

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

By

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ABSTRACT

ALYSSA RENAYE OLIVERI. 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 negative biological sequelae that can be caused by ionizing radiation exposure. CRNAs must remain compliant 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.). 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 aid in minimizing workplace exposure. The PICO question for the quality improvement (QI) project is, "In Certified Registered Nurse Anesthetists, does a radiation safety online educational intervention improve knowledge of radiation safety measures?" For the implementation of this project, an online education intervention was distributed to 157 CRNAs at a Level I trauma center. 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 CRNAs knowledge of radiation safety. Moreover, CRNAs demonstrated the most improvement in their knowledge of potential health hazards of occupational exposure to ionizing radiation. The QI project recommends a strong emphasis on increasing distance away from the radiation source, custom fit lead, acknowledgement of ionizing radiation use during the surgical time-out, and for CRNAs to be sent their quarterly dosimeter reports.

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DEDICATION

This project is dedicated to my parents, Chris and Laurie Oliveri for their unwavering support and love throughout this extremely difficult journey. They believed in me when I sometimes did not believe in myself. I cannot thank my parents enough for being my role models and two best friends. I would also like to dedicate this project to my nieces, Capri and Avielle Oliveri. Each of their births during the nurse anesthesia program brought me excitement during the most difficult times. Watching them grow has brought me so much happiness and love – they have truly been gifts to me during this journey.

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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
Rem	roentgen equivalent man
RN	registered nurse
Sv	sievert
UNCC	University of North Carolina at Charlotte

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

This quality improvement (QI) project aims to promote radiation safety precautions and awareness of the health hazards of ionizing radiation for CRNAs. This radiation safety project

was part of a larger QI project that contains two settings: a Level I trauma center and a full-service urban community hospital. 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.

Clinical Question

The overarching clinical question and area of interest is, “In Certified Registered Nurse Anesthetists (CRNAs), does a radiation safety online educational intervention improve knowledge and practice 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 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). Gy 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). 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 (weeks four through eight of intrauterine development) increases the risk for neuropathology, malformations, and intrauterine growth restriction (Mattsson et al., 2021). The susceptibility of the fetus during organogenesis, 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 and the square of the distance from the radiation source have an inverse relationship (Kim, 2018). For example, when 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

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 (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 likelihood 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 interventional radiology physicians who were pregnant 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 (2020). 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 only. 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 investigators searched for scholarly articles that discussed radiation safety practices in anesthesia environments, as well as 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 accurately evaluate outcomes. 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 investigators responsible for this project first made the CRNAs at the two participating clinical sites aware of the details, instructions, and goals of the project 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. Analysis of the pre-test and post-test data was performed using Survey Monkey and Excel. An Excel spreadsheet captured the demographic information of each participant from and both their pre-and-post test scores from Survey Monkey. The final step, taking action, consisted of statistical analysis of the investigators making their final determination of the degree of success of the project's voice-over infographic intervention, based on the comparison of the pre-and post-assessment scores. Once the investigators have decided on the official outcome of this QI project, they can further assess some of the rationales as to what led to the end result, and what the primary takeaway of the project is.

SECTION III: METHODOLOGY

Project Design

This Quality Improvement (QI) project used a quantitative non-experimental, comparative design. A narrated infographic designed to enhance CRNA's radiation safety knowledge was situated between a pre-intervention and post-intervention test. Each component of the education intervention was sent simultaneously via a single Survey Monkey link to streamline the process. Numerical data from pre and post-test scores were compared and analyzed from a sample of CRNAs across an urban Level I trauma center. Approval by the International Review Board (IRB) of both the University of North Carolina at Charlotte (UNCC) and Atrium Health Wake Forest University Health Sciences was received for this QI project. The IRB letters of approval are contained within Appendix A and B, respectively. The PICO question is, "In Certified Registered Nurse Anesthetists, does a radiation safety online educational intervention improve knowledge of radiation safety measures?"

Setting & Population

This QI project occurred at the largest hospital in a Southern metropolitan city, an 874-bed Level I trauma center. This facility employs 157 CRNAs who provide anesthesia care for high acuity surgeries and procedures that require ionizing radiation for varying amounts of time. All major surgical specialties are offered at this center, including cardiothoracic, hepatobiliary, neuro, organ transplant, orthopedic trauma, obstetrics, and pediatrics, amongst many others. There are 38 operating rooms (ORs) and 22 non-operating room anesthesia (NORA) department sites – many of which implement the use of ionizing radiation. This facility performs 33,000 surgeries annually, with a daily surgical case count of approximately 100 cases (Atrium Health,

2019). This QI project invited the participation of all CRNAs employed at the Level I trauma center, while realizing that not all individuals would choose to participate.

Intervention, Data Collection Plan, and Measurement Tools

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. Participants accessed SurveyMonkey via an emailed link sent to CRNAs or a QR code. QR codes were available in the facility's breakrooms to increase access to the QI project. SurveyMonkey was fully accessible by phone or desktop devices and allowed the de-identification of sensitive information. SurveyMonkey was programmed to identify correct answer responses, which were only available to the QI project team. Data was then transferred into an Excel sheet for data analysis.

This QI project collected data via a 15-question pre-test and 11-question post-test created within SurveyMonkey. 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. The two-page online infographic was originally created within Ease.ly and included a seven-minute narration and pictures to appeal to different learning styles. The infographic contained five sections of information which pertained to the significance of ionizing radiation used for medical imaging, units of measurement, the As Low As Reasonably Achievable (ALARA) principle, annual dose limits and potential health hazards, including cancer, cataracts, and teratogenesis. The estimated total time to complete the entire education intervention was under 20 minutes.

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. Answers to the 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 Level I trauma center. Emails were sent to all 157 CRNAs. The sample size was compiled from pre-test that were fully completed and post-tests that were fully completed. Participants who had incomplete pre-test or post-tests were excluded from the sample size. Forty-eight individuals participated in this study. Among them, one person did not complete the pre-test and post-test, and eleven additional individuals did not complete a post-test. Of the eleven individuals who did not complete a post-test, they all had fully completed pre-tests. This QI project chose to include the eleven individuals who fully completed a pre-test but did not complete a corresponding post-test within the data analysis. because the eleven pre-test scores aids in contributing to the baseline radiation safety knowledge assessment of the population of CRNAs within the Level I trauma center.

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

Data was collected after receiving IRB approval from both Wake Forest Baptist and UNC Charlotte. An overview of the QI project was given during anesthesia grand rounds on July 6, 2023. 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 Level I trauma center 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.

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, provider training, 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. Standardizing the project design allowed investigators to compare results from the pre-and-post

tests to determine whether the radiation safety educational intervention was an effective method to enhance CRNA radiation safety awareness and practices. 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 and chi-square analysis to convey the statistical significance of the radiation safety education intervention.

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 university 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

Forty-eight CRNAs from the Level I trauma center participated in the radiation safety QI project. This equates to a 31% response rate from the total population (157) of CRNAs at the Level I trauma center. One participant did not complete the pre-test and post-test. Eleven individuals did not complete a post-test. In terms of age, most participants were ages 25 to 35 years old (47.9%). The 56 years or older age group represented the smallest age group of participants (8.3%). Most participants had 1 to 5 years of experience as a CRNA (58.3%).

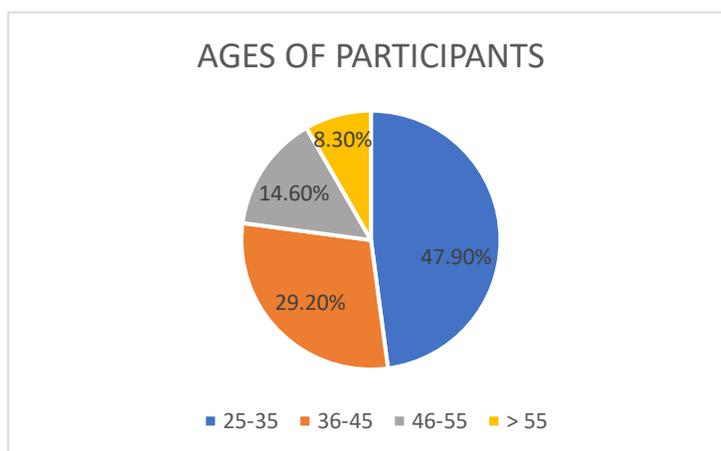


Figure I: Ages of participants

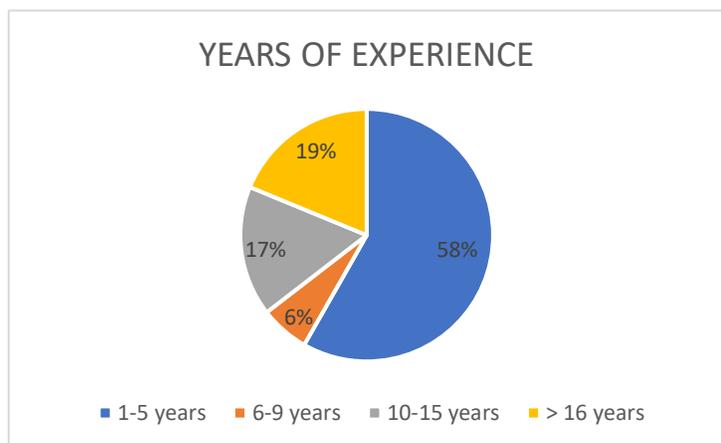


Figure II: Years of experience of participants

For amount of radiation exposure, most participants selected that they are exposed more than once a week (60.4%). Only 2.1% selected that they were exposed to ionizing radiation less than once a month.

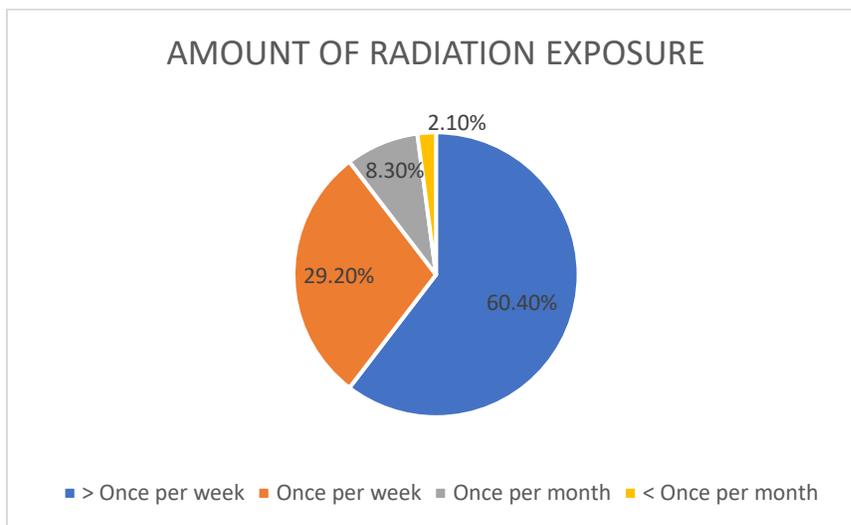


Figure III: Amount of radiation exposure

Pre-and-Post Test Results

Table I depicts the average pre-and-post test scores by age and years of experience for all participants. All test scores are expressed in terms of percentage of correct answers out of 11 questions. This QI project chose to include the eleven individuals who fully completed a pre-test but did not complete a corresponding post-test within Table I. The eleven pre-test scores aid in contributing to the baseline radiation safety knowledge assessment of the population of CRNAs within the Level I trauma center. However, the *t*-test used pairwise deletion. This means that the eleven individuals who completed the pre-test but who did not have a corresponding post-test were not included within *t*-test analysis.

Age was associated with pre-test score ($F = 4.21, p = .011$), with individuals ages 25 to 35 having highest average scores on the pre-test (66.1%). Individuals of age 46 to 55 had fewer

overall correct answers than individuals of age 25 to 35. Years of experience and reported radiation exposure were not related to pre-test or post-test scores.

Table I: Average pre-and-post test scores by age and years of experience groups

	Pretest ($n = 47$) % correct	Posttest ($n = 36$) % correct
Age		
25-35 years old	66.1	79.5
36-45 years old	56.5	70.4
46-55 years old	45.5	67.3
56 years old or older	52.3	84.8
Years of experience		
1-5 years	61.9	76.2
6-9 years	55.7	77.9
10-15 years	51.5	74.2
16 years or more	63.6	59.0

Table II depicts pre-and-post-test comparison for each question and total score. In terms of incomplete pre-tests and/or post-tests, there was no association of missingness of data with any demographic variables. Additionally, missingness of post-tests was not associated with pre-test score. Post-test scores ($M = 75.24$, $SD = 20.80$) were significantly higher than pre-test scores ($M = 58.98$, $SD = 15.94$), $t = 5.41$, $p < .001$. *T*-test used pairwise deletion. Thus, the online educational intervention significantly enhanced CRNAs post-test scores related to knowledge of radiation safety measures.

Table II: Pre-and-post test comparison for each question and total score

Question #	Item	Pretest (n = 48) % correct	Posttest (n = 37) % correct	p-value
1	Which two statements about ionizing radiation are true?	81.2	81.1	1.00
2	How much radiation is an individual exposed to while undergoing a single full-body CT scan?	22.9	62.2	< .001
3	What are the three basic components of the ALARA principle?	81.2	86.5	.123
4	Which two statements about ionizing radiation dose limits are true?	70.2	81.1	.789
5	What are two commonly referenced types of cancer that can be caused by ionizing radiation exposure?	25.5	54.1	.014
6	Which of the following body tissues are highly radiosensitive? (select 2)	87.2	73.0	.170
7	By doubling the distance from a radiation source, what fraction can the radiation exposure dose be decreased by?	23.4	45.9	.052
8	Which factor is most closely associated with the highest risk for cataract development due to increased exposure of the lens of the eye?	25.5	83.8	< .001
9	Which of the following are recommended radiation safety measures for pregnant women? (select 2)	77.1	70.3	.645
10	Which timeframe during pregnancy is the fetus most at risk for teratogenic effects of ionizing radiation exposure?	54.2	97.3	< .001
11	What three major health concerns could radiation safety precautions prevent?	97.9	81.1	.024

Note. *p*-values for the individual questions were based on chi-squared tests.

There was significant post-test improvement over pre-test on question 2 ($\chi^2(1) = 11.80$, $p < .001$); question 5 ($\chi^2(1) = 5.98$, $p = .014$); question 8 ($\chi^2(1) = 25.80$, $p < .001$); and question 10 ($\chi^2(1) = 17.60$, $p < .001$). Of the most improved questions, three out of four (questions 5, 8, and 10) related to health hazards of ionizing radiation, including cancer, cataracts, and teratogenic effects. Potential health hazards of ionizing radiation comprised the bulk of the literature review.

Of the information presented within the educational infographic, 25% was related to health hazards. Post-test scores revealed that the ALARA principle was the most missed question (question 7). This question also ranked the second most missed question on the pre-test. Despite the low scores, participants responding to the ALARA question showed near significant improvement ($p = 0.52$) following completion of the intervention.

SECTION V: DISCUSSION

Implications for Practice & Recommendations

The findings of the radiation safety education intervention demonstrate many parallels with the review of literature. According to Barash et al. (2017), exposure of CRNAs to ionizing radiation has increased in recent years, and most survey participants reported they are exposed to ionizing radiation multiple times per week. Out of department anesthesia has become increasingly busier at the Level I trauma center, with approximately 90 non-operating room anesthesia (NORA) cases completed each day. NORA cases commonly utilize fluoroscopy, which is the primary source of radiation exposure to nurse anesthetists (Smith M., Yanko, et al., 2023). Pre-test results revealed that while CRNAs scored high in recognizing that fluoroscopy poses the greatest risk of exposure, they scored much lower in their understanding of the potential consequences. Cancer, cataracts, and teratogenic effects are three biological ramifications that are extensively outlined in the literature. Post-educational intervention, CRNAs were not only able to better recognize these overarching areas of concern but were also able to respond more correctly to questions that asked of these potential consequences in greater detail. For example, organogenesis is the timeframe in which ionizing radiation has an increased risk to the developing fetus (Mattsson et al., 2021). CRNAs better distinguished organogenesis as being the most at-risk timeframe for the fetus after the educational intervention. In addition, another question asked to choose two of the most common types of cancer the literature has linked to ionizing radiation exposure - thyroid cancer and basal cell carcinoma (Matityahu et al., 2017). Again, this was one of the most improved post-intervention questions.

The basis of reducing the risk of any of the aforementioned sequela lies in the As Low As Reasonably Achievable (ALARA) principle. Phillips & Monaghan (2011) outlined the importance of time, distance, and shielding as the basic components of this principle. Although the question pertaining to the three pillars scored high on the pre-test, the application question of the ALARA principle was the second most-missed question on the pre-test and the most-missed question on the post-test. This question pertained to increasing distance away from the source of ionizing radiation, as application of the As Low As Reasonably Achievable (ALARA) principle in the clinical setting is imperative to understand. The education intervention included a diagram of the Inverse Square Law. This visual representation would be advantageous to have displayed within ORs as a visual cue of how distance decreases exposure. In addition, tape on the floor that measures one meter could aid in reminding CRNAs how doubling the distance from one to two meters decreases radiation exposure by 25%.

In consistency with the ALARA principle, the project investigator suggests that CRNAs make every attempt to properly shield themselves and increase distance away from the source. Custom fit lead and thyroid shields are common and are suggested for all anesthesia providers. Leaded eyewear and leaded scrub caps are not commonly seen within the clinical setting but are recommended when procedures require continuous fluoroscopy, such as in the cardiac catheterization lab or interventional radiology. A further suggestion to aid in ensuring proper shielding is to include the use of ionizing radiation in the procedural time out. This would allow the surgeon to announce to the OR staff plans to use ionizing radiation and the estimated timing of use such as in the beginning or end of the case.

CRNAs who participated in the project proved knowledge was gained in topic areas relating to the potential biological hazards of occupational ionizing radiation exposure. The

project investigator suggests that the radiation safety educational infographic be placed in the ORs and out-of-department sites where ionizing radiation use is utilized most frequently. Since this educational infographic proved useful in significantly improving radiation safety knowledge, it would serve as a point of reference in the clinical setting for continued education. Furthermore, extending this education intervention to all hospitals in the larger system would be invaluable in order to reach smaller outlying communities and additional populations of CRNAs.

Acknowledgement of ionizing radiation use during the surgical time-out could also aid in mitigating exposure risk by highlighting the need for protective precautions under these circumstances. Additionally, CRNAs dosimeter reports should be compared and used as a resource to make assignments. Those who have higher than the average absorbed dose in one quarter should be placed where little to no ionizing radiation is used the next quarter.

Strengths

The major success of this project was that data analysis showed statistical significance for the educational infographic improving CRNAs knowledge of radiation safety. This is attributable to an extensive literature review of important radiation safety topics and concerns. This information was carefully extrapolated into an infographic that was detailed yet succinct in conveying key points. The educational infographic included both written and narrated words, colors, and pictures to appeal to different kinds of learners. The pre-and-post test questions were made based off the information contained within the infographic. Validity of the survey questions was established by review of clinical experts.

The data collection process was another strength of this project. Access to the QI project was readily available and easy to access from computers via email or from SmartPhones via QR codes. This strategy was intended to aid in participation of busy anesthesia providers at a Level I

trauma center. Multiple email reminders were sent to further enhance participation. Introducing the topic at anesthesia grand rounds also served as a means of promoting participation.

Finally, having a Radiation Safety Officer (RSO) on the committee who was employed at the same hospital system that the QI project took place at was invaluable. Radiation doses and concepts can quickly become convoluted, so having an expert in the field was an important part of the success of this topic.

Limitations

A limitation of this project was the number of participants. A larger sample size would be able to reflect radiation safety knowledge of the CRNAs at the Level I trauma center more accurately. A response rate of 31% did not necessarily come by surprise based off the RSO's past experiences with trying to reach the nursing population. Another limitation was the length of the education intervention. A total of 26 questions and a two-page infographic is lengthy. Shortening the intervention may have increased participation at a facility as busy as an urban Level I trauma center. Finally, the out of pocket cost to the project investigator for creation of the education intervention using Survey Monkey and Easel.ly was over \$400.

Conclusion

In conclusion, the radiation safety infographic improved CRNAs knowledge of radiation safety. A thorough understanding of this topic by all anesthesia providers is necessary in order to mitigate occupational health risks from ionizing radiation.

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APPENDIX A: UNCC IRB LETTER OF APPROVAL



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 UNIVERSITY HEALTH SCIENCES IRB LETTER OF APPROVAL



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.



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APPENDIX C: PRE & POST-TEST QUESTIONS

Content Questions on Pre-and-Post Tests

1. 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.
2. 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
3. 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
4. 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.
5. 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
6. Which of the following body tissues are highly radiosensitive? (select 2)
- a. **Thyroid**
 - b. Lung Tissue
 - c. **Optic lens**
 - d. Skin
7. 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
8. 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)
9. 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
10. 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
11. What three major health concerns could radiation safety precautions prevent? (Select 3)
- a. Cancer**
 - b. Damage to the skin
 - c. Teratogenic complications**
 - d. Cataracts**

Demographic Questions on Pre-Test

- A. Which facility are you employed at?

- a. CMC Main
- b. Atrium Health Mercy

B. 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

C. 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

D. 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