Physician assistant knowledge of patient radiation exposure from diagnostic imaging modalities

Stephanie Lynn Illian

The University of Toledo

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Dedication Page

To my husband, Josua, for his never-ending support throughout the process of this entire project. His kindness and understanding have allowed me to remain focused and his encouragement has been the source of my motivation.

To my parents, for their continuous support and guidance throughout my educational endeavors.
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Introduction

The growth of medical imaging technology in the past three decades has changed the face of medicine. Traditional clinical judgment and evaluation were once sufficient for making a diagnosis and imaging modalities were reserved only for confirmation and clarification of tough diagnoses. Today, imaging modalities are often being used as first line options in the course of evaluation of common complaints from patients. Radiographic use has more than doubled within the past 25 years (Mettler, Bhargavan et al., 2009), with roughly 377 million radiographic procedures performed annually in the United States (Hricak, Brenner et al., 2010). Since the beginning of medical imaging with the first medical use of x-rays in 1896, the field of diagnostic imaging has come a long way and is one of the fastest growing areas of medical technology. In the 1950’s, ultrasonography began to be used clinically to assist in diagnoses and also served as an alternative diagnostic tool. The ability to view structures in three dimensions came later, with the advent of MRI and CT scans (Seibert, 1995). These advancements in diagnostic imaging have added an immensely dynamic aspect to clinical diagnostics, and have revolutionized the way medicine is practiced.

Increased access to diagnostic imaging modalities has contributed to increased use by healthcare practitioners. This trend has been justified by the clinical benefits of imaging, with earlier, more precise diagnoses leading to less morbid disease (Ho, 2008). Furthermore, the increased use of imaging allows for more effective surgical treatment, shorter hospital stays, fewer exploratory surgeries, earlier diagnosis and more precise treatments of cancer, better treatment of stroke and cardiac conditions and rapid diagnosis of life-threatening vascular problems (Hricak, Brenner et al., 2010). The widespread availability has also led to an expansion of the indications for certain modalities such as CT scans (Hricak, Brenner et al.,
2010). Not only do these imaging modalities enhance diagnostic capabilities of healthcare practitioners, but when utilized in medical evaluations, they also increase confidence levels among patients (Baumann, Chen et al., 2010).

The benefits of imaging, however, are opposed not only by increased healthcare costs, but also by increased radiation exposure to patients. The average radiation dose that patients in the United States are being exposed to has doubled in the past 30 years (Brenner and Hricak, 2010). Furthermore, the collective dose imposed on the U.S. population due to medical imaging has increased six-fold in the past 25 years (Hricak, Brenner et al., 2010). In 1987, medical x-rays and nuclear medicine studies contributed only about 15% of the overall radiation dose to the U.S. population (Amis, Butler et al., 2007). Today, medical imaging accounts for 50% of the total radiation exposure to people in the United States (Brenner and Hricak, 2010). The largest contributor to the drastic increase in radiation exposure is CT scans. In 1980, fewer than 3 million CT scans were performed annually (Mettler, Bhargavan et al., 2009). Currently the annual number of CT scans approaches 80 million, with continued increases of approximately 10% per year (Mettler, Bhargavan et al., 2009; Brenner and Hricak, 2010). The potential physiologic effects of this widespread increase in the use of diagnostic imaging cannot be overlooked.

Before discussing the physiological effects of radiation exposure, it is important to first understand the different types of radiation that exist. Electromagnetic radiation is a form of energy that exhibits wavelike behavior as it travels through space and is arranged on a spectrum based on the frequency of the waves (World Health Organization [WHO], 2011). In order of increasing frequency and decreasing wavelength, the electromagnetic spectrum includes: radio waves, microwaves, infrared light, visible light, ultraviolet light, x-rays and gamma rays (WHO,
Beyond the classifications of the electromagnetic spectrum, radiation can further be classified as either ionizing or non-ionizing radiation. Ionizing radiation includes x-rays or gamma rays, both of which are high frequency, shorter wavelength forms of radiation that are associated with high energy (WHO, 2011). These high energy forms of radiation interact with physiologic molecules and displace electrons in the body causing molecules to be ionized. This creates chemically reactive species that have the ability to cause cellular DNA and tissue damage, dependent upon the thickness of the tissues that are penetrated (Wakeford, 2005; WHO, 2011). Alterations in normal cell maintenance processes such as DNA repair and cell apoptosis, or programmed cell death, are caused by exposure to ionizing radiation creating a disruption in normal cellular regulation and potentially leading to the induction of cancerous processes (Strzelczyk, Damilakis et al., 2007). Conversely, non-ionizing radiation includes the majority of the electromagnetic spectrum that does not have sufficient energy to displace electrons from molecules to cause ionization (WHO, 2011). This form of radiation causes excitation of electrons but does not create the chemically reactive molecules induced by ionizing radiation. Non-ionizing radiation does have the potential to cause non-mutagenic effects to human tissue, such as heat or chemical burns, however the concern with induction of mutations is not associated with this type of radiation. Included in the classification of non-ionizing medical radiation are radio waves that are combined with high-field magnets and used in magnetic resonance imaging (MRI) (Seibert, 1995). Ultrasonography is another common medical imaging modality that is not associated with any radiation exposure; rather, high frequency sound waves are interpreted to produce images of subcutaneous structures.

Given the potentially detrimental physiological effect of ionizing radiation, it is important to note that there are two main sources of this radiation that exist: natural, or background
radiation from the environment, and man-made radiation, such as that from medical imaging (Hansen, 2009). Natural background radiation sources include cosmic radiation and gamma rays from naturally occurring radionuclides in the ground and building materials, food and drink, as well as inhalation of radon gas that emanates from the soil (Wakeford, 2005). In the United States, the average individual effective dose of radiation due solely to background sources is 3 mSv (Wakeford, 2005; Weiner, 2005; Lin, 2010). Furthermore, nuclear power plants release radioactive materials into the environment and may contribute to increased exposure in surrounding areas (Anspaugh, Bennett et al., 2000). The exposure due to medical imaging is the largest man-made contributor to radiation exposure (Wakeford, 2005). The medical forms of ionizing radiation include the use of diagnostic radiology (x-ray and computed tomography), nuclear medicine that uses radioactive tracers and compounds, and radiation therapy that uses ionizing radiation for treatments (Valentin, 2001). The combination of both ionizing background radiation and man-made exposures contributes to an individual’s lifetime risk of cancer induction.

The terminology that is used to describe radiation doses varies based upon the context as well as the system of measurement being used: either System Internationale (SI) or conventional (U.S. Centers for Disease Control and Prevention [CDC], 2011). Radioactive molecules emit energy in the form of radiation through a process called disintegration. By releasing radioactive energy, a molecule becomes nonradioactive, or stable. The amount of radiation that is being emitted by a radioactive material is measured using the conventional unit curie (Ci) and the SI unit Becquerel (Bq). These units are measures of the number of disintegrations over a period of time (Ci = 37 billion/second and Bq = one/second). The energy that is emitted from radioactive sources can be absorbed by the human body and deposited into tissues. The absorbed dose (amount of energy deposited per unit weight) is measured using the conventional unit rad
(radiation absorbed dose) and the SI unit gray (Gy = 100 rad). Lastly, a person’s risk of adverse health effects due to ionizing radiation exposure is measured using the conventional unit rem and the SI unit sievert (Sv = 100 rem). Each type of radiation (alpha and beta particles, gamma rays, x-rays) has been assigned a number based upon the inherent ability to transfer energy to human cells. This number is known as the quality factor (Q) for each type of radiation. Human radiation exposure risk then can be determined by multiplying the dose in rad by the quality factor for the particular type of radiation and reported in units of rem (rem = rad x Q).

One should also consider and understand the two classes of biological effects secondary to ionizing radiation exposure: deterministic and stochastic (Valentin, 2001). Deterministic effects are due largely to cell killing and are visible changes seen after large doses of radiation, while stochastic effects are due to mutations that may result in malignant neoplasms or hereditary mutations that take years to develop (Valentin, 2001). The ability of ionizing radiation to create unstable molecules that can cause mutations in cellular DNA and cell death has pushed the World Health Organization to label ionizing radiation as a human carcinogen (International Agency for Research on Cancer, 2000; American Cancer Society [ACS], 2010; Agency for Toxic Substances and Disease Registry, 2011; CDC, 2011; WHO, 2011).

**Background and significance:**

The evidence that supports the carcinogenicity of ionizing radiation comes from epidemiologic studies of individuals exposed to high doses of radiation that exceed natural background radiation (Brenner, Doll et al., 2003). Two of the most comprehensive and profound studies that show an increased risk in the development of cancer associated with high dose radiation are the survivors of the Japanese atomic bombings of 1945 and of the Chernobyl
The acute effects of the two atomic bombs in Japan at the end of World War II included the death of 150,000 – 250,000 people within the first few months after the attack (Radiation Effects Research Foundation, 2007). Many more deaths were reported in the ensuing months secondary to burns, radiation sickness, and other injuries that were compounded by illness. Furthermore, the effects of these atomic bombings were not only acute. The Life Span Study (LSS) has been used to track survivors of these atomic bombings since 1950. The results of the LSS estimate that nearly half of all leukemias and 10% of all solid cancers in this cohort of people are attributable to the radiation exposure from these bombings (Wakeford, 2005; Radiation Effects Research Foundation, 2007). While many were subjected to very large doses of radiation during the bombings, there is a large portion of the cohort that represents low-dose exposures and associated increased cancer risks (Pierce and Preston, 2000).

The Chernobyl accident of 1986 was the worst catastrophe of a nuclear power reactor that has been studied to date (Strzelczyk, Damilakis et al., 2006). Doses of exposure associated with this catastrophe ranged from 30-500 mSv. Studies on individuals exposed to radioactive substances during this time show an increase in the incidence of thyroid cancers, especially in those who were children at the time of the accident. In 2002, more than 4,000 thyroid cancer cases had been diagnosed in relation to the exposures of the Chernobyl accident (Strzelczyk, Damilakis et al., 2006). As this incident was only 25 years ago, studies are still being conducted on the effects of the radiation exposure among these individuals.
While many of the survivors of the previously mentioned catastrophes were exposed to very high doses of radiation, the effects associated with lower doses of radiation have been inferred from studies done on these survivors. Despite correlative evidence that shows increased risks of cancers among low doses of radiation exposure, quantification of the excess cancer risk associated with low-dose radiation is still under debate. One theory, called the linear or no-threshold theory, holds that there is an increased risk with ionizing radiation exposure that is directly proportional to the dose (Cohen, 2002). This reasoning then can be used to extrapolate excess risk associated with low doses from the known risk at higher doses (Lin, 2010). Presently there are no conclusive studies that demonstrate an increased risk of cancer with low doses of radiation, but there is considered to be no threshold below which ionizing radiation is thought to be totally safe (ACS, 2010). Thus, it cannot be assumed that there is no risk induced with the radiation exposures of diagnostic imaging modalities, no matter how low the level of exposure. Further, epidemiologic data indicates a statistically significant increase in cancer at radiation exposure doses in excess of 50-100 mSv (Pierce and Preston, 2000; Lin, 2010). While doses associated with single imaging modalities aren’t typically in that same range, patients undergoing multiple diagnostic tests could be at increased risk for the development of cancer. The cumulative effects of multiple exposures to medical radiation are difficult to quantify and are therefore unclear. Experts estimate that medical imaging radiation exposure is the culprit for one to two percent of cancer cases in the US (29,000 cases per year) (Berrington de Gonzalez and Darby, 2004; Amis, Butler et al., 2007) (Brenner and Hall, 2007; Berrington de Gonzalez, Mahesh et al., 2009).

Despite the aforementioned physiologic risks involved with the use of diagnostic imaging modalities, patients often report a higher level of confidence in their healthcare providers when
imaging modalities are utilized in the patient’s care (Baumann, Chen et al., 2010). In 2008-2009, Baumann et al. conducted a cross-sectional study that assessed patient perceptions of healthcare provided and the associated risks involved with radiation exposure and found patient’s confidence in medical evaluation was approximately four times greater when laboratory testing and diagnostic imaging were included in their evaluation, with the use of CT yielding the highest increases in patient confidence levels (Baumann, Chen et al., 2010). In addition, despite increased confidence, patients have a poor understanding of the related radiation exposure and risks associated from imaging (Baumann, Chen et al., 2010). This lack of understanding is likely a result of failure of practitioners to provide information regarding radiation exposure to patients. In a study done in the United States in 2004, only 7% of patients reported being told about the risks and benefits associated with the CT scans they were exposed to, while 22% of ED physicians reported providing information to their patients (Lee, Haims et al., 2004). Patients also were found more often than not to underestimate their own previous exposures to medical imaging and radiation (Baumann, Chen et al., 2010), demonstrating a widespread lack of knowledge associated with radiation exposure. While there are many benefits to using diagnostic imaging, there is still a large need for discretion in use, as well as patient education regarding the risks and potential effects of radiation exposure.

Studies that have hypothesized a relationship between educational level, seniority level, and level of knowledge of radiation exposure among healthcare practitioners have reached differing conclusions. A questionnaire study conducted in Ireland in 2007 assessed the level of awareness of radiation doses among 500 practicing physicians and found a 39% average knowledge score (Soye and Paterson, 2008). Approximately half of the participants in the study had received formal training about ionizing radiation and subsequently scored higher than those
without prior training (p=0.003) (Soye and Paterson, 2008). The study also showed that radiologists were more familiar with radiation doses and risk than other specialties, further suggesting that educational background and training improves knowledge scores (Soye and Paterson 2008). Similarly, a study conducted in Turkey in 2005 reported that 93.1% of doctors underestimated actual radiation doses of common medical imaging tests and suggested that this lack of awareness may lead physicians to order more radiologic studies and expose patients to more radiation than if they were “properly educated” (Arslanoglu, Bilgin et al., 2007). The investigators concluded by suggesting that undergraduate and postgraduate radiation safety courses might prove to be beneficial in reducing patient exposure to potentially harmful ionizing radiation (Arslanoglu, Bilgin et al., 2007). Furthermore, Gower-Thomas et. al. and Jacob et. al. reported that the degree of physician knowledge was inversely proportional to seniority (Gower-Thomas, Lewis et al., 2002) (Jacob, Vivian et al., 2004). A study performed in Israel in 2002 reported that senior physicians were more likely to underestimate the risk and also to order more radiological tests than were residents, however, the authors also suggested that there is still a need for better education regarding radiation exposure (Finestone, Schlesinger et al., 2003).

A 2004 study conducted in a U.S. emergency department assessed patient, physician and radiologist awareness of radiation dose and risks associated with CT scans and found there to be a poor level of knowledge among all three populations evaluated, regardless of experience or education level (Lee, Haims et al., 2004). Likewise, a questionnaire study involving two Australian emergency departments investigated emergency physicians’ understanding of risks to patients from radiation exposure and reported a mean knowledge score of 40% among all respondents. There was not a difference in those who had received formal education on the topic compared to those who had not (Keijzers and Britton, 2010). Furthermore, there was no
statistically significant difference reported in knowledge scores in relation to seniority (Keijzers and Britton, 2010). A gross lack of knowledge is demonstrated by more than 75% of respondents who underestimated the lifetime attributable risk (LAR) of fatal cancer from a single abdominal CT scan, and 60% of doctors who overestimated the radiation dose associated with a single chest x-ray (Keijzers and Britton, 2010). Although some doctors overestimated the radiation dose of a single chest x-ray, a general underestimation of the exposure of other imaging tests, as well as the associated risks, was demonstrated (Keijzers and Britton, 2010). Moreover, an assessment of pediatricians by Heyer et. al. in 2009 also found that regardless of length of professional training, correct estimation of doses was difficult for participants (Heyer, Hansmann et al., 2010).

A 2009 systematic review conducted by Krille and Hammer analyzed published studies that assessed physicians’ knowledge regarding radiation dosages and risks due to the use of computed tomography (CT). The study identified and analyzed 14 articles that assessed physician knowledge and ability to correctly estimate radiation doses (Krille, Hammer et al., 2010). Although there were large differences between the methodologies of the studies included in the review, making interpretation difficult, the conclusion of the review was that there is only a minority of physicians who are well informed about radiation exposure associated with CT scans (Krille, Hammer et al., 2010).

In addition, many studies have demonstrated that some providers wrongly associate radiation exposure with non-radiating exams (Shiralkar, Rennie et al., 2003; Jacob, Vivian et al., 2004; Arslanoglu, Bilgin et al., 2007; Soye and Paterson, 2008; Heyer, Hansmann et al., 2010; Keijzers and Britton, 2010; Zhou, Wong et al., 2010). Arslanoglu et. al. reported that 42% of general practitioners incorrectly reported radiation exposure with MRI and US (Arslanoglu,
Bilgin et al., 2007). Jacob et. al. found similar results and reported that 28% and 10% of doctors associated doses of ionizing radiation with MRI and US, respectively (Jacob, Vivian et al., 2004). Heyer et. al. also reported that 14% of physicians were unaware of the fact that MRI does not utilize ionizing radiation and suggested that this finding could indicate that some fundamental knowledge of modern imaging has not reached all practicing physicians (Heyer, Hansmann et al., 2010). The lack of knowledge regarding non-ionizing imaging modalities such as ultrasound and MRI has also been demonstrated among students, contributing to the suggested need for further education (Mubeen, Abbas et al., 2008).

Investigation of patient knowledge of radiation exposure has similarly demonstrated an overwhelming lack of knowledge (Lee, Haims et al., 2004; Baumann, Chen et al., 2010; Takakuwa, Estepa et al., 2010). Patients often underestimate radiation exposure associated with imaging modalities as well as their own lifetime cumulative imaging exposure (Lee, Haims et al., 2004; Baumann, Chen et al., 2010). Furthermore, patients display increased confidence when their medical evaluations involve imaging, yet remain unfamiliar with the potential health risks (Baumann, Chen et al., 2010). Takakuwa et. al. found that 74% of patients preferred to have their condition properly diagnosed with the use of a CT scan regardless of the radiation exposure, although, 68% desired their physician to discuss the risks and benefits (Takakuwa, Estepa et al., 2010). The study by Keijzers et. al. showed variance among provider practices of informing patients of the risks involved with radiological tests, but reported that doctors with formal training were more likely to discuss the risks involved (Keijzers and Britton, 2010). Keijzers et. al. also found that doctors reported rarely being asked about the potential risks of radiation from diagnostic imaging, but nevertheless still indicated only moderate confidence in their ability to counsel patients regarding radiation exposure (Keijzers and Britton, 2010).
Another issue that has been raised involves the topic of radiation exposure and associated risks in pediatric populations (Heyer, Hansmann et al., 2010) (Kleinerman, 2006; Rice, Frush et al., 2007). From 1995-2008, there was a five-fold increase in the number of pediatric emergency department visits associated with CT scans in the United States, with an annual growth rate of 13.2% (Larson, Johnson et al., 2011). Specifically, abdominal and pelvic CT scans have increased secondary to the advent of fast helical CT, reducing the need for sedation in this population (Brenner, Elliston et al., 2001). Despite its advantages, the increased use in the pediatric population is not without increased risks. Children not only have longer life expectancies that lead to increased lifetime risk of exposure, but also are more sensitive to the carcinogenic effects of ionizing radiation, increasing the window of opportunity for the development of tissue damage from radiation (Brenner, Elliston et al., 2001; Kleinerman, 2006; Hansen, 2009). Furthermore, children often receive repeated examinations over time in order to evaluate their condition, leading to increased exposure (Kleinerman, 2006). It is because of these risks that principles associated with radiation doses such as the ALARA (as low as reasonably achievable) principle and dose control programs have been initiated (Frush, Donnelly et al., 2003). A recent study showed that children with minor head injuries who are observed for a period of time prior to making a decision for head CT scan lead to reduced use of CT scans (Nigrovic, Schunk et al., 2011). This finding is only the beginning of an effort to limit CT scans and radiation exposure in the pediatric population.

Given the increased risks among the pediatric population, it has been hypothesized that pediatric healthcare providers might demonstrate a higher awareness and knowledge level than providers of other specialties. While some studies have reported an increased awareness of radiation exposure and associated risks among pediatricians (Heyer, Hansmann et al., 2010), this
is not uniformly supported in the literature (Rice, Frush et al., 2007). The discrepancy of findings in published literature suggests that even among pediatric healthcare providers knowledge of the risks associated with radiation exposure is limited and suggests a need for further education in all specialties. Furthermore, the increased use of medical imaging tests in the pediatric population, along with the potential for long term health risks, has had an impact on parental interference with pediatric healthcare (Larson, Rader et al., 2007). The ability of a practitioner to provide accurate and concise information regarding the tests being requested had proven very beneficial.

Despite widely varied findings in regard to knowledge of radiation exposure and risks associated, all authors have suggested a need for further education in the field. Studies that have been performed on medical students demonstrate that the majority of students have limited knowledge about various aspects of radiation, it’s risks and protection (Mubeen, Abbas et al., 2008; Subramaniam, Hall et al., 2005; Zhou, Wong et al., 2010). These studies suggest that better teaching methods and programs are needed for medical education in order to better serve patients and minimize unnecessary radiation exposure (Subramaniam, Hall et al., 2005; Mubeen, Abbas et al., 2008; Zhou, Wong et al., 2010).

Studies that have assessed physician knowledge of patient radiation exposure associated with diagnostic imaging modalities have fundamentally concluded that their knowledge is lacking (Gower-Thomas, Lewis et al., 2002; Finestone, Schlesinger et al., 2003; Shiralkar, Rennie et al., 2003; Jacob, Vivian et al., 2004; Lee, Haims et al., 2004; Arslanoglu, Bilgin et al., 2007; Rice, Frush et al., 2007; Soye and Paterson, 2008; Keijzers and Britton, 2010). The qualitative measure of knowledge can be difficult to quantify, however, and has typically been assessed by the accuracy of dose estimations of radiation associated with specific imaging tests.
A further complicating factor involved with assessing knowledge about radiation is the variation in doses of common imaging tests by geographic area, patient population, radiologist practices, and equipment. Despite the difficulties in assessing knowledge as well as varied methods of assessment, there is still an overwhelming commonality of poor physician knowledge of patient radiation exposure in the literature.

Overall, it is critically important for patient-centered healthcare providers to be aware of the potential risks involved with imaging modalities and be willing and able to discuss the risks with patients and family members. Physician assistants (PAs) have become a vital part of healthcare teams across the United States. Serving in multiple capacities, PAs can act as liaisons between physicians and patients and can often spend more time counseling patients about their symptoms, evaluations and diagnoses. Because of this role, it is essential for PAs to be knowledgeable about the risks associated with diagnostic imaging modalities and radiation exposure. Previous studies have been conducted on physicians and residents, revealing that in general, knowledge of patient radiation exposure is poor among these healthcare providers. There is not currently any published information about PAs’ knowledge of radiation exposure associated with common diagnostic imaging modalities. This survey of PAs serves as a baseline of information about PAs’ knowledge of diagnostic imaging modalities and also allows for comparison with other healthcare providers.
Methods

This original research project involved the use of an electronic survey distributed to subjects via e-mail. The survey was developed electronically using Survey Monkey, a program that enables users to develop and distribute Web-based surveys and utilizes anonymous collection of data with programmed integration of data into programs for analysis. The study was conducted among practicing PAs in the state of Ohio and was approved by The University of Toledo Biomedical Institutional Review Board.

The survey was first trialed for readability and usability with PA faculty from the University of Toledo. A member directory from the American Academy of Physician Assistants (AAPA) was then utilized to reach practicing PAs in the state of Ohio and included 968 listed e-mail addresses without indication of “not in practice”.

All specialties of practice were included, as well as all working statuses (full time, part time). An initial introduction e-mail was sent to potential respondents with the link to the survey included in the e-mail. There were two reminder e-mails, with the first sent one week after, and the second sent two weeks after the initial introduction email. Only those who had not yet completed the survey were sent the reminder e-mails. There was no compensation provided to subjects in this study.

Some questions utilized in the study were adapted from previous surveys conducted on physicians with the permission of the respective authors. The survey first collected relevant demographic data on participants, including: gender, age, years in practice as a PA, specialty of medical practice, practice setting, formal education regarding risks of radiation exposure, and estimates of the number of imaging tests ordered per month. Participants who indicated that they were not currently practicing as a PA were not eligible to complete the survey beyond indicating their gender and age. The second section of the questionnaire assessed PAs’ knowledge of
radiation dose exposure associated with common diagnostic imaging modalities (radiographs, CT scans, MRI, US). Participants were instructed to consider one chest x-ray an arbitrary unit of measure and to approximate the exposure of each test in terms number of chest x-rays. Questions in this section also addressed total lifetime risk of radiation, background environmental radiation exposure and effective dose. Participants’ answers to the 15 components in this section were utilized to calculate a total knowledge score (TKS) that was reported as a percentage (number correct/15). This created variable of the study was modeled and adapted from a prior study conducted on physicians in Germany (Keijzers and Britton 2010). The third section of the questionnaire included questions investigating how frequently PAs inform patients about the risks associated with different imaging modalities. This was accomplished by offering three clinical scenarios, for each of which the clinician estimated how often as a percentage of time they typically discuss risks associated with radiation exposure with patients/families prior to them undergoing requested imaging studies. Questions in this section were also modeled after the previous study done on physicians in Germany, which used a visual analog scale to assess the likelihood of participants informing patients of the risks in each given scenario. Modifying this section of the survey created ratio data that could be analyzed with descriptive statistics. Subjects were also asked how often they are questioned as to the potential risks of the imaging studies for which they are requesting as well as their confidence level in delivering concise and accurate information regarding risks associated with radiation exposure when asked. Lastly, participants were asked if they feel a need for further education relating to the risks of patient radiation exposure.

Doses of ionizing radiation associated with medical imaging can vary greatly by geographic location, medical institution and equipment. This study utilized dose data from the
United States National Council on Radiation Protection and Measurements, which had been utilized by a previous study conducted in Germany. Use of the same data in this study allowed for a more reliable comparison between studies.
Results

Of the 968 AAPA members from the state of Ohio who were sent email invitations to participate in this survey, 29 e-mails were returned due to incorrect or inactive email addresses and 31 subjects opted out of the survey. A total of 192 individuals participated in this survey (20.4% response rate). Analysis of results was performed using SPSS (SAS) with direct integration from Survey Monkey. There were 135 subjects who qualified (practicing PA) to complete all questions, of which one participant answered only minimal demographic information and was eliminated from further analysis, yielding 134 subjects who answered all or some of the survey.

Respondent demographics & Practice characteristics:

The mean age of eligible respondents was 38.27 years, with a range of 23-74 years, 90 were female (67%) and 44 male (33%). The number of years in practice ranged from one to forty, with an average time in practice of 9.2 years, with nearly half of respondents (49.3%) practicing 5 years or less (median 6 years; mode 1 year). The options for specialty of practice were modeled from the AAPA 2009 East/North Central Census Report, and the following results were shown by this study: 20.9% of respondents worked in Emergency Medicine, 6% in Family Medicine, 12.7% in Orthopedic surgery and 22.4% in other surgery subspecialties. See Table 1 for further breakdown of specialty of practice for respondents. Eighty-four percent (84.3%) of respondents worked in suburban or urban settings (31.3% and 53%, respectively) and 12.7% in rural settings (Table 2). Most participants (79.9%) reported not having any formal teaching or courses regarding the risks to patients from ionizing radiation and 72.4% reported that they would have preferred to have received more teaching in PA school regarding the effects of ionizing radiation.
The estimated amounts of diagnostic imaging studies (XR, US, CT, MRI) ordered by participants per month are shown in Tables 3-6. More than one third (42.1%) of respondents reported ordering less than one x-ray test per day (0 or 1-25 per month) and nearly three-quarters of respondents reported ordering less than two x-ray tests per day (0, 1-25, 26-50 or 51-75 per month). Furthermore, most respondents reported ordering less than one test per day for each of US, CT and MRI exams (83.5%, 76.1% and 91.8% respectively). Comparison of the number of imaging tests ordered per month and TKS did not show significantly different TKS scores for those participants who indicated a higher number of tests ordered per month. There was also a low correlation found ($r = 0.175$) between number of x-ray tests ordered per month and TKS.

About half of respondents (52.5%) indicated that they would discuss the risks due to radiation exposure with the parents of a six year old boy with a closed head injury prior to CT 100% of the time. Almost 80% (78.6%) would discuss the risks in the same scenario 50% or more of the time. When given a scenario of a 23 year old pregnant female with abdominal pain following a motor vehicle accident, 74.8% reported that they would always discuss the risks prior to a CT scan. Most respondents (84%) reported that they would discuss the risks associated with an abdominal CT with a 76 year old lady with acute abdominal pain 50% or less of the time, with 26.1% responding that they would never discuss the risks in this scenario. Virtually all of those surveyed (95%) reported that they are asked by patients or relatives of patients about the risks associated with radiation exposure 50% or less of the time. The median value of time respondents recorded being asked about the risks with radiation exposure was 5% of the time, with an average of 13.63%. Nearly all respondents (90%) reported being asked about the risks 25% or less of the time. Only 12.2% of respondents reported that they would be confident enough to provide patients with concise and accurate information if asked about the risks
involved with exposure to ionizing radiation from medical imaging and most respondents (95.8%) felt a need for further education regarding the risks of patient radiation exposure.

**Knowledge of radiation exposure**

Pearson correlations and one-way analysis of variance (ANOVA) tests were utilized to determine correlations among the demographic data collected and the mean TKS. T-tests were utilized to compare participant’s total knowledge scores with their confidence in knowledge and opinions regarding needs for further education.

Less than forty percent (37.9%) of respondents accurately indicated an individual’s average yearly natural background radiation exposure. Eighty percent (79.5%) of respondents underestimated the lifetime risk of a fatal cancer from exposure to a single CT of the abdomen, while nearly three-quarters (74.4%) overestimated the average amount of radiation absorbed by a patient during a single chest x-ray. Less than twenty percent (17.9%) of respondents accurately estimated the average amount of radiation absorbed by a patient during a single chest x-ray. Participants received one point for each question answered correctly for questions 13-16 and for each part of question 17 (total = 15). The cumulative score was recorded as each participant’s total knowledge score (TKS). A TKS was not able to be obtained for 18 respondents due to incompleteness of the TKS components (skipped questions). There were four respondents who only did not answer one of the fifteen components of TKS and for these respondents the skipped question was considered incorrect (n=117 complete TKS participants). The average TKS of participants who responded to all 15 components that contributed to total knowledge score (n=117) was 5.21 (34.7% correct) with a standard deviation of 2.34, and the average TKS of all respondents, including partial responders (n=134), was 4.59 with a median TKS of 5/15 (33%).
Correct estimates of the radiation dose were given for lumbar spine, abdominal and pelvic x-rays by 7% to 33% of PAs, while 65% to 90% underestimated the radiation dose associated with these tests. Furthermore, the radiation dose from a single chest x-ray (in terms of CXRs) was overestimated by 56.4% of respondents. The doses associated with abdominal, head, chest and pulmonary CT scans were also underestimated by 50% to 72% of respondents and only accurately estimated by 7% to 42%. Most PAs (85.5%) correctly assessed the radiation dose of an abdominal ultrasound, but only 55.6% accurately assessed the radiation dose of an MRI. Over fourteen percent (14.5%) and almost forty-five percent (44.4%) falsely associated ionizing radiation with ultrasound and MRI, respectively. The radiation dose associated with MRI was correctly identified by 46% of female respondents and 74% of male respondents ($p = 0.039$).

Among those respondents who indicated that they would be confident enough to provide concise and accurate information to patients regarding the risks involved with exposure to ionizing radiation associated with imaging modalities the mean TKS was 6.214 (n = 14). The mean TKS for those who indicated they would not feel confident enough to discuss the risks with patients was 5.07 (n = 101), but a t-test failed to reveal a statistically significant difference in TKS for participants who indicated feeling confident or those who did not ($p = 0.245$, $\alpha = 0.05$). Furthermore, the mean TKS for participants who indicated they feel a need for further education regarding the risks of patient radiation exposure was 5.25 (n = 110), while the mean TKS for those who did not feel a need for further education was 5.00 (n = 5), but again an equal variance t-test failed to reveal a statistically significant difference in TKS for participants who indicated a need for further education and those who did not ($p = 0.812$, $\alpha = 0.05$). Respondents who indicated that they had undergone prior teaching about the risks to patients from ionizing
radiation (n = 23) were found to have a lower mean TKS than those who had not had any prior teaching (4.96 and 5.27, respectively).

There was not a significant correlation found between TKS and number of years in practice as a PA ($r = 0.094, p = 0.312$). A one-way analysis of variance (ANOVA) did not reveal a significant difference in TKS based on number of years in practice ($p = 0.702$). Likewise, there was not a significant correlation found between TKS and number of XR, US, CT or MRI imaging tests ordered per month. The correlation between number of XR tests ordered per month and TKS was the strongest of the imaging tests ($r = 0.175$) but this was still statistically insignificant ($p = 0.061$). A one-way ANOVA was used to test for differences in TKS based on specialty of practice. A significant difference ($p = 0.008$) was found and the two-sided Dunnett post-hoc test revealed the difference to be between PAs in Emergency medicine and those in unspecified surgical specialties ($p = 0.038$). Table 7 shows a cross-tabulation of TKS and specialty of practice. One-way ANOVA was also used to test for differences in TKS based on practice setting and there was no significant difference found in TKS based on setting of practice ($p = 0.691$).
Discussion

Demographics

Based on the 2010 AAPA census report, the median age of practicing physician assistants is 38 years, with seven years as the median number of years in practice. This study reported a median age of 33 years and six years as the median number of years in practice. Furthermore, 32.6% of the respondents to the study were younger than 30 years of age and the AAPA census reports only 17.7% of practicing PAs to be in this age bracket. These comparisons indicate that the study cohort was younger than what is representative of all practicing PAs. The number of years in practice seen in the subjects of the study, however, is similar to the numbers published by the AAPA. This finding may indicate that PAs in Ohio are graduating and starting to practice at a younger age. The gender breakdown of the study participants appears similar to that reported by the AAPA (AAPA: 38% male and 61% female; research study: 33.3% male and 66.7% female). There do appear to be differences compared to AAPA data in relation to specialty of practice. The current study returned a rate of 20.7% who practice in emergency medicine, compared to a rate of 11% reported by the AAPA. Furthermore, 31.2% and 5.9% of respondents work in surgical subspecialties (excluding general surgery) and family/primary care, respectively, compared to 23% and 31% as reported by the AAPA. These findings indicate a higher representation of emergency medicine and surgical subspecialties among the participants of the study, and a lower representation of primary care PAs as compared to the national numbers reported by the AAPA. The varied representation of specialties in this study cohort is likely multi-factorial but may indicate that family practice PAs in Ohio are more likely to choose not to participate in research studies. Another possible explanation is that there may be fewer primary care PAs who have listed e-mail addresses with the AAPA and therefore a fewer number
of primary care PAs received the survey. Overall, the demographic information from respondents has a mixture of similarities and differences to national AAPA numbers, but it can be inferred that PAs of a particular gender and number of years in practice would answer similarly to participants in this study.

**Discussion of Results & Comparison to Previous Studies**

The clinical benefit of diagnostic imaging modalities in diagnosis and treatment of disease is immeasurable; however, the drastic increase in use worldwide is not without concern of increased radiation exposure and the associated risks. This study found that PA knowledge of patient radiation exposure from diagnostic imaging modalities is limited, with an average mean knowledge score of 34.7%. Frequency of informing patients of the risks involved with imaging tests that were ordered varied greatly based on clinical scenario and most PAs did not even feel confident enough to provide patients with accurate information regarding the risks involved with ionizing radiation. Furthermore, most participants had never had any formal training regarding the risks involved with radiation exposure but wished that it would have been a part of their education. Overall, the radiation exposure associated with common imaging modalities was underestimated, which may lead to increased numbers of tests ordered secondary to lack of knowledge of radiation exposure and the risks involved with each test.

Often times it is difficult to directly compare results of research studies due to differences in methodologies and study populations. Many prior studies that have been conducted on physicians report limited knowledge of patient radiation exposure. This study showed an average knowledge score of 34.7% among practicing PAs. Prior studies that have been conducted on physicians and utilized a similar “total knowledge score” system have reported average knowledge scores of 35-40% (Soye and Paterson, 2008; Keijzers and Britton, 2010).
While differences exist between the previous studies on physicians and this study on PAs, these numbers indicate that PA knowledge does not vary greatly from that of physicians. Other studies conducted on physicians have reported 45-50% pass rates (given a 20% deviation for correct responses), however this study on PAs was analyzed differently and thus direct comparison is inhibited (Gower-Thomas, Lewis et al., 2002; Jacob, Vivian et al., 2004). Overall, knowledge of patient radiation exposure among healthcare providers has been demonstrated to be poor. The source of poor knowledge in this study, however, is likely multi-factorial. It may indicate poor undergraduate and graduate education in the field because nearly 80% of PAs report never having any formal education regarding radiation risks. Interestingly though, PAs who indicated that they had undergone prior teaching about the risks to patients from ionizing radiation were found to have a lower mean TKS than those who had not had any prior teaching. This differs from findings among physicians, and is without a known reason. Some studies conducted on physicians report better knowledge scores with prior education (Soye and Paterson 2008), and others report no difference (Keijzers and Britton, 2010).

An alarming finding of both previous studies conducted on physicians, as well as this study done on PAs, is the number of practitioners who falsely associate non-radiating exams such as MRI and US with doses of ionizing radiation. This study found that over 14% and nearly 45% of PAs wrongly indicated radiation doses with ultrasound and MRI, respectively. Furthermore, while most PAs (85%) correctly associated the radiation dose of an abdominal US, only 56% of PAs correctly indicated the radiation dose associated with MRI. These findings are slightly higher than findings in the literature on physicians. Prior studies on physicians report a 4-5% incorrect association for ultrasound and 5-30% rate for MRI (Shiralkar, Rennie et al., 2003; Arslanoglu, Bilgin et al., 2007; Heyer, Hansmann et al., 2010; Keijzers and Britton, 2010).
Studies conducted on medical students further demonstrate inaccurate associations of ionizing radiation with MRI at rates of 18-25% (Mubeen, Abbas et al., 2008; Zhou, Wong et al., 2010). These findings further indicate a broad lack of practitioner knowledge regarding ionizing radiation associated with imaging modalities. Significantly more male than female PAs (74% and 46%, respectively) accurately recognized that MRI is not associated with ionizing radiation, which is consistent with previous findings among physicians (Arslanoglu, Bilgin et al., 2007; Keijzers and Britton, 2010; Zhou, Wong et al., 2010).

The varied responses in PAs practices of informing patients of the potential risks involved with ionizing radiation may have many causes. First of all, the degree of risk to the patient may be different based on each clinical scenario (i.e. the risk to a small child or a pregnant female may be greater than the risk imposed on a 75 year old lady). Secondly, the variation may just be representative of PAs’ confidence in discussing the risks as well as limited knowledge. PAs may be more likely to discuss the risks of radiation exposure with patients if they were more knowledgeable about the subject. Finally, PAs in different specialties may have more exposure to specific types of imaging modalities (i.e. CT scans in the ED, MRI in orthopedics, US in obstetrics) and thus may have more knowledge about some tests than others. This may affect the likelihood of informing patients of the risks involved with the different imaging modalities.

The gross underestimation of radiation doses associated with XR and CT scans (65-90% and 50-72%, respectively) are consistent with previous studies done on physicians (Shiralkar, Rennie et al., 2003; Arslanoglu, Bilgin et al., 2007; Heyer, Hansmann et al., 2010; Keijzers and Britton, 2010), however the contrasting overestimation of radiation dose associated with a single chest x-ray (mSv) by nearly three-quarters of PAs (74.4%) may indicate unfamiliarity with units
of radiation. Also consistent with published studies on physicians, more than half of the PAs indicated that a chest x-ray was equivalent to more than one CXR (Keijzers and Britton, 2010). This finding, as reported in prior studies, may be due to respondents considering both a posterior-anterior and lateral view film as part of a single chest x-ray.

**Study Limitations & Future Research**

This study had a number of limitations but also offered some insight into further research needs. The questionnaire survey that was utilized was adapted with permission from a previous study conducted on physicians in Germany in 2009; however neither that survey, nor the newly adapted survey used in this study were validated. Furthermore, there are some factors that may contribute greater to an individual’s knowledge of radiation exposure and the equal weighting of all 15 items of the total knowledge score may have limited interpretation of the score. Analysis of the results showed that there was a 13.3% partial response rate with wide variance in those who only partially participated. There was one participant who answered yes to being a practicing PA but quit the survey after that question. There were 7 who answered no further than question 12 and six respondents who only answered through question 16. Four respondents skipped all parts of question 17 but finished the survey. The length and cumbersome questions (specifically question 17) of the electronic survey were likely the causes that contributed to the 13% (18/135) partial response rate. This drawback limited the sample size for analysis. The study group comprised a large proportion of newly and younger practicing PAs, which may have led to poorer knowledge, however if this were the case, it indicates a need for better education in PA school. The study group was younger than what is representative of all practicing PAs based on data from AAPA, but was representative of gender and years in practice of all PAs. Furthermore, the study cohort showed a much higher representation of PAs
practicing in emergency medicine and surgical subspecialties, and a lower representation of primary care PAs as compared to the national numbers reported by the AAPA. These differences may have contributed to the varied knowledge found among the study cohort and also may limit extrapolation of the results. A different sampling of PAs may reveal different results.

This study served to provide a baseline of PA knowledge on patient radiation exposure and further studies should be conducted. A better means of comparing PAs’ knowledge to that of other healthcare providers would be to evaluate the populations concurrently using the same study. Despite the common practice of using dose estimates to gauge knowledge of radiation, varying approaches with varying ranges of procedures and patients makes interpretation difficult. Evaluating multiple types of providers in the same study would likely help to eliminate the difficulty in interpretation that is caused by varying methodologies. Furthermore, this would allow for the utilization of the same scoring system regarding radiation dose exposures that vary with geographical location. In addition, PA students were not included in this study, but assessment of PA student knowledge could help to guide future changes in PA education regarding radiation exposure. An area of study that may contribute to improving the limited knowledge among healthcare professionals regarding the risks associated with radiation exposure is assessment of current educational regimens about radiation. To date, the most effective form of radiation exposure education is undetermined and analyzing current educational regimens would likely offer direction for improvement in future education.

A field of research associated with radiation exposure that may be of interest for future exploration is the study of dose exposures in patients with higher body mass indices (BMI). Typically, patients with higher BMIs require higher radiation doses to penetrate the increased
amount of adipose tissue (Lin 2010), and these increased exposures may be associated with increased risks of cancerous processes. The combination of the obesity epidemic in the United States and the increased use of diagnostic imaging modalities create the need for evaluation of potential increased risks of radiation exposure in this population. Additionally, the radiation catastrophe that occurred in Japan in 2011 created another cohort of individuals exposed to varied doses of radiation that could be followed and possibly offer further insight as to the risks associated with radiation exposure.
Conclusion

Physician assistants display varied knowledge of radiation exposure and risks associated with diagnostic imaging modalities, but overall have limited knowledge of ionizing radiation, consistent with published literature on physicians. The limited knowledge displayed among PAs is in accordance to the reported low confidence in offering patients information regarding the risks associated with radiation exposure. Although this is the only study to be conducted on PAs, the results indicate a need for further education in the field in order to minimize unnecessary exposure to patients. A suggested target of better education regarding the risks of ionizing radiation associated with imaging modalities should be PA schools; however continuing education is needed to reach all practicing PAs. The existing transition of healthcare to electronic medical records could offer an opportunity to provide dose ranges and statistics for requested imaging studies that could be accessed by providers and contribute to clinical decision making and provider awareness of radiation exposure.
References


Krille, L., G. P. Hammer, et al. Systematic review on physician's knowledge about radiation


Lee, C. I., A. H. Haims, et al. (2004). Diagnostic CT scans: Assessment of patient, physician,


Mettler, F. A., M. Bhargavan, et al. (2009). Radiologic and nuclear medicine studies in the
United States and worldwide: Frequency, radiation dose, and comparison with other


Table 1

Specialty of practice

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<th>Specialty of Practice</th>
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<th>Percent</th>
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Practice Setting

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Table 3
Number of XR tests ordered per month

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<th>Cumulative Percent</th>
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Number of US tests ordered per month

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### Table 5

Number of CT tests ordered per month

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Table 6

Number of MRI tests ordered per month

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Table 7
TKS and Specialty of Practice cross-tabulation

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<tr>
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Appendix A: Survey

Physician Assistant Knowledge of Patient Radiation Exposure from Common Diagnostic Imaging Modalities

1. Please indicate your gender. (choose male/female)

2. Please indicate your age. (drop down box)

3. Are you currently practicing medicine as a physician assistant? (choose yes/no)
   o Yes
   o No – this completes your survey. Thank you for your time and cooperation.

4. Please indicate the number of years you have been practicing as a physician assistant. (Please round time to the nearest year – drop down box)

5. Please indicate your specialty of practice. (Adapted from 2009 AAPA Census – East North Central Division Census Report – Table 3.6 – drop down box)
   • Cardiothoracic surgery
   • Dermatology
   • Emergency Medicine
   • Family/General medicine
   • Internal Medicine – Cardiology
   • Internal Medicine – General
   • Internal Medicine - Other
   • Neurosurgery
   • Ob/GYN
   • Occupational Medicine
   • Orthopedic surgery
   • Other
   • Pediatrics – General
   • Pediatrics – Sub-specialty
   • Surgery – General
   • Surgery – Other

6. Please indicate the setting in which you currently practice (choose one of the following).
   o Rural
   o Urban
   o Suburban
   o Other (please specify): _______________________

7. Have you ever undergone any formal teaching or courses as to the risks to patients from ionizing radiation? (choose yes/no)
   o Yes
8. Would you have preferred to have received more teaching in PA school as to the effects on patients of ionizing radiation? (choose yes/no)
   - Yes
   - No

9. Please estimate the average number of X-ray tests you order per month: (drop down box)
   - 0
   - 1 – 25
   - 26 – 50
   - 51 – 75
   - 76 – 100
   - 101 – 125
   - 126 – 150
   - 151 – 175
   - 176 – 200
   - >200

10. Please estimate the average number of ultrasound (US) tests you order per month: (drop down box)
    - 0
    - 1 – 25
    - 26 – 50
    - 51 – 75
    - 76 – 100
    - 101 – 125
    - 126 – 150
    - 151 – 175
    - 176 – 200
    - >200

11. Please estimate the average number of CT tests you order per month: (drop down box)
    - 0
    - 1 – 25
    - 26 – 50
    - 51 – 75
    - 76 – 100
    - 101 – 125
    - 126 – 150
    - 151 – 175
12. Please estimate the average number of MRI tests you order per month: (drop down box)

- 0
- 1 – 25
- 26 – 50
- 51 – 75
- 76 – 100
- 101 – 125
- 126 – 150
- 151 – 175
- 176 – 200
- >200

The following questions are multiple-choice. Please choose the single best answer from the options available to you.

13. Please indicate in milliSieverts the average natural background radiation exposure to an individual per year (mSv = SI derived unit of effective dose of radiation).

- 0.5 mSv
- 1.0 mSv
- 3.0 mSv
- 5.0 mSv
- 20 mSv

14. Please indicate how many days of normal background environmental radiation exposure equates to the dose given by a single chest X-ray?

- 1 day
- 3 days
- 10 days
- 30 days
- 90 days

15. Please approximate the average amount of radiation absorbed by a patient during a single chest X-ray (one view). Answers are given in milliSieverts.

- 0.002
- 0.02
- 0.2
- 2.0
- 20.0
16. In addition to everyday background risk please indicate what you consider to be the life
time risk of a fatal cancer from exposure to a single CT abdomen?

   o 1 in 200
   o 1 in 2000
   o 1 in 20,000
   o 1 in 200,000
   o 1 in 2,000,000

The following questions assume the radiation exposure from one chest x-ray to be taken as 1
arbitrary unit (CXR). Please answer in number of CXR’s.

17. Please choose the approximate radiation dose from the following commonly requested
tests in terms of number of CXR’s.

<table>
<thead>
<tr>
<th>Test</th>
<th>0-1</th>
<th>1.1-10</th>
<th>10-50</th>
<th>50-100</th>
<th>100-500</th>
<th>500-1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Limb XR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b) Lumbar spine XR</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>c) Chest XR – PA</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d) Abdominal XR</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e) Pelvic XR</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>f) CT Abdomen</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g) Ultrasound Abdomen</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>h) CT Head</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i) MRI Head</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>j) CTPA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>k) CT Chest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Please indicate how often (as a percentage of time) you would discuss any risks due to radiation
exposure with patients/relatives prior to them undergoing imaging requested.

18. A six year old boy with a closed head injury with Glasgow Coma Score of 15 where the
child’s parents are convinced that he needs a head CT scan.
   - Type in the % of time (how often) you would discuss the risks: ______

19. A 23 year old pregnant lady with abdominal pain after a low speed road traffic accident
for a CT abdomen.
   - Type in the % of time (how often) you would discuss the risks: ______

20. A 76 year old lady with acute abdominal pain for a CT abdomen.
   - Type in the % of time (how often) you would discuss the risks: ______
21. Please indicate how often a patient or a relative of a patient you are treating inquires as to the potential risks of the imaging studies you are requesting.
   - Type in the % of time (how often) patients/relatives ask: ______

22. If you were to be asked by a patient for information regarding the specific future risks of exposure to ionizing radiation from imaging you were requesting, would you be confident enough to provide them with concise and accurate information? (choose yes/no)
   - Yes
   - No

23. Do you feel a need for further education regarding the risks of patient radiation exposure? (choose yes/no)
   - Yes
   - No

The Questionnaire is now complete. Thank you for your time and support.
## Appendix B: Dose Estimates of Common Imaging Modalities

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Dose* (mSv)</th>
<th>Number of chest x-rays</th>
<th>Equivalent period of background radiation</th>
<th>Approx number of hrs flying at 39,000 ft</th>
<th>Approx cost of procedure</th>
<th>Approx risk of fatal cancer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Projective Radiography</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limbs and joints (except hips)</td>
<td>0.01</td>
<td>&lt;0.5</td>
<td>&lt;1.5 days</td>
<td>2</td>
<td>35.64</td>
<td>1 in 2,000,000</td>
</tr>
<tr>
<td>Dental bitewing</td>
<td>0.02</td>
<td>1</td>
<td>3 days</td>
<td>4</td>
<td>39.83</td>
<td>1 in 1,000,000</td>
</tr>
<tr>
<td>Chest x-ray</td>
<td>0.02</td>
<td>1</td>
<td>3 days</td>
<td>4</td>
<td>39.83</td>
<td>1 in 2,000,000</td>
</tr>
<tr>
<td>Skull</td>
<td>0.07</td>
<td>3.5</td>
<td>11 days</td>
<td>14</td>
<td>54.55</td>
<td>1 in 285,000</td>
</tr>
<tr>
<td>Hip</td>
<td>0.3</td>
<td>15</td>
<td>7 weeks</td>
<td>60</td>
<td>35.93</td>
<td>1 in 67,000</td>
</tr>
<tr>
<td>Mammography</td>
<td>0.4</td>
<td>20</td>
<td>2 months</td>
<td>90</td>
<td>73.57</td>
<td>1 in 50,000</td>
</tr>
<tr>
<td>Thoracic spine</td>
<td>0.7</td>
<td>35</td>
<td>4 months</td>
<td>140</td>
<td>46.61</td>
<td>1 in 30,000</td>
</tr>
<tr>
<td>Pelvis</td>
<td>0.7</td>
<td>35</td>
<td>4 months</td>
<td>140</td>
<td>51.54</td>
<td>1 in 30,000</td>
</tr>
<tr>
<td>Abdomen</td>
<td>1.0</td>
<td>50</td>
<td>6 months</td>
<td>200</td>
<td>40.74</td>
<td>1 in 20,000</td>
</tr>
<tr>
<td>Lumbar spine</td>
<td>1.3</td>
<td>65</td>
<td>7 months</td>
<td>260</td>
<td>65.09</td>
<td>1 in 15,000</td>
</tr>
<tr>
<td><strong>Fluroscopy</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barium swallow or enema</td>
<td>1.5</td>
<td>75</td>
<td>8 months</td>
<td>300</td>
<td>114.39</td>
<td>1 in 13,000</td>
</tr>
<tr>
<td>IVU</td>
<td>2.5</td>
<td>125</td>
<td>14 months</td>
<td>500</td>
<td>133.55</td>
<td>1 in 6,000</td>
</tr>
<tr>
<td>Femoral DSA</td>
<td>2.0</td>
<td>100</td>
<td>1 year</td>
<td>400</td>
<td>994.82</td>
<td>1 in 10,000</td>
</tr>
<tr>
<td>Cerebral DSA</td>
<td>6.0</td>
<td>300</td>
<td>3 years</td>
<td>1200</td>
<td>994.82</td>
<td>1 in 3,300</td>
</tr>
<tr>
<td>Renal pelvis / stent</td>
<td>25</td>
<td>1250</td>
<td>12 years</td>
<td>5000</td>
<td>476.95</td>
<td>1 in 500</td>
</tr>
<tr>
<td>Endovascular stent</td>
<td>5.0</td>
<td>250</td>
<td>2.5 years</td>
<td>1000</td>
<td>476.95</td>
<td>1 in 4,000</td>
</tr>
<tr>
<td>Hip arthroplasty</td>
<td>0.2</td>
<td>10</td>
<td>1 month</td>
<td>40</td>
<td>82.62</td>
<td>1 in 100,000</td>
</tr>
<tr>
<td>Diagnostic coronary angiogram</td>
<td>6.7</td>
<td>335</td>
<td>3 years</td>
<td>1300</td>
<td>850.00</td>
<td>1 in 3,000</td>
</tr>
<tr>
<td>Angiography</td>
<td>12*</td>
<td>600</td>
<td>6 years</td>
<td>2400</td>
<td>1,196.40</td>
<td>1 in 1,700</td>
</tr>
<tr>
<td><strong>Nuclear Medicine</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lung scan VQ (Tc99m)</td>
<td>3.0</td>
<td>150</td>
<td>16 months</td>
<td>600</td>
<td>438.95</td>
<td>1 in 4,700</td>
</tr>
<tr>
<td>non pregnant dose - body dose</td>
<td>1.3</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>breast dose (mGy)</td>
<td>1.1</td>
<td>55</td>
<td>6 months</td>
<td>200</td>
<td>1 in 13,000</td>
<td></td>
</tr>
<tr>
<td>pregnant dose - breast dose</td>
<td>0.5</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>breast dose (mGy)</td>
<td>0.3</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>foetal (0-3 months) dose (mGy)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Bone Scan (Tc99m)</td>
<td>4.6</td>
<td>220</td>
<td>2 years</td>
<td>1315</td>
<td>475.36</td>
<td>1 in 4,300</td>
</tr>
<tr>
<td>Stress test - Thallium</td>
<td>31</td>
<td>1540</td>
<td>14 years</td>
<td>5810</td>
<td>958.20</td>
<td>1 in 1,500</td>
</tr>
<tr>
<td>Cardiac stress test – Tc99m</td>
<td>12</td>
<td>600</td>
<td>6 years</td>
<td>2400</td>
<td>958.20</td>
<td>1 in 1,650</td>
</tr>
<tr>
<td>Whole body (Ga) - Tumour</td>
<td>40</td>
<td>2000</td>
<td>18 years</td>
<td>11440</td>
<td>537.40</td>
<td>1 in 500</td>
</tr>
<tr>
<td>Renal function (MAAGS)</td>
<td>1.3</td>
<td>65</td>
<td>7 months</td>
<td>260</td>
<td>329.20</td>
<td>1 in 15,000</td>
</tr>
<tr>
<td>PET (including low dose CT)</td>
<td>9</td>
<td>450</td>
<td>4 years</td>
<td>1800</td>
<td>N/A</td>
<td>1 in 2,200</td>
</tr>
</tbody>
</table>

Data assumes 2.3 mSv/year for natural background and 5% risk of fatal cancer for 1.5x exposure to adult patient, and is compiled from NCRF documentation and measurements taken in Queensland Health facilities. All doses are effective whole body dose, except where marked with an asterisk, which denote absorbed dose to tissue quoted in mGy.

From “First do no harm - Typical risks for common radiological procedures,” Queensland Health.
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Appendix C: Definitions

Absorbed Dose— the magnitude of radiation to which a person or object has been exposed, as measured by the amount of radiation energy absorbed per unit mass or electric charge absorbed per unit mass. Units: Gray (1 Gy = 1 J/kg), rad (100 rad = 1 Gy), roentgen (1 R = 258 microcoulombs per kilogram, µC/kg)

Background radiation – widespread radiation from space as well as from natural and man-made radionuclides (HPS)

Carcinogen – substances and exposures that may lead to cancer

Diagnostic Imaging - the use of X-ray, ultrasound, radioactive isotopes, or magnetic resonance to produce a visual display or representation of structural and/or functional information of the “inside” of the human body

Effective dose—The equivalent dose multiplied by tissue weighting factor. The dose to the entire body that carries with it the same risk of a higher dose to a part of the body. Units: Sievert (Sv), rem

Equivalent dose—The dose multiplied by a quality factor or radiation weighting factor that depends on the type of radiation. Units: Sievert (Sv), rem (100 rem = 1 Sv)

Gamma rays – high energy electromagnetic photons that can be emitted from radionuclides and have moderate-high penetrating power

High dose radiation – doses greater than 10 rem (100 mSv) to a human body

Lifetime attributable risk (LAR) – the difference in rate of a disease or condition between an exposed population and an unexposed population over the course of one’s lifetime

Low dose radiation – doses less than 10 rem (100 mSv) to a human body
rad – radiation absorbed dose → the conventional unit of the amount of energy deposited per unit weight (absorbed dose)

Radionuclide – an atom with an unstable nucleus and excess energy that can be emitted in the form of radiation

rem – traditional U.S. unit used to describe equivalent or effective radiation dose (1 rem = 1/100 Sv)

Sievert/millisievert – SI unit used to describe equivalent or effective radiation dose (1 Sv = 100 rem)

X-rays – electromagnetic photons that can be emitted from radionuclides, but have lower energies than gamma rays
Appendix D: Variables & Research Hypotheses

Variables:

- Dependent Variables: Knowledge score of common radiation doses
- Independent Variables: Number of imaging tests ordered per year, number of years in practice, specialty of practice, practice setting

Statistical hypotheses:

1. Demographics:
   a. $H_0$: There will be no statistically significant difference (SSD) between the average number of years in clinical practices and total knowledge score
      $H_1$: The longer PAs have been in clinical practice, the higher the total knowledge score will be.
   b. $H_0$: There will be no SSD between the number of imaging tests ordered per year and knowledge of patient radiation exposure.
      $H_1$: PAs who order more imaging tests will have a greater total knowledge score.
   c. $H_0$: There will be no SSD between participant specialty of practice and total knowledge score.
      $H_1$: PAs working in emergency medicine and surgery will have higher total knowledge scores than other specialties.
   d. $H_0$: There will be no SSD between participant setting of practice and total knowledge score.
      $H_1$: PAs working in urban and suburban settings will have higher total knowledge scores than those working in rural areas.
2. Total knowledge scores:
   a. $H_0$: There will be no SSD between mean total knowledge score of PAs and the physicians in previous studies.
   b. $H_1$: PAs will have a higher mean total knowledge score.

3. Confidence and Opinion:
   a. $H_1$: Participants that indicate they feel confident enough to provide concise and accurate information when asked about the risks associated with radiation exposure will not have higher total knowledge scores.
   b. $H_1$: Participants that indicate a necessity for further education regarding the risks of radiation exposure will have lower total knowledge scores.
Abstract

**Objective:** Assess physician assistant (PA) knowledge of radiation exposure associated with diagnostic imaging modalities.

**Methods:** An electronic survey was distributed to PAs in Ohio that assessed PA knowledge of radiation doses and investigated practices and perceptions regarding imaging modalities.

**Results:** The average total knowledge score of PAs was 34.7% (n=117), with no difference based on number of years in practice. Nearly 80% of PAs underestimated the lifetime risk of a fatal cancer from an abdominal CT, while 74.4% overestimated the radiation associated with a single chest x-ray. Some PAs falsely associated ionizing radiation with ultrasound and MRI (14.5% and 44.4% respectively). Few PAs felt confident in providing radiation-related information to patients, with 95.8% indicating a need for further education.

**Conclusion:** PAs showed limited knowledge of ionizing radiation, consistent with published literature on physicians. There is a need for further education regarding medical radiation exposure and common imaging modalities.