.

SECTION III: METHODOLOGY

Project Design

This Quality Improvement (QI) project used a quantitative, non-experimental, comparative design. This project was part of a larger QI group project and was individualized based on the project's setting. A narrated infographic was designed to enhance CRNAs' radiation safety knowledge. This infographic, along with surveys, was distributed to CRNAs via email. Numerical data from pre and post-test scores were compared and analyzed from a sample of CRNAs across the full-service community hospital. Approval was received for this QI project from the International Review Board (IRB) of the University of North Carolina at Charlotte (UNCC) and Atrium Health Wake Forest University Health Sciences. The IRB approval letters are contained within Appendix B and C, respectively. The PICO question is, "In Certified Registered Nurse Anesthetists, does a radiation safety online educational intervention enhance knowledge of radiation safety measures?"

Setting & Population

The full-service, 185-bed, community hospital in the QI project is located within Charlotte, North Caroline. It provides a full range of medical services, specializing in the care of seniors and complex orthopedic surgeries, bariatric surgery, and women's pelvic health (Atrium Health, 2023a). This facility has 16 ORs with three NORA sites. Approximately 30-50 surgeries per day occur at this location. There were 49 CRNAs employed at this location to provide anesthesia to a diverse population within the metropolitan city. There is potential for ionizing radiation exposure in all ORs where orthopedic surgeries occur and NORA sites where cystoscopy procedures are performed. The anesthesia departments in the two hospitals are responsible for providing the highest quality anesthesia care to patients undergoing all surgical, diagnostic, and therapeutic procedures.

Intervention and Data Collection Plan

This QI project collected data via a 15-question pre-test and 11-question post-test. Four questions on the pre-test collected demographic information, and the remaining questions were related to ionizing radiation information discerned from the literature review. Participation remained anonymous. The post-test questions were the same as the knowledge-based pre-test questions but contained no additional demographic questions. Survey Monkey was the platform utilized to create the tests and collect responses from the CRNAs. Quick Response (QR) codes were available in the facility's breakrooms to increase access to the QI project tests. An initial email was sent to CRNAs with instructions to complete three items: the radiation safety baseline knowledge pre-test, a narrated infographic containing radiation safety information for CRNAs, and a post-test to assess CRNA knowledge after reading and/or listening to the infographic. These three items were all attached to one Survey Monkey link and sent to the CRNAs simultaneously to streamline the process. SurveyMonkey was the platform used to collect data for this QI project. This software provided a centralized electronic location where all the project data was stored, sorted, and analyzed. SurveyMonkey was fully accessible by phone or desktop devices. The pre-and post-education tests were created within the SurveyMonkey software. SurveyMonkey allowed the de-identification of sensitive information and was programmed to identify correct answer responses, which were only available to the QI project team. Survey Monkey data was then transferred into an Excel sheet for data analysis.

Measurement Tools

A narrated infographic was created by the project team containing evidence-based facts about ionizing radiation. The narration for the infographic was approximately 5 minutes. The entire pre-test, infographic, and post-test took approximately 10 to 15 minutes for CRNAs to complete. Answers to the pre and post-tests were contained within the radiation safety infographic. The pre-test did not show the correct answers, and the post-test rearranged the order of the multiple-choice responses. Appendix C contains the pre-and post-test questions used in the QI project

Inclusion/Exclusion Criteria

The inclusion criteria for the QI project required participants to be a CRNA employed at the full-service community. There were 49 CRNAs that could have participated in the QI project at the community hospital. The sample size was only compiled from pre and post-tests that were fully completed. Participants who had incomplete pre or post-tests were excluded from the sample size.

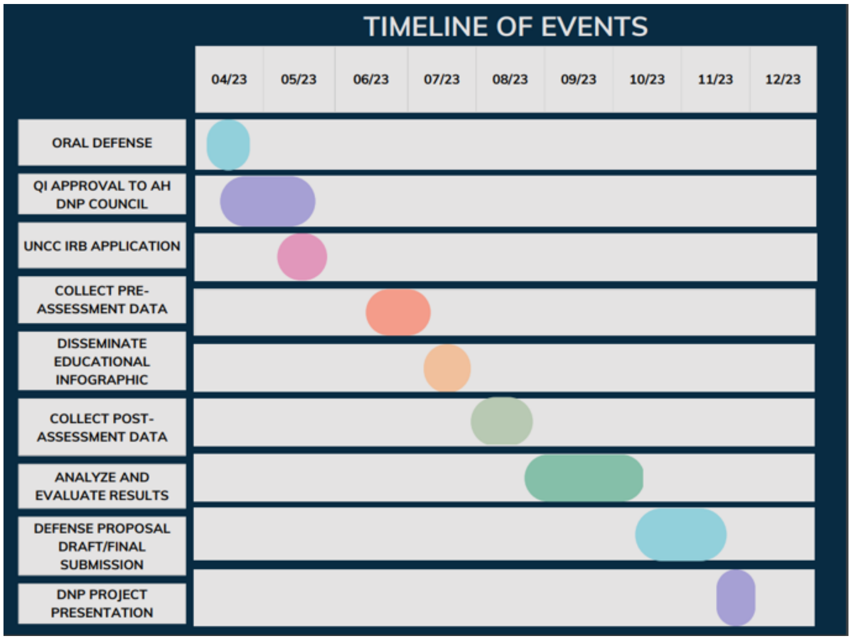
Data Management and Security

The project participants, CRNAs, were not required to include identifying information, such as names or birthdates, on the tests to maintain their anonymity. Participants accessed Survey Monkey via a QR code or a link sent via email with the project instructions. This link collected responses without participants needing to enter an email address. The results of the surveys were only accessible to authorized team members. Survey Monkey data that was transferred into the Microsoft Excel spreadsheet also remained anonymous.

Timeline

The data collection period was initially planned to take place over six weeks. An initial email was sent to all CRNAs on July 10, 2023. A reminder email was sent every two weeks to recruit CRNAs to participate in the project. In addition, multiple QR code flyers were posted at the full-service community to facilitate CRNAs' access to the radiation safety education intervention. A final two-week reminder email was sent on August 7, 2023, to notify CRNAs that the data collection period had only two weeks left. However, after notifying the project chair of the number of participants, an extension of one additional week for data collection was allowed to encourage more CRNAs to participate in the QI project. The data collection period ended on August 26, 2023, thus allowing seven weeks for data collection. At this time, the Survey Monkey link was closed. Below is a Gantt Chart of the QI project timeline of events.

Table 1: Timeline of events



Data Analysis and Evaluation

Assessment of the QI project fidelity allowed the project investigators to have confidence in the results (Bellg et al., 2004). This was achieved by incorporating the Behavior Change Consortium (BCC) treatment fidelity recommendations into the project design, delivery, and enactment. Standardizing the radiation safety pre-test questions, post-test questions, and infographic information allowed the CRNAs access to the same educational material across the two hospitals where the QI project occurred. Standardizing the project design allowed investigators to compare results from the pre-and-post tests to determine whether the educational intervention was effective in enhancing CRNA radiation safety awareness and practices. To ensure the adequacy of training providers, the investigators included a test question to identify years of provider experience and age. Treatment delivery was standardized so that all CRNAs accessed the same educational material. The investigators assessed comprehension (enactment) by comparing pre-test and post-test scores. Statistical analysis was conducted using a *t*-test to convey the statistical significance of the radiation safety education intervention. Chi-square analysis compared individualized test questions' performance before and after viewing the educational infographic.

Anticipated Resources and Challenges

A Radiation Safety Officer (RSO) served as the clinical expert for this QI project. The RSO is a Doctor of Education and the Director of Radiologic Technology at the college partnered with the healthcare system where the QI project was conducted. This individual was a vital resource and guide for the project investigators. Radiation safety policies of the healthcare system were provided by the RSO, as well as pertinent radiation dose limits and standardized units of measurement. Challenges anticipated by the QI project team included maximizing CRNA participation, including an appropriate number and type of questions within the tests, and meeting the deadline for test completion. Limiting the educational intervention to 20 minutes was prioritized to encourage CRNA participation. Sending out a reminder email in two-week increments also served as an opportunity for more CRNA participation. In addition, the project team created QR codes and posted flyers in participating sites' break rooms to enhance test access. The program faculty supported the investigators in gaining CRNA participation at the two facilities. Open communication was instituted throughout the QI project collection period to facilitate the success of the QI intervention.

SECTION IV: RESULTS

The radiation safety education intervention had twenty-seven CRNA participants. One participant did not complete a post-test. The years of experience and ages varied among respondents. For years of experience, 11.1% had 1 to 5 years, 18.5% had 6 to 9 years, 22.2% had 10 to 15 years, and 48.1% had 16 years or more experience (see Figure 1). Regarding age, 11.1% were 25 to 35 years old, 29.6% were 36 to 45 years old, 18.5% were 46 to 55 years old, and 40.7% were 56 years or older (see Figure 2). Most respondents had 16 years or more of experience and were 56 years or older. Radiation exposure was reported by 88.9% of participants to be greater than once a week.

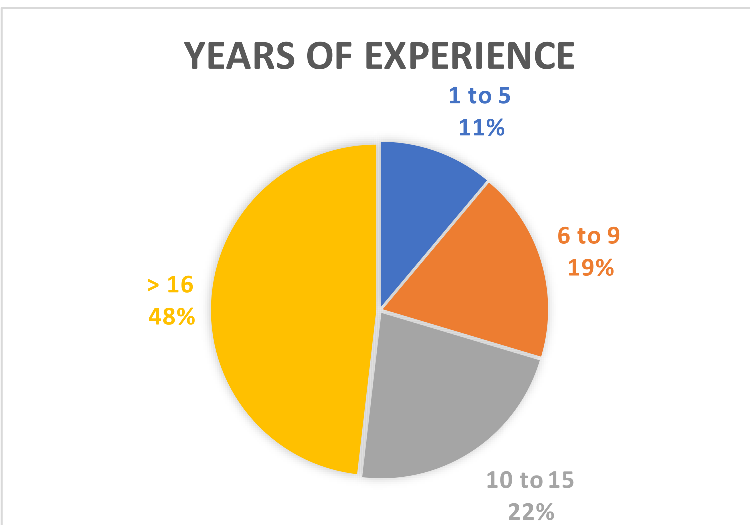


Figure 1

Years of experience among participating CRNAs

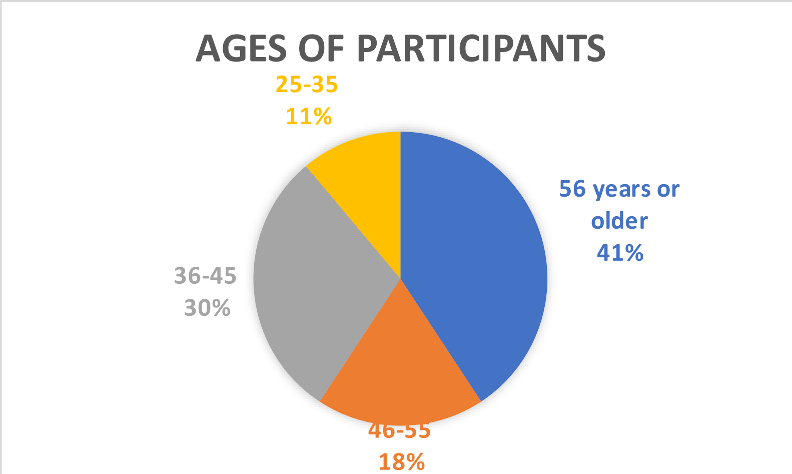


Figure 2

Ages among participating CRNAs

The frequencies for each item on the pretest and posttest are reported in Table 2. One person did not respond to the posttest. The 11 questions in Table 2 are knowledge-based questions about ionizing radiation. The percentage of correct answers to each question is also included in Table 2.

Table 2: Pretest and posttest comparisons for each question and total score

Item	Pretest (n= 27) % correct	Posttest (n = 26) % correct	*p*-value
Q1 Which two statements about ionizing radiation are true? (select 2)	51.9	76.9	.106
Q2 How much radiation is an individual exposed to while undergoing a single full-body CT scan?	22.2	69.2	.002
Q3 What are the three basic components of the ALARA principle?	81.5	92.3	.448
Q4 Which two statements about ionizing radiation dose limits are true? (select 2)	59.3	96.2	.004
Q5 What are two commonly referenced types of cancer that can be caused by ionizing radiation exposure? (select 2)	22.2	61.5	.009
Q6 Which of the following body tissues are highly radiosensitive? (select 2)	77.8	65.4	.486

Q7 By doubling the distance from a radiation source, what fraction can the radiation exposure dose be decreased by?	48.1	73.1	.115
Q8 Which factor is most closely associated with the highest risk for cataract development due to increased exposure of the lens of the eye?	51.9	84.6	.024
Q9 Which of the following are recommended radiation safety measures for pregnant women? (select 2)	70.4	84.6	.363
Q10 Which timeframe during pregnancy is the fetus most at risk for teratogenic effects of ionizing radiation exposure?	63	100	.002
Q11 What three major health concerns could radiation safety precautions prevent? (select 3)	100	65.4	.003

Overall, the online radiation educational intervention enhanced CRNA's post-test scores. The Posttest score (in terms of percentage of correct answers out of 11 questions, M = 80.05, SD = 14.55) was significantly higher than the pretest score (M = 58.91, SD = 16.59), $t = 5.42$, $p < .001$ (see Table 2). There was significant posttest improvement over 5 pretest questions, including question 2 ($\chi 2(1) = 9.99$, $p = .002$); question 4 ($\chi 2(1) = 8.30$, $p = .004$); question 5 ($\chi 2(1) = 6.89$, $p = .009$); question 8 ($\chi 2(1) = 5.11$, $p = .024$); and question 10 ($\chi 2(1) = 9.57$, $p = .002$).

On the pretest, questions 2 and 5, about how much radiation an individual is exposed to while undergoing a single full-body CT scan and two commonly referenced types of cancer caused by ionizing radiation exposure, were answered with the lowest accuracy at 22.2%. Participants showed significant improvement with correct answers on the posttest. The lower scores on the radiation safety content areas suggest that CRNAs at the surveyed site would benefit from an online ionizing radiation safety educational intervention.

Question 4 on the post-test showed a significant improvement in CRNA knowledge about ionizing radiation's recommended annual dose limit of 5 REM. After viewing the narrated infographic, CRNAs also identified that OSHA recommends limiting the annual radiation exposure to less than 50% of the annual whole-body occupational dose equivalent. Questions 8 and 10 on the post-test were significantly improved as well. CRNAs identified that standing lateral to ionizing radiation sources is most closely associated with the highest risk for cataract development due to increased exposure to the eye's lens (Wagner, 2020). All participants answered question 10 correctly on the post-test, successfully identifying the organogenesis period during pregnancy is when the fetus is at most risk for teratogenic effects from ionizing radiation exposure.

There was a lack of improvement on question 11 from the pre-test to the post-test. Participants' scores were lower when asked to identify the three major health concerns that radiation safety precautions prevented (p =.003). The health concerns could be bolded on the radiation safety infographic for better clarity to enhance participants' education on what health concerns are caused from ionizing radiation.

None of the demographic variables of age and years of experience affected the performance of CRNAs on the pretest and posttest questions. CRNAs reported radiation exposure did not appear to relate to either pretest or posttest scores, yielding a p >.146.

SECTION V: DISCUSSION

Implications for Practice

Overall, participants showed a significant improvement in their knowledge upon completion of the online radiation educational intervention The findings from the pretest and posttest scores revealed initial knowledge deficits about ionizing radiation exposure that could be addressed by implementing an online radiation education intervention. For example, the question about how much radiation an individual is exposed to while undergoing a single full-body CT scan was one of the most missed questions on the pretest, yielding 22.2% correct answers from 27 participants. After reviewing the online educational infographic, 69.2% (*n*=26) answered correctly (Table 2).

Five questions had significant improvement in CRNA knowledge. Those questions were items 2, 4, 5, 8, and 10 (Table 2). The content of those questions was: the occupational annual radiation dose limit, ionizing radiation dose limits facts, two commonly referenced types of cancer that can be caused by ionizing radiation exposure, standing lateral to the source of ionizing radiation is closely associated with the highest risk for cataract development, and the timeframe during pregnancy when the fetus is at most risk for teratogenic effects from ionizing radiation exposure.

Respondents of the pretests demonstrated a solid knowledge base surrounding the three major health concerns that radiation safety precautions prevent. All 27 respondents answered correctly about the three major health concerns that radiation safety precautions prevent: cancer, cataracts, and teratogenic effects. However, this question performed lower on the posttest, yielding 65.4% (n=26) correct answers. There was one less participant in the post-test compared to the pre-test, which may have affected the percentage of correct answers on this question on the post-test. Understanding what hazards CRNAs can protect themselves from is essential to ensure proper safety practices against occupational exposure to ionizing radiation. Question 8 revealed significant improvement in CRNA knowledge about lateral orientation to a radiation source that exposes the eye lens to high radiation, risking cataract development (Wagner, 2020). CRNAs also identified the organogenesis period as the most vulnerable timeframe for fetal radiation exposure.

Limitation

CRNA participation was a challenge during the data collection period. The CRNAs were encouraged to participate in multiple student QI project surveys, discouraging their overall participation. Another limitation was the size of the sample site chosen, which had a potential of approximately 49 CRNAs. Data was gathered from 27 respondents, a 55% response rate. The response rate was considerable because, based on prior QI project surveys, the expectation was approximately a 30% response rate.

Recommendations

CRNAs demonstrated enhanced knowledge of ionizing radiation after completing the radiation safety online intervention quality improvement project. Therefore, the recommendations include - using the radiation safety infographic and posting it to workplace areas to refresh CRNA knowledge about radiation. Areas that frequently use ionizing radiation, such as orthopedic operating rooms and non-operating room (NORA) sites, should have the infographic accessible as a cognitive aid to CRNAs and other providers in the room. In addition, future tests should be distributed to enhance CRNA participation while no other surveys are sent to CRNAs because the data collection period for this project coincided with multiple other projects that required CRNAs to partake in other surveys. Multiple surveys from different projects could play a role in lowering participation. Another vital way to expand radiation safety knowledge is to extend the intervention to all the hospitals within the system. Lastly, CRNA evaluation of the QI project should be collected in the future to get feedback about improving the project and radiation safety in the workplace.

Conclusion

CRNAs must have a strong understanding of the hazards and protective measures against ionizing radiation. The educational radiation safety infographic contained evidence-based radiation safety practices and it significantly improved radiation safety knowledge among CRNAs.

REFERENCES

Agency for Healthcare Research and Quality. (2020). *Plan-Do-Study-Act (PDSA) Directions and Examples*. AHRQ. Retrieved March 13, 2023, from https://www.ahrq.gov/health-literacy/improve/precautions/tool2b.html

Ainsbury, E. A., & Barnard, S. G. R. (2021). Sensitivity and latency of ionising radiation-induced cataract. *Experimental Eye Research*, *212*, 1–6. https://doi.org/10.1016/j.exer.2021.108772

Ainsbury, E. A., Dalke, C., Hamada, N., Benadjaoud, M. A., Chumak, V., Ginjaume, M., Kok, J. L., Mancuso, M., Sabatier, L., Struelens, L., Thariat, J., & Jourdain, J.-R. (2021). Radiation-induced lens opacities: Epidemiological, clinical and experimental evidence, methodological issues, research gaps and strategy. *Environment International*, *146*, 1–14. https://doi.org/10.1016/j.envint.2020.106213

Akram, S., & Chowdhury, Y. S. (2021) Radiation exposure of medical imaging.
https://www.ncbi.nlm.nih.gov/books/NBK565909/

Alex, M. R. (2011). Occupational hazards for pregnant nurses. *The American Journal of Nursing*, *111*(1), 28–39. https://www.jstor.org/stable/25769677

Atrium Health. (2019). *Atrium Health Carolinas Medical Center Operating Rooms.* Retrieved March 12, 2023 from https://cltledger.com/wp-content/uploads/2019/11/2019-CMC-ORs-Application.pdf

Atrium Health. (2023a). *Atrium Health Mercy, a facility of Carolinas Medical Center.* Retrieved March 7, 2023 from https://atriumhealth.org/locations/detail/atrium-health-mercy?u

Atrium Health. (2023b). *Atrium Health Pineville.* Retrieved March 12, 2023 from https://atriumhealth.org/locations/detail/atrium-health-pineville

Barash, P. G., Cullen, B. F., Stoelting, R. K., Calahan, M. K., Stock, M. C., Ortega, R., Sharar, S. R. & Holt, N. F. (2017). *Clinical anesthesia* (8th ed). Wolters Kluwer.

Bellg, A. J., Borrelli, B., Resnick, B., Hecht, J., Minicucci, D. S., Ory, M., Ogedegbe, G., Orwig, D., Ernst, D., Czajkowski, S., & Treatment Fidelity Workgroup of the NIH Behavior Change Consortium. (2004). Enhancing treatment fidelity in health behavior change studies: best practices and recommendations from the NIH behavior change consortium. *Health psychology: official journal of the Division of Health Psychology, American Psychological Association, 23*(5), 443–451. https://doi.org/10.1037/0278-6133.23.5.443

Bolus, N. E. (2013). NCRP Report 160 and What It Means for Medical Imaging and Nuclear Medicine. *Journal of Nuclear Medicine Technology*, *41*(4), 255–260. https://doi.org/10.2967/jnmt.113.128728

Centers for Disease Control and Prevention. (2021, October 20). *Radiation in healthcare: fluoroscopy*. https://www.cdc.gov/nceh/radiation/fluoroscopy.html

Chew, B. H. (2019). Planning and conducting clinical research: The whole process. *Cureus*, *11*(2), 1–18. https://doi.org/10.7759/cureus.4112

Chestnut, D. H, Wong, C. A., Ngan Kee, W. D., Beilin, Y., Mhyre, J. M, & Bateman, B. T. (2019). *Obstetric anesthesia* (6th ed). Elsevier.

DeSantis M., DiGianantonio E., Straface G., Cavaliere A. F., Caruso A., Schiavon F., Berletti R., & M. Clementi M. (2005). Ionizing radiations in pregnancy and teratogenesis: A review of literature. *Reproductive Toxicology, 20*, 323–329.

Englander, M. J., & Ghatan, C. (2021). Radiation and the pregnant IR: Myth versus fact. *Cardiovascular and Interventional Radiology*, *44*(6), 877–882. https://doi.org/10.1007/s00270-020-02704-1

Food and Drug Administration. (2020, September 28). *Fluoroscopy*. https://www.fda.gov/radiation-emitting-products/medical-x-ray-imaging/fluoroscopy

Ghatan, C. E. (2021). Understanding and managing occupational radiation exposure for the pregnant interventional radiology nurse. *Journal of Radiology Nursing*, *39*(1), 20–23. https://doi.org/10.1016/j.jradnu.2019.10.004

International Commission on Radiological Protection. (2019). Dose limits. *ICRPaedia*. http://icrpaedia.org/Dose_limits

Kim, J. H. (2018). Three principles for radiation safety: Time, distance, and shielding. *The Korean Journal of Pain*, *31*(3), 145–146. https://doi.org/10.3344/kjp.2018.31.3.145

Klingler, J.-H., Hoedlmoser, H., & Naseri, Y. (2021). Radiation protection measures to reduce the eye lens dose in spinal surgery. *The Spine Journal*, *21*(8), 1243–1245. https://doi.org/10.1016/j.spinee.2021.04.002

Lee, W. J., Ko, S., Bang, Y. J., Choe, S.-A., Choi, Y., & Preston, D. L. (2021). Occupational radiation exposure and cancer incidence in a cohort of diagnostic medical radiation workers in South Korea. *Occupational and Environmental Medicine*, *78*(12), 876–883. https://doi.org/10.1136/oemed-2021-107452

Li, C., & Athar, M. (2016). Ionizing radiation exposure and basal cell carcinoma pathogenesis. *Radiation Research*, *185*(3), 217–228. http://www.jstor.org/stable/44028556

Marx, 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

Matityahu, A., Duffy, R. K., Goldhahn, S., Joeris, A., Richter, P. H., & Gebhard, F. (2017). The great unknown—A systematic literature review about risk associated with intraoperative imaging during orthopaedic surgeries. *Injury, 48*(8), 1727–1734. https://doi.org/10.1016/j.injury.2017.04.041

Mattsson, S., Leide-Svegborn, S., & Andersson, M. (2021). X-ray and molecular imaging during pregnancy and breastfeeding – when should we be worried? *Radiation Protection Dosimetry*, *195*(3-4), 339–348. https://doi.org/10.1093/rpd/ncab041

Moriarty, H. K., Clements, W., Phan, T., Wang, S., & Goh, G. S. (2021). Occupational radiation exposure to the lens of the eye in Interventional Radiology. *Journal of Medical Imaging and Radiation Oncology*, *66*(1), 34–40. https://doi.org/10.1111/1754-9485.13307

Neel, J. V. & Schull, W.J. (1956). The effect of exposure to the atomic bombs on pregnancy termination in Hiroshima and Nagasaki. *National Academies Press*.

Occupational Safety & Health Administration. (n.d.). *Ionizing radiation: Standards.* https://www.osha.gov/ionizing-radiation/standards

Tomà, P., Bartoloni, A., Salerno, S., Granata, C., Cannatà, V., Magistrelli, A., Arthurs, O. (2019). Protecting sensitive patient groups from imaging using ionizing radiation: Effects during pregnancy, in fetal life and childhood. *Radiologia Medica, 124*(8), 736-744. https://doi.org/10.1007/s11547-019-01034-8

Phillips, G., & Monaghan, W. P. (2011). Radiation safety for anesthesia providers. *AANA Journal*, *79*(3), 257–267. https://www.aana.com/docs/default-source/aana-journal-web-documents-1/jcourse2_0611_p257-2674c8137731dff6ddbb37cff0000940c19.pdf?sfvrsn=a47e5ab1_6.

REDCap. (n.d.). *About.* REDCap. Retrieved March 13, 2023, from https://projectredcap.org/about/

Shore, R. E. (2016). Radiation and Cataract Risk: Impact of recent epidemiologic studies on ICRP judgments. *Mutation Research*, *770*, 231–237. https://doi.org/10.1016/j.mrrev.2016.06.006

Smith M, Yanko E, Huynh M, & Chan, G. (2023). X-ray therapy safety and awareness education for medical trainees and attending physicians. *Canadian Urological Association Journ*al, *17*(2), 25–31. http://dx.doi.org/10.5489/cuaj.8087

Smith, T., Quencer, K., Smith, T., & Agrawal, D., (2021). Radiation effects and protection for technologists and other health care professionals. *Radiologic Technology*, 92(5), 445–458.

Sun, Z., AbAziz, A., & Khairuddin Md Yusof, A. (2013). Radiation-induced noncancer risks in interventional cardiology: Optimisation of procedures and staff and patient dose reduction. *BioMed Research International*, 1–11. https://doi.org/10.1155/2013/976962

United States Nuclear Regulatory Commission. (2022, April 26). *Doses in Our Daily Lives.* https://www.nrc.gov/about-nrc/radiation/around-us/doses-daily-lives.html

Wagner, J. B. (2020). Radiation protection and safety in interventional radiology. *Radiologic Technology*, *91*(5), 431–444. Retrieved February 5, 2023, from https://web.p.ebscohost.com/ehost/pdfviewer/pdfviewer?vid=5&sid=5f935d6a-3738-40cf-8e2d-98b77d8babbd%40redis

Yu, E., & Khan, S. N. (2014). Does less invasive spine surgery result in increased radiation exposure? A systematic review. *Clinical Orthopaedics and Related Research*, *472*(6), 1738–1748. https://doi.org/10.1007/s11999-014-3503-3

APPENDIX A: UNCC IRB LETTER OF APPROVAL

CHARLOTTE
DIVISION OF RESEARCH

To:	Alyssa Oliveri University of North Carolina at Charlotte
From:	Office of Research Protections and Integrity
Approval Date:	05-Jul-2023
RE:	Notice of Determination of Exemption
Exemption Category:	1
Study #:	IRB-23-1136
Study Title:	Online Radiation Safety Educational Intervention for Certified Registered Nurse Anesthetists (CRNAs)

This submission has been reviewed by the Office of Research Protections and Integrity (ORPI) and was determined to meet the Exempt category cited above under 45 CFR 46.104(d). This determination has no expiration or end date and is not subject to an annual continuing review. However, you are required to obtain approval for all changes to any aspect of this study before they can be implemented and to comply with the Investigator Responsibilities detailed below.

Your approved consent forms (if applicable) and other documents are available online at Submission Page.

Investigator's Responsibilities:

1. Amendments **must** be submitted for review and the amendment approved before implementing the amendment. This includes changes to study procedures, study materials, personnel, etc.
2. Researchers must adhere to all site-specific requirements mandated by the study site (e.g., face mask, access requirements and/or restrictions, etc.).
3. Data security procedures must follow procedures as described in the protocol and in accordance with OneIT Guidelines for Data Handling.
4. Promptly notify the IRB office (uncc-irb@charlotte.edu) of any adverse events or unanticipated risks to participants or others.
5. Five years (5) following this approval/determination, you must complete the Admin-Check In form via Niner Research to provide a study status update.
6. Be aware that this study is included in the Office of Research Protections and Integrity (ORPI) Post-Approval Monitoring program and may be selected for post-review monitoring at some point in the future.
7. Reply to the ORPI post-review monitoring and administrative check-ins that will be conducted periodically to update ORPI as to the status of the study.

8. Complete the Closure eform via Niner Research once the study is complete.

Please be aware that approval may still be required from other relevant authorities or "gatekeepers" (e.g., school principals, facility directors, custodians of records).

APPENDIX B: WAKE FOREST BAPTIST IRB LETTER OF APPROVAL

WAKE FOREST
UNIVERSITY
HEALTH SCIENCES

Office of Research
INSTITUTIONAL REVIEW BOARD

MEMORANDUM

To: Exie Earnhardt
Atrium/Carolinas Healthcare System

From: Jeannie Sekits, Senior Protocol Analyst
Institutional Review Board

Date: 6/17/2023

Subject: Exempt Protocol: IRB00097730
Use of a narrated, online ionizing radiation educational intervention to enhance Certified Registered Nurse Anesthetist's (CRNAs) knowledge of radiation safety.

No protected health information will be used or disclosed in this research proposal; therefore the requirement for individual Authorization does not apply.

Note that only the Wake Forest University School of Medicine IRB can make the determination for its investigators that a research study is exempt. Investigators do not have the authority to make an independent determination that research involving human subjects is exempt. Each project requires a separate review and approval or exemption. The Board must be informed of any changes to this project, so that the Board can determine whether it continues to meet the requirements for exemption.

The Wake Forest School of Medicine IRB is duly constituted, has written procedures for initial and continuing review of clinical trials; prepares written minutes of convened meetings, and retains records pertaining to the review and approval process; all in compliance with requirements of FDA regulations 21 CFR Parts 50 and 56, HHS regulations 45 CFR 46, and International Conference on Harmonisation (ICH) E6, Good Clinical Practice (GCP), as applicable. WFSM IRB is registered with OHRP/FDA; our IRB registration numbers are IRB00000212, IRB00002432, IRB00002433, IRB00002434, IRB00008492, IRB00008493, IRB00008494, and IRB00008495.
WFSM IRB has been continually fully accredited by the Association for the Accreditation of Human Research Protection Programs (AAHRPP) since 2011.

Association for the Accreditation of Human Research Protection Programs, Inc.
Full Accreditation

Medical Center Boulevard, Winston-Salem, NC 27157-1023 (336) 716-4542 / fax (336) 716-4480

APPENDIX C: RADIATION SAFETY PRE & POST-TEST QUESTIONS

Please follow the instructions before answering each question.

1. Which facility are you employed at?
    a. CMC Main
    b. Atrium Health Mercy
2. How many years of experience as a CRNA do you have?
    a. 1-5 years
    b. 6-9 years
    c. 10-15 years
    d. 16 years or more
3. Approximately how many times per week are you exposed to sources of ionizing radiation?
    a. Less than once a month
    b. Once a month
    c. Once a week
    d. More than once a week
4. What is your age?
    a. 25-35 years old
    b. 36-45 years old
    c. 46-55 years old
    d. 55 years old or older
5. Which two statements about ionizing radiation are true? (Select 2)
    a. The primary source of ionizing radiation to healthcare personnel is fluoroscopy.

- **b. Rems are the Dose Equivalent units that can be measured & tracked by dosimeters.**
- c. Ionizing radiation exposure to healthcare personnel is negligible.
- d. The primary source of ionizing radiation to healthcare personnel is from X-rays.

6. How much radiation is an individual exposed to while undergoing a single full-body CT scan?
   - **a. 1 Rem**
   - b. 1 mRem
   - c. 5 Rem
   - d. 10 Rem
7. What are the three basic components of the ALARA Principle?
   - a. Time, shielding & leaded wear
   - **b. Time, distance & shielding**
   - c. Shielding, distance & leaded wear
   - d. Shielding, inverse-square law & shielding
8. Which two statements about ionizing radiation dose limits are true? (Select 2)
   - **a. The OSHA annual whole-body occupational dose limit equivalent is 5 rem.**
   - b. The OSHA annual whole-body occupational dose limit equivalent is 5 mrem.
   - **c. OSHA recommends limiting the annual radiation exposure to < 50% of the annual whole-body occupational dose equivalent.**
   - d. OSHA recommends limiting the annual radiation exposure to < 75% of the annual whole-body occupational dose equivalent.

9. What are two commonly referenced types of cancer that can be caused by ionizing radiation exposure? (Select 2)
    - **a. Thyroid cancer**
    - b. Ovarian cancer
    - **c. Basal cell carcinoma**
    - d. Glioma
10. Which of the following body tissues are highly radiosensitive? (select 2)
    - **a. Thyroid**
    - b. Lung Tissue
    - **c. Optic lens**
    - d. Skin
11. By doubling the distance from a radiation source, what fraction can the radiation exposure dose be decreased by?
    - **a. 1/4th**
    - b. 1/8th
    - c. 1/3rd
    - d. 1/2
12. Which factor is most closely associated with the highest risk for cataract development due to increased exposure of the lens of the eye
    - a. Not wearing aluminum eyewear
    - **b. Standing lateral to the source of ionizing radiation**
    - c. Standing to right of the source of ionizing radiation
    - d. Magnetic Resonance Imaging (MRI)

13. Which of the following are recommended radiation safety measures for pregnant women? (Select 2)

    a. 1 mm of wraparound lead at the level of the fetus

    b. 0.5 mm of wraparound lead at the level of the fetus

    c. 2 dosimeters, with one worn under the lead at the level of the fetus

    d. 1 dosimeter worn under the lead at the level of the fetus

14. Which timeframe during pregnancy is the fetus most at risk for teratogenic effects of ionizing radiation exposure?

    a. First two weeks of pregnancy

    b. Anytime during pregnancy

    c. Organogenesis period

    d. Second trimester of pregnancy

15. What three major health concerns could radiation safety precautions prevent? (Select 3)

    a. Cancer

    b. Damage to the skin

    c. Teratogenic complications

    d. Cataracts