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Using the Theory of Planned Behavior as a Predictor of Radiologic Technologists' Use of Patient Radiation Protection Best Practices: a Regional Study

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ABSTRACT

USING THE THEORY OF PLANNED BEHAVIOR AS A PREDICTOR
OF RADIOLOGIC TECHNOLOGISTS' USE OF PATIENT
RADIATION PROTECTION BEST PRACTICES:
A REGIONAL STUDY

by

Brenda L. Boyd

Chair: Shirley Freed

ABSTRACT OF GRADUATE STUDENT RESEARCH

Dissertation

Andrews University

School of Education

Title: USING THE THEORY OF PLANNED BEHAVIOR AS A PREDICTOR OF RADIOLOGIC TECHNOLOGISTS' USE OF PATIENT RADIATION PROTECTION BEST PRACTICES: A REGIONAL STUDY

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Problem

A growing concern exists that patients are receiving an increase in radiation exposure while undergoing medical imaging exams. According to a March 2009 report by the National Council on Radiation Protection and Measurements (NCRP), the U.S. population's total exposure to ionizing radiation has nearly doubled over the past two decades. With the introduction of new digital radiology equipment, patient dose is on the rise. Possible reasons for a radiologic technologist's behavior include: influence by availability or lack of equipment, policies, social pressure, attitudes, and a safety culture. Little research has been done in this area, specifically with applying a theoretical framework to a study. This study attempts to fill a gap to understand the attitudes, social pressures, behavioral control issues, impact of new digital technology, and the

demographic factors that influence the demonstration of patient radiation protection best practices in order to reduce patient radiation exposure during radiography exams.

Method

This study used *ex post factor* research design. The most sophisticated type of *ex post facto* research design was used, which is *ex post facto* with hypotheses and controls for viable alternative explanations of research outcomes.

Statistical analysis was conducted on the data that were gathered using descriptive statistics of demographic factors of the study sample: scale descriptives for reliability of the variables and modified variables in the study; power analysis; correlations and analysis of variance between the components of Ajzen's theory of planned behavior (intentions, past behaviors, attitudes, social pressures/norms, perceived behavioral control); and multiple regression analysis for controlling for demographics and the constructs of the theory of planned behavior.

The development of an 80-item quantitative questionnaire and the design of this study were based on Ajzen's theory of planned behavior. The purpose of the study was to predict the intentions and past behaviors of radiologic technologists in the area of patient radiation protection best practices and to predict the use of new digital equipment and digital techniques to lower patient dose. Experts in the field of radiologic technology were consulted using qualitative-type questions to develop the variables in the survey. Dr. Icek Ajzen, the developer of the theory of planned behavior, consulted on the questionnaire development.

Participants from the Southwestern Region of the United States, but primarily in Southern California, were asked in an online questionnaire to self-report on their intentions and past behaviors regarding patient radiation protection best practices and the use of new digital technology and digital techniques, on the topics of attitude, social pressures/norms, and perceived behavioral control. The participants answered questions using a 7-point Likert scale.

Results

The survey was sent to 365 participants with a return of 173 respondents, yielding a 47% response rate. Data were used to calculate descriptive statistics, correlations, and multiple linear regressions.

Significant correlational findings include the following: intentions predict past behaviors; attitudes, social pressures/norms, and perceived behavioral control predict intentions and past behavior; intention scores are higher than past behavior scores; attitudes have more significance to predicting intentions and past behavior over social pressures/norms and perceived behavioral control; patients have more significant influence on radiologic technologists than do their co-workers; demographic variables of age, gender, and years in practice are significant in predicting intentions—specifically, females, more years in practice, and older radiologic technologists demonstrate higher intentions than past behaviors; demographic variables of age, gender, years in practice, primary roles (specifically students), and facility type are significant in predicting past behavior; a radiologic technologist’s attitudes of reducing patient radiation exposure, being a positive role model, and doing something ethical/moral are significant in predicting intentions; and feeling rushed, trauma situation, lack of equipment in the department, policies, and a safety culture are predictive of intentions.

Conclusions

The intent of this research has been to fill a gap in knowledge about how a radiologic technologist's attitudes, social pressures/subjective norms, perceived behavioral control, demographic factors, and certain organizational variables are correlated with the behavior that supports patient radiation protection best practices. The goal was to address the growing concern that patients are receiving an increase in radiation exposure while undergoing medical imaging exams.

It is important to understand what drives a radiologic technologist to perform patient radiation protection best practice behavior. Based on Ajzen's theory of planned behavior that intentions and past behavior could predict future behavior, and the drivers of the best practice behavior can be identified, then hospital and education facilities could use this information to assess and develop organizational plans to instill and promote patient radiation protection best practice behavior in radiologic technologist staff and students.

The major findings of this study provide data to predict the behaviors of radiologic technologists in the area of patient radiation protection best practices and the use of new digital technology and digital techniques. Further research is needed to understand the organizational issues that impact the use of patient radiation protection.

Andrews University

School of Education

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A Dissertation

Presented in Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

by

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DEDICATION

This academic accomplishment is dedicated to my mother. My mother was my cheerleader throughout my life, but especially when I first started my doctoral program in leadership at Andrews University in 2007. Although she is not here to see this day come to fruition, I am very aware that her influence has kept me going. I can hear her say, "Would you rather be 54 with it or without it?" Of course, my answer to this question has always been "with it!" One month and a few days from the day of my defense is my 54th birthday.

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I would like to thank my husband, Jim, for his dedication and love to me, along with his “Go, Brenda, Go!” cheerleading, and his “I can do it!” response to each request I made of him. I would not be where I am today without him.

I am grateful for my best friend, Janice, for her steady strength and constant reminders of blessings in disguise. She has brought me balance like none other! When I thought I had lost my way a few times, she was there to make me laugh and get me back on track.

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Finally, I would like to praise God for His perfect timing, perfect will, and perfect way. Because of this journey, I have discovered that the challenges in my life are really not about the "stuff" but really about the person I am if God is really going to be truly evident in my life. Additionally, through this educational process I have discovered the true source of strength, comfort, and deepening faith, which can only be found in a personal, daily relationship with Jesus.

CHAPTER 1

THE PROBLEM

Background to the Problem

From the first discovery of radiation by Wilhelm Roentgen in 1895 (Bushong, 2008; Sherer, Visconti, & Ritenour, 2006), the risks and the benefits of radiation exposure have been at odds with each other. On one hand, when human cells come in contact with ionizing radiation, detrimental effects can occur. On the other, diagnostic and therapeutic benefit is also possible with radiation exposure.

In medical imaging,

> the exposure amount in these exams is very small, to the extent that the health risk associated with such low levels of exposure is frequently debated in scientific meetings. Nonetheless, the prevailing scientific view is that there is a finite (though small) amount of risk involved with such exposures. The risk is increased with the amount of exposure, with repeated exposures, and when the patient is young. (Peck & Samei, 2013)

Even with the known benefits of radiation in medical imaging, exposure to radiation must be minimized. Long-term exposure to ionizing radiation, even at low doses, has been shown to lead to several health conditions. Cancer is usually the most feared radiation effect (Peck & Samei, 2013).

> Cataracts, leukemia, and several types of cancer have been linked to radiation exposure in certain populations, including radiation physicists and early radiologists who practiced before modern safeguards were in use. Clusters of thyroid, bone, and breast cancers have been attributed to the overzealous use of radiation treatment for thymus enlargement, ankolysing spondylitis, and postpartum mastitis. (Bradley, 2012, p. 1)

Although a one-time unnecessary exposure may not have visual or significant adverse effects, the impact of radiation exposure over the lifetime of an individual is cumulative and could result in eventual harm to those exposed. Even though radiation research has led to many medically significant benefits, soon after the time of Roentgen's discovery, radiation research also led to documented cases of severe x-ray burns and death (Bushong, 1991).

"The primary risk associated with exposure to ionizing radiation is cancer," according to Schueler et al. (2007). Regardless of the etiologic process, radiation exposure could have a latent period of 10-20 years. It is important to remember that in addition to radiation exposure from imaging procedures, individuals are exposed to background radiation from natural sources, including radon, cosmic rays, soil, building materials, and food (Colangelo, Johnston, Killion, & Wright, 2009). A person can only conclude that from high doses to low doses all the way down to a zero dose, only at zero dose will the risk drop to zero (Brock & Sherbini, 2012, p. 39).

Radiologic technology students are taught the best practices of radiation protection when they are in school. The best practices include: correct patient, correct procedure, correct part, collimation, lead shielding, positioning aids, optimal radiographic technique, continuing education, and ALARA (as low as reasonably achievable). Students are also taught and are responsible for the ARRT Code of Ethics (2011b) and the ARRT Standards of Practice (2011c).

The seventh Code of Ethics (ASRT, 2011b) specifically addresses radiation protection: "The radiologic technologist uses equipment and accessories, employs techniques and procedures, performs services in accordance with an accepted standard of practice, and demonstrates expertise in minimizing radiation exposure to the patient, self, and other members of the healthcare team" (p. 1).

Additionally, radiologic technology students learn legal and ethical practices when it comes to providing quality patient care, performing appropriate procedures, and protecting the patient from unnecessary exposure to radiation. Students are also taught that protecting patients from unnecessary radiation exposure is their primary concern, as well as their social responsibility.

It is evident that leaders in the field of radiologic technology need to understand the issues impacting the practice of patient radiation protection by radiologic technologists so that appropriate measures in the areas of organizational behavior, education, and policy development can be taken to continue to keep patients safe when being exposed to radiation. Workload and the pressures of increased speed to perform exams, vague department policies and behavior expectations, the influence of seasoned technologists regarding shielding and radiographic techniques, and rapid changes toward digital technology (Goodman & Oakley, 2003) are some of the main factors impacting the actual practice of radiologic technologists to perform patient radiation protection (Colangelo et al., 2009; Joint Commission, 2011; Marshall & Keene, 2007; Slechta & Reagan, 2008).

Academic researchers have indicated that the practices of a radiologic technologist are contributing to the problem (Slechta & Reagan, 2008). Colangelo et al. (2009) have stated the continued need for continuing education regarding reducing patient radiation exposure, and compliance with radiation safety practices (Slechta & Reagan, 2010). Marshall and Keene (2007) are suggesting that the need for increased speed when performing an exam is impacting how patient radiation protection best practices are demonstrated. These studies are supporting the benefits of patient radiation protection standards and practices.

Radiologic technology educators and hospital radiology department managers are worried that radiologic technologists are losing sight of the “as low as reasonably achievable” (ALARA) goal since digital imaging provides for a wider range of radiation exposures while still providing diagnostic results (Limley, Hedl, & Griffin, 1987; Slechta & Reagan, 2008; Tilson, 1982). Experiments in the academic setting indicate that digital technology is one of the contributors (Bowman, 2009; Sachs, 2012). Experts disagree on the extent of the risks of cancer from diagnostic imaging; however, agreement is found on the point that steps must be taken to eliminate unnecessary exposure to radiation (Bowman, 2009; Joint Commission, 2011; Sachs, 2012).

The Joint Commission (2011) has suggested that the following actions be taken in order to reduce patient radiation exposure: (a) adhere to the ALARA guidelines as required by the Nuclear Regulatory Commission (2012), (b) follow the Image Wisely guidelines for adults developed by the American College of Radiology, Radiological Society of North American, American Association of Physicists in Medicine, and the American Society of Radiologic Technologists (Image Wisely, 2012); (c) provide training on how to use new, complex equipment, (d) develop policies and protocols for proper radiographic techniques and dose, (e) develop policies for the appropriate use of lead shielding, and (f) develop standards for promoting a safety culture.

Statement of the Problem

In the past 20 years, total exposure to ionizing radiation has doubled in the United States (National Council on Radiation Protection and Measurements [NCRP], 2009). With the new digital age of radiology, patient dose has increased even more (Marshall & Keene, 2007).

Researchers and educators have suggested possible reasons for the dramatic increase of patient radiation exposure, including: radiologic technology behavior, increased number of exams ordered by primary care providers, availability of self-referred exams, increased number of computed tomography exams ordered, and a lack of a thorough understanding of how to decrease exposure using digital equipment versus analog (film) technology. Marshall and Keene (2007) indicate growing evidence that radiologic technologists could have general disregard for basic, yet essential, radiation safety practices in the new "digital age" of radiology. With digital radiography, an overexposed digital radiograph looks good and will not be recognized as one made with unnecessary exposure (International Atomic Energy Agency, 2009).

Limited research has been done in the area of understanding the behavior of radiologic technologists. Research is needed in the area of understanding the behaviors of radiologic technologists to understand the impact of new technology introductions, the adequacy of initial and ongoing training, the influence of the absence or presence of clearly defined policies, the impact of workload pressure, and the influence of social pressures (Marshall & Keene, 2007). In addition to understanding radiologic technologists' behavior, it is important to understand what organizations can do to increase compliance with safety practices (Slechta & Reagan, 2008).

Research that applies a theoretical framework to understand the intentions, attitudes, social pressures/norms, and perceived behavioral control of radiologic technologists to perform radiation protection best practices has not been studied.

Understanding the issues related to a radiologic technologist's behavior regarding patient radiation protection best practices using a theoretical framework could help to positively address the concern that patient exposure to radiation is increasing.

Purpose of the Study

The purpose of this study was to fill the gap in research by using Dr. Icek Ajzen's (1985) highly validated theory of planned behavior to study the problem:

1. Investigate the relationships between the intentions, attitudes, social pressures, and perceived behavioral control of radiologic technologists when it comes to using patient radiation protection best practices.

2. Identify the relationships between the intentions, attitudes, social pressures, and perceived behavioral control of radiologic technologists when it comes to using new digital x-ray equipment to lower patient dose.

3. Determine the relationship of organizational and demographic factors as it relates to the performance of best practice behavior and the use of new digital equipment.

4. Create a survey instrument with good estimates of reliability and validity to assess the attitudes and behaviors of health care personnel.

Assumptions

This research was based on the assumption that intention to perform the behavior and past behavior are the best predictors of actual behavior (Ajzen, 1985). It is also assumed that the respondents will answer truthfully; that the sample set understands the best practices in radiologic technology; that the radiologic technologists in the sample set understand the ALARA principle, and the standards of practice and codes of ethics for radiologic technologists as defined by the ARRT.

Research Questions

The following research questions were used to form the basis of this study of a radiologic technologist's patient radiation protection best practices, as defined by ALARA and the radiologic technologists' practices standards (collimation, shielding, and optimized radiation exposure technique).

1. Is there a relationship among selected demographic variables (age, gender, years in practice, primary role, area of practice, place of practice) and a radiologic technologist's intention to use patient radiation protection best practices?

2. Do the intentions of radiologic technologists predict past behavior?

3. Do the direct and indirect attitudes of radiologic technologists predict intentions to perform patient radiation protection best practices?

4. Do the direct and indirect social pressures/norms of radiologic technologists predict intentions to perform patient radiation protection best practices?

5. Do the direct and indirect perceived behavioral controls of radiologic technologists predict intentions to perform patient radiation protection best practices?

6. Do the direct attitudes of radiologic technologists predict intentions to use digital equipment and digital techniques to lower patient dose?

7. Do the direct social pressures/norms of radiologic technologists predict intentions to use digital equipment and digital techniques to lower patient dose?

8. Do the direct and indirect perceived behavioral controls of radiologic technologists predict intentions to use digital equipment and digital techniques to lower patient dose?

9. Do the components of Ajzen's theory of planned behavior (attitudes, social norms, perceived behavioral norms) predict intentions and past behavior of radiologic technologists regarding patient radiation protection best practices?

10. Do the components of Ajzen's theory of planned behavior (attitudes, social norms, perceived behavioral norms) predict intentions and past behavior of radiologic technologists regarding the use of digital equipment and digital techniques to lower patient dose?

Research Design

Using the constructs in the theory of planned behavior, this research study investigated the radiologic technologist's use of patient radiation protection best practices and the use of new digital equipment and digital techniques to lower patient dose. This study used an *ex post facto* research design with hypotheses and controls for viable alternative explanations of research outcomes, considered to be the most sophisticated type of *ex post facto* research (Kerlinger & Lee, 1999).

Correlations were found between the variables based on behavior that has already occurred (Newman, Newman, Brown, & McNeely, 2006). The research was based on a quantitative questionnaire. The study was non-experimental in nature. The research was guided by research questions and does not attempt to suggest causation. *Ex post facto* research design frequently "uses analysis of covariance techniques to control for age, gender, race, socioeconomic status, experience, and so forth as alternative explanation," according to Newman et al. (2006, pp. 116-117). See Chapter 3 for more information about the research design.

Theoretical Framework

The design of this study was based on Ajzen's (1985, 1991, 2001, 2002) theory of planned behavior. The theory of planned behavior was used to help understand and predict why people make decisions; it has become one of the most influential conceptual frameworks in the study of human behavior and action (Ajzen, 2001).

"The theory of planned behavior is one of the most thoroughly tested and robust of the social psychological models," state Walker, Watson, Grimshaw, and Bond (2004, pp. 673-674) and has also been widely used to explore factors associated with health professionals' beliefs and attitudes in health-related behavior. It is one of the most predictive behavior theories used in health care, public relations, and advertising.

The theory of planned behavior proposes that a person's behavior can be predicted by the strength of the intention of an individual, which helps researchers to understand the link between attitudes toward the behavior, the subjective norms (social pressures), and perceived behavioral control. "Given a sufficient degree of actual control over the behavior, people are expected to carry out their intentions when the opportunity arises" (Ajzen, 2002, p. 665).

According to Ajzen (1985), "people intend to perform a behavior when they evaluate it positively and when they believe that important others think they should perform it" (p. 12), as well as whether they have power to control the behavior they want to perform. In the radiologic technology setting, the important others may include other radiologic technologists, patients, and the department director/manager. Factors that could facilitate or inhibit behavior might include the work environment, education, and social pressure.

For this study, I chose to create two categories of behaviors: (a) patient radiation protection best practices, and (b) use of new digital equipment and digital techniques to lower patient dose. According to Ajzen (2013), “it is possible to deal with such a criterion by assessing attitudes, subjective norms, perceptions of control, intentions, and actual behavior with respect to each of a representative set of actions that comprise the category of interest.” The validity of these scales was supported by using a table of specifications (see Appendix F) (Newman, Lim, & Pineda, 2011) and table of alignment (see Appendix G).

In addition to using the key constructs in the theory of planned behavior to structure the quantitative questionnaire, the recommendations by The Joint Commission (2011) in order to reduce patient radiation exposure guided the development and direction of the study, specifically in how organizational and leadership issues influence and impact behavior.

Significance of the Study

The intent of this research was to fill a gap in knowledge about how a radiologic technologist’s attitudes, social pressures/subjective norms, perceived behavioral control, demographic factors, and certain organizational variables are correlated with the behavior that supports patient radiation protection best practices. The goal was to address the growing concern that patients, both adult and pediatric, are receiving an increase in radiation exposure while undergoing medical imaging exams.

With the rapid advancement of radiographic imaging technology, specifically with digital imaging and computed tomography, technologists and students have been on a steep learning curve to understand the new equipment, as well as the new policies, procedures, exam outcomes, and workload that go along with the changes in new equipment. It was anticipated that knowledge gained from this research would assist in clarifying the most important factors that will lead to a reduction of patient radiation exposure. Hospital and departmental radiology leadership and radiologic technology educators can use this study to gain a clearer picture of what is needed to ensure that patients continue to be safe during radiologic imaging exams.

This study helps leaders and educators to understand the environment and departmental pressures that keep technologists from transferring their knowledge of patient radiation protection to actual practices. This study also helps us to understand the factors impacting the radiologic technologist's influence on others in the area of patient radiation protection and exposure. The knowledge gained from this research could serve to enhance primary radiologic technology education, as well as help leadership in the development of policies and procedures in a radiology department.

Delimitations

This research was conducted within the following parameters:

1. The focus of this study was delimited to the research questions, variables, and Ajzen's theory of planned behavior.

2. Only radiologic technologists from the following groups were surveyed: working technologists at clinical sites associated with Loma Linda University's Medical Radiography program; Loma Linda University Medical Radiography alumni in the past 7

years; clinical instructors and educators who are members of the Association of Collegiate Educators in Radiologic Technology (ACERT); radiologic technologist educators associated with the Radiologic Health Branch of the Department of Public Health in California; and the current two cohorts of Medical Radiography students at Loma Linda University.

3. Patient radiation protection best practices for this study were defined as shielding, collimation, and optimized radiographic radiation exposure technique.

4. The measure of intent to use patient radiation exposure was studied, not actual observable behavior.

Definition and Operational Terms

The following definitions clarify key terms used in this study:

ALARA Principle: A concept that holds that radiation exposure is to be kept “as low as reasonably achievable” (Nuclear Regulatory Commission, 2012; Sherer et al., 2006).

Attitude: Multiplying behavioral beliefs with the evaluation of the outcome determines attitude. Attitude, in this context, is a psychological tendency that is expressed by an individual when evaluating a particular behavior with some degree of favor or disfavor (Francis et al., 2004). For this study, items 11-22 in the questionnaire measure attitude. See Chapter 3 for a complete listing of the variables that were tested.

Behavioral Beliefs: A behavioral belief is a person’s underpinning perceived consequence toward performing a behavior (Francis et al., 2004). Behavioral beliefs are one aspect of determining attitudes (see Chapter 3).

Best Practices: For this study, patient radiation protection best practices were defined as shielding, collimation, and optimized radiographic radiation exposure technique.

Control Beliefs: What a person believes about the likelihood that one possesses the resources and opportunities necessary to perform a behavior (Francis et al., 2004). Control beliefs are one aspect of determining perceived behavioral control (see Chapter 3).

Digital Imaging: An electronic image that can be viewed and modified on a computer screen (Carter & Veale, 2008).

Elicitation Study: A qualitative investigation of a subset of a population to discover the behavioral, social pressures/norms, and control beliefs about the behavior (Francis et al., 2004).

Influence of Control Beliefs: Influence of a control belief is how difficult a person determines a control belief to be (Francis et al., 2004). Influence of control beliefs is one aspect of determining perceived behavioral control (see Chapter 3).

Intention: Intention is a person's plan to exert effort to perform the behavior. Intention is determined through attitudes, social pressures/norms, and perceived behavioral control (Francis et al., 2004). For this study, items 7-9 in the questionnaire measure perceived behavioral control. See Chapter 3 for a complete listing of the variables that were tested.

Ionizing Radiation: The type of radiation that is used in diagnostic medical imaging, such as radiologic technology and computed tomography. At the correct dose, ionizing radiation is beneficial; however, it has the potential to create molecular activity to cause high biologic damage, depending on the unit of energy of ionizing radiation.

Lead Shield: A shield, whether in the form of a thyroid or gonadal shield, or an apron, protects the patient, radiologic technologist, or radiologist from ionizing radiation exposure. The shield is usually placed in the thyroid and/or gonadal area.

Radiologic Technologist: The person who takes x-rays or radiographs. Other terms used could be medical radiographer or x-ray tech.

Motivation: The extent to which a person feels motivated to comply, or inclined to match behavior to the sources of social pressure (Francis et al., 2004). Motivation is one aspect of determining social pressure/norms (see Chapter 3).

Normative Beliefs: What a person believes about the influence of important others (Francis et al., 2004). Normative beliefs are one aspect of determining social pressures/norms (see Chapter 3).

Outcome Evaluation: How important a person determines a behavioral belief to be (Francis et al., 2004). Outcome evaluations are one aspect of determining attitudes (see Chapter 3).

Past Behavior: A person's self-reported account of behavior performed in the past. For this study, item 10 in the questionnaire measures past behavior. See Chapter 3 for a complete listing of the variables that were tested.

Perceived Behavioral Control: The perceived control over performing a behavior, to the extent that a behavior is believed to be easy or difficult to perform. Perceived behavioral control is determined by multiplying control beliefs by the influence of the control beliefs. For this study, items 38-57 in the questionnaire measure perceived behavioral control. See Chapter 3 for a complete listing of the variables being tested.

Self-efficacy: The confidence or conviction in a person's own ability to carry out a particular behavior. Self-efficacy is a key component when researching attitude and behavior theory.

Social Pressure/Subjective Norms: These terms are used interchangeably to refer to the social pressure from important others to comply with these groups or individuals. For this study, items 23-37 in the questionnaire measure social pressure/norms. See Chapter 3 for a complete listing of the variables that were tested.

Technique: Technique, or radiographic exposure technique, is the term used to describes the amount of miliAmpere seconds (mAs) and kiloVoltage peak (kVp) used to create a radiographic image. The combination of these two items determines the dose of radiation exposure a patient receives during the exam.

Theory of Planned Behavior: A theory that developed out of Ajzen's (1985, 1991, 2001, 2002) work on the theory of reasoned action, stating that people make decisions about their behavior based on their attitude toward the behavior and the subjective norm, but also whether they perceive that they have actual control over the behavior under consideration.

Theory of Reasoned Action: A theory developed by Fishbein and Ajzen (1975) stating that people make decisions about their intended behavior based on their attitude toward the behavior and the subjective norm.

Organization of This Document

Chapter 1 presents the background to the problem, statement of the problem, purpose of the study, research questions, research design, theoretical framework, significance of the study, delimitations, and definitions of terms. Chapter 2 contains a review of the literature and research related to the problem under investigation. Additionally, chapter 2 explores the theory of planned behavior and the application of Ajzen's theoretical framework to predicting the behavior of radiological technologists when using patient radiation protection best practices. Chapter 3 presents the methodology and procedures used to gather data for the study. The results of analyses and findings that emerged from the study are contained in chapter 4. Chapter 5 summarizes the study and findings, and makes recommendations for further study.

Summary

Patient radiation exposure during medical imaging exams has increased in the last 20 years (NCRP, 2009). Some research has been done to suggest that possible reasons may involve the behavior of radiologic technologists. This study was guided by a thorough literature review and the recommendations by the Joint Commission (2011) in order to reduce patient radiation exposure, the theory of planned behavior, aligned research questions, and hypotheses.

CHAPTER 2

REVIEW OF THE LITERATURE

Introduction

Although the risk of cancer from exposure to any single test is likely to be small, concern still exists as the average amount of radiation a person is exposed to from medical tests has risen. According to the American Cancer Society (n.d.), any exposure, however small, is still a real risk.

The focus of this study is on the intentions, past behaviors, attitudes, social pressures/norms, and perceived behavioral control of radiologic technologists regarding patient radiation protection during radiographic imaging exams, as well as the factors that influence patient radiation protection best practices. This chapter contains selected references regarding the problem under study, which is the behavior of radiologic technologists when it comes to patient radiation protection best practices and the use of new digital equipment and digital techniques to lower patient dose. This review of the literature identifies what has been done in research up to this point in order to substantiate the purpose of the study and the contribution that this study will make to the body of knowledge that already exists. The review of literature also played a role in delimiting the problem under investigation (Newman, Lim, & Pineda, 2011).

The organization of this literature review was conducted by identifying the major categories of investigation; reviewing the literature that was both current (in the last 10 years) and historical (as far back as the invention of radiation in 1895); and identifying the major works and dissertations done in the major categories.

The history related to patient radiation exposure and patient radiation protection is important to understand in order to positively address the concern that patient exposure to radiation is increasing. The factors contributing to the increase in medical imaging exams is coming from a variety of sources: the change to digital technology, the increase in the number of exams ordered by physicians, and the increase in computed tomography and nuclear medicine studies.

Chapter 2 is organized in the following way: the historical background of ionizing radiation; the transition from film to new digital technology; society's growing concern about the increase of patient radiation exposure; and the responsibility of the radiologic technologist. Finally, this chapter includes a discussion of the theoretical framework for conducting this quantitative study. Specifically, the literature in the field of the theory of planned behavior developed by Icek Ajzen (1985) was reviewed. See Table 1 for a listing of categories, search criteria, and major sources.

History of Ionizing Radiation and Radiologic Technology

To be able to see inside a solid human body was something that electrified the general public and scientific community when Wilhelm Conrad Röntgen discovered the unprecedented power of "x" radiation in his lab on November 8, 1895 (Bushong, 2008). It didn't take long, though, for both the positive and negative effects of radiation exposure to be discovered (Bushong, 2008; Sherer et al., 2006). By 1897, 69 cases of skin damage were already reported (Edwards, 2010). By 1902, several hundred cases of injuries were documented and directly linked to x-ray exposure.

Table 1

Structure of Literature Review

CATEGORY	SEARCH	MAJOR SOURCES
History	History of radiation, radiation exposure, discovery of radiation, effects of radiation exposure	Medical radiography textbooks, Google word searches
Digital Technology	Digital radiography, effects of radiation exposure, impact of new digital imaging	ASRT white papers, radiology journals, Google word searches, EBSCO (Academic Search Complete), ProQuest (dissertations), ACERT professional meeting, digital equipment manufacturers.
Radiation Exposure	Effect of radiation exposure, Image Gently, Image Wisely, ASRT, ALARA	ASRT white papers, radiography journals, Google word searches, EBSCO (Academic Search Complete), ProQuest (dissertations), medical radiography textbooks, technical reports.
Radiologic Technologist Behavior	Behavior, attitudes, social pressures, organizational issues, code of ethics, best practice behavior, standards of practice	Radiography journals, Google word searches, EBSCO (Academic Search Complete), ARRT Code of Ethics.
Theoretical	Theory of Planned Behavior, Theory of Reasoned Action, self-efficacy, attitude theories, belief theories, behavioral theories, knowledge to action theories	Google word searches, EBSCO (Academic Search Complete), ProQuest (dissertations), Dr. Icek Ajzen's website.

Clarence Dally, Thomas Edison's research assistant, was the first American to die of radiation exposure (Marshall & Keene, 2007). In 1904, soon after the discovery of x-rays in 1895, Mr. Edison and Mr. Dally exposed themselves to x-rays to investigate this new technology. Mr. Dally, who repeatedly exposed his own hands, soon discovered that the burns on his hands were not ordinary burns that would eventually heal; the excessive radiation exposure had turned to cancer. Unfortunately, cancer from his hands soon spread to other parts of his body. Despite efforts to surgically remove the cancer, the radiation exposure that he received ultimately turned fatal. It was not until Dally's death that the medical community seriously considered the idea that excessive radiation exposure could lead to cancer and, eventually, death. Mr. Dally's documentation of his struggle with burns after exposure, multiple health problems that surfaced soon after he started experimentation, his multiple amputations, and his lymph node involvement helped to advance the understanding of x-ray exposure. Even after his death, the current scientific community found it hard to believe that cancer could be directly linked to radiation exposure.

Early Findings: Negative Results of Radiation Exposure

In addition to discovering that radiation overexposure could cause death, the early years of radiation experimentation produced many more negative findings. By 1903, researchers used x-rays to permanently sterilize rabbits and guinea pigs of both genders, as well as produce leukemia in mice. By 1904, researchers linked the development of cataracts with the direct exposure of ionizing radiation to the lens of an animal's eyes. Also, in 1904 researchers discovered that immature cells and rapidly dividing cells were more sensitive to ionizing radiation. Researchers also found that blood-forming cells in bone marrow were more sensitive to injury. According to Edwards (2010), radiation burns, even though the burns had healed, often turned into cancer later on in life. Additionally, in the 20-year period prior to 1949, radiologists involved with radiation exposure were diagnosed with leukemia at a factor nine times more than the normal rate.

By the late 1920s, researchers discovered the biological effects of ionizing radiation, such as damage to genes and chromosomes. Researchers also discovered that some of this damaged genetic material could be transmitted to future generations. According to Edwards (2010), in 1929, two doctors, Goldstein and Murphy, published a study of children born after their mothers had received pelvic x-rays. While the numbers were small (650 pregnancies in all), the results were of interest to the research community because of the ramifications. Over half of the children born to women irradiated during pregnancy were unhealthy, while the corresponding figure for women irradiated before conception was only 11%.

Early Findings: Benefits of Radiation Exposure

The early years of radiation experimentation not only provided knowledge of the harmful impact of overexposure, but researchers were also pushing toward discovering the benefits of radiation exposure. The first medical application of x-rays for diagnosis and therapy was made in 1896 (Bushong, 2008), 1 year after the initial discovery of ionizing radiation. After painfully injuring his hand with x-rays, medical student Emil Grubbe convinced one of his professors to allow him to use radiation to treat one of his patients, Rosa Lee, who was suffering from advanced breast cancer. Lee responded to the treatment, and as a result, Grubbe is credited with the first recorded therapeutic use of x-rays to shrink tumors (University of California, 2010).

Implications of Radiation Exposure

Because of the serious implications of excessive or unnecessary radiation exposure, understanding the importance of radiation protection is vital. Three factors must be considered when identifying the need for continued focus on patient radiation protection best practices.

First, radiation exposure, for the most part, is painless. People absorb low levels of radiation every day (Lee, 2011) from the sun, rocks and soil, and household appliances. The human body can absorb large amounts of x-rays without seeing or feeling any immediate signs. If the radiation dose is spread out over a long period of time, such as days or weeks, it is possible to absorb enough radiation to cause death, without even feeling it (Bushong, 2008). The negative effects of radiation exposure usually occur long after a specific exposure to radiation (Sherer et al., 2006).

Second, radiation exposure is cumulative, which means that every incidence of radiation exposure is added together over a person's lifetime (Bushong, 2008). The dose-response relationship from radiation exposure is not necessarily predictable, meaning that a particular dose of radiation may or may not generate a response in one person, but it could in another.

Third, people are more sensitive to radiation exposure at younger ages, particularly the fetus and pediatric children (Peck & Samei, 2013). With a multiplication factor for risk at x1 at the age of 30, a child less than 10 years of age has a multiplication factor for risk of x3, 10-20 years of age is x2, 20-30 years of age is x1.5, 30-50 years of age is x0.5, 50-80 years of age is x0.3, and over 80 years of age is negligible risk (Janssens, 2004).

High energy, high frequency, and short wavelength electromagnetic waves result in cell damage. This type of radiation is called ionizing radiation because it possesses the ability to alter cells within tissue. Any time ionizing radiation, or x-rays, interacts with living tissue, biological changes occur. These biological changes may be beneficial or harmful. Biological changes are caused by the ionization of atoms, which causes chemical changes to the cells. Ionizing radiation creates change, and potential damage, to living systems by removing (ionizing) electrons from the atoms composing the molecular structures of those systems (Sherer et al., 2006).

At certain levels, ionization and the chemical changes of the cells have no harmful effect on living beings; however, as radiation exposure increases, harmful effects can occur. The absorbed energy, or absorbed dose, from ionizing radiation in the patient's body tissue is responsible for biologic damage (Sherer et al., 2006). If radiation exposure is great enough, cell damage or cell death can occur. As evidenced from the very beginning of radiation experimentation, burns, diseases such as cancer or leukemia, or even genetic effects in future generations can occur as a result of cell damage or cell death (Bushong, 2008; Sherer et al., 2006).

Early in the discovery of the impact of radiation exposure, imaging practitioners assumed that any dose below a dose that produces a sunburn-like reddening of the skin (the "erythema dose") is safe (Bushong, 2008; Edwards, 2010). What Bushong (2008) and Sherer et al. (2006) report is that reddening of the skin after radiation exposure is the first observed biologic response to high levels of radiation exposure; additionally, Picano (2004) points out that now "current radiation protection standards and practices are based on the premise that any radiation dose, no matter how small, can result in detrimental health effects" (p. 576).

When the biological change caused by ionizing radiation is significant, somatic and genetic damage can also occur. The somatic effects of biologic damage from ionizing radiation are changes that are not genetic in nature. Early somatic effects can occur within minutes, hours, days, or weeks from the time of exposure. Late somatic effects are non-genetic effects that appear after a period of months or years following exposure to ionizing radiation. Genetic effects are biologic damage from ionizing radiation that affects reproductive cells, and radiation exposure to reproductive cells can cause genetic effects (Edwards, 2010) in future generations that are yet unborn (Sherer et al., 2006).

Every radiation dose-response relationship has two characteristics: linear or nonlinear, and threshold or non-threshold. See Figure 1. A linear dose-response is a response that is directly proportionate to the dose. A nonlinear dose-response is a response that is indirectly proportional to the dose. The terms threshold and non-threshold refer to the point at which a dose-response occurs. A threshold dose is a dose at which a response to increasing x-ray intensity first occurs. A non-threshold dose indicates that any dose, no matter how small, is expected to produce a response.

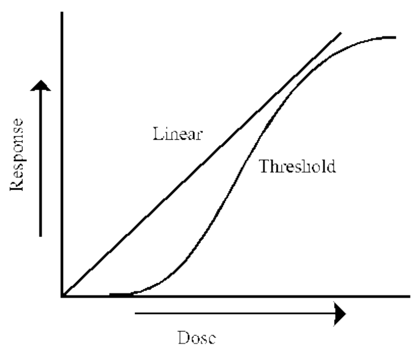

Figure 1. Dose-response relationship.

According to Bushong (2008), “radiation-induced cancer, leukemia, and genetic effects follow a linear non-threshold dose-response relationship” (p. 517). This means that a patient could get cancer or leukemia, or even display genetic effects from radiation exposure, after a specific exposure to radiation at any dose.

Another important concept to understand about radiation exposure is the reference levels for different types of exams (Peck & Samei, 2013). As shown in Tables 2-5 (Peck

& Samei, 2013; Schueler et al., 2007), some medical imaging exams produce an effective dose that is minimal, low, medium, and high. Understanding these ranges places the concern for patient radiation exposure in perspective.

When the concepts of dose-response relationships, cumulative absorption, and latent effects are understood, the value of patient radiation protection using ALARA (as low as reasonably achievable) can be more fully appreciated.

Table 2

Relative Radiation Level Scale

Relative Radiation Level	Effective dose range
None	0
Minimal ☢	Less than 0.1 mSv
Low ☢☢	0.1–1.0 mSv
Medium ☢☢☢	1.0–10 mSvq
High ☢☢☢☢	10–100 mSv

Note. Data from "How to Understand and Communicate Radiation Risk," by D. J. Peck and E. Samei, 2013, *Image Wisely: Radiation Safety in Adult Medical Imaging.* Retrieved from http://www.imagewisely.org/Imaging-Professionals/Medical -Physicists/Articles/How-to-Understand-and-Communicate-Radiation-Risk.

Table 3

Average Effective Dose in Diagnostic Radiology

Exam	Relative Radiation Level	Range of values (mSv)
Extremity	☢	0.0002-0.1
Chest X-ray PA / LAT	☢	0.007-0.24
Mammography	☢☢	0.1–0.6
Abdomen / Pelvis	☢☢	0.04-1.2
Thoracic / Lumbar Spine	☢☢☢	0.5–1.8
IVU	☢☢☢	0.7–3.7
Upper GI w/fluoroscopy	☢☢☢	1.5-12
Barium enema w/fluoroscopy	☢☢☢	2-18

Note. Data from "How to Understand and Communicate Radiation Risk," by D. J. Peck and E. Samei, 2013, *Image Wisely: Radiation Safety in Adult Medical Imaging.* Retrieved from http://www.imagewisely.org/Imaging-Professionals/Medical -Physicists/Articles/How-to-Understand-and-Communicate-Radiation-Risk.

Table 4

Average Effective Dose in CT

Exam	**Relative Radiation Level**	**Range of values (mSv)**
Head	☢☢☢	0.9–4
Chest (standard)	☢☢☢	4–18
Chest (high resolution, e.g., pulmonary embolism)	☢☢☢☢	13–40
Abdomen	☢☢☢	3.5–25
Pelvis	☢☢☢	3.3–10
Coronary Angiogram	☢☢☢☢	5–32

Note. Data from "How to Understand and Communicate Radiation Risk," by D. J. Peck and E. Samei, 2013, *Image Wisely: Radiation Safety in Adult Medical Imaging.* Retrieved from http://www.imagewisely.org/Imaging-Professionals/Medical-Physicists/Articles/How-to-Understand-and-Communicate-Radiation-Risk.

Table 5

Average Effective Dose in Interventional Radiology

Exam	Relative Radiation Level	Range of values (mSv)
Head/Neck angiography	☢☢☢	0.8–19.6
Coronary angiography (diagnostic)	☢☢☢	2–15.8
Coronary angioplasty, stent placement, RF ablation	☢☢☢☢	6.9–57

Note. Data from "How to Understand and Communicate Radiation Risk," by D. J. Peck and E. Samei, 2013, *Image Wisely: Radiation Safety in Adult Medical Imaging.* Retrieved from http://www.imagewisely.org/Imaging-Professionals/Medical-Physicists/Articles/How-to-Understand-and-Communicate-Radiation-Risk.

From Film to Digital

From 1895 when the x-ray was discovered (Bushong, 2008), to 1978 when the first analog wave form medical image was converted to a digital image (Goodman & Oakley, 2003), to 1984 when the first computed radiography x-ray systems pioneered by Fuji Systems came on the market (Bushong, 2008; Hensley, 1997), x-ray images have been displayed on film transparences, and then hung on a lighted view box. With computed and digital technology, x-ray images can be viewed on computer displays, or printed on film to be viewed on a lighted view box.

Digital radiography (DR), whether it is computed radiography (CR) or direct digital radiography (DDR), does have some specific advantages over film/screen radiography. Digital radiography (a) eliminates chemical processing of films, (b) reduces the space requirements needed for storing film images, (c) makes it possible to optimize image quality and visibility of pathologic conditions after the exposure is made, and (d) provides a way to rapidly transmit images to any computer for viewing by a physician. Additionally, early clinical studies showed that digital images have some advantages in contrast (Hensley, 1997).

Moving from film to digital imaging is rapidly expanding. Herrmann (2012) reports that a census conducted between 2005 and 2006 indicated that of the 4,860 hospitals surveyed, 56% had already installed digital computed radiography (CR) equipment and 30% had installed direct DR systems.

According to the International Atomic Energy Agency (IAEA, 2009), digital radiography does offer many definite advantages; however, several disadvantages also exist. Digital radiography can cause increased patient radiation exposure. Because of the wide dynamic exposure range of digital radiographic receptors, images can look good and possess the appropriate contrast, while at the same time the patient can be either overexposed or underexposed. Digital radiography makes it possible to have a wide range of exposures, yet still create good images. Sprawls Education Foundation (2012) states:

> Excessively high and unnecessary exposures can be used to form images. While these images will have good quality there will be unnecessary exposure to the patient. This problem does not exist with film radiography because the increased exposure will result in a visibly overexposed film. (p. 1)

In film radiography, “overexposure” produced dark films, thus, requiring a repeat exam. Likewise in film radiography, “underexposure” produced light films, thus, requiring a repeat exam. With digital radiography, an overexposed digital radiograph looks good and will not be recognized as one made with unnecessary exposure (International Atomic Energy Agency, 2009).

According to the International Atomic Energy Agency (2009), digital imaging systems do have the potential for reducing patient radiation dose, but current practice shows that many facilities provide increased dose to patients. The main reason for patient overexposure is that image overexposure goes undetected. With film, when an image is dark, you see it as dark; however, with digital imaging, the radiologist is still able to interpret the images, even though the images are overexposed (or dark). The International Atomic Energy Agency also states that the tendency is to take more images unnecessarily. The IAEA has also noted that several hospitals documented that the number of examinations per inpatient day and outpatient day increased after transitioning from film to digital. Another point that the IAEA reveals is that, with digital, repeat rates due to wrong positioning, wrong exposure, or motion blur are going undetected since radiologic technologists can delete unwanted views. As a result, patient radiation exposure due to repeat exams is going undocumented.

According to the International Commission on Radiological Protection (2004) it is not easy to recognize overexposure. First, actual dose values in radiographic terms, such as rem or rad, are not recorded or displayed. Second, automatic algorithms are run prior to image display, which create a screen image that looks correct. As a result, patient overexposure may go undetected. Third, the quality of display monitors in the technologist area is at a lower resolution quality than the monitors used by radiologists, so images may appear of good quality even when they are over- or underexposed. Fourth, the dose capture and dose reporting systems vary depending on the x-ray equipment manufacturer.

Herrmann et al. (2012) state:

> Historically, radiation exposure from diagnostic medical imaging was not considered a problem, and there was no evidence that exposure to low doses of ionizing radiation increased cancer risk. The benefits of radiography have remained clear over the more than 100 years of diagnostic medical imaging's history. Another fact that has remained clear is the critical role that radiographers play in ensuring patient radiation safety during medical imaging procedures. Radiographers must adhere to the "as low as reasonably achievable" (ALARA) principle by keeping radiation dose as low as is reasonably achievable when performing digital radiography. (p. 83)

Loren Sachs, Program Director at Orange Coast College, who presented at the Association of Collegiate Educators in Radiologic Technology (ACERT) meeting (February 2012), reported consistent thoughts from Herrmann et al. (2012) stating that digital imaging is contributing to an increase of radiation exposure to patients because of a lack of understanding and training on the technologist's part regarding how digital imaging exposure impacts image quality. Sachs, who teaches physics and imaging principles in his digital radiography lab, shared results of his lab experiments with students. The experiments show students how digital imaging technology can impact the increase of patient radiation exposure, if the new technology is not properly understood or used.

The results of Sachs's academic lab experiences confirm the experiments conducted by Dennis Bowman, a presenter at the Association of Educators in Imaging and Radiologic Science (AIERS) meeting in April 2009. Bowman (2009) states that in the film/screen world, when a film was light, you couldn't do anything about it. As a result, the motto "when in doubt, dark it out" was born. The coined phrase meant that whenever a technologist was not sure about a radiographic technique, the best guess was to always go on the dark side. This concept, according to Bowman, is completely different in the digital world. In the digital world, computerized algorithms, windowing, and cropping, a low technique and a high technique could generate an acceptable image. Bowman stresses that radiologic technologists need to understand how digital imaging works so that the least amount of radiation possible is used to create a great diagnostic image. Bowman says, "We had to be so much better in the film/screen world" because there was a narrower margin of error. Bowman stressed that now, with digital radiography, "it's like taking a picture on your digital camera. It is now way too easy to repeat an image! Techs have forgotten that *every* exposure causes tissue damage to their patient."

Herrmann et al. (2012) offer a balanced perspective of the changes in digital radiography and the best practices of radiographers:

> As radiographers have adjusted to the advent of digital radiography, they have had to refine exposure technique selection and pay closer attention to radiation protection. Newer digital technologies offer many benefits over film-screen technology, such as time savings, greater dynamic range, wider exposure latitude and post-processing capabilities, plus advantages such as image manipulation that enable radiologists to adjust images at their workstations. As a result, there is a tendency to be less concerned about exposure technique and the opportunity to use more radiation than necessary, a trend that often is referred to as "dose creep." Exposure techniques that radiographers can use to ensure that digital images are of optimal quality and minimal patient radiation dose differ from those used for film-screen imaging. Because digital imaging technology is relatively new and rapidly changing, radiographers' skill levels vary, and resources often are scattered and even conflicting. Radiographers, and their patients, would benefit from a single source that offers background information, best practices and recommendations on optimizing digital radiography and patient radiation safety. (p. 1)

Hermmann et al. (2012) suggest that a best practice with digital x-ray exams involves the following:

> The use of higher kVp values along with an appropriate decrease in mAs is a practice advocated by some imaging professionals for many adult digital exams. Increasing the kVp by 15% with a corresponding decrease in mAs reduces patient radiation exposure. Because increasing kVp decreases image contrast and increases scatter radiation reaching the image receptor, the use of a grid may be necessary. Specifying the kVp level for digital exams along with grid use are important exposure technique variables to standardize in a radiology department. A best practice in digital imaging is to use the highest kVp within the optimal range for the position and part coupled with the lowest amount of mAs needed to provide an adequate exposure to the image receptor. (p. 8)

Hermmann et al. (2012) also suggest the following best practices in digital radiography: (a) use of exposure technique charts that are continuously updated and applied to a wide range of patient sizes; (b) collimate the x-ray beam to the anatomic area appropriate to the procedure; (c) use of lead shielding for anatomic parts that are adjacent to the x-ray field; (d) ALARA principles; (e) become familiar with the exposure index standards for their digital equipment; (f) take specific steps to lower exposure on pediatric patients; (g) ensure the base knowledge and continued applications training on digital equipment; and (h) develop collaborative and supportive work team that fosters safety and ethical behavior.

Society and Organizational Concerns of Increasing Radiation Exposure

The behavior of diagnostic radiologic technologists is a key factor in lowering patient dose. Collimation, adequate shielding, appropriate distance, optimal kVp and mAs, correct positioning, and effective patient communication must all be considered for each examination in order to perform a diagnostic study with minimal exposure (Adams, 2012). For each examination, radiologic technologists must assess the patient condition correctly, use critical thinking skills, perform professionally and effectively, and adjust to the environment, such as surgery, trauma, fluoroscopy, or intensive care.

In April 2007, the American College of Radiology released a white paper on the radiation dose in medicine. The researchers concluded that with the expanding use of radiologic modalities using ionizing radiation, an increased incident of radiation-related cancer was likely to occur (Picano, Vano, Semelka, & Regulla, 2007). Berrington de Gonzalez et al. (2009) estimate that CT scans performed in the United States in 2007 could be the cause of approximately 29,000 future cancers. Picano (2004) raises the issue and the United States Federal Drug Administration (FDA, 2010) agrees that to reduce the number of inappropriate examinations, and the impending biological burden on future generations, both doctors and patients need to increase their awareness of the hazards of radiation exposure. Physicians ordering radiologic exams may lack or be unaware of the criteria to guide their decisions on whether a specific imaging exam has medical efficacy.

According to a report by the National Council on Radiation Protection and Measurements (NCRP, 2009), the United States population's total exposure to ionizing radiation has nearly doubled in the past 20 years from 3.6 mSV to 6.25 mSv, and medical imaging exams using ionizing radiation have increased from 15% to 48% per capita exposure. Current reports estimate that 400 million medical imaging procedures are performed annually in the U.S. (Beckman, 2010). Furthermore, concerns have been raised regarding the standardization of imaging exam protocols. For instance, Smith-Bindman et al. (2009) report a 13-fold variation between the lowest dose and highest dose on the same exam done at several medical institutions in the San Francisco area.

Although advances in medical imaging allow physicians to detect diseases and make more accurate diagnoses, radiation safety experts at the International Atomic Energy Agency (IAEA, 2009) say that overuse of high-tech scanning procedures may unnecessarily expose patients to increased radiation levels.

The IAEA (2009), in collaboration with other international organizations, has developed a series of measures aimed at strengthening patient protection. "The medical application of ionizing radiation is the fastest growing source of radiation exposure to human beings today," says Renate Czarwinski, Head of the IAEA´s Radiation Safety and Monitoring Section. "We acknowledge the great value of the new technologies, but want to ensure that each and every examination is justified. The radiation protection of patients is also important," Czarwinski says.

According to the latest estimates of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), as many as 4 billion diagnostic x-ray examinations are carried out worldwide each year. This represents an increase of more than 17% over the last 10 years in the collective dose to the world's population. In particular, the use of CT scanning has grown dramatically in recent years (IAEA, 2009).

The objective of the IAEA (2009), as one of the key international players in the field of patient radiation protection, is that the radiation protection of patients is given increased attention by health professionals, manufacturers, trainers, and policy makers. IAEA (2009) Radiation Safety Specialist Madan Rehani states: “We´re attacking the issue from every angle.”

Picano (2004) supports the findings of the IAEA, stating that “contemporary medicine relies heavily on radiological and mediconuclear investigations and procedures; however, the often essential information derived from such investigations is obtained at a risk that few doctors are fully aware of” (p. 579). Over 5 billion imaging examinations are performed worldwide each year (Picano et al., 2007), and two out of three of these exams use ionizing radiation. Picano (2004) further reveals that in some hospitals, patients may be more likely to receive a total body scan (using ionizing radiation to the whole body) than they are to receive a thorough history and physical exam. Another trend that is occurring in the medical field, according to Picano (2004), is that patients are demanding “more examinations and feel reassured by high tech ones” (p. 579). In addition, the economic drive for expensive testing, as well as the doctor’s concerns for medicolegal action if they don't use the latest investigations, has also helped to increase the use of radiologic studies using ionizing radiation.

Another concern is the risk of radiation exposure to pediatric children and young adults. Smith-Bindman et al. (2009) estimate that the risks of developing cancer for 20-year-olds undergoing a coronary angiography CT scan are approximately twice as much as for those who are 40 when they undergo the same procedure. The IAEA (2009) concurs with Smith-Bindman et al. (2009) on the discussion of CT exams: “It´s been estimated that the average radiation dose of one CT scan is equal to roughly 500 chest X-rays. And that can increase a patient´s lifetime risk of cancer, particularly if CT scans are repeated” (IAEA, 2009).

Dorfman et al. (2011) suggest that exposure to ionizing radiation from medical diagnostic imaging procedures is occurring frequently among children, and efforts to optimize the appropriate use of pediatric radiographic procedures should be prioritized. In their study of 355,088 children, 436,711 imaging procedures using ionizing radiation were performed on 150,930 patients (42.5%). Children older than 10 years and infants younger than 2 years received the most procedures. Radiography accounted for 84.7% of imaging procedures performed; CT scans, associated with higher doses of radiation, accounted for 11.9% of all procedures during the study period. Overall the researchers found that 7.9% of children received at least one CT scan and 3.5% received two or more, with computed tomographic scans of the head being the most frequent.

Picano (2004) points out: “Long-term risks are not being weighed against the immediate short term diagnostic benefit” (p. 579). Several factors indicate that radiation exposure is needlessly increasing. In some countries, reports Picano, patients can have a CT exam without referral from a physician. Some patients are receiving a total body scan without a physical exam from a physician. In addition, patients are receiving the same radiologic exams as follow-up for benign disease. This serial scanning has created concerns because of the increased radiation dose with CT, especially with children (Picano, 2004). Finally, CT scans and radiography exams are sometimes done without adjusting the dose to the weight of the child, resulting in up to 50% more dose, which is unnecessary (Ron, 2002). When this small individual risk is multiplied by millions of examinations a year worldwide, it has the potential to become an important population risk.

According to the Royal College of Radiologists and National Radiological Protection Board (1990) in the United Kingdom, about 100-250 deaths occur each year from cancers directly related to medical exposure to radiation. Few doctors know the level of radiation that their patients are exposed to during radiological investigations, states Shiralkar et al. (2003). One reason why doctors are unaware of the radiation dose of radiologic exams is that basic radiological information is often difficult to find and understand. The terminology is also non-standardized and is reported at a technical or scientific level, making it difficult for researchers and clinicians to understand the radiation dose and risks connected to procedures. Picano (2004) is calling for an increased awareness in the medical community of the risks of radiation exposure, and to make medical providers more aware of the medical and social priority of reducing patient radiation exposure.

For more than 100 years, ionizing radiation has been used in medicine to diagnose. Advancements in medical imaging (diagnostic radiography, nuclear medicine, and computer tomography) have made it possible to reduce invasive, surgical studies; however, the diagnostic and therapeutic role of imaging has created a significant increase in the cumulative exposure to ionizing radiation (Amis & Butler, 2010). “The number of radiographic and fluoroscopic studies skyrocketed from 25 million to 1950 to 293 million in 2006” (Herrmann et al., 2012, p. 1). This increases the potential risk of cancer. Some of the reasons for a significant growth in imaging use include access to more accurate technology, increased need for more immediate diagnosis, increased need for increased patient throughput in a busy clinic, increased patient demand, and lack of radiation safety training for non-radiologist providers (Amis & Butler, 2010).

A variety of suggestions have been made to help address the radiologic technology use of best practices to reduce radiation exposure, from installing radiation shields to training workers to do their work efficiently and correctly the first time.

The American College of Radiology White Paper on Radiation Dose in Medicine, published in May 2007 (Amis & Butler, 2010), suggests that education in radiation safety principles could help address this growing concern. Training on how to use complex, new digital technology is also appropriate (Joint Commission, 2011).

Colangelo et al. (2009) report that education is a significant component for ensuring compliance with protective standards and practices. They also state that radiologic technologists have both a professional and ethical duty to protect their patients. Marshall & Keene (2007) observe, however, a change in radiologic technologists from when they are students to becoming seasoned professionals:

> Sadly, as time progresses in some technologists' careers, they tend to forget the importance of some of the basic, yet essential radiation safety practices they once learned. It is commonplace to see technologists holding patients during procedures, a practice clearly taught against in radiologic technology education programs and in medical literature. Also, technologists may sometimes be seen in procedure rooms during exposures without even wearing a lead apron. New imaging technologies now make overexposing the patient the quickest way to complete a procedure. Clearly, the field of diagnostic radiology is changing, putting pressure on technologists to produce

> quality images in very short periods of time, which can lead to technologists putting themselves or others in harm's way. (p. 2)

Slechta and Reagan (2008) found in their literature examination of factors related to radiation protection practices that the majority of research centered on factors related to radiation protection when doing an exam properly, rather than the noncompliance with safety and patient radiation protection best practices.

Additionally, Tilson (1982) studied the relationship between age, gender, professional training, years since completion of training, years of professional experience, and radiation safety practices. Tilson found that age and years of professional experience positively correlated with radiation protection practices. Repeat rate was also significantly related to level of training, with college-trained radiologic technologists producing a lower repeat rate. In a study by Limley et al. (1987), the results of a survey to Texas hospitals showed that larger hospitals were more likely than smaller hospitals to offer radiation safety education at the department level, and to offer it formally. The authors concluded that a need for increased radiation safety education existed, especially in small hospitals.

Slechta and Reagan (2008) also found that when a radiologic technologist was deficient in the knowledge of or adherence to radiation safety practices, the result was an increase in unnecessary exposure to patients and personnel. Even when a one-time unnecessary exposure may not have significant adverse effects, the effect of radiation exposure over the lifetime of an individual is cumulative and can result in eventual harm to those exposed (Adler, Carlton, & Wold, 1992; Barker, 1978; Franz, 1983).

“The radiologic technologist plays an important role in the radiation protection equation that includes adhering to strict protective guidelines, avoiding unnecessary exposures and remaining current with radiation biology and radiation protection continuing education" (Colangelo et al., 2009, p. 438). Limiting the radiation dose to the patient is a shared responsibility between the ordering physician, the hospital, the radiologist, the equipment manufacturer, the radiologic technologist, the patient, and the radiation safety officer.

Tight staffing ratios, long shifts, overtime, and workload stress can negatively impact the desire and time of radiologic technologists to be a patient advocate, learn new technology, understand the principles of digital technology, increase in computer literacy, and adjust to a changing work environment (Watson & Odle, 2013). Studies have shown that with the implementation of PACS (Picture Archiving and Communication Systems), electronic health records (EHR) and digital imaging, shorter turnaround times and increased medical imaging department volume have occurred without a subsequent staffing increase (Nitrosi, Borasi, & Nocoli, 2007). Clear policies and protocols that identify maximum doses, standardized doses, and ensure the use of shielding are suggested by the Joint Commission (2011).

Johnston, Killion, Veale, and Comello (2011) conducted a study to determine the reasons for the practices of radiologic technologists to reduce radiation dose to patients. The study showed that 55% of the radiologic technologists reported that they routinely use precise collimation, area shielding, appropriate technique, and attention to proper SID as ways of reducing patient dose. Overall, 41% report that their facilities have policies for a higher kVp/low mAs technique system with the transition to digital. When asked about the monitoring of exposure index values, responses ranged from 13% saying this never happened, to 37% responding it always is the case. Johnston et al. (2011) state:

> It would seem that the issues identified with this research question can be addressed with proper departmental policies and protocols followed by strict administrative enforcement of the same. Again, in-service education regarding the importance of adherence to policies and protocols would seem appropriate. (pp. 317-318)

Studies by Tilson (1982) and Limley et al. (1987) identified factors related to compliance with radiation safety practices and provided a foundation for further research. Slechta and Reagan (2010) found that knowledge of safety practices was higher than compliance with safety practices. Additionally, participation in continuing education about radiation safety was high, yet compliance was low. Slechta and Reagan suggest the need for further research in the area of compliance and transferring learning to practice.

Colangelo et al. (2009) propose that even though researchers have shown that policies and procedures for radiation protection can be simple and effective, those policies have not been fully explained or implemented, and are not part of widespread practice. The position of the American Society of Radiologic Technologists (ASRT, 2011a) is that "all personnel performing digital radiography be educationally prepared and clinically competent in the operation of this equipment, including methods to reduce patient radiation dose" (p. 3).

Colangelo et al. (2009) agree and encourage radiologic technologists to become educated with institutional policies and procedures, verify that they are in compliance with standards and recommendations set by the ACR and other regulating agencies, expand their knowledge and expertise in protective practices and policies, use continuing education materials to review the basics of radiation biology and radiation physics, use protective equipment, and strive to accurately describe radiation protection principles to patients in understandable language so the public can respect the risks of radiation while understanding the medical benefit.

The Responsibility of Radiologic Technologists

Radiologic technology is a term used by the American Society of Radiologic Technologists to describe the medical specialties that use ionizing and non-ionizing radiation for diagnostic imaging and therapeutic intervention (ASRT, 2011a). The specialties include radiography (x-ray), radiation therapy, ultrasound/sonography, nuclear medicine, mammography, cardiovascular-interventional radiography, computerized tomography (CT), magnetic resonance imaging (MRI), and bone densitometry.

The specialties using ionizing radiation include: radiography, radiation therapy, mammography, cardiovascular-interventional, and computerized tomography. As a combined discipline, radiologic technologists are the third largest category of health care professionals, exceeded only by nurses and physicians (American Registry of Radiologic Technologists, 2011).

Radiography is the allied health profession where radiologic technologists manipulate radiation equipment and patients, as well as use a dose of ionizing radiation to produce anatomic images of the human body that aid in the diagnosis of disease or injury by physicians (American Medical Association, 2006). The radiologic technologist is the main person responsible for radiation protection when radiographic exams using ionizing radiation are being performed.

Radiation from diagnostic radiology is the largest contributor to radiation dose in developed countries (Hufton, Doyle, & Carty, 1998). As a result, radiologic technologists are bound by a Code of Ethics and a Standards of Practice, along with federal laws, to provide quality patient care, perform appropriate procedures, and protect the patient from unnecessary exposure to radiation. From the early 1950s to the present day, the expectation of any ARRT-certified and state-licensed radiologic technologist is to hold high standards for quality of care and to implement the ALARA principle (Sherer et al., 2006). As previously mentioned, the ALARA principle is to administer radiation “as low as reasonably achievable.” Although the medical profession and the general public agree that the use of radiation exposure for medical diagnosis is acceptable, radiation exposure must be minimized due to the harmful effects of excessive exposure over the entire life of an individual.

The state of New York was the first state to start licensing procedures for individuals who operated radiation equipment (Beckman, 2010). New Jersey and California were the second and third states to draft laws in 1969 for licensing radiologic technologists. In 1970, Senator Randolph Jennings from West Virginia introduced a bill to set minimum federal standards for education and licensure for radiologic technologists and radiation therapists. Unfortunately the bill was not heard by the full Senate; it was not until 1978 that the bill was renamed the Consumer-Patient Radiation Health and Safety Act. Yet it wasn’t until 1981 that the bill was reintroduced in the Senate and 1 month later in the House of Representatives. Approximately 42 states have some level of regulation and licensure laws, but these laws have a wide variance between them. The Consistency, Accuracy, Responsibility, and Excellence in Medical Imaging and Radiation Therapy (CARE) bill being considered in Congress will amend and enforce the Consumer-Patient Radiation Health and Safety Act of 1981 (American Registry of Radiologic Technologists, 2010).

Because of responsibility that radiologic technologists have, not only to protect their patients but also to protect themselves and other individuals in the vicinity of radiologic exams, students are taught, from the very beginning of their medical radiography education, the importance of radiation safety.

Medical radiography best practices include: correct patient, correct procedure, correct part, appropriate collimation, lead shielding when it is called for by the exam, positioning aids, optimal radiographic technique, ALARA, and continuing education (ASRT, 2011b, 2011c; Bradley, 2012; Colangelo et al., 2009; Herrmann et al., 2012; Joint Commission, 2011; Watson & Odle, 2013).

Students are also taught and are responsible for the ASRT Code of Ethics (2011b). The seventh Code of Ethics specifically addresses radiation protection:

"The radiologic technologist uses equipment and accessories, employs techniques and procedures, performs services in accordance with an accepted standard of practice, and demonstrates expertise in minimizing radiation exposure to the patient, self, and other members of the healthcare team" (p. 1). Additionally, radiography students learn legal and ethical practices when it comes to providing quality patient care, performing appropriate procedures, and protecting the patient from unnecessary exposure to radiation. Students are also taught that protecting patients from unnecessary radiation exposure is their primary concern, as well as their social responsibility.

According to Bushong (2008),

> the benefits derived from the application of x-rays in medicine are indisputable; however, such applications must be made with prudence and with care taken to reduce unnecessary exposure of patients and personnel. This responsibility falls primarily on the radiologic technologist because the technologist usually controls the operation of the x-ray imaging system during a radiologic examination. (p. 6)

“No other health professional is responsible for understanding radiation safety and imaging and interventional procedures. In fact, protecting patients, coworkers and themselves from excessive radiation exposure is the fundamental cornerstone to the practice of radiologic technologists” (Colangelo et al., 2009).

Although the occupational dose of radiation to radiologic technologists has decreased over the past 20 years, patient dose has increased, according to Marshall & Keene (2007). Marshall & Keene also state that a general disregard for basic, yet essential, radiation safety practices in the new digital age of radiology is evident. Even though recent advancement in diagnostic radiology equipment concerning speed and imaging quality exists, few improvements limiting aspects of radiation dose exist.

As stated earlier, for the radiography student, a large portion of the curriculum is on the topic of radiation protection, not only for the patient, but for the health care team and the technologist. One of the first courses taught in a radiologic technology program includes principles for radiation protection. For a radiologic technologist, the three key principles of patient radiation protection include reducing the time of radiation exposure, increasing distance between the source of radiation and the person being exposed, and placing a shield between the person being exposed and the source of radiation (Marshall & Keene, 2007). These principles of radiation protection and exposure are to be used to reduce patient and technologist radiation dose when used properly in diagnostic radiology (Bushong, 2008). Additionally, the radiography students and radiologic technologists are trained to use the proper x-ray beam collimation, appropriate radiographic technique selection including killovoltage power (kVp) and milliamperage-seconds (mAs) to decrease radiation dose (Bushong, 1991).

Colangelo et al. (2009) state that radiologic technologists "play an important role in the triad of protection. Radiology professionals have a duty to understand the concepts behind radiation protection so they can be fully equipped to protect themselves and the patients they serve" (p. 440). Colangelo et al. also assert that with the increasing use of CT scans and interventional fluoroscopic procedures, the general public is at a greater risk, now more than ever, for overexposure to ionizing radiation from medical imaging sources.

Theoretical Framework: The Theory of Planned Behavior

Why do people act the way they do? Why do people believe what they believe? Why do people have the attitudes that they hold? Are a person's actions random or predictable? Can those behaviors and attitudes be influenced, or even changed? What does the perception of someone else have on a person's behavior? Asking these questions is very pertinent when attempting to understand and explain behavioral intention.

Nunnally (1994) argues that measurement is the major issue in psychological studies. He states that there "are many theories, but a theory can be tested only to the extent that its hypothesized attributes can be adequately measured" (p. 6).

As it relates to this study, why do radiologic technologists believe and practice patient radiation protection the way they do? What are their attitudes, social pressures, and perceived control over performing patient radiation protection best practices? What are their attitudes, social pressures, perceived behavioral control, and organizational issues that impact their intention to use new digital equipment and techniques in order to lower patient dose?

Heider (1958), a social psychologist, suggests that human behavior is generally directed by goals and well-formulated plans. Some behaviors are so routine that they are even habitual or automatic, but the plans are still intentional. The theory of planned behavior is a model of how human behavior and action are guided (Ajzen, 1985, 1988, 1991, 2001, 2002, 2013). The theory of planned behavior, modified from the theory of reasoned action (Fishbein & Ajzen, 1975), takes into account perceived control over the behavior.

Ajzen (1985, 1991, 2001, 2002) proposes that a person's behavior can be predicted based on his/her attitudes, subjective norms, perceived behavioral control, and intentions. Specifically, Ajzen's theory maintains that subjective norms, perceived behavioral control, and attitudes have a direct impact on intention. See Figure 2. The rationale is that as any of the three predictors change, a person's action can either increase or decrease, which could impact subsequent behavioral change.

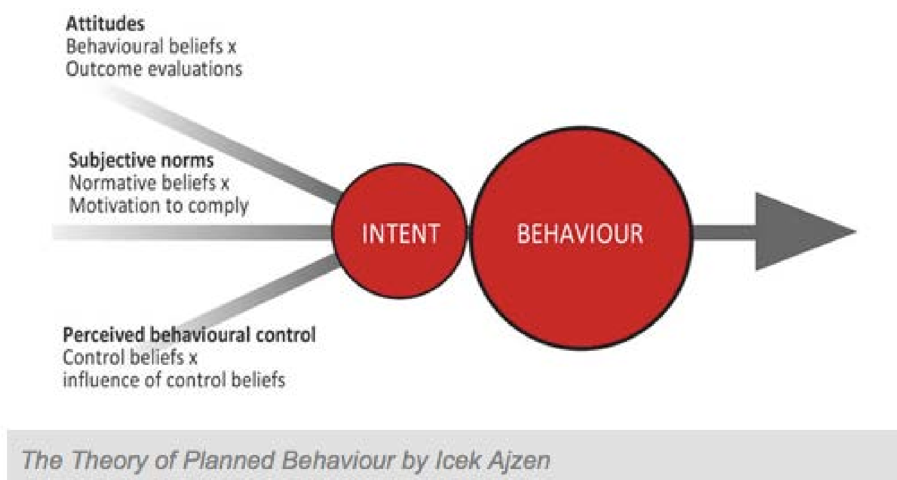

Figure 2. Model of theory of planned behavior. Data from "The A-B-C of Behavior: Changing Behavior Through Good Design, One Step at a Time," by J. Moule, 2011. Retrieved from http://johnnyholland.org/2011/01/the-a-b-c-of-behaviour/

The theory of planned behavior suggests that attitude toward the behavior is an individual’s overall evaluation of the behavior. Evaluation of the behavior is assumed to have two components that work together: beliefs about consequences of the behavior and the corresponding positive or negative judgments about the behavior (Francis et al., 2004).

Subjective norms represent perceptions of what he or she thinks about what the significant person wants him or her to do. Subjective norms “are a person’s own estimate of the social pressure to perform or not perform the target behavior,” state Francis et al. (2004, p. 9). Subjective norms have two components that work in interaction: beliefs about how other people, who may be in some way important to the person, would like them to behave (normative beliefs) and the positive or negative judgments about each belief (outcome evaluations). An example of a subjective norm in the radiologic technology field could look like this: I feel pressure from other technologists to use commonly held patient radiation protection best practices during an x-ray that calls for collimation and shielding. An example of the possible judgments about the belief would look like this: In regard to my decision to use commonly held patient radiation protection best practices such as collimation and shielding, doing what my patients think I should do is important/unimportant to me.

Francis et al. (2004) explain that perceived behavioral control is the extent to which a person feels able to enact the behavior. “It has two aspects: how much a person has control over the behavior and how confident a person feels about being able to perform or not perform the behavior” (p. 9). It is determined by control beliefs about the power of both situational and internal factors to inhibit or facilitate the performing of the behavior.

Ajzen (2002) states that,

> like attitude and subjective norm, perceived behavioral control can be measured by asking direct questions about capability to perform a behavior or indirectly on the basis of beliefs about ability to deal with specific inhibiting or facilitating factors. The great majority of studies performed to date have used the direct approach, but belief-based measures have the advantage of providing insight into the cognitive foundation underlying perceptions of behavioral control. (p. 668)

Accounting for perceived behavioral control is important as Ajzen (1985) states:

> The theory assumes that perceived behavioral control has motivational implications for intentions. People who believe that they have neither the resources, nor the opportunities to perform a certain behavior are unlikely to form strong behavioral intentions to engage in it even if they hold favorable attitudes toward the behavior and believe that important others would approve of their performing the behavior. (p. 133)

Ajzen (2013) also defines perceived behavioral control as different from self-efficacy. According to Ajzen, the difference between perceived behavioral control (PBC) and self-efficacy (SE) does not exist. Both PBC and SE refer to a person's beliefs that it is possible to perform a given behavior; however, PBC and SE are assessed differently. Ajzen (2013) asserts that with Bandura's concept of self-efficacy, participants are asked to indicate how likely it is that they would overcome each obstacle. With PBC, participants are asked to rate their ability to perform the behavior and how much the behavior is under their control.

What this means is that the theory of planned behavior is an appropriate theoretical lens for examining attitudes and beliefs, subjective norms or the thoughts of significant others, and the external resources or constraints influencing perceptions about volitional control, which are all "factors that shape men's intentions related to their involvement, as well as their ability to act on those intentions," according to Perry and Langley (2013, p. 182).

Francis et al. (2004) state:

> With the exception of behavior, the variables in the theory of planned behavior model are psychological (internal) constructs. Each predictor variable may be measured directly by asking respondents about their overall attitude, or indirectly by asking respondents about specific behavioral beliefs and outcome evaluations. Direct and indirect measurement approaches make different assumptions about the underlying cognitive structures, and neither approach is perfect. When different methods are tapping the same construct, scores are expected to be positively correlated, so it is recommended that both be included in theory of planned behavior questionnaires. (p. 9)

The theory of planned behavior has been used in over 1,200 studies, and it has validity in predicting different behaviors, including exercise behavior, condom use, and testicular or breast self-examination (Aiken, 2002). In the recent past it was used as a model to predict on-line shopping behavior, exercise, and downloading music from the Internet (Harvey, 2009). Historically, studies have shown that theory of planned behavior has predicted a variety of behaviors across social and individual characteristics. One such study by Kim and Park (2005) determined that the theory of planned behavior provided strong support for the relationships between attitude and perceived behavioral control with online purchase. The theory of planned behavior has also been used internationally, specifically in Saudi Arabia, to study the effect of gender and age on new technology implementation in a developing country (Baker et al., 2007). The value of this study is that it validated the theory of planned behavior as a multi-cultural model for investigating the impact of attitudes, beliefs, and subjective norms on technology adoption.

According to Ajzen (1985, 1991, 2001, 2002), performance of a behavior

> is a joint function of intentions and perceived behavioral control. For accurate prediction, several conditions have to be met. First, the measures of intention and

> of perceived behavioral control must correspond to or be compatible with the behavior that is to be predicted. (Ajzen, 1991, p. 185)

Ajzen (1991) also explains that "prediction of behavior from perceived behavioral control should improve to the extent that perceptions of behavioral control realistically reflect actual control" (p. 185). Additionally, "the relative importance of intentions and perceived behavioral control in the prediction of behavior is expected to vary across situations and across different behaviors" (p. 185).

Empirical support for the theory of planned behavior (Ajzen, 1985, 1991, 2001, 2002) in predicting health behavior has been demonstrated in scores of investigations (Armitage & Conner, 2001). A person's attitudes, subjective norms, and perceived behavioral control have all been significantly linked to intention. Of all the studies conducted using the theory of planned behavior, attitudes, perceived behavioral control, and subjective norms contribute to 30%-50% of variance in behavioral intention.

Boyko, Lavis, Dobbins, and Souza (2011) explain the theory of planned behavior in health care:

> The efficacy of the theory of planned behavior in predicting individual health-related behaviors has been demonstrated in several systematic reviews. For example, a meta-analytic review in the psychology field demonstrated that the theory of planned behavior can explain 20% of the variance in prospective measures of the actual behavior of individuals. There is also evidence to support using the theory of planned behavior to predict the use of research evidence (e.g., clinical practice guideline implementation) in the practice of healthcare professionals. For example, a systematic review focused on the relationship between intention and behavior among clinicians found that the proportion of the variance in clinicians' behavior explained by intention was similar in magnitude to that found in the broader literature. Since the theory of planned behavior has been useful in predicting behavior among health professionals in terms of patient care, it may also be useful in evaluating behavior among other professional groups involved in more system-level decision-making, such as policymakers and stakeholders. The efficacy of other social cognition models (e.g., social cognitive theory and theory of interpersonal behavior) in predicting behavior among health professionals has been less well established. (p. 1)

Harding, Mayhew, Finelli, and Carpenter (2007) found that "the theory of planned behavior construct of perceived behavioral control was not significantly related to either intention or behavior." According the Harding et al., "this seems to imply that students' perceptions of the relative difficulty of cheating on tests and homework have no effect on their intention to do so or their reported engagement in these behaviors" (p. 13). Harding et al. propose that some questions still exist about how respondents in their study interpreted the individual survey items, and whether the items really "measured perceived behavioral control as described by Ajzen (2002) or some other psychological construct such as self-efficacy" (p. 13).

During the process of researching theories about attitude and behavior, the theories having to do with knowledge translation and knowledge-to-action were reviewed. Graham et al. (2006) developed the knowledge-to-action (KTA) conceptual framework, suggesting usefulness for facilitating how policymakers, practitioners, patients, and the public use research knowledge. Estabrooks, Thompson, Lovely, and Hofmeyer (2006) argue that an official, overarching knowledge-translation theory does not exist yet, even though calls for theory development have been going on for the last four decades.

The KTA process is based on two components: (a) created knowledge, and (b) action. The concept of the authors was that the KTA process would be dynamic and complex, with no specific boundaries between the two components, as well as among the different phases of the two components (Graham et al., 2006).

Estabrooks et al. (2006) reviewed a range of models and theoretical perspectives, as well as literature in the areas of organizational innovation, health, and social science that are relevant to the topic of knowledge translation. Estabrooks et al. state:

> Because one theory will not fit all contexts, it is helpful to understand and use several different theories. Although there are often barriers associated with combining theories from different disciplines, such obstacles can be overcome, and to do so will increase the likelihood that knowledge-translation initiatives will succeed. (p. 25)

The desire for having an umbrella theory for knowledge translation will help, not only in diagnosis of problems, but also prescriptions for how to address the knowledge translation issues. Another driving force for the need of a theory in the study of knowledge translation is the ability to use consistent terms. In addition to the term *knowledge translation*, other terms exist, such as: evidence-based decision-making, research utilization, innovation diffusion, knowledge transfer, research dissemination, research implementation, and research uptake.

In light of this literature review of the theory of planned behavior (Ajzen, 1985, 1991, 2001, 2002), it would appear that the theory of planned behavior has the highest potential to fill the gap of understanding on the radiologic technologist's behavior, and it can be used as a predictor of best practice behavior. It can also be suggested that Ajzen's theory, as a nomological network (Newman et al., 2013)—with the sources of data, methods of data collection and analysis, and relationships among the sources of the data—can be used to predict and assume cause.

Summary

The purpose of this chapter was to review the literature that addresses the formation of a radiologic technologist's knowledge and beliefs about patient radiation exposure, as well as the continued practice of patient radiation protection. The purpose of this chapter was also to review the literature that addresses the theory of planned behavior and how this theory is used to help understand the attitudes, the social pressure, and the perceived behavioral control and dispositions of radiologic technologists.

The literature suggested that continuing the education and performance of patient radiation protection best practices is vital for keeping radiation exposure as low as possible; that patient radiation exposure is increasing with the introduction of digital imaging technology; and that leadership implications exist in the areas of policy and policy compliance, continuing education, and workload and stress. The research that links radiologic technologist best practices and leadership issues is minimal.

CHAPTER 3

METHODOLOGY

Research Design

The research design used for this study was *ex post facto* design guided by past and present theoretical and empirical data, and by specific research hypotheses with controls for viable alternative explanations of research outcomes. This research was non-experimental in nature.

According to Kerlinger and Lee (1999):

> "*Ex post facto* research is a systematic inquiry in which the scientist does not have direct control of independent variables because their manifestations have already occurred or because they are inherently not manipulatable. Inferences among variables are made, without direct intervention, from concomitant variation of independent and dependent variables." (p. 379)

Three levels, or types, of *ex post facto* research exist (Kerlinger & Lee, 1999). The first level looks at relationships, but without hypotheses. The second level of *ex post facto* research considers relationships with hypotheses. The third level, considered to be the most sophisticated type of *ex post facto* research, considers "hypotheses and controls for viable alternative explanations of the research outcomes" (Newman et al., 2006, pp. 116-117; Kerlinger & Lee, 1999). *Ex post facto* research contains assigned variables that demonstrate relationships, not cause (Newman et al., 2006).

According to Newman et al. (2006), "controlling for the possible alternative explanations makes the analyses and the logic of the warrants being used to support the conclusions much more transparent" (p. 184). Additionally, "because the sample population was studied without imposing experimental controls, the results of *ex post facto* research are more easily generalized to the general population" (p. 184).

Hypotheses

For this study, the following hypotheses were made (refer to Appendix G for the alignment of research questions, hypotheses, and content validity):

Hypothesis 1: Demographic variables (age, gender, years in practice, primary role, area of practice, place of practice) are predictive of the intentions and past behaviors of a radiologic technologist to use patient radiation protection best practices.

Hypothesis 2: Intentions predict past behaviors.

Hypothesis 3: Direct and indirect attitudes are predictive of intentions to perform patient radiation protection best practices.

Hypothesis 4: Direct and indirect social pressures/norms are predictive of intentions to perform patient radiation protection best practices.

Hypothesis 5: Direct and indirect perceived behavioral controls are predictive of intentions to perform patient radiation protection best practices.

Hypothesis 6: Direct attitudes are predictive of intentions to use digital equipment and digital techniques to lower patient dose.

Hypothesis 7: Direct social pressures/norms are predictive of intentions to use digital equipment and digital techniques to lower patient dose.

Hypothesis 8: Direct and indirect perceived behavioral controls are predictive of intentions to use digital equipment and digital techniques to lower patient dose.

Hypothesis 9: The components of Ajzen's theory of planned behavior will predict intentions and past behaviors to perform patient radiation protection best practices when controlling for age, gender, years of practice, role, area of practice, and place of practice.

Hypothesis 10: The components of Ajzen's theory of planned behavior will predict intentions and past behaviors to use new digital equipment and digital techniques to lower patient dose when controlling for age, gender, years of practice, role, area of practice, and place of practice.

Participants

A convenience sample was gathered of 365 participants from the Southwestern Region of the United States, primarily in Southern California. The criteria for including subjects in this study are as follows: students and alumni of a radiologic technology program, working radiologic technologists, and current faculty in this field, between the ages of 21 and 65+ years of age.

The sources for obtaining names of potential subjects are as follows: alumni of the Medical Radiography Program at Loma Linda University; radiologic technologists associated with Loma Linda University through the clinical instruction program in the Inland Empire of Southern California; radiologic technologists, including clinical instructors and faculty across the United States being associated with the Association of Collegiate Educators in Radiologic Technology *(*ACERT); and radiologic technologist educators who are associated with the Radiologic Health Branch of the Department of Public Health in California. Additionally, the current two cohorts of Medical Radiography students at Loma Linda University are included to the study.

Sampling Procedures

Participants received, read, and digitally "signed" the informed consent prior to taking the survey. See Appendices A-C. The survey was anonymous. The final survey was composed of 80 questions. See Appendix E. The participants were asked to self-report on their intentions, past behaviors, attitudes, social pressures, and perceived behavioral control when it comes to the use of patient radiation protection best practices and the use of new digital x-ray equipment. The participants were briefed on the risks and benefits of the study, the purpose of the study, and how the data will inform the radiologic technology community.

Instrumentation

The survey instrument (Appendix E) used in this study was developed using manuals designed to guide the development of a questionnaire for use with health care professionals, based on the key constructs of the theory of planned behavior (attitude, social pressures/norms, and perceived behavioral control) (Ajzen, 1991; Frances et al., 2004). The questionnaire consisted of 80 questions, including topics in the area of demographics of the participants, intentions, past behavior, attitudes, social pressures/norms, and perceived behavior control. Two types of behavior were studied: radiation protection best practices and the use of new digital imaging technology and digital techniques to lower patient dose.

As outlined by Frances et al. (2004) in a manual for health services researchers entitled *Constructing Questionnaires Based on The Theory of Planned Behavior*, the steps in the construction of a theory of planned behavior questionnaire are listed below:

1. Define the population of interest and decide how best to select a representative sample from this population.

2. Define the behavior under study so that each question in the study refers to that specific behavior.

3. Decide how best to measure intentions (intention performance, generalized intention, or intention simulation).

4. Decide how to measure past behavior.

5. Include items to measure direct attitudes, direct social pressures/norms, and direct perceived behavioral control for the behavior to use patient radiation protection best practices.

6. Determine the most frequently perceived advantages and disadvantages of performing the behavior based on a qualitative elicitation study to experts in this field in order to identify indirect attitudes when it comes to patient radiation protection best practices.

7. Determine the most important people or groups of people who would approve or disapprove of the behavior based on a qualitative elicitation study to experts in this field in order to identify indirect social pressures/norms when it comes to patient radiation protection best practices.

8. Determine the perceived barriers or facilitating factors that could make it easier or more difficult to adopt the behavior based on a qualitative elicitation study to experts in this field in order to identify indirect perceived behavioral controls when it comes to patient radiation protection best practices.

9. Include items to measure direct attitudes, direct social pressures/norms, and direct perceived behavioral control for the behavior to use new digital imaging equipment and digital techniques to lower patient dose.

10. Determine the perceived barriers or facilitating factors that could make it easier or more difficult to adopt the behavior based on a qualitative elicitation study to experts in this field in order to identify indirect perceived behavioral control using new digital imaging equipment and techniques to lower patient dose.

11. Review the draft questionnaire with experts in the field of radiologic technology and patient radiation protection.

12. Consult with Dr. Icek Ajzen on the development of the survey.

13. Review the draft again with experts in this field, and reword items as needed to ensure that questions are written in a non-defensive manner.

14. Administer the questionnaire. See Appendices A-E.

To define the target behavior, a thorough literature review was conducted, following The Joint Commission (2011) and literature review suggestions for reducing patient radiation exposure, and consulted with expert sources—specifically, veteran radiologic technologists and seasoned radiologic technologist educators at Loma Linda University. Following the questionnaire development model provided by Ajzen (1985, 1991, 2001, 2002) and the handbook written by Frances et al. (2004), the target behavior was defined in terms of its target, action, and context.

Semi-structured qualitative-type interviews were conducted with three radiologic technologists, two of whom are specialists in teaching radiation protection and biology. The purpose of the qualitative-type interviews was to determine the most frequently perceived advantages and disadvantages of performing the behavior, the most important people or groups of people who would approve or disapprove of the behavior, and the perceived behaviors or facilitating factors that could make it easier or more difficult to adopt the behavior. With that information, an initial draft of the questionnaire was developed.

The initial questionnaire was then reviewed with two expert radiologic technologist educators to determine if the questions were easy to understand, non-threatening, non-judgmental, and focused on the intent of the research questions.

To review the draft survey, the questionnaire was sent through Survey Monkey to the same radiologic technologists who helped to develop the topics in each question.

The 80 questions included in the final survey instrument were developed to determine the radiologic technologists' intentions, direct and indirect attitudes, direct and indirect social pressures/norms, and direct and indirect perceived behavioral control about the practice of patient radiation protection best practices. Additionally, items were added to measure the direct attitudes, direct social pressures/norms, and direct and indirect perceived behavioral control when using new digital equipment and new digital techniques to lower patient dose. The direct attitude questions were answered using a 7-point bipolar adjective scale (Ajzen, 2013). The remaining items were answered on a 7-point Likert scale (Frances et al., 2004). With the inclusion of demographic information, a modified theory of planned behavior model (Harding et al., 2007) was conducted.

Variables

Attitudes, social pressures/norms, and perceived behavioral control were measured for intentions and past behavior when using patient radiation protection best practices and when using new digital equipment and digital techniques to lower patient dose.

This study operationally defined attitudes as the behavioral beliefs and evaluations of patient radiation protection best practices; social pressures/norms as the perceived social pressure from specific individuals or groups to perform or not perform patient radiation protection best practices; and perceived behavioral control as the perceived control over performing a behavior, to the extent that a behavior is believed to be easy or difficult to perform patient radiation protection best practices.

According to Ajzen (2013), if you want to predict intentions and past behavior, all you need to know are the direct measures of attitude, subjective norm, and perceived behavioral control. But if you want to understand the reasons for these factors, you must also find out and assess the behavioral, normative, and control beliefs.

Items in the questionnaire were generated to assess all constructs specified in the theory of planned behavior: behavior intention (three items); past behavior (one item); direct attitudes (five items); indirect attitude (eight items); direct social pressures/norms (five items); indirect social pressures/norms (10 items); direct perceived behavioral control (four items); indirect perceived behavioral control (16 items); direct attitudes (five items), social pressures/norms (four), direct perceived behavioral control (four items), and indirect perceived behavioral control (10 items) using new digital equipment; and demographic descriptors (six items). Refer to Table 6 for a listing of the variables in this study. Refer to Appendix E for the 80-item questionnaire.

Table 6

List of Variables

VARIABLE	ITEM	SCALE
Age	#1	18-20 21-29 30-39 40-49 50-59 60-65 65 or older
Gender	#2	Male Female
Years in Practice	#3	current student <than a year 1-4 5-9 10-14 15-19 20-24 25+
Primary Role	#4	1-Radiologic technologist 2-Radiologic technologist in the role of Shift Leader/Supervisor 3-Radiologic technologist in the role of Department Manager/Director 4-Educator/Faculty in Radiologic Technology 5-Hospital Administrator 6-Student 7-Other
Area of Primary Practice	#5	1-General Diagnostic only 2-General Diagnostic plus a specialty 3-Mammography Specialty only 4-CT Specialty only 5-Interventional Specialty only 6-Other Specialty 7-Student
Place of Practice	#6	1-Small Hospital: 99 beds or less 2-Medium Hospital: 100-199 beds 3-Large Hospital: 200-299 beds 4-X-Large Hospital 300+ beds 5-Urgent Care Facility 6-Imaging Center 7-Outpatient Office 8-Educational Facility 9-Other
Intentions: #7-Plan to Use #8-Will Make an Effort #9-Intend to Us Sum of Intentions	7-9	1 to 7 Likert Scale

Table 6—*Continued.*

VARIABLE	ITEM	SCALE
Past Behaviors: #10	10	1 to 7 Likert Scale
Direct Attitudes: #11-Bad-Good #12-Unpleasant-Pleasant #13-Harmful-Beneficial #14-Punishing-Rewarding #15-Waste of time-worth the time Sum of Direct Attitudes	11-15	1 to 7 Likert Scale
Indirect Attitudes: 1-Reduce radiation 2-Be a positive role model 3-Do something ethical/moral 4- It will take longer Sum of Indirect Attitudes	16-22 (Pairs)	Eight (Four pairs rating outcome/problem with importance/seriousness of problem) 1 to 7 Likert Scale
Direct Social Pressures/Norms: #23-Most people who are important to me think that… #24-Most people in my role use… #25-It is expected of me that I use… #26-I feel under social pressure to NOT use #27-People who are important to me want me to use… Sum of Direct Social Pressures/Norms	23-27	1 to 7 Likert Scale
Indirect Social Pressures/Norms: 1-Patients 2-Patient's Family 3-Rad Tech Peers 4-Rad Manager 5-Radiologist Sum of Indirect Social Pressures/Norms	28-37 (Pairs)	10 (Five pairs) 1 to 7 Likert Scale
Direct PBC: #38- I am confident… #39-For me, using PRPBP in x-ray exams impossible/possible #40-Whether or not I use…is entirely up to me. #41-Whether I use…is sometimes beyond my control Sum of Direct PBC	38-41	1 to 7 Likert Scale

Table 6—*Continued*.

VARIABLE	ITEM	SCALE
Indirect PBC: 1-Rushed 2-Trauma 3-Lack of equipment-Portable 4-Lack of equipment-Department 5-Policies 6-Reward 7-Continuing education 8-Safety culture Sum of Indirect PBC	42-57 (Pairs)	16 (Eight pairs) 1 to 7 Likert Scale
Direct Attitudes (Digital): #58-Bad-Good #59-Unpleasant-Pleasant #60-Harmful-Beneficial #61-Punishing-Rewarding #62-Waste of time-worth the time Sum of Direct Attitudes (Digital)	58-62	1 to 7 Likert Scale
Direct Social Pressures/Norms (Digital): #63-Most people who are important to me think that… #64-Most people in my role use… #65-It is expected of me that I use… #66-People who are important to me want me to use. Sum of Direct Social pressures/Norms (Digital)	63-66	1 to 7 Likert Scale
Direct PBC (Digital: #67- I am confident… #68-Whether or not I use…is entirely up to me. #69-Whether I use…sometimes beyond my control #70-For me, using PRPBP in x-ray exams impossible/possible Sum of Direct PBC (Digital)	67-70	1 to 7 Likert Scale
Indirect PBC (Digital): 1-Revert 2-Policies 3-Continuing Ed 4-Unprepared 5-Initial education insufficient Sum of Indirect PBC (Digital)	71-80	10 (Five pairs) 1 to 7 Likert Scale

Note. PBC=Perceived Behavioral Control.

Intentions were measured by asking participants to respond to three general statements regarding the use of patient radiation protection best practices in x-ray exams: "I plan to use . . . ," "I will make an effort to use . . . ," and "I intend to use. . . ." Responses to all items were rated on 7-point scales and scored from 1 (*extremely unlikely*) to 7 (*extremely likely*).

Past behaviors were measured by asking one question: "In the past, how often have you used patient radiation protection best practices in x-ray exams?" Responses to all items were rated on 7-point scales and scored from 1 (*never*) to 7 (*always*).

Direct attitudes were measured by asking participants to respond to the general statement: "For me, using patient radiation protection best practices in x-ray exams is. . . ." Examples of the five bipolar adjectives used were: "good—bad," "unpleasant—pleasant," "harmful—beneficial," "punishing—rewarding," and "a waste of time—worth the time."

Indirect attitudes were measured by asking participants to respond to five paired statements having to do with different scenarios and then rating the importance of those scenarios. The five scenarios had to do with reducing a patient's exposure, being a positive role model, doing something ethical/moral, and taking longer to complete exams.

Direct social pressures/norms were measured by five questions having to do with what other people think about the participant using patient radiation protection best practices in x-ray exams: "Most people who are important to me think that . . . ," "Most people in my role who are radiologic technologists . . . ," "It is expected of me that I use . . . ," "I feel under social pressure to not use . . . ," and "People who are important to me want me to use. . . ." Responses to all items were rated on 7-point scales.

Indirect social pressures/norms were measured by five pairs of questions identifying specific groups of people: patients, patients' family, radiologic technologist coworkers, radiology manager, and radiologist. The significance of that approval was rated on a 7-point scale from 1—*not at all*, to 7—*very much*.

Direct perceived behavioral control was measured with four items: "I am confident in my own ability . . . ," "For me, using patient radiation protection best practices in x-ray exams is . . . ," "Whether or not I use patient radiation protection best practices in x-ray exams is entirely up to me," and "Whether I use patient radiation protection best practices in x-ray exams is sometimes beyond my control."

Indirect perceived behavioral control was measured with eight pairs of questions, dealing with different scenarios, such as "feeling rushed," "trauma/challenging situations," "availability of equipment when doing portables," "availability of equipment when in the main department," "policies," "reward," "continuing education," and "presence of a safety culture." The ease of use to each of these scenarios was rated on a 7-point scale from 1—*highly disagree,* to 7—*highly agree*.

Direct attitudes for using new digital equipment and new digital exposure techniques to lower patient dose were measured by asking participants to respond to the general statement: "For me, using patient radiation protection best practices in x-ray exams is . . ." Examples of the five bipolar adjectives used were: "good—bad," "unpleasant—pleasant," "harmful—beneficial," "punishing—rewarding," and "a waste of time—worth the time."

Direct social pressures/norms for using new digital equipment and new digital exposure techniques to lower patient dose were measured by the following types of questions: “Most people who are important to me think that . . . ,” “Most people in my role who are radiologic technologists . . . ,” “It is expected of me that I use . . . ,” “I feel under social pressure to not use . . . ,” and “People who are important to me want me to use. . . .” Responses to all items were rated on 7-point scales.

Direct perceived behavioral control for using new digital equipment and new digital exposure techniques to lower patient does were measured by four items: “I am confident in my own ability . . . ,” “For me, using patient radiation protection best practices in x-ray exams is . . . ,” “Whether or not I use patient radiation protection best practices in x-ray exams is entirely up to me,” and “Whether I use patient radiation protection best practices in x-ray exams is sometimes beyond my control.”

Indirect perceived behavioral control was measured with eight pairs of questions, dealing with different scenarios, such as “reverting back to previously-learned exposure techniques,” “trauma/challenging situations,” “policies,” “feeling unprepared,” “continuing education,” and “initial training.” The ease of use to each of these scenarios was rated on a 7-point scale from 1—*highly disagree*, to 7—*highly agree*.

Finally, the survey contained demographic variables that were separate from the theory of planned behavior variables, such as radiologic technologist’s age, gender, years in practice, primary role, area of primary practice, and place of practice.

Data Collection

Data were gathered using an emailed invitation (Appendix A) to access an online survey through Survey Monkey during a 4-week period between mid-June and mid-July 2013 to 365 radiologic technologists, medical radiography students, and radiation science faculty. An email invitation was initially sent, followed by three email reminders about 1 week apart. An incentive was given for a drawing. The incentives were either a gift certificate to Starbucks, or gift certificates to receive a personalized thyroid lead shield or personalized lead markers. Over 173 responded, yielding a return rate of 47%.

Statistical Analysis

The *F* test was used to test the statistical significance of the proposed relationships in the hypotheses. The *F* test was used to determine if the R^2 of the full model was significantly different from the R^2 of the restrictive model in both hypotheses 9 and 10 at an alpha of .05 for the hypotheses (McNeil, Newman, & Fraas, 2011).

Multiple regression analysis was conducted to examine the predictability of the variables and external characteristics and to test the research hypotheses (Newman, Benz, Weis, & McNeil, 1997).

According to Ajzen (1985, 1991, 2001, 2002), the theory of reasoned action predicts behavioral intentions. This is usually evaluated by linear multiple regression analysis. Ajzen states that the regressing coefficients produced by this analysis serve as estimates of the weights of the attitudinal and normative predictors.

Newman et al. (2013) support the supposition that theory is a nomological network: “The nomological network provides a venue for the researcher to use both data and logic to confirm patterns of evidence in low incidents situations” (pp. 34-35). A nomological network provides: sources of data; methods of data collection and analysis; and relationships among the sources of the data; and proposes that the data support the nomological network, that is, the theory. Newman et al. explain by saying that if data collected by *ex post facto* methods support the theory, then the theory can assume cause. The data do not assume cause.

Two-tailed tests of significance were used to test the relationships of the variables when the direction of the correlation is uncertain. One-tailed tests of significance were used when the direction of the correlation is certain based on previous research and experience (McNeil et al., 2011).

The required sample size was determined by statistical power analysis, and this requires the specification of the study design and the expected effect size. A power analysis using Cohen's f^2 for medium size effect of .15 (Cohen, 1988; McNeil, Newman, & Kelly, 1996) was calculated for an approximate sample size of 162, an alpha of .05. The yielding statistical power for this study was between .90-.93.

Francis et al. (2004) suggest that "it is reasonable to assume at least a moderate effect size for theory of planned behavior studies using a multiple regression approach." With theory of planned behavior studies, a minimum sample size of 80 would be acceptable, so with a 50% response rate, the minimum total questionnaires sent out should be 160. For this study, 365 invitations were sent out, with 173 returns, yielding a 47% response rate.

One-way ANOVA examined the relationship between cognitive variables and external variables. Pearson correlation coefficients examined the association between intention with the cognitive variables and some external characteristics.

Cronbach's alpha, a very common measure of reliability to test for internal consistency (Cronbach, 1990; Morgan, Leech, Gloeckner, & Barret, 2012; Tabachnick & Fidel, 2001), was used for attitude (direct and indirect), intentions (direct and indirect), social pressures/norms (direct and indirect), and perceived behavioral control (direct and indirect) for both best practice behavior and digital equipment behavior, based on recommendations by Ajzen's (1985) theory of planned behavior.

Finally, a mean of the item scores was calculated to give an overall score for overall intention, attitude, subjective norm, and perceived behavioral control.

Statistical analysis was done using SPSS 21 for Mac. An alpha level of .05 was used to determine whether to accept or reject each hypothesis. For this type of study, based on the review of the literature, the alpha level of .05 is acceptable. This confidence level was appropriate for this study and for estimating the probability of making a Type I error. Type II error was estimated through the power analysis equation:

power = 1 – (Probably of Type II error).

As a comparison, Armitage and Conner (2001) provide a table (see Table 7) in their meta-analysis of the theory of planned behavior. What this table shows is that a variety of statistical analyses is possible with the theory of planned behavior, including the following: multiple correlation (behavioral intention + perceived behavioral control) with behavior; behavioral intention–past behavior correlation; perceived behavioral control–past behavior correlation; % variance added by perceived behavioral control to past behavior; multiple correlation (attitude + social norm + perceived behavioral control) with behavioral intention; attitude–behavioral intention correlation; social norm–behavioral intention correlation; perceived behavioral control–behavioral intention correlation; % variance added by perceived behavioral control to behavioral intention; behavioral belief–attitude correlation; normative belief–social norm correlation; and control belief–perceived behavioral control correlation.

Table 7

Types of Relationship Tests Conducted on the Constructs of the Theory of Planned Behavior

Relationship	*N* of tests
Multiple correlation (behavioral intention + perceived behavioral control) with behavior	63
Behavioral intention—behavior correlation	48
Perceived behavioral control—behavior correlation	60
% variance added by perceived behavioral control to behavior	66
Multiple correlation (attitude + social norm + perceived behavioral control) with behavioral intention	154
Attitude—behavioral intention correlation	115
Social norm—behavioral intention correlation	137
Perceived behavioral control—behavioral intention correlation	144
% variance added by perceived behavioral control to behavioral intention	136
Behavioral belief—attitude correlation	42
Normative belief—social norm correlation	34
Control belief—perceived behavioral control correlation	18

Note. "Efficacy of the Theory of Planned Behavior: A Meta-analytic Review," by C. Armitage and M. Conner, 2001, *British Journal of Social Psychology*, *40*(4), 471–499.

This is a cumulative list, so it is not reflective of the types of analysis that are performed in every research study. Each study reviewed in the literature review used a combination of statistical analysis.

For this study, the following was computed: behavioral intention–past behavior correlation; perceived behavioral control–past behavior correlation; multiple correlation (attitude + social norm + perceived behavioral control) with behavioral intention; attitude–behavioral intention correlation; social norm–behavioral intention correlation; perceived behavioral control–behavioral intention correlation.

Additionally, I computed the following: demographics–behavioral intention correlation, and multiple regression (attitude + social norm + perceived behavioral control) while controlling for demographics.

Validity

Content validity, also called “definition validity” and “logical validity” (Newman et al., 2006), is an estimation of how the instrument items are representative “of the content or subject matter that instrument seeks to measure” (p. 48).

“The validity of the instrument is probably the most important psychometric characteristic of an instrument,” according to Newman, Newman, and Newman (2011, p. 206). Newman, Newman, and Newman suggest examples such as “types of validity include face, expert judge, content or logical validity, concurrent validity, predictors, and construct validity” (p. 186), and that it is desirable to have more than one form of validity. More estimates of validity support a greater truth-value, confidence, and credibility (Ridenour & Newman, 2008).

According to Newman, Lim, and Pineda (2011), “While there has been much written on the topic of content validity (logical validity), there is paucity of information in the literature on how to develop procedures for estimating it” (p. 1). They continue to state that “a need exists to explore methods for improving the estimation and trustworthiness of this measure of validity. Trustworthiness in this context is understood to be the transparency and the accumulation of evidence that supports the logical argument” (p. 2). These authors also share Teddlie and Tashakkori’s (2009) position that “the most effective way of providing this multitude of evidence would be through a mixed methods approach, which requires the triangulation of several types of data” (p. 2). Newman, Lim, and Pindea (2011) suggest a table of specifications (see Appendix F) for estimating content validity. The table of specifications requires the presentation of evidence that has transparency to increase the trustworthiness of validity estimates by “maintaining an audit trail-triangulating multiple data sources, and by expert debriefing, and using peer review” (p. 2).

For this study, radiologic technologists and educators in the field of radiation protection were interviewed to identify some of the issues involved in best practices, based on the constructs of Ajzen’s theory of planned behavior (1985, 1991, 2001, 2002). The results of this qualitative aspect of the survey development directly influenced the operational definitions of the indirect contributors to attitude, social pressure/norms, and perceived behavior control. Additionally, Dr. Icek Ajzen consulted on the creation of the research instrument and provided specific feedback for consistency in writing questions, and development of the items to meet the specifications for the theory of planned behavior. Also, validity was estimated through the creation of a table of specifications (see Appendix F) (Newman, Lim, & Pineda, 2011).

Reliability

According to Newman, Newman, and Newman (2011), “reliability is generally defined as the consistency of the measurement instrument” (p. 205). This means that the instrument should produce the same or similar results every time it is used. Reliability is generally estimated with correlational techniques (Newman, Newman, & Newman, 2011), and the most frequently used techniques include: test-retest reliability, equivalent form reliability, and internal consistency.

Additionally, Newman et al. (2006) suggest that “increasing the number of items, using objective methods of scoring, measuring only one concept in any test or subscale, equivalency of item difficulty, and having a standardized procedure for test administration” will also influence the reliability of an instrument (p. 205).

Francis et al. (2004) suggest that when using Ajzen's (1985) theory of planned behavior, for direct measures, one form of reliability may be established using an index of internal consistency, such as Cronbach's alpha.

Cronbach's alpha is a very common measure of reliability to assess the internal consistency of items (Morgan et al., 2012). "There is some debate around this, with some statisticians suggesting 0.7 or higher whereas others recommend 0.8 . . . but 0.75 is a sensible compromise value to take as the benchmark," state Hinton, Brownlow, McMurry, and Cozens (2004, p. 357). According to Morgan et al. (2012), alpha should be positive and greater than .70 in order to provide good support for internal consistency reliability.

Ajzen (2013) summarizes the topic of reliability and validity:

> The reliability and validity of direct theory of planned behavior measures are estimated in formative research. First, a theory of planned behavior questionnaire is constructed in accordance with established guidelines. The direct items designed to assess a given theory of planned behavior construct (attitude, subjective norms, perceived behavioral control, intention, or behavior) are then submitted to an internal consistency analysis to establish reliability. Cronbach's alpha is the most commonly used coefficient. However, internal consistency is not a requirement of the behavioral, normative, and control belief composites because different accessible beliefs may well be inconsistent with each other. If reliability in the sense of temporal stability is also considered important, the questionnaire must be administered a second time and test- retest correlations are computed. Estimation of validity is, as always, more difficult. Usually, all we can do in pilot work is to establish the convergent and discriminant validities of the theory of planned behavior measures. Confirmatory factor analyses are employed to show that the items measuring a given construct can be considered indicators of the same latent variable; and that a model in which the attitude, subjective norm, perceived control, and intention items are treated as assessing separate constructs is superior to a model in which all items are considered to measure the same underlying constructs.

The data supporting these concepts are found in Ajzen's published works (1985, 1988, 1991, 2001, 2002).

Limitations

As with all research, methodological limitations exist and bear mentioning. The following is a list of limitations that apply to this study:

1. Sample Size: The size of the sample was 173, which may not be representative of radiologic technologists in North America. Also, the study included a 45.3% representation of educators, which could bias the results. A future study could include a larger sample size to ensure a representative distribution of the population and to be considered representative of this group.

2. Incomplete Responses: Some questions in the survey were not completed by the respondents, which could cause some limitations to the study.

3. Self-reported Data: Self-reported data include limitations in the following areas: (a) selective memory; (b) recalling events that occurred at one time as if they occurred at another time; (c) attributing positive events and outcomes to one's self, but attributing negative events and outcomes to external factors; and (d) exaggeration.

4. The ability of a quantitative study using the theoretical framework to address the problem and purpose of the study could be a limitation if the problems that really exist are outside of the key constructs of the theory of planned behavior. In the future, a qualitative or mixed-methods study could be used to further identify the challenges in performing best practice behavior.

Summary

This chapter discussed all of the important elements of the study methodology. The pilot study and the procedures for the research were also described.

CHAPTER 4

RESULTS OF THE STUDY

This study was an investigation into contributing factors of a radiologic technologist's intentions and past behaviors to use patient radiation protection best practices. All analyses were performed using the SPSS, version 21, statistical software package. The following results are reported: descriptive statistics of demographic factors of the study sample; scale descriptives of the variables and modified variables in the study; correlations and analysis of variance between the components of Ajzen's theory of planned behavior (intentions, past behaviors, attitudes, social pressures/norms, perceived behavioral control); and multiple regression analysis (McNeil et al., 2011; Newman & McNeil, 1998) to predict best practices based on intentions and past behavior. Tabachnick and Fidell (2001) state that "regression analyses reveal relationships among variables but do not imply that the relationships are causal. Demonstration of causality is a logical and experimental, rather than statistical, problem" (p. 122). No interpretations or interpretations are drawn in this chapter (Newman et al., 1997).

Descriptive Statistics

Demographic Descriptives of Participants

This study of radiologic technologists from the Southwestern Region of the United States located mostly in Southern California used a convenience sample of 365 participants to collect 173 responses, which yielded a response rate of 47%. The statistical power of .90-.93 for a Cohen's medium-size effect of .15 was calculated on a sample size of *n*=162, because not all of the respondents answered all of the questions. The sources for obtaining names of the subjects were alumni of the Medical Radiography Program at Loma Linda University; radiologic technologists associated with Loma Linda University through the clinical instruction program in the Inland Empire of Southern California; radiologic technologists, including clinical instructors and faculty across the United States being associated with the Association of Collegiate Educators in Radiologic Technology *(*ACERT); and radiologic technologist educators who are associated with the Radiologic Health Branch of the Department of Public Health in California. Additionally, the current two cohorts of Medical Radiography students at Loma Linda University are included to the study.

In this section, descriptive results are presented for the demographic variables of age, gender, years in practice, primary role, primary area of practice, and type of facility. The demographics of the participants are shown in Tables 8 through 13.

The largest age group was 21-29 years old, representing 26% of the participants; the next largest age group was 30-39 years old, representing 22.5%. Together 50% of the participants were between 21 and 39 years of age (see Table 8).

It is interesting to note that 35.3% were over the age of 50. The percentage of females (55.6%) was higher than the percentage of males (44.4%). See Table 9.

Table 8

Age: Participant Descriptives (n=173)

Age	*n*	%
21-29	45	26.0
30-39	39	22.5
40-49	28	16.2
50-59	34	19.7
60-65	20	11.6
65 or older	7	4.0

Table 9

Gender: Participant Descriptives (n=171)

Gender	*N*	%
Male	76	44.4
Female	95	55.6

Of the radiologic technologists (employed, students, and faculty) who responded to the years in practice question, 13.5% were current students, 10.5% had less than a year of experience, 22.8% had between 1 and 9 years of experience, 12.2% had between 10-19 years of experience, and 49.2% had over 20 years of experience (see Table 10).

The largest group of participants stated that their primary role was educator/faculty (45.3%), and 33.2% were radiologic technologists working in that role or in the role of shift leader or manager/director (see Table 11).

Table 10

Years in Practice: Participant Descriptives (n=171)

Years in Practice	*n*	%
Current Student	23	13.5
< than a Year	18	10.5
1-4 Years	20	11.7
5-9 Years	19	11.1
10-14	11	6.4
15-19	10	5.8
20-24	20	11.7
25+	50	29.2

Table 11

Primary Role: Participant Descriptives (n=172)

Primary Role	*n*	%
Radiologic technologist	44	25.6
Radiologic technologist–Shift Leader/Supervisor	8	4.7
Radiologic technologist–Manager/Director	5	2.9
Educator/Faculty	78	45.3
Hospital Administrator	0	0.0
Student	29	16.9
Other	8	4.7

The two largest groups of participants in the category of primary area of practice were those who work in general diagnostic radiology (38.7%) or in general diagnostic radiology with one specialty (37.5%). The mammography and interventional radiology primary area of practice had no representation (see Table 12).

The facility type that 39.8% of the participants worked at was an educational facility. The combined facility types that referred to hospitals was 49% (small—2.3%, medium—17.5%, large—15.2%, x-large—14%). See Table 13.

Scale Descriptives for Reliability

Cronbach's (1990) alpha was calculated to determine reliability of the questionnaire and the reliability of each of the computed variables for attitude (direct and indirect), intentions (direct and indirect), social pressures/norms (direct and indirect), and perceived behavioral control (direct and indirect) for both best practice behavior and digital equipment behavior, based on recommendations by Ajzen's theory of planned behavior (Ajzen, 1985).

Table 12

Primary Area of Practice: Participant Descriptives (n=168)

Primary Area of Practice	*n*	*%*
General Diagnostic Only	65	38.7
General Diagnostic Plus a Specialty	63	37.5
Mammography Only	0	0.0
CT Only	7	4.2
Interventional Only	0	0.0
Other Specialty	13	7.7
Student	20	11.9

Table 13

Facility Type: Participant Descriptives (n=171)

Facility Type	*n*	%
Small Hospital (<99 beds)	4	2.3
Medium Hospital (100-199)	30	17.5
Large Hospital (200-299)	26	15.2
X-Large Hospital (300+ Beds)	24	14.0
Urgent Care Facility	3	1.8
Imaging Center	3	1.8
Outpatient Office	4	2.3
Educational Facility	68	39.8
Other	9	5.3

Cronbach's alpha (1990) for the questionnaire based on primary items and modified variables to total 37 items was 0.766. Cronbach's alpha was also computed for each of the major categories (see Tables 14 through 24).

Table 14

Scale Descriptives: Intentions and Past Behavior

Survey Items	*N*	*M*	*SD*
Cronbach's α estimated to be 0.916			
Item 7–Plan to use	164	6.9024	.38721
Item 8–Will make an effort to use	162	6.8951	.37974
Item 9–Intend to use	161	6.9068	.36744
Item 10–Past behavior	163	6.5583	.64882

The Cronbach's alpha scores are as follows: intentions (0.916; Table 15); direct attitudes (0.824; Table 16); indirect attitudes (0.383; Table 17); direct social pressures/norms (0.549; Table 18); indirect social pressures/norms (0.797; Table 19); direct perceived behavioral control (0.117; Table 20); indirect perceived behavioral control (0.420; Table 21); direct attitudes (digital) (0.806; Table 22); direct social pressures/norms (0.787; Table 23); direct perceived behavioral control (digital) (0.132; Table 24); and indirect perceived behavioral control (digital) (0.489; Table 25).

Table 15

Scale Descriptives: Direct Attitudes

Survey Items	*n*	*M*	*SD*
Cronbach's α estimated to be 0.824			
Item 11–Bad-Good	163	6.8712	.46010
Item 12–Unpleasant-Pleasant	161	6.5217	.89503
Item 13–Harmful-Beneficial	160	6.8000	.63246
Item 14–Punishing-Rewarding	161	6.6460	.76982
Item 15–Waste of time-Worth the time	161	6.7640	.59703

Table 16

Scale Descriptives: Indirect Attitudes

Survey Items	*n*	*M*	*SD*
Cronbach's α estimated to be 0.383			
Reduce radiation	160	46.4813	5.92720
Be a positive role model	159	42.5151	3.19146
Do something ethical/moral	160	47.3875	3.08913
It will take longer	160	21.3625	13.43912

Table 17

Scale Descriptives: Direct Social Pressures/Norms

Survey Items	*N*	*M*	*SD*
Cronbach's α estimated to be 0.549			
Item 23–Most people who are important to me think that…	159	6.6541	.75463
Item 24–Most people in my role use…	159	5.5157	1.41804
Item 25–It is expected of me that I use…	160	6.6813	.80386
Item 26–I feel under social pressure to NOT use	160	5.8500	1.83330
Item 27–People who are important to me want me to use…	159	6.5732	.88917

Table 18

Scale Descriptives: Indirect Social Pressures/Norms

Survey Items	*N*	*M*	*SD*
Cronbach's α estimated to be 0.797			
Patients	158	43.4241	8.97008
Patient's Family	158	42.9557	9.92093
Radiologic Technology Peers/Coworkers	157	35.2038	13.06872
Radiology Manager	156	41.9359	10.54678
Radiologist	155	41.2194	10.94750

Table 19

Scale Descriptives: Direct Perceived Behavioral Control

Survey Items	*n*	*M*	*SD*
Cronbach's α estimated to be 0.117			
Item 38–I am confident…	159	6.8679	.40742
Item 39–For me, using…is impossible/possible	159	6.8428	.44344
Item 40–Whether or not I use…is entirely up to me	159	5.3711	2.06095
Item 41–Whether I use…sometimes is beyond my control	159	3.7673	2.20240

Table 20

Scale Descriptives: Indirect Perceived Behavioral Control

Survey Items	*n*	*M*	*SD*
Cronbach's α estimated to be 0.420			
Rushed	152	9.9737	11.96349
Trauma	154	21.7468	14.66380
Lack of equipment-portables	150	17.2333	15.59230
Lack of equipment-department	151	45.9007	7.39798
Policies	150	41.3400	11.66468
Reward	150	14.4067	16.20386
Continuing education	150	29.5400	15.88830
Safety culture	149	34.5772	14.14174

Table 21

Scale Descriptives: Direct Attitudes (Digital)

Survey Items	*N*	*M*	*SD*
Cronbach's α estimated to be 0.806			
Item 58–Bad-Good	153	6.8039	.62890
Item 59–Unpleasant-Pleasant	153	6.2680	1.14712
Item 60–Harmful-Beneficial	152	6.8092	.59505
Item 61–Punishing-Rewarding	152	6.5882	.78245
Item 62–Waste of time-Worth the time	151	6.8553	.50701

Table 22

Scale Descriptives: Direct Social Pressures/Norms (Digital)

Survey Items	*n*	*M*	*SD*
Cronbach's α estimated to be 0.787			
Item 63–Most people who are important to me think that…	153	6.4771	1.05185
Item 64–Most people in my role use…	151	5.8079	1.55656
Item 65–It is expected of me that I use…	153	6.3464	1.26865
Item 66–People who are important to me want me to use…	151	6.2715	1.16581

Table 23

Scale Descriptives: Direct Perceived Behavioral Control (Digital)

Survey Items	*n*	*M*	*SD*
Cronbach's α estimated to be 0.132			
Item 67–I am confident…	151	6.5762	.92691
Item 68–Whether or not I use…is entirely up to me	149	5.0940	2.10643
Item 69–Whether I use…sometimes is beyond my control	152	4.5395	2.08076
Item 70–For me, using…is impossible/possible	152	6.7171	.90193

Table 24

Scale Descriptives: Indirect Perceived Behavioral Control (Digital)

Survey Items	*n*	*M*	*SD*
Cronbach's α estimated to be 0.489			
Revert back under pressure	151	14.1325	17.87127
Policies	149	32.2617	16.17729
Continuing education	151	35.4305	13.66334
Feeling unprepared	151	24.4106	14.72697
Initial education insufficient	149	22.5839	14.58484

Results: Research Question and Hypothesis 1

Research Question 1: Is there a relationship among selected demographic variables (age, gender, years in practice, primary role, area of practice, place of practice) and a radiologic technologist's intentions and past behavior to use patient radiation protection best practices?

Hypothesis 1: The demographic variables (age, gender, years in practice, primary role, area of practice, place of practice) are predictive of the intentions of a radiologic technologist's intentions and past behaviors to use patient radiation protection best practices.

To help interpret hypothesis 1, Pearson's correlation was run to determine if a correlation exists between intentions and past behavior with age, gender, years in practice, primary role, primary area of practice, and facility type.

Pearson r shows that age is significant in predicting intentions (p=.017, r =.189) and past behavior (p=.005, r =.220). Gender is significant in predicting intentions (p=.006, r =.218) and past behavior (p=.000, r =.285). Years in practices is significant in predicting intentions (*p*=.011, *r* =.201) and past behavior (*p*=.000, *r* =.335). The results are listed in Table 25.

Primary role is not significant in predicting intentions (*p*=.216, *r* =.098) or past behavior (*p*=.936, *r* =.006). Primary area of practice is not significant in predicting intentions (*p*=.223, *r* =-.098) or past behavior (*p*=.150, *r* =-.114). Facility type is significant in predicting intentions (*p*=.034, *r* =.168) and past behavior (*p*=.002, *r* =.243). The results are listed in Table 26.

The results of a one-way ANOVA (Analysis of Variance) while correcting for a Type 1 error using Bonferroni shows that when it comes to predicting past behavior to perform patient radiation protection best practices while controlling for primary role, there is a significant difference in past behavior with students. In Table 27 the significance (*p*=.002) of the inverse link (*M*=-.54815) between students and faculty in the area of past behavior is shown.

The results of a one-way ANOVA (Analysis of Variance) while correcting for a Type 1 error using Bonferroni shows that there is no significant difference between the facility type when it comes to intentions to perform patient radiation protection best practices (*p*=.097) at an alpha level of .05; however, a significant difference between facility type and past behaviors was evident (*p*=.003) at an alpha level of .05 (see Table 28).

Table 25

Correlation of Intentions and Past Behavior with Age, Gender, and Years in Practice

Dependent Variables		Sum of Intentions (#7-#9)	Past Behavior	Age	Gender
Past Behavior	Pearson *r*	.405**			
	Sig. (2-tailed)	.000			
	N	160			
Age	Pearson *r*	.189*	.220**		
	Sig. (2-tailed)	.017	.005		
	N	160	163		
Gender	Pearson *r*	.218**	.285**	.019	
	Sig. (2-tailed)	.006	.000	.804	
	N	159	162	171	
Years in Practice	Pearson *r*	.201*	.335**	.843**	.153*
	Sig. (2-tailed)	.011	.000	.000	.047
	N	159	162	171	169

Note. Past behavior was based on Item 10 in the survey. Sum of Intentions were based on the sum of items 7-9. See Chapter 3 for further details.
* Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

Table 26

Correlation of Intentions and Past Behavior With Primary Role, Primary Area of Practice, and Facility Type

Dependent Variables		Sum of Intentions (#7-#9)	Past Behavior	Primary Role	Primary Area of Practice
Past Behavior	Pearson Correlation	.405**			
	Sig. (2-tailed)	.000			
	N	160			
Primary Role	Pearson Correlation	.098	.006		
	Sig. (2-tailed)	.216	.936		
	N	160	163		
Primary Area of Practice	Pearson Correlation	-.098	-.114	.435**	
	Sig. (2-tailed)	.223	.150	.000	
	N	157	160	168	
Facility Type	Pearson Correlation	.168*	.243**	.269**	-.157*
	Sig. (2-tailed)	.034	.002	.000	.042
	N	159	162	171	167

Note. Past behavior was based on Item 10 in the survey. Sum of Intentions were based on the sum of items 7-9. See Chapter 3 for further details.
* Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

Table 27

Bonferroni Multiple Comparisons—Predicting Past Behavior While Controlling for Primary Role of Student-Faculty

Past Behavior	(I) Primary Role	(J) Primary Role	*M* Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
	Student	Radiologic technologist	-.21016	.15141	1.000	-.6615	.2412
		Rad Tech Shift Leader/ Supervisor	-.43981	.24821	1.000	-1.1797	.3001
		Rad Tech Department Manager/ Director	-.81481	.30021	.111	-1.7097	.0800
		Educator/ Faculty in Radiologic Technology	-.54815*	.13839	.002	-.9607	-.1356
		Other	-.61481	.30021	.633	-1.5097	.2800

* The mean difference is significant at the 0.05 level.

Table 28

Bonferroni Multiple Comparisons—Predicting Sum of Intentions and Past Behavior While Controlling for Facility Type

		Sum of Squares	*df*	Mean Square	*F*	Sig.
Sum of Intentions (#7-#9)	Between Groups	1.661	8	.208	1.724	.097
	Within Groups	18.062	150	.120		
	Total	19.723	158			
Past Behavior	Between Groups	9.323	8	1.165	3.039	.003
	Within Groups	58.677	153	.384		
	Total	68.000	161			

Note. When correcting with Bonferroni, there was no significant difference between facility type and past behaviors. Past behavior was based on Item 10 in the survey. Sum of Intentions were based on the sum of items 7-9. See Chapter 3 for further details.

Results: Research Question and Hypothesis 2

Research Question 2: Do the intentions of radiologic technologists predict past behavior?

Hypothesis 2: Intentions predict past behavior.

2a. A correlation exists between the intention "plan to use" (#7) with past behaviors (#10).

2b. A correlation exists between the intention "will make an effort" (#8) with past behaviors (#10).

2c. A correlation exists between the intention "intend to use" (#9) with past behaviors (#10).

2d. A correlation exists between the sum of intention (#7-#9) with past behaviors (#10).

To help interpret hypothesis 2, tests of significance and descriptive statistics were performed. As noted in Table 29, the mean of each of the individual intention questions (#7 *M*=6.90; #8 *M*=6.90; #9 *M*=6.91) and the sum of intentions (*M*=6.9) are higher than self-reported past behavior (#10 *M* =6.56).

Table 29

Means of Intention and Past Behavior

Dependent Variables	N	Minimum	Maximum	M	SD
#7 Plan to use…	164	4	7	6.90	0.39
#8 Will make an effort to use…	162	4	7	6.90	0.38
#9 Intend to use…	161	5	7	6.91	0.37
Sum of Intentions	160			6.9	0.35
#10. Past Behavior	163	5	7	6.56	0.65

Pearson correlations were run to determine if there was significance in predicting past behavior with each of the intention questions. A significance was found between Question #7—Plan to use . . . with Question #10—Past Behaviors; Question #8—Will make an effort . . . with Question #10—Past Behaviors; Question #9—Intend to use . . .with Question #10—Past Behaviors; and the sum of intentions (#7-#9) with #10—Past Behaviors. Correlations were shown for each intention question with past behaviors, as well as the sum of intentions with past behaviors. See Table 30.

Table 30

Correlations Between Intentions and Past Behaviors

Dependent Variables		#7 Plan to Use	#8 Will Make An Effort	#9 Intend to Use	Sum of Intentions (#7-#9)
#8 Will Make An Effort	Pearson *r*	.811**			
	Sig. (2-tailed)	.000			
	N	162			
#9 Intend to Use	Pearson *r*	.719**	.822**		
	Sig. (2-tailed)	.000	.000		
	N	161	160		
Sum of Intentions (#7-#9)	Pearson *r*	.914**	.949**	.912**	
	Sig. (2-tailed)	.000	.000	.000	
	N	160	160	160	
#10 Past Behavior	Pearson *r*	.317**	.414**	.400**	.405**
	Sig. (2-tailed)	.000	.000	.000	.000
	N	163	162	161	160

** Correlation is significant at the 0.01 level (2-tailed).

Results: Research Question and Hypothesis 3

Research Question 3: Do the direct and indirect attitudes of radiologic technologists predict intentions to perform patient radiation protection best practices?

Hypothesis 3: Direct and indirect attitudes are predictive of intentions to perform patient radiation protection best practices.

3a. Direct attitudes are predictive of intentions to perform patient radiation protection best practices.

3b. Indirect attitudes are predictive of intentions to perform patient radiation protection best practices.

3c. Direct and indirect attitudes are predictive of behavioral intentions to perform patient radiation protection best practices.

To help interpret hypotheses 3, tests of significance and descriptive statistics were run between direct attitudes, sum of direct attitudes, and sum of intentions. A significant amount of unique variance was found between the direct attitudes: bad-good (*p*=.000, *r*=.688); unpleasant-pleasant (*p*=.000, *r*=.290); harmful-beneficial (*p*=.000, *r*=.583); punishing-rewarding (*p*=.000, *r*=.519); waste of time-worth the time (*p*=.000, *r*=.628; and the sum of direct attitudes (*p*=.000, *r*=.667); with the sum of intentions (see Table 31).

Correlations were run between indirect attitudes, sum of direct attitudes, and sum of intentions. A significant amount of unique variance was found between the indirect attitudes: reduce radiation (*p*=.000, *r*=.626); positive role model (*p*=.000, *r*=.427); ethical/moral (*p*=.000, *r*=.460); and the sum of direct attitudes (*p*=.000, *r*=.477) with the sum of intentions. No significant amount of unique variance was found between "taking longer" (*p*=.141, *r*=118) and intentions (see Table 32).

Regression analysis was calculated for both direct and indirect attitudes, and it is noted that both direct and indirect attitudes account for a significant amount of unique variance in predicting intentions (*p*=.000) at an alpha of .05 (see Table 33).

Coefficient analysis was calculated for both the sum of direct and indirect attitudes, and it is noted that both the sum of direct attitudes (*p*=.000) and indirect attitudes (*p*=.007) account for a significant amount of unique variance in predicting intentions (see Table 34).

Table 31

Correlations Between Direct Attitudes, Intentions, and Sum of Direct Attitudes

Dependent Variables		Sum of Intentions (#7-#9)	#11 Bad-Good	#12 Unpleasant-Pleasant	#13 Harmful-Beneficial	#14 Punishing-Rewarding	#15 A Waste-Worth
#11 Bad-Good	Pearson *r*	.688**					
	Sig. (2-tailed)	.000					
	N	159					
#12 Unpleasant-Pleasant	Pearson *r*	.290**	.211**				
	Sig. (2-tailed)	.000	.007				
	N	158	161				
#13 Harmful-Beneficial	Pearson *r*	.583**	.724**	.252**			
	Sig. (2-tailed)	.000	.000	.001			
	N	157	160	159			
#14 Punishing-Rewarding	Pearson *r*	.519**	.571**	.534**	.565**		
	Sig. (2-tailed)	.000	.000	.000	.000		
	N	158	161	160	159		
#15 A Waste of Time-Worth the Time	Pearson *r*	.628**	.702**	.371**	.704**	.654**	
	Sig. (2-tailed)	.000	.000	.000	.000	.000	
	N	158	161	160	159	160	
Sum of Direct Attitudes (#11-#15)	Pearson *r*	.667**	.760**	.679**	.786**	.862**	.847**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000
	N	154	157	157	157	157	157

Note. Any negatively worded responses were recorded; for a description of these items, refer to Chapter 3.
** Correlation is significant at the 0.01 level (2-tailed).

Table 32

Correlations Between Indirect Attitudes, Intentions, and Sum of Indirect Attitudes

		Sum of Intentions (#7-#9)	Reduce Radiation	Positive Role Model	Ethical/ Moral	Take Longer
Reduce Radiation	Pearson *r*	.626**				
	Sig. (2-tailed)	.000				
	N	157				
Positive Role Model	Pearson *r*	.427**	.431**			
	Sig. (2-tailed)	.000	.000			
	N	156	157			
Ethical/ Moral	Pearson *r*	.460**	.349**	.469**		
	Sig. (2-tailed)	.000	.000	.000		
	N	157	158	157		
Take Longer	Pearson *r*	.118	.053	.154	.088	
	Sig. (2-tailed)	.141	.508	.054	.273	
	N	158	158	157	158	
Sum of Indirect Attitudes	Pearson *r*	.477**	.517**	.534**	.591**	.836**
	Sig. (2-tailed)	.000	.000	.000	.000	.000
	N	151	153	153	153	153

Note. For a description of these items, see the variables section in Chapter 3. Any negative items were reversed.
** Correlation is significant at the 0.01 level (2-tailed).

Table 33

Regression Analysis Between Direct and Indirect Attitudes and the Sum of Intentions

Model		Sum of Squares	*df*	Mean Square	*F*	Sig.
	Regression	4.954	2	2.477	46.172	.000
1	Residual	7.671	143	.054		
	Total	12.625	145			

Note. Dependent Variable: Sum of Intentions (#7-#9). Predictors: (Constant), Sum of. Direct Attitudes (#11-#15), Sum of Indirect Attitudes (#16-#23 pairs).

Table 34

Coefficients for Intentions, Sum of Direct Attitudes, and Sum of Indirect Attitudes

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	*t*	Sig.
1	(Constant)	4.410	.267		16.543	.000
	Sum of Indirect Attitudes	.003	.001	.215	2.753	.007
	Sum of Direct Attitudes	.291	.047	.482	6.180	.000

Note. Dependent Variable: intentions.

Results: Research Question and Hypothesis 4

Research Question 4: Do the direct and indirect social pressures/norms of radiologic technologists predict intentions to perform patient radiation protection best practices?

Hypothesis 4: Direct and indirect social pressures/norms are predictive of intentions to perform patient radiation protection best practices.

4a. Direct social pressures/norms are predictive of intentions to perform patient radiation protection best practices.

4b. Indirect social pressures/norms are predictive of intentions to perform patient radiation protection best practices.

To help interpret hypothesis 4, tests of significance and descriptive statistics were run between direct social pressures/norms, sum of direct social pressures/norms, and sum of intentions. A significant amount of unique variance was found between each of the direct social pressures/norms and the sum of direct social pressures/norms with the sum of intentions, except for the questions “Most people in my role” (*p*=.117, *r*=.126) and “I feel under social pressure to NOT use . . .” (*p* =.448, *r*=061) (see Table 35).

Correlations were run between indirect social pressures/norms, sum of direct social pressures/norms, and sum of intentions. A significant amount of unique variance was found between patients (*p*=.001, *r*=.276) and sum of indirect social norms (*p*=.021, *r*=.191) with sum of intentions. No significant amount of unique variance was found between any of the other indirect social pressures/norms (see Table 36).

Regression analysis was calculated for both direct and indirect social pressures/norms, and it is noted that both direct and indirect social pressures/norms account for a significant amount of unique variance in predicting intentions (*p*=.003). This means that direct social pressures/norms and indirect social pressures/norms are predictors of intention (see Table 37).

Coefficient analysis was calculated for both the sum of direct and indirect social pressures/norms, and it is noted that both the sum of direct social norms (*p*=.013) accounts for a significant amount of unique variance in predicting intentions; however, no significant amount of unique variance was found between the sum of indirect social norms (*p*=.583) and predicting intentions (see Table 38).

Table 35

Correlations of Direct Social Pressures/Norms with Intentions

Dependent Variables		Sum of Intentions (#7-#9)	#23	#24	#25	#26	#27
#23 Most people who are important to me . . .	Pearson Correlation	.207**					
	Sig. (2-tailed)	.010					
	N	156					
#24 Most people in my role . . .	Pearson Correlation	.126	.237**				
	Sig. (2-tailed)	.117	.003				
	N	156	158				
#25 It is expected of me that I use . . .	Pearson Correlation	.273**	.420**	.345**			
	Sig. (2-tailed)	.001	.000	.000			
	N	157	159	159			
#26 I feel under social pressure to NOT use . . .	Pearson Correlation	.061	.100	.068	.147		
	Sig. (2-tailed)	.448	.210	.396	.064		
	N	157	159	159	160		
#27 People who are important to me want me to use . . .	Pearson Correlation	.380**	.507**	.335**	.434**	.191*	
	Sig. (2-tailed)	.000	.000	.000	.000	.016	
	N	156	158	158	159	159	
Sum of Direct Social Norms (#23-#27)	Pearson Correlation	.275**	.570**	.645**	.632**	.633**	.678**
	Sig. (2-tailed)	.001	.000	.000	.000	.000	.000
	N	154	157	157	157	157	157

Note. Any negative items were reversed.
* Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

Table 36

Correlations of Indirect Social Pressures/Norms

Dependent Variables		Sum of Intentions (#7-#9)	Patients	Patient's Family	Rad Tech Coworkers	Radiology Manager	Rad-iologist
Patients	Pearson Correlation	.276**					
	Sig. (2-tailed)	.001					
	N	155					
Patient's Family	Pearson Correlation	.124	.620**				
	Sig. (2-tailed)	.124	.000				
	N	155	157				
Rad Tech Coworkers	Pearson Correlation	.052	.299**	.337**			
	Sig. (2-tailed)	.521	.000	.000			
	N	154	155	155			
Radiology Manager	Pearson Correlation	.118	.334**	.389**	.515**		
	Sig. (2-tailed)	.147	.000	.000	.000		
	N	153	155	155	154		
Radiologist	Pearson Correlation	.123	.350**	.379**	.589**	.700**	
	Sig. (2-tailed)	.132	.000	.000	.000	.000	
	N	152	154	154	153	154	
Sum of Indirect Social Norms	Pearson Correlation	.191*	.668**	.680**	.765**	.785**	.821**
	Sig. (2-tailed)	.021	.000	.000	.000	.000	.000
	N	147	150	150	150	150	150

* Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

Table 37

Regression Analysis Between Direct and Indirect Social Pressures/Norms and the Sum of Intentions

Model	Sum of Squares	*df*	Mean Square	*F*	Sig.
Regression	1.509	2	.754	5.931	.003
Residual	18.059	142	.127		
Total	19.568	144			

Note. Dependent Variable: Sum of Intentions (#7-#9); Predictors: (Constant), Sum of Indirect Social Norms, Sum of Direct Social Norms.

Table 38

Coefficients for Intentions, Social Pressures/Norms, and Sum of Indirect Social Pressures/Norms

		Unstandardized Coefficients		Standardized Coefficients		
Model		*B*	Std. Error	Beta	*t*	Sig.
1	(Constant)	5.989	.264		22.700	.000
	Sum of Direct Norms	.127	.050	.244	2.521	.013
	Sum of Indirect Norms	.001	.001	.053	.550	.583

Note. Dependent Variable: intentions.

Results: Research Question and Hypothesis 5

Research Question 5: Do the direct and indirect perceived behavioral controls of radiologic technologists predict intentions to perform patient radiation protection best practices?

Hypothesis 5: Direct and indirect perceived behavioral control is predictive of intentions to perform patient radiation protection best practices.

5a. Direct perceived behavioral controls are predictive of intentions to perform patient radiation protection best practices.

5b. Indirect perceived behavioral controls are predictive of intentions to perform patient radiation protection best practices.

5c. Direct and indirect perceived behavioral controls are predictive of behavioral intentions to perform patient radiation protection best practices.

To help interpret hypothesis 5, tests of significance and descriptive statistics were run between direct perceived behavioral control, sum of direct perceived behavioral control, and sum of intentions. A significant amount of unique variance was found between each of the direct perceived behavioral control variables: “I am confident” (*p*=.000, *r*=.360), “impossible/possible” (*p*=.000, *r*=.399); and the sum of direct perceived behavioral control (*p*=.013, *r*=.198) with the sum of intentions. A nearly significant amount of unique variance was found between the variable “sometimes beyond my control” (*p*=.057, *r*=.153) and the sum of intentions. No significant amount of unique variance for predicting intentions was found with “Whether or not I use . . . is entirely up to me” (*p*=.892, *r*=-.011). See Table 39.

Correlations were run between indirect perceived behavioral control, sum of direct perceived behavioral control, and sum of intentions. A significant amount of unique variance in predicting intentions was found with the following indirect perceived behavioral controls: “feels rushed” (*p*=.019, *r*=-.192), “trauma situations” (*p*=.041, *r* = -.116), “lack of equipment-department” (*p*=.000, *r*=.511), “policies” (*p*=.003, *r*=.243), “safety culture” (*p*=.001, *r*=.270). No significant amount of unique variance was found in predicting intentions for the following indirect perceived behavioral controls: “lack of equipment-portables” (*p*=.053, *r*=.158), “reward” (*p*=.916, *r*=-.009), “continuing education” (*p*=.075, *r*=.147), and the sum of indirect

Table 39

Correlations Between Direct Perceived Behavior Control

		Sum of Intentions (#7-#9)	#38	#39	#40	#41
#38 I am confident . . .	Pearson Correlation	.360**				
	Sig. (2-tailed)	.000				
	N	156				
#39 For me, using . . . is impossible/possible.	Pearson Correlation	.399**	.410**			
	Sig. (2-tailed)	.000	.000			
	N	156	159			
#40 Whether or not I use . . . is entirely up to me	Pearson Correlation	-.011	.044	-.026		
	Sig. (2-tailed)	.892	.585	.747		
	N	156	159	159		
#41 Whether I use . . . sometimes is beyond my control	Pearson Correlation	.153	.064	.189*	.028	
	Sig. (2-tailed)	.057	.421	.017	.731	
	N	156	159	159	159	
Sum of Direct PBC (#38-#41)	Pearson Correlation	.198*	.255**	.302**	.661**	.736**
	Sig. (2-tailed)	.013	.001	.000	.000	.000
	N	156	159	159	159	159

Note. Any negative items were reversed.
* Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

perceived behavioral control (*p*=.614, r=.044) (see Table 40).

Regression analysis was calculated for both direct and indirect perceived behavioral control, and it is noted that both the sums of direct and indirect perceived behavioral control account for a significant amount of unique variance in predicting intentions (see Table 41). This means that direct perceived behavioral control and indirect perceived behavioral control are predictors of intention.

Coefficient analysis was calculated for both the sum of direct and indirect perceived behavioral control. It is noted that the sum of direct perceived behavioral control (*p*=.000) accounts for a significant amount of unique variance in predicting intentions; however, sum of indirect perceived behavioral control (*p*=.455) does not account for a significant amount of unique variance in predicting intentions (see Table 42).

Results: Research Question and Hypothesis 6

Research Question 6: Do the direct attitudes of radiologic technologists predict intentions to use digital equipment and digital techniques to lower patient dose?

Hypothesis 6: Direct attitudes are predictive of intentions to use digital equipment and digital techniques to lower patient dose. To help interpret hypothesis 6, tests of significance and descriptive statistics were run between direct attitudes (digital), sum of direct attitudes (digital), and sum of intentions. A significant amount of unique variance was found between the following direct attitudes (digital) when predicting intentions: bad-good (*p*= .023, *r*=.185); harmful-beneficial (*p*= .014, *r*=.200); punishing-rewarding (*p*= .010, *r*=.210); waste of time-worth the time (*p*= .001, *r*=.259); and the sum of direct attitudes (digital) (*p*= .012, *r*=.206). No significant amount of unique variance was found with the direct attitude (digital) of “unpleasant-pleasant” (*p*= .501, *r*=.055). See Table 43.

Table 40

Correlations Between Sum of Intentions and Indirect Perceived Behavior Control

Dependent Variables		Sum of Intentions (#7-#9)	FR	T	LEP	LED	P	R	CE	SC
Feels Rushed (FR)	Pearson Correlation	-.192*								
	Sig. (2-tailed)	.019								
	N	149								
Trauma Situations (T)	Pearson Correlation	-.166*	.372**							
	Sig. (2-tailed)	.041	.000							
	N	152	151							
Lack of Equip-Portables (LEP)	Pearson Correlation	.038	.238**	.158						
	Sig. (2-tailed)	.642	.004	.053						
	N	148	147	150						
Lack of Equip-Dept (LED)	Pearson Correlation	.511**	-.195*	.012	-.191*					
	Sig. (2-tailed)	.000	.017	.889	.021					
	N	149	149	150	147					
Policies (P)	Pearson Correlation	.243**	-.170*	-.036	-.236**	.377**				
	Sig. (2-tailed)	.003	.038	.659	.004	.000				
	N	147	148	149	146	148				
Reward (R)	Pearson Correlation	-.009	.089	.070	-.087	.084	.304**			
	Sig. (2-tailed)	.916	.285	.396	.293	.309	.000			
	N	148	148	150	147	148	147			
Cont. Edu. (CE)	Pearson Correlation	.147	-.025	-.116	-.136	.155	.349**	.462**		
	Sig. (2-tailed)	.075	.764	.160	.102	.061	.000	.000		
	N	147	147	149	146	147	147	147		

Table 40—*Continued.*

Dependent Variables		Sum of Inten-tions (#7-#9)	FR	T	LEP	LED	P	R	CE	SC
Safety Culture (SC)	Pearson Correlation	.270**	-.155	-.060	-.268**	.354**	.472**	.390**	.690**	
	Sig. (2-tailed)	.001	.061	.467	.001	.000	.000	.000	.000	
	N	146	147	148	145	147	147	147	146	
Sum of Indirect PBC	Pearson Correlation	.044	.256**	.352**	.218*	.173*	.482**	.693**	.648**	.610**
	Sig. (2-tailed)	.614	.003	.000	.011	.044	.000	.000	.000	.000
	N	135	136	136	136	136	136	136	136	136

Note. Any negative items were reversed. FRvFeels Rushed; TvTrauma; LEP=Lack of Equipment on Portables; LEDvLack of Equipment in Department; P=Policies; R=Reward; CD=Continuing Education; SC=Safety Culture; PBC=Perceived Behavioral Control.
* Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

Table 41

Regression Analysis Between Intentions and the Sum of Direct and Indirect PBC

Model	Sum of Squares	*df*	Mean Square	*F*	Sig.
Regression	.657	2	.329	3.846	.024
Residual	11.280	132	.085		
Total	11.937	134			

Note. Dependent Variable: Sum of Intentions (#7-#9). Predictors: (Constant), Sum of Direct Perceived Behavioral Control, Sum of Indirect Perceived Behavioral Control.

Table 42

Coefficients of Intentions and Perceived Behavioral Control

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	6.345	.222		28.597	.000
Sum of Indirect PBC	.000	.001	.064	.749	.455
Sum of Direct PBC	.084	.031	.231	2.725	.007

Note. Dependent Variable: intentions.

Table 43

Correlations of Direct Attitudes to Use Digital Equipment to Lower Patient Dose

Dependent Variables		Sum of Intentions (#7-#9)	#58	#59	#60	#61	#62
#58 Good—Bad	Pearson Correlation	.185*					
	Sig. (2-tailed)	.023					
	N	150					
#59 Unpleasant—Pleasant	Pearson Correlation	.055	.420**				
	Sig. (2-tailed)	.501	.000				
	N	150	153				
#60 Harmful—Beneficial	Pearson Correlation	.200*	.605**	.453**			
	Sig. (2-tailed)	.014	.000	.000			
	N	149	152	152			
#61 Punishing—Rewarding	Pearson Correlation	.210**	.517**	.505**	.596**		
	Sig. (2-tailed)	.010	.000	.000	.000		
	N	150	153	153	152		
#62 Waste of time—Worth the time	Pearson Correlation	.259**	.595**	.377**	.863**	.576**	
	Sig. (2-tailed)	.001	.000	.000	.000	.000	
	N	150	152	152	151	152	
Sum of Direct Attitudes—Digital	Pearson Correlation	.206*	.741**	.785**	.819**	.801**	.790**
	Sig. (2-tailed)	.012	.000	.000	.000	.000	.000
	N	149	151	151	151	151	151

Note. Any negative items were reversed. * Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

Results: Research Question and Hypothesis 7

Research Question 7*:* Do the direct social pressures/norms of radiologic technologists predict intentions to use digital equipment and digital techniques to lower patient dose?

Hypothesis 7: Direct social pressures/norms are predictive of intentions to use digital equipment and digital techniques to lower patient dose.

To help interpret hypothesis 7, tests of significance and descriptive statistics were run between direct social pressures/norms (digital), sum of direct social pressures/norms (digital), and sum of intentions. A significant amount of unique variance was found between the direct social pressures/norms (digital) when predicting intentions: most people who are important to me (p=.030, r=.177); it is expected of me that I use (p=.011, r=.207); people who are important to me want me to use (p=.002, r=.254); and the sum of direct social pressures/norms (digital) (p=.002, r=.253). No significant amount of unique variance was found for the question "Most people in my role" (p=.069, r=.150) (see Table 44).

Results: Research Question and Hypothesis 8

Research Question 8: Do the direct and indirect perceived behavioral controls of radiologic technologists predict intentions to use digital equipment and digital techniques to lower patient dose?

Hypothesis 8: Perceived behavioral controls (direct and indirect) are predictive of intentions to use digital equipment and digital techniques to lower patient dose.

8a. Direct perceived behavioral controls are predictive of intentions to use digital equipment and digital techniques to lower patient dose.

8b. Indirect perceived behavioral controls are predictive of intentions to use digital equipment and digital techniques to lower patient dose.

To help interpret hypothesis 8, tests of significance and descriptive statistics were run between direct perceived behavioral controls (digital), sum of direct perceived behavioral controls (digital), and sum of intentions.

Table 44

Correlations of Direct Social Pressures/Norms-Digital With Sum of Intentions

Dependent Variables		Sum of Intentions (#7-#9)	#63	#64	#65	#66
#63 Most people who are important to me. . .	Pearson Correlation	.177*				
	Sig. (2-tailed)	.030				
	N	150				
#64 Most people in my role. . .	Pearson Correlation	.150	.331**			
	Sig. (2-tailed)	.069	.000			
	N	148	151			
#65 It is expected of me that I use. . .	Pearson Correlation	.207*	.339**	.553**		
	Sig. (2-tailed)	.011	.000	.000		
	N	150	153	151		
#66 People who are important to me want me to use. . .	Pearson Correlation	.254**	.588**	.551**	.593**	
	Sig. (2-tailed)	.002	.000	.000	.000	
	N	148	151	149	151	
Sum of Direct Norms-Digital	Pearson Correlation	.253**	.668**	.818**	.799**	.854**
	Sig. (2-tailed)	.002	.000	.000	.000	.000
	N	146	149	149	149	149

Note. Any negative items were reversed.
* Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

No significant amount of unique variance was found between any of the direct perceived behavioral controls (digital) when predicting intentions: I am confident (*p*=.079, *r*=.144); Whether or not I use . . . is entirely up to me (*p*=.346, *r*=-.079); beyond my control (*p*=.483, *r*=.058); impossible/possible (*p*=.088, *r*=.140); and the sum of direct perceived behavioral controls (digital) (*p*=.470, *r*=-.061) (see Table 45).

Correlations were run between indirect perceived behavioral control (digital), sum of direct perceived behavioral control (digital), and sum of intentions. A significant amount of unique variance was not found between each of the indirect perceived behavioral control (digital) variables when predicting intentions: revert back (*p*=.919, *r*=-.008); policies (*p*=.078, *r*=.146); continuing education (*p*=.072, *r*=.148); feels unprepared (*p*=.106, *r*=.133); initial education insufficient (*p*=.527, *r*=.053); and the sum of direct perceived behavioral control (digital) (*p*=.077, *r*=.149) (see Table 46).

Regression analysis was calculated for both direct and indirect perceived behavioral control (digital). No significant amount of unique variance in predicting intentions (*p*=.159) at an alpha of .05 was found. See Table 47. This means that the sum of direct perceived behavioral control and the sum of indirect perceived behavioral control are not predictors of intention.

Coefficient analysis was calculated for both the sum of direct and indirect perceived behavioral control (digital), and it is noted that both the sum of direct perceived behavioral control (digital) (*p*=.641) and indirect perceived behavioral control (digital) (*p*=.077) account for no significant amount of unique variance in predicting intentions (see Table 48).

Table 45

Correlations Between Digital—Direct Perceived Behavioral Control and Sum of Intentions

Dependent Variables		Sum of Intentions (#7-#9)	#67	#68	#69	#70
#67 I am confident. . .	Pearson Correlation	.144	1	-.011	.176*	.742**
	Sig. (2-tailed)	.079		.894	.031	.000
	N	149	151	147	150	150
#68 Whether or not I use. . .is entirely up to me	Pearson Correlation	-.079	-.011	1	-.201*	.012
	Sig. (2-tailed)	.346	.894		.014	.886
	N	146	147	149	148	148
#69 Beyond my control	Pearson Correlation	.058	.176*	-.201*	1	.229**
	Sig. (2-tailed)	.483	.031	.014		.005
	N	149	150	148	152	151
#70 Impossible—possible	Pearson Correlation	.140	.742**	.012	.229**	1
	Sig. (2-tailed)	.088	.000	.886	.005	
	N	149	150	148	151	152
Digital PBC Sum	Pearson Correlation	.061	.578**	.503**	.604**	.627**
	Sig. (2-tailed)	.470	.000	.000	.000	.000
	N	143	145	145	145	145

Note. PBC—Perceived Behavioral Control.
* Correlation is significant at 0.05 (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed). Negative items were reversed.

Table 46

Correlations Between Digital—Indirect Perceived Behavioral Control and Sum of Intentions

Dependent Variables		Sum of Intentions (#7-#9)	Revert	Policies	Continuing Education	Feels Unprepared	Initial Ed insufficient
Indirect PBC Digital Revert	Pearson Correlation	-.008					
	Sig. (2-tailed)	.919					
	N	148					
Indirect PBC Digital Policies	Pearson Correlation	.146	.044				
	Sig. (2-tailed)	.078	.592				
	N	146	148				
Indirect PBC Digital Continuing Education	Pearson Correlation	.148	.130	.632**			
	Sig. (2-tailed)	.072	.114	.000			
	N	149	149	148			
Indirect PBC Digital Feels Unprepared	Pearson Correlation	.133	.082	-.028	.026		
	Sig. (2-tailed)	.106	.320	.736	.750		
	N	148	149	149	150		
Indirect PBC Digital Initial Education Insufficient	Pearson Correlation	.053	.157	.223**	.196*	.213**	
	Sig. (2-tailed)	.527	.058	.007	.017	.009	
	N	146	147	146	148	148	
Indirect PBC Digital Sum	Pearson Correlation	.149	.532**	.644**	.657**	.459**	.596**
	Sig. (2-tailed)	.077	.000	.000	.000	.000	.000
	N	142	144	144	144	144	144

Note. Any negative items were reversed. PBC-Perceived Behavioral Control.
* Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

Table 47

Regression Analysis Between Intentions and the Sum of Direct and Indirect Perceived Behavioral Control for Digital

Model	Sum of Squares	*df*	Mean Square	*F*	Sig.
Regression	.494	2	.247	1.863	.159
Residual	17.764	134	.133		
Total	18.258	136			

Note. Dependent Variable: Sum of Intentions (#7-#9). Predictors: Indirect Perceived Behavioral Control Sum for Digital, Direct Perceived Behavioral Control Sum for Digital.

Table 48

Coefficients of Intentions and Perceived Behavioral Control for Digital

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	*T*	Sig.
(Constant)	6.637	.224		29.688	.000
Direct PBC Sum for Digital	.018	.038	.040	.467	.641
Indirect PBC Sum for Digital	.001	.001	.154	1.785	.077

Note. Dependent Variable: intentions. PBC=Perceived Behavioral Control.

Results: Research Question and Hypothesis 9

Research Question 9: Do the components of Ajzen's theory of planned behavior (attitudes, social norms, perceived behavioral norms) predict intentions and past behavior of radiologic technologists regarding patient radiation protection best practices when controlling for age, gender, years of practice, role, area of practice, and place of practice?

Hypothesis 9: The components of Ajzen's theory of planned behavior will predict intentions and past behaviors to perform patient radiation protection best practices when controlling for age, gender, years of practice, role, area of practice, and place of practice.

Direct and Indirect Constructs of the Theory of Planned Behavior on Intentions

Regression analysis was done to test the direct and indirect constructs of the theory of planned behavior with intentions. Predicting intentions from these variables together is significant (p=.000) (see Table 49). This means that direct and indirect attitudes, direct and indirect social/pressures norms, and direct and indirect perceived behavioral control are significant predictors of intention when performing patient radiation protection best practices.

Table 49

Regression Analysis Between Intentions and the Constructs of Theory of Planned Behavior

Model	Sum of Squares	*df*	Mean Square	*F*	Sig.
Regression	5.357	6	.893	16.324	.000
Residual	6.071	111	.055		
Total	11.428	117			

Note. Dependent Variable: Sum of Intentions (#7-#9). Predictors: Direct Perceived Behavioral Control, Direct Norms, Direct Attitudes, Indirect Perceived Behavioral Control, Indirect Norms, Indirect Attitudes.

Additionally, as seen in Table 50, it is noted that direct attitudes (*p*=.000) account for a significant amount of unique variance in predicting intentions when controlling for social pressures/norms and perceived behavioral control. In other words, direct attitudes predict intentions when the indirect attitudes, direct and indirect social pressures/norms, and direct and indirect perceived behavioral control are controlled for.

Predicting Intentions When Controlling for Gender, Age, and Years in Practice

The constructs of theory of planned behavior account for significant amounts of unique variance when controlling for gender, age, and years in practice (*p*=.000) (see Table 51). Additionally, age (*p*=.019), years in practice (*p*=.028), and attitude (*p*=.000) show a significant unique variance when the constructs of the theory of planned behavior and age, gender, and years in practice are controlled for (see Table 52).

Table 50

Coefficients of Intentions and the Constructs of Theory of Planned Behavior

	Unstandardized Coefficients		Standardized Coefficients		
Model	*B*	Std. Error	Beta	*T*	Sig.
(Constant)	3.623	.356		10.166	.000
Direct Attitudes	.420	.068	.612	6.136	.000
Indirect Attitudes Sum	.002	.002	.095	1.053	.295
Direct Social Pressures/Norms	.022	.043	.050	.514	.608
Indirect Social Pressures/Norms	-.001	.001	-.092	-1.021	.310
Direct PBC	.021	.028	.056	.762	.448
Indirect PBC Sum	.001	.000	.079	1.076	.284

Note. Dependent Variable: Sum of Intentions (#7-#9).

Table 51

Summary of Hypotheses 9 When Demographics Are Controlled For

Intentions	Intention	Past Behavior
Direct Perceived Behavioral Control, Direct Norms, Direct Attitudes, Indirect Perceived Behavioral Control, Indirect Norms, Indirect Attitudes	*p*=.000	*p*=.000
Age + Gender + Years in Practice	*p*=.000	*p*=.000
Primary Role	*p*=.000	*p*=.000
Primary Area of Practice	*p*=.000	*p*=.000
Facility Type	*p*=.000	*p*=.000

Predicting Intentions When Controlling for Primary Role

The constructs of theory of planned behavior account for significant amounts of unique variance when controlling for role (*p*=.000) (see Table 51).

Table 52

Summary of Hypotheses 9 When the Constructs of the Theory of Planned Behavior Are Controlled For

Intentions	Theory of Planned Behavior Controlled For
Age	*p*=.019
Years in Practice	*p*=.028
Gender + Age + Years in Practice + Attitude	*p*=.000
Primary Area of Practice + Attitude	*p*=.000
Facility Type + Attitudes	*p*=.000

Predicting Intentions When Controlling for Primary Area of Practice

The constructs of theory of planned behavior account for significant amounts of unique variance when controlling for primary area of practice (*p*=.000) (see Table 51). Additionally, attitude accounts for a significant amount of unique variance in predicting intentions (*p*=.000) when the constructs of the theory of planned behavior and primary area of practice are controlled for (see Table 52).

Predicting Intentions When Controlling for Facility Type

The constructs of theory of planned behavior account for significant amounts of unique variance when controlling for facility type (*p*=.000). See Table 51. Additionally, attitude accounts for a significant amount of unique variance in predicting intentions (p=.000) when the constructs of the theory of planned behavior and facility type are controlled for. See Table 52.

Direct and Indirect Constructs of the Theory of
Planned Behavior on Past Behavior

Regression analysis was calculated to test the direct and indirect constructs of the theory of planned behavior when predicting past behavior. Predicting past behavior from these variables together is significant (p=.000). See Table 53. This means that direct and indirect attitudes, direct and indirect social/pressures norms, and direct and indirect perceived behavioral control are significant predictors of past behavior when performing patient radiation protection best practices.

Additionally, as seen in Table 54, it is noted that the sum of direct attitudes (p=.002) and indirect attitudes (p=.031) accounts for a significant amount of unique variance in predicting past behavior when co-varying, for social pressures/norms and perceived behavioral control in past behavior. In other words, direct attitudes and indirect attitudes predict past behaviors when the direct and indirect social pressures/norms and direct and indirect perceived behavioral controls are removed.

Predicting Past Behavior When Controlling for Gender, Age, and Years in Practice

The constructs of theory of planned behavior account for significant amounts of unique variance when controlling for gender, age, and years in practice (p=.000). See Table 51. Additionally, gender (p=.025) and attitude (p=.005) show a significant amount of unique variance when the constructs of the theory of planned behavior and age, gender, and years in practice are controlled for. See Table 55.

Table 53

Regression Analysis Between Past Behavior and the Constructs of the Theory of Planned Behavior

Model	Sum of Squares	*df*	Mean Square	*F*	Sig.
Regression	17.578	7	2.511	8.690	.000
Residual	31.786	110	.289		
Total	49.364	117			

Note. Dependent Variable: Past Behavior. Predictors: Direct Perceived Behavioral Control, Direct Norms, Direct Attitudes, Indirect Perceived Behavioral Control, Indirect Norms, Indirect Attitudes.

Table 54

Coefficients Between Past Behavior and the Constructs of the Theory of Planned Behavior

	Unstandardized Coefficients		Standardized Coefficients		
Model	*B*	Std. Error	Beta	*t*	Sig.
(Constant)	1.795	1.138		1.577	.118
Intentions	-.004	.218	-.002	-.020	.984
Direct Attitudes	.586	.182	.411	3.223	.002
Indirect Attitudes Sum	.008	.003	.219	2.187	.031
Direct Social Pressures/Norms	-.087	.098	-.096	-.889	.376
Indirect Social Pressures/Norms	.002	.002	.134	1.336	.184
Direct PBC	.014	.065	.018	.216	.829
Indirect PBC Sum	-.002	.001	-.140	-1.708	.090

Note. Dependent Variable: Past Behavior.

Table 55

Summary of Hypothesis 9 When the Constructs of the Theory of Planned Behavior Are Controlled for Past Behavior

Past Behavior	Theory of Planned Behavior Controlled For
Gender	*p*=.025
Gender + Age + Years in Practice + Attitude	*p*=.005
Primary Role + Attitude	*p*=.001
Primary Area of Practice + General Diagnostic Only	*p*=.033
Primary Area of Practice + General Diagnostic Plus a Specialty	*p*=.019
Primary Area of Practice + Other	*p*=.015
Primary Area of Practice + Attitude	*p*=.000
Facility Type + Attitude	*p*=.009

Predicting Past Behavior When Controlling for Primary Role

The theory of planned behavior accounts for significant amounts of unique variance when controlling for role (*p*=.000). See Table 51. Additionally, attitude (*p*=.001) accounts for a significant amount of unique variance when the constructs of the theory of planned behavior and primary role are controlled for. See Table 55.

Predicting Past Behavior When Controlling for Primary Area of Practice

The constructs of theory of planned behavior account for significant amounts of unique variance when controlling for primary area of practice (*p*=.000). See Table 51. Additionally, it is noted that general diagnostic only (*p*=.033), general diagnostic plus a specialty (*p*=.019), other (*p*=.015), and attitude (*p*=.001) account for a significant amount of unique variance when the constructs of the theory of planned behavior and primary area of practice are controlled for. See Table 55.

Predicting Past Behavior When Controlling for Facility Type

The constructs of theory of planned behavior account for significant amounts of unique variance when controlling for facility type (p=.000). See Table 51. Additionally, attitudes (p=.009) show a significant unique variance when the constructs of the theory of planned behavior and facility type are controlled for. See Table 55.

Results: Research Question and Hypothesis 10

Research Question 10: Do the components of Ajzen's theory of planned behavior (attitudes, social norms, perceived behavioral norms) predict intentions and past behavior of radiologic technologists regarding the use of digital equipment and digital techniques to lower patient dose?

Hypothesis 10: The components of Ajzen's theory of planned behavior will predict intentions and past behavior to use new digital equipment and digital techniques to lower patient dose when controlling for age, gender, years of practice, role, area of practice, and place of practice.

Digital: Direct and Indirect Constructs of the Theory of Planned Behavior on Intentions

Regression analysis was done to test the direct and indirect constructs of the theory of planned behavior with intentions for using new digital equipment. Predicting intentions from these digital variables together is significant (p=.021, see Table 56). This means that digital direct attitudes, digital direct social/pressures norms, and digital direct and indirect perceived behavioral control are significant predictors of intention to lower patient dose while using new digital equipment and digital techniques.

Additionally, as seen in Table 57, it is noted that none of the variables account for a significant amount of unique variance in predicting intentions. In other words, intentions can be predicted only when the constructs of the theory of planned behavior constructs are controlled for.

Digital: Intentions When Controlling for Gender, Age, and Years in Practice

The constructs of theory of planned behavior account for significant amounts of unique variance when controlling for gender, age, and years in practice (p=.003). See Table 58. This information is specific to the use of new digital equipment and digital techniques to lower patient dose. Additionally, gender (p=.022) accounts for a significant amount of unique variance when the theory of planned behavior and gender, age, and years in practice are controlled for, specific to the use of new digital equipment and digital techniques to lower patient dose. See Table 59.

Table 56

Regression Analysis Between Intentions and the Constructs of the Theory of Planned Behavior (Digital)

Model	Sum of Squares	*df*	Mean Square	*F*	Sig.
Regression	1.545	4	.386	2.987	.021
Residual	16.684	129	.129		
Total	18.229	133			

Note. Dependent Variable: Intentions. Predictors: Digital-Direct Perceived Behavioral Control, Digital-Direct Norms, Digital-Direct Attitudes, Digital-Indirect Perceived Behavioral Control.

Table 57

Coefficients of Intentions and the Constructs of Theory of Planned Behavior (Digital)

	Unstandardized Coefficients		Standardized Coefficients		
Model	*B*	Std. Error	Beta	*t*	Sig.
(Constant)	5.795	.381		15.202	.000
Direct Attitudes-Digital	.098	.061	.155	1.594	.113
Direct Norms-Digital	.058	.039	.151	1.475	.143
Direct PBC-Digital	.002	.039	.004	.043	.966
Indirect PBC-Digital Sum	.001	.001	.073	.775	.440

Note. Dependent Variable: Intentions

Table 58

Summary of Hypothesis 10 When Demographics Are Controlled For (Digital)

Intentions	Intention-Digital	Past Behavior-Digital
Direct Perceived Behavioral Control, Direct Norms, Direct Attitudes, Indirect Perceived Behavioral Control, Indirect Norms, Indirect Attitudes	p=.021	p=.000
Age + Gender + Years in Practice	p=.003	p=.000
Roles	p=.000	p=.000
Primary Area of Practice	p=.000	p=.000
Facility Type	p=.000	p=.000
Past Behavior	p=.000	p=.000

Table 59

Summary of Hypothesis 10 When the Constructs of the Theory of Planned Behavior Are Controlled for Intentions (Digital)

Intentions	Theory of Planned Behavior Controlled For
Gender	p=.022
Roles (students)	p=.030
Roles + Attitudes	p=.000
Primary Area of Practice + Indirect Attitudes	p=.000
Facility Type + Attitudes	p=.000

Digital: Intentions When Controlling for Roles

The constructs of theory of planned behavior account for significant amounts of unique variance when controlling for primary roles. Predicting intentions from these variables together is significant (p=.000). See Table 58. Additionally, it is noted that students accounts for a significant amount of unique variance in predicting intentions (p=.030) when the constructs of the theory of planned behavior and roles are controlled for. Also, attitudes show a significant unique variance (p=.000) when the constructs of the theory of planned behavior and roles are controlled for. This information is specific to the use of new digital equipment and digital techniques to lower patient dose.

Digital: Intentions When Controlling for Primary Area of Practice

The constructs of theory of planned behavior account for significant amounts of unique variance when controlling for primary area of practice (p=.000). See Table 58. Additionally, the sum of indirect attitudes accounts for a significant amount of unique variance in predicting intentions (p=.000) when controlled for primary area of practice when the theory of planned behavior is used with roles. This information is specific to the use of new digital equipment and digital techniques to lower patient dose. See Table 59.

Digital: Intentions When Controlling for Facility Type

The constructs of theory of planned behavior account for significant amounts of unique variance when controlling for facility type (*p*=.000). See Table 58. Additionally, attitudes account for a significant amount of unique variance in predicting intentions (*p*=.000) when the constructs of the theory of planned behavior and facility type are controlled for. See Table 59. This information is specific to the use of new digital equipment and digital techniques to lower patient dose.

Digital: Direct and Indirect Constructs of the Theory of Planned Behavior on Past Behavior

Multiple regression analysis was done to test the direct and indirect constructs of the theory of planned behavior with past behavior for using new digital equipment. Predicting past behavior from these variables together is significant (*p*=.030). Refer to Table 60. This means that direct and indirect perceived behavioral control, direct social pressures/norms, and direct attitudes are predictors of past behavior for using new digital equipment.

Additionally, as seen in Table 61, it is noted that the sum of direct attitudes (digital) (*p*=.004) accounts for a significant amount of unique variance in predicting past behavior for using new digital equipment. This information is specific to the use of new digital equipment and digital techniques to lower patient dose. In other words, direct attitudes predict past behaviors when the direct social pressures/norms and direct and indirect perceived behavioral control are controlled for.

Table 60

Regression Analysis Between Past Behavior (Digital) and the Constructs of the Theory of Planned Behavior

Model	Sum of Squares	*df*	Mean Square	*F*	Sig.
Regression	4.364	4	1.091	2.768	.030
Residual	51.236	130	.394		
Total	55.600	134			

Note. Dependent Variable: Past Behavior. Predictors: Sum of Direct Social Norms for Digital, Sum of Direct PBC for Digital, Sum of Indirect PBC for Digital, Sum of Direct Attitudes for digital.

Table 61

Correlation Between Past Behavior (Digital) and the Constructs of the Theory of Planned Behavior

	Unstandardized Coefficients		Standardized Coefficients		
Model	*B*	Std. Error	Beta	*t*	Sig.
(Constant)	4.875	.665		7.329	.000
Sum PBC Digital	-.082	.068	-.107	-1.197	.233
Sum Indirect PBC Digital	.000	.001	-.017	-.179	.858
Sum Direct Attitudes Digital	.314	.107	.285	2.945	.004
Sum Direct Social Norms Digital	.011	.067	.016	.157	.876

Note. Dependent Variable: Past Behavior.

Digital: Past Behavior When Controlling for Gender, Age, and Years in Practice

The constructs of theory of planned behavior account for significant amounts of unique variance when controlling for gender, age, and years in practice (*p*=.000). See Table 58. Additionally, gender (*p*=.028), years in practice (p=.001), intentions (p=000), direct attitude-digital (*p*=.012), and direct perceived behavioral control-digital (p=.016) show a significant unique variance when the constructs of the theory of planned behavior and gender, age, and years in practice are controlled for. See Table 62. This information is specific to the use of new digital equipment and digital techniques to lower patient dose.

Digital: Past Behavior When Controlling for Primary Role

The constructs of theory of planned behavior account for significant amounts of unique variance when controlling for role. See Table 58. Predicting past behavior from these variables together is significant (*p*=.000). Predicting past behavior from primary roles on their own is also significant (*p*=.004). Additionally, student (*p*=.000), intentions (*p*=.000), direct attitude-digital (*p*=.023), and direct perceived behavioral control-digital (*p*=.044) show a significant amount of unique variance when the constructs of the theory of planned behavior and primary role are controlled for. See Table 62.

Table 62

Summary of Hypotheses 10 When the Constructs of the Theory of Planned Behavior Are Controlled for Past Behavior (Digital)

Past Behavior	Theory of Planned Behavior Controlled For
Years in Practice	*p*=.001
Gender	*p*=.028
Gender + Years in Practice + Age + Direct Attitude	*p*=.012
Gender + Years in Practice + Age + Intentions	*p*=.000
Gender + Years in Practice + Age + Direct perceived behavioral control	*p*=.016
Primary Role (students)	*p*=.000
Primary Role + Intentions	*p*=.000
Primary Role + Direct Attitude	*p*=.023
Direct Perceived Behavioral Control	*p*=.044
Primary Area of Practice + Intentions	*p*=.000
Primary Area of Practice + Direct Attitudes	*p*=.012
Primary Area of Practice + Direct Perceived Behavioral Control	*p*=.045
Facility Type + Intentions	*p*=.000
Facility Type + Direct Attitudes	*p*=.000
Facility Type + Direct Perceived Behavioral Control	*p*=.053*

*Nearly Significant.

Digital: Past Behavior When Controlling for Primary Area of Practice

The constructs of theory of planned behavior account for significant amounts of unique variance when controlling for primary area of practice (*p*=.000). See Table 58. Additionally, intentions (*p*=.000), direct attitudes-digital (*p*=.012), and direct perceived behavioral control-digital (*p*=.045) show a significant unique variance when the constructs of the theory of planned behavior and primary area of practice are controlled for (see Table 62). This information is specific to the use of new digital equipment and digital techniques to lower patient dose.

Digital: Past Behavior When Controlling for Facility Type

The constructs of theory of planned behavior account for significant amounts of unique variance when controlling for facility type (*p*=.000) (see Table 58). Additionally, it is noted that intentions (*p*=.000) and direct attitudes-digital (*p*=.042) show a significant unique variance when the theory of planned behavior is controlled for. Also, direct perceived behavioral control-digital shows a nearly significant unique variance (*p*=.053) when the constructs of the theory of planned behavior and facility type are controlled for (see Table 62). This information is specific to the use of new digital equipment and digital techniques to lower patient dose.

Summary

This chapter summarizes all of the findings for each of the hypotheses in this study.

CHAPTER 5

CONCLUSIONS, DISCUSSION, AND IMPLICATIONS

Introduction

Since radiation was first discovered by Wilhelm Roentgen in 1895 (Bushong, 2008; Sherer et al., 2006), the risks and the benefits of radiation exposure have been at odds with each other. On one hand, when human cells come in contact with ionizing radiation, detrimental effects can occur. On the other, diagnostic and therapeutic benefit is also possible with radiation exposure. The risk is increased with the amount of exposure, with repeated exposures, and when the patient is young (Peck & Samei, 2013). Even with the known benefits of radiation in medical imaging, exposure to radiation must be minimized. Although a one-time unnecessary exposure may not have visual or significant adverse effects, the impact of radiation exposure over the lifetime of an individual is cumulative and could result in eventual harm to those exposed.

A growing concern exists that patients are receiving an increase in radiation exposure while undergoing medical imaging exams. In the past two decades, total exposure to ionizing radiation has doubled in the United States (NCRP, 2009). With the new “digital age” of radiology, patient dose has increased even more (Marshall & Keene, 2007).

Researchers and educators have suggested possible reasons for the dramatic increase of patient radiation exposure, including: radiologic technology behavior, increased number of exams ordered by primary care providers, availability of self-referred exams, increased number of computed tomography exams ordered, and a lack of a thorough understanding of how to decrease exposure using digital equipment versus analog (film) technology (Colangelo et al., 2009; Marshall & Keene, 2007; Slechta & Reagan, 2008).

The Joint Commission (2011) has suggested that the following actions be taken in order to reduce patient radiation exposure: (a) adhere to the ALARA guidelines as required by the Nuclear Regulatory Commission (2012); (b) follow the Image Wisely guidelines for adults developed by the American College of Radiology, Radiological Society of North American, American Association of Physicists in Medicine, and the American Society of Radiologic Technologists (Image Wisely, 2012); (c) provide training on how to use new, complex equipment; (d) develop policies and protocols for proper radiographic techniques and dose; (e) develop policies for the appropriate use of lead shielding; and (f) develop standards for promoting a safety culture.

Limited research has been done in the area of understanding the behavior of radiologic technologists. Understanding the issues related to a radiologic technologist's behavior regarding patient radiation protection best practices using a theoretical framework could help to positively address the concern that patient exposure to radiation is increasing.

This study attempts to understand the attitudes, social pressures, behavioral control issues, organizational issues, the impact of new digital technology, and the demographic factors that influence the demonstration of patient radiation protection best practices in order to reduce patient radiation exposure during radiography exams.

This study was guided by Ajzen's (1985) theory of planned behavior to determine whether or not the constructs of the theory of planned behavior could predict radiation protection best practice behavior. This chapter is divided into three major sections: summary of the study, conclusions and discussion, implications, and suggestions for further research.

Summary of the Study

This study investigated the descriptive and correlational relationships of the constructs of the theory of planned behavior (Ajzen, 1985) (intentions, past behaviors, attitudes, social pressures/norms, and perceived behavioral control). The behaviors studied were patient radiation protection best practices and the use of new digital technology and digital techniques to lower patient dose, both from the aspect of predicting intentions and past behaviors of radiologic technologists.

Radiologic technologists, faculty, and students in the Southwestern United States, primarily in Southern California, were used in this investigation. Data were generated from a convenience sample of 365 radiologic technologists yielding a 47% response rate from 173 respondents. An 80-item survey instrument was administered over a 4-week period. Hypotheses were derived from the theory of planned behavior.

This study used the most sophisticated type of *ex post facto* research design—*ex post facto* with hypotheses and controls for viable alternative explanations of research outcomes. The results were tested using a variety of methods, including multiple linear regression, Cronbach's alpha, Cohn's statistical power analysis, correlations, descriptive statistics, and analysis of variance.

The major goal of this study was to fill the gap in research by using Dr. Icek Ajzen's (1985, 1991, 2001, 2002) theory of planned behavior to study the problem that patient radiation exposure has increased in the past 20 years (NCRP, 2009). By using Ajzen's theory of planned behavior, the intent was to predict the intentions and past behavior of radiologic technologists based on their attitudes, social pressures, perceived behavioral control, demographic factors, and organizational issues of radiologic technologists when it comes to using patient radiation protection best practices and using new digital x-ray equipment to lower patient dose.

Ajzen (1985) proposes through the theory of planned behavior that a person's behavior can be predicted by the strength of the intention of an individual, which helps to understand the link between attitudes toward the behavior, the subjective norms (social pressures), and perceived behavioral control. "Given a sufficient degree of actual control over the behavior, people are expected to carry out their intentions when the opportunity arises" (Ajzen, 2002, p. 665). This means that it could be assumed that since the constructs of the theory of planned behavior can predict intentions, and past behavior predicts intentions, then intentions could predict future behavior.

Additionally, the goal was to create a survey instrument with good estimates of reliability and validity to assess the attitudes and behaviors of health care personnel so that hospital leadership could assess and develop a safety culture at their own facilities.

Significant correlational findings include the following:

1. Intentions predict past behaviors.

2. Attitudes, social pressures/norms, and perceived behavioral control predict intentions and past behavior.

3. Intentions are slightly higher than self-reported past behavior.

4. Attitudes have more significance to predicting intentions and past behavior over social pressures/norms and perceived behavioral control.

5. Patients have more significant influence on radiologic technologists than do their co-workers.

6. The demographic variables of age, gender, and years in practice are significant in predicting intentions—specifically, females, more years in practice, and older radiologic technologists demonstrate higher intentions and past behaviors.

7. The demographic variables of age, gender, years in practice, primary roles (specifically students), and facility type are significant in predicting past behavior.

8. In general, it can be assumed from this study that radiologic technologists have an attitude that patient radiation protection best practices are good, pleasant, beneficial, rewarding, and worth the time.

9. A radiologic technologist's attitudes of reducing patient radiation exposure, being a positive role model, doing something ethical/moral, and the sum of all indirect attitudes are significant in predicting intentions.

10. The sum of direct and indirect social pressure/norms has significance in predicting best practice behavior, specifically from patients.

11. Feeling confident to perform the behavior, viewing the behavior as possible to perform, feeling rushed, trauma situation, lack of equipment in the department, policies, and a safety culture have significance in predicting of intentions.

12. Regarding the behavior of using new digital technology and digital techniques to lower patient dose, significant contributors to predicting intentions include attitudes and social pressures/norms. Neither direct nor indirect perceived behavioral control was significant in predicting intentions in this area.

Findings and Discussion

First, the results of this study have concluded that the constructs in the theory of planned behavior are significant for predicting a radiologic technologist's use of patient radiation protection best practices and the use of new digital equipment and digital techniques to lower patient dose. Second, the survey tool that was developed using the constructs of the theory of planned behavior showed to be beneficial in predicting intentions and past behaviors of radiologic technologists. Third, the results of this research could be descriptive and prescriptive in the hospital and educational setting when assessing and creating a safety culture for radiologic patient care best practices. If it can be assumed that intentions and past behavior could predict future behavior, and the drivers of the best practice behavior can be identified, then hospital and education facilities could use this information to assess and develop organizational plans to instill and promote patient radiation protection best practice behavior in radiologic technologist staff and students.

Demographic Significance

Specifically, age is significant in predicting intentions (r =.189, p=.017) and past behavior (r =.202, p=.005), meaning that as age increases, intentions and past behavior to perform patient radiation protection best practices increase. Gender is significant in predicting intentions (*r* =.218, *p*=.006) and past behavior (*r* =2.85, *p*=.001), meaning that females score significantly higher than do males. Years in practice is also positively related to intentions (*r* =.201, *p*=.011) and past behavior (*r* =.335, *p*=.001), meaning that as years in practice increase, intentions and past behavior increase. See Table 64. The findings of this study are consistent with what Tilson (1982) found, in that age and years of professional experience positively correlated with radiation protection practices.

As to why females score significantly higher than do males, and why increased age has more significance, more research would need to be done to fully understand this.

Primary roles, primary area of practice, and facility type do not influence intentions or past behavior; however, students are inversely linked to educator/faculty when it comes to the performance of past behaviors. What this means is that when educator/faculty are compared with students in the area of past behaviors, students' past behaviors are lower than educator/faculty's past behaviors. This could be that students are new to the field of radiography, so their past behavior is reported as lower, or it could be an alarming finding since it could be assumed that students, who are still new to the field and who you would expect to have a higher acceptance of learning new information about the effects of radiation exposure, should have at least equal past behavior as their faculty. More research is needed in this area of understanding student behavior.

Significance Between Intentions and Past Behavior

A significant correlation exists between intentions and past behavior (*p*=.000, *r*=.405) to perform patient radiation protection best practices, which is what was expected. See Table 63. Self-reported past behavior is lower than intentions, which is also what was expected. See Table 64. Armitage and Conner (2001) report that the intention—behavior correlation from the present meta-analysis is comparable with those of recent meta-analyses devoted to intention—behavior relations. The intention—behavior correlation in the present meta-analysis is $r = .47$. For this study it is $r=.40$.

Table 63

Summary of Demographic Factors That Predict Intentions and Past Behavior

Hypothesis/Variable	Significance of Intention	Significance of Past Behavior
H1: Age	p=.017	p=.005
H1: Gender	p=.006	p=.000
H1: Years in Practice	p=.011	p=.001
H1: Primary Roles		p=.001
H1: PR-Student-Faculty		p=.002
H1: Facility Type		p=.003

Note. Correlation is significant at the 0.05 level (2-tailed).

Table 64

Intentions Predict Past Behavior

Intentions	Significance of Past Behavior	Mean
Plan to Use	p=.000	6.90
Will Make an Effort	p=.000	6.89
Intend to Use	p=.000	6.90
Sum of Intentions	p=.000	6.90
Past Behavior		6.55

Note. Correlation is significant at the 0.05 level (2-tailed).

Significance of the Constructs in the Theory of Planned Behavior

Attitudes (direct and indirect) are predictive of intentions to perform patient radiation protection best practices, except for the question “By using radiation protection best practices in x-ray exams, I will take longer to complete exams” and the corresponding evaluation question “Taking longer to complete exams is [a serious problem—not a serious problem],” where no significant correlation to intentions was found. What this means is that taking longer to complete an exam was not found to be significant as a predictor for intentions to perform radiation protection best practices. This is important in that radiologic technologists are more concerned about patient radiation protection best practices even if the time to complete the exam will take longer. Reducing radiation exposure, being a positive role model, doing something ethical/moral, and the sum of all indirect attitudes do have a significant correlation to intentions (see Table 65).

Attitudes (direct and indirect) are predictive of intentions to perform patient radiation protection best practices, except for the question “By using radiation protection best practices in x-ray exams, I will take longer to complete exams” and the corresponding evaluation question “Taking longer to complete exams is [a serious problem—not a serious problem],” where no significant correlation to intentions was found. What this means is that taking longer to complete an exam was not found to be significant as a predictor for intentions to perform radiation protection best practices. This is important in that radiologic technologists are more concerned about patient radiation protection best practices even if the time to complete the exam will take longer.

Reducing radiation exposure, being a positive role model, doing something ethical/moral, and the sum of all indirect aptitudes do have a significant correlation to intentions (see Table 65).

Social pressures/norms (direct and indirect) are predictive of intentions to perform patient radiation protection best practices, except for the direct question “most people in my role” and “I feel under social pressure to NOT use patient radiation protection best

Table 65

Predictors of Intentions of Patient Radiation Protection Best Practices

Variable	Significance
Direct Attitude: Good-Bad	*p*=.000 *r*=.688
Direct Attitude: Unpleasant-Pleasant	*p*=.000 *r*=.290
Direct Attitude: Harmful-Beneficial	*p*=.000 *r*=.583
Direct Attitude: Punishing-Rewarding	*p*=.000 *r*=.519
Direct Attitude: Waste Of Time-Worth The Time	*p*=.000 *r*=.628
Sum Of Direct Attitudes	*p*=.000 *r*=.667
Indirect Attitude: Reduce Radiation	*p*=.000 *r*=.626
Indirect Attitude: Positive Role Model	*p*=.000 *r*=.427
Indirect Attitude: Ethical/Moral	*p*=.000 *r*=.460
Sum of Indirect Attitudes	*p*=.000 *r*=.477
Direct Social Pressures/Norms: Most People Who Are Important to Me	*p*=.010 *r*=.207
Direct Social Pressures/Norms: Expected	*p*=.001 *r*=.273
Direct Social Pressures/Norms: People Important to Me Want Me	*p*=.000 *r*=.380
Sum of Direct Social Pressures/Norms	*p*=.001 *r*=.275
Indirect Social Pressures/Norms: Patients	*p*=.001 *r*=.276
Sum of Indirect Social Pressures/Norms	*p*=.021 *r*=.191
Direct Perceived Behavioral Control: I Am Confident	*p*=.000 *r*=.360
Direct Perceived Behavioral Control: For Me, Using…Is Impossible/Possible	*p*=.000 *r*=.399
Direct Perceived Behavioral Control: Sum	*p*=.013 *r*=.198
Indirect Perceived Behavioral Control: Rushed	*p*=.019 *r*=.192
Indirect Perceived Behavioral Control: Trauma	*p*=.041 *r*=.166

Table 65—*Continued*.

Indirect Perceived Behavioral Control: Lack of Equipment in the Department	*p*=.000 *r*=.511
Indirect Perceived Behavioral Control: Policies	*p*=.003 *r*=.243
Indirect Perceived Behavioral Control: Safety Culture	*p*=.001 *r*=.270

Note. Correlation is significant at the 0.05 level (2-tailed).

practices," where no significant amount of variance with intentions to perform patient radiation protection best practice behavior was evident. What this means is that feeling under social pressure to not use patient radiation protection nor the social pressure of other people in their role was not found to be significant as a predictor for intentions, but it was found to be significant with past behavior. Also of interest is that significance was found with the approval of all indirect social norms (patients, patient's family, radiologic technologist peer, radiology manager, and radiologist). This means that indirect social pressures/norms do influence the behavior of radiologic technologists, but patients (*p*=.001, *r*=.276; see Table 65) have the most influence.

Perceived behavioral controls (direct and indirect) are predictive of intentions to perform patient radiation protection best practices, except for the questions "lack of equipment-portables," "reward," and "continuing education," where no significance to intention was found.

Significance of the Constructs in the Theory of Planned Behavior—Digital

The sum of direct attitudes is predictive of intentions to use digital equipment and digital techniques to lower patient dose (*p*=.012, *r*=.206). See Table 66. Direct social pressures/norms are predictive of intentions to use digital equipment and digital techniques to lower patient dose. Direct and indirect perceived behavioral control was not predictive of intentions to use digital equipment and digital techniques to lower patient dose. This is consistent with the findings of Harding et al. (2007) who found that the perceived behavioral control was not significantly related to either intention or behavior.

It is noted that Cronbach's alpha falls below the recommended 0.70 score for all of the following categories: indirect attitudes (0.383), direct social pressures/norms (0.549), direct perceived behavioral control (0.117), indirect perceived behavioral control (0.420), digital-direct perceived behavioral control (0.132), and digital-indirect perceived behavioral control (0.489). Ajzen (2013) comments that Cronbach's alpha is the most commonly used coefficient; however, "internal consistency is not a requirement of the behavioral, normative, and control belief composites because different accessible beliefs may well be inconsistent with each other."

Implications

The results of this study have implications for the hospital and educational environments. This study demonstrated that constructs of the theory of planned behavior have significance when predicting intentions and past behavior when it comes to using patient radiation protection best practices.

The results of this study can be used to drive leadership and educational practices, both descriptively and prescriptively, and to provide insight into the behavior of radiologic technologists and assess and develop a safety culture for best practice behavior.

Table 66

Predictors of Intentions to Use New Digital Technology and Digital Techniques to Lower Patient Dose

Variable	Significance
Digital: Direct Attitudes-Intentions: good—bad	p=.023 r=.185
Digital: Direct Attitudes-Intentions: harmful—beneficial	p=.014 r=.200
Digital: Direct Attitudes-Intentions: punishing—rewarding	p=.010 r=.210
Digital: Direct Attitudes-Intentions: waste of time—worth the time	p=.001 r=.590
Digital: Direct Attitudes—Intentions Sum	p=.012 r=.206
Digital: Direct Social Pressures /Norms—Intentions: Most people important to me think that…	p=.030 r=.177
Digital: Direct Social Pressures /Norms—Intentions: Expected	p=.011 r=.207
Digital: Direct Social Pressures /Norms—Intentions: People who are important to me want me to use…	p=.002 r=.254
Digital: Direct Social Pressures /Norms—Intentions Sum	p=.002 r=.253

Note. Correlation is significant at the 0.05 level (2-tailed).

For leadership in a hospital and the educational setting, the following implications are outlined:

1. Improve intentions of males, those who are younger, and those who have fewer years of practice. Suggestions could be that radiologic technologists could be mentored by other radiologic technologists in order to improve the use of best practices.

2. Develop a safety culture framework that includes clearly defined policies, availability of equipment, and the patient-technologist relationships to positively impact intentions.

3. Recognize a radiologic technologist's high positive attitudes toward patient radiation protection best practices, such as their desire to reduce radiation exposure, do something ethical/moral, and be a positive role model.

4. Create human resource policies and practices for hiring for high ethical/values held by the radiologic technologist toward patient care and best practices.

5. Develop a curriculum to support a safety culture framework that includes instilling the self-motivation and intrinsic values of excellence in patient care, patient radiation protection best practices, and learning practices that will address the differences in males and females in best practice behavior.

Suggested Further Research

As a result of conducting this study, a variety of additional unanswered questions have surfaced that could be the impetus for future investigations.

Qualitative and/or Mixed Methods

The ability of a quantitative study using Ajzen's (1985, 1991, 2001, 2002) theoretical framework to address the problem and purpose of the study could be a limitation of this study if the problems that really exist are outside of the key constructs of the theory of planned behavior. In the future, a qualitative or mixed-methods study could be used to further identify the challenges in performing best practice behavior.

According to Newman and Benz (1998):

> The qualitative, naturalistic approach is used when observing and interpreting reality with the aim of developing a theory that will explain what was experience. The quantitative approach is used when one begins with a theory (or hypothesis) and test for confirmation or disconfirmation of that hypothesis. (p. 3)

Newman and Benz also suggest that the modern-day scientific method supports both the inductive and deductive, objective and subjective research process, which builds in more design validity. Where this study started with a theory, Ajzen's (1985) theory of planned behavior, and aimed to test the theory, a qualitative study would observe the behaviors of radiologic technologists and inductively evaluate the data to propose a theory. A mixed-methods study would provide a holistic approach to close the gaps of knowledge that a one-perspective approach provides (Newman & Benz, 1998).

Qualitative studies that could be conducted to shed more light on the issues surrounding radiologic technology best practice behavior could include observational studies, interview studies, or a case study, where the phenomenological basis of the study provides more meaning to the radiologic technology culture being studied. We need to understand what the predictors of intentions are when using new digital equipment. We also need to understand the differences in behavior between females and males.

Observed Behavior

Self-reported data, which were used for this study, bring with them limitations such as selective memory, exaggeration, incorrect recall of actual events, and attributing positive events and outcomes to one's self, but attributing negative events and outcomes to external factors. A study that could prove valuable is one that observes actual behavior, along with a quantitative study that uses the constructs of the theory of planned behavior, so that intentions, self-reported past behavior, and observed behavior could be analyzed.

Larger Sample Size National

A future study could include a larger sample size to ensure a representative distribution of the population and to be considered representative of this group.

Use of Other Theories

Another suggestion for further research is to conduct a study based on other theories, such as self-determination theory (SDT; Deci & Ryan, 2002) and knowledge translation (knowledge-to-action theory) (Estabrooks et al., 2006; Graham et al., 2006). Self-determination theory (Deci & Ryan, 2002) is a theory that deals with human motivation and personality, concerning people's inherent growth tendencies and their innate psychological needs. It is concerned with the motivation behind the choices that people make without any external influence and interference. SDT focuses on the degree to which a person’s behavior is self-motivated and self-determined. While this study looked at the attitudes, social pressures, and behavior control, a study using self-determination theory could look at the motivation and personality of a radiologic technologist when in a situation of using patient radiation protection best practices. The knowledge-to-action (KTA) or knowledge translation (KT) conceptual framework (Estabrooks et al., 2006; Graham et al., 2006) suggests usefulness for facilitating how research knowledge is used when translated to behavior. The potential information found from this type of theory-based qualitative study could shed light on the behaviors of radiologic technologists when they are equipped with the knowledge and research of the impact of exposure to ionizing radiation.

Investigation of Student Attitudes and Behavior

Another topic could be the further study of students and their attitudes and behaviors of patient radiation protection best practices. I have observed a phenomenon occurring between first-year students and second-year students, where the observed importance of patient radiation protection goes down. Supporting the suggestion for further research is the finding in this study where students are inversely linked to educator/faculty with regard to the performance of past behaviors. As stated earlier, this is somewhat alarming, since it could be assumed that students, who are still new to the field and who you would expect to have a higher acceptance of learning new information about the effects of radiation exposure, should have at least equal past behavior as their faculty.

Other Suggestions for Further Study

A study is needed in the area of understanding the factors that are influencing the ordering of exams, whether they are necessary or not. According to the American Cancer Society, the fact that radiation exposure from all sources does add up over a person's lifetime, imaging tests that use ionizing radiation should only be done if a good medical reason to do so exists. The usefulness of the test must always be balanced against the possible risks from exposure to the radiation.

Finally, this research study has looked into understanding the attitudes and behaviors of radiologic technologists, specifically in the general diagnostic radiology area, but this study did not address the growing concern of radiation exposure due to increased ordering of CT exams. The growing number of CT exams that are ordered is a key contributor to the increase in patient radiation exposure over the past 20 years (NRCP, 2009). As revealed in Chapter 2 by the International Atomic Energy Association (2009), one CT scan is equal to roughly 500 chest x-rays, and that can increase a patient´s lifetime risk of cancer, particularly if CT scans are repeated. Further research is needed regarding issues related to the increase in CT exams, and the steps that can be taken to reduce patient radiation exposure.

Summary

The intent of this research was to fill a gap in knowledge about the influencing factors in a radiologic technologist's behavior that supports patient radiation protection best practices. The goal was to address the growing concern that patients, both adult and pediatric, are receiving an increase in radiation exposure while undergoing medical imaging exams. The key findings indicate attitudes (doing something good for the patient, being a positive role model, doing something ethical, etc.), about patients, a safety culture, availability of equipment, and policies have a significant influence on intentions. Creating a useful survey tool for predicting intentions and past behavior based on the attitudes, social pressures/norms, perceived behavioral control, and key organizational factors was also a significant result of this study.

This study examined the attitudes, social pressures/norms, and perceived behavior control of radiologic technologists regarding patient radiation protection best practices, as well as the attitudes, social pressures/norms, and perceived behavior control of radiologic technologists when using new digital equipment and digital exposure techniques to lower patient radiation dose. Results demonstrated that attitudes, social pressures/norms, and perceived behavioral control are predictive of intentions and past behavior.

The findings of this study suggest that the theory of planned behavior (Ajzen, 1985, 1991, 2001, 2002) appears to be a solid theory that can be used to understand a radiologic technologist's behavior, and it can be used as a predictor of best practice behavior. It can also be suggested that Ajzen's theory, as a nomological network (Newman et al., 2013)—with the sources of data, methods of data collection and analysis, and relationships among the sources of the data—can be used to predict and assume cause.

The implications of this study are important to leadership in the clinical setting and to educators, which suggest that policies, availability of equipment, a safety culture, age, gender, years in practice, and attitude have a direct correlation to a radiologic technologist performing radiation protection best practices.

APPENDIX A

EMAIL INVITATION

EMAIL INVITATION

Dear Radiologic technologist:

You are being asked to be in a research study by a researcher at Andrews University to investigate radiologic technologists' attitudes and beliefs about the use of patient radiation protection best practices.

The purpose of the study is to increase the understanding of the factors influencing radiologic technologists' attitudes and beliefs about patient radiation protection.

Since you are a radiologic technologist, radiography faculty, or radiography student, you are being invited to participate.

If you take part in the study, you will be asked to fill out one short questionnaire that measures your beliefs and attitudes about using patient radiation protection best practices, which should take approximately 15-20 minutes.

By participating in this study you will be given the opportunity to enter your name into a drawing for either personalized lead markers, personalized lead thyroid shield, or a Starbuck card, depending on how soon you respond to this survey. The first 50 people will receive the highest value on the gift card.

Taking part in this study is voluntary.

Your participation is needed and appreciated!

If you have any questions now or in the future, you may contact Brenda Boyd, MA, MS, R.T.(R)(M) at the following phone number 909-583-3033.

Thank you in advance for your participation. Please use the link below to start the survey.

Most sincerely,

Brenda Boyd
Investigator

APPENDIX B

ONLINE CONSENT PAGE

ONLINE CONSENT PAGE

Dear Radiologic technologist:

You are invited to participate in a survey about the behaviors of radiologic technologists. Because you are either a working radiologic technologist, a current faculty in radiography, or a medical radiography student, you are being asked to participate.

The purpose of the study is to understand the issues that a radiologic technologist has when performing the behavior of patient radiation protection best practices. Participation in this study involves answering questions about your attitudes, pressures, organizational issues, and experiences with patient radiation protection best practices, and will take approximately 15-20 minutes. Whether or not you participate is entirely voluntary and will not affect your relationship with the researcher or the organization at which you work.

There is a very minimal risk in completing this survey, and there is minimal risk of breach of confidentiality; however, using Survey Monkey, which allows you to complete and submit this online survey anonymously, will minimize this possibility.

If you wish to proceed and participate after reading this consent page, you will click on the link provided. This link will take you to the survey and upon completion of the survey you will submit it electronically. When we receive the results, there will be no information linking your answers back to you.

Although you will not benefit directly from this study, the information provided will potentially benefit future radiography education practices, hospital policies and procedures, and the promotion of a safety culture.

You may contact an impartial third party not associated with this study regarding any question or complaint, by calling 909-558-4647 or e-mailing xxxxxx@llu.edu for information and assistance.

Thank you in advance for giving consideration to this invitation. If you have any questions, please give me a call at 909-583-3033.

By clicking on the link provided below you will be giving your consent to participate.
Sincerely,

Brenda Boyd

APPENDIX C

INSTRUCTIONS

Instructions:

Many questions in this survey make use of rating scales with 7 places.

Please mark the number that best describes your opinion.

For example, if you were asked to rate "How you like Italian food" on such a scale, the 7 places should be interpreted as follows:

How you like Italian food:

bad :____1___:____2___:____3___:___4___:____5___:____6___:____7___: good

extremely quite slightly neither slightly quite extremely

If you think that Italian food is slightly bad, then you would mark 3.
If you think it is neither good nor bad, then you would mark 4.
If you think that Italian food is extremely good, then you would make 7.
Other questions on this survey ask you to mark a range of agreement/disagreement using a rating scale of 7 places.
For example, if you were asked to rate your agreement/disagreement of "I am supported at work" on such a scale, the 7 places should be interpreted as follows:

I am supported at work:

Strongly
Disagree:___1___:___2___:___3___:___4__:___5___:___6___:___7___:Strongly Agree

extremely quite slightly neither slightly quite extremely

If you extremely strongly disagree with the statement, then you would make 1.
If you neither agree nor disagree with the statement, then you would mark 4.
If you quite strongly agree with the statement, then you would make 6.

APPENDIX D

QUESTIONNAIRE

DEMOGRAPHIC

1. Age groups:
18-20
21-29
30-39
40-49
50-59
60-65
65 or older
2. Gender (male-0, female-1)
3. Years in Practice (current student, <than a year, 1-4, 5-9, 10-14, 15-19, 20-24, 25+)
4. Primary Role:
1-Radiologic technologist
2-Radiologic technologist in the role of Shift Leader/Supervisor
3-Radiologic technologist in the role of Department
Manager/Director
4-Educator/Faculty in Radiologic Technology
5-Hospital Administrator
6-Student
7-Other
5. Area of Primary Practice:
1-General Diagnostic only
2-General Diagnostic plus a specialty
3-Mammography Specialty only
4-CT Specialty only
5-Interventional Specialty only
6-Other Specialty
7-Student
6. Place of Practice
1-Small Hospital: 99 beds or less
2-Medium Hospital: 100-199 beds
3-Large Hospital: 200-299 beds
4-X-Large Hospital 300+ beds
5-Urgent Care Facility
6-Imaging Center
7-Outpatient Office
8-Educational Facility
9-Other

INTENTIONS–(#7-#9)
PAST BEHAVIOR–(#10)

7. I plan to use patient radiation protection best practices in x-ray exams.

unlikely 1 2 3 4 5 6 7 likely

8. I will make an effort to use patient radiation protection best practices in x-ray exams.

unlikely 1 2 3 4 5 6 7 likely

9. I intend to use patient radiation protection best practices in x-ray exams.

unlikely 1 2 3 4 5 6 7 likely

10. In the past, how often have you used patient radiation protection best practices in x-ray exams?

never 1 2 3 4 5 6 7 always

ATTITUDE–DIRECT (#11-#15)
For me, using patient radiation protection best practices in x-ray exams is:

11. bad	1	2	3	4	5	6	7 good
12. unpleasant	1	2	3	4	5	6	7 pleasant
13. harmful	1	2	3	4	5	6	7 beneficial
14. punishing	1	2	3	4	5	6	7 rewarding
15. a waste of time	1	2	3	4	5	6	7 worth the time

ATTITUDE–INDIRECT (#16-#23)
16-17–Reduce Radiation
18- (Pair missing in online survey)–Positive Role Model
19-20–Doing something ethical/moral
21-22–Take Longer

16. By using patient radiation protection best practices in x-ray exams, I will reduce the patient's exposure to harmful radiation.

unlikely 1 2 3 4 5 6 7 likely

17. Reducing my patients' exposure to radiation is:

not very important -3 -2 -1 0 +1 +2 +3 extremely important

18. By using radiation protection best practices in x-ray exams, I can be a positive role model to other radiologic technologists.
unlikely 1 2 3 4 5 6 7 likely

Being a positive role model to other radiologic technologists is:
not very important -3 -2 -1 0 +1 +2 +3 extremely important

19. By using radiation protection best practices in x-ray exams, I will be doing something ethical/moral.
unlikely 1 2 3 4 5 6 7 likely

20. Doing something ethical/moral is:
not very important -3 -2 -1 0 +1 +2 +3 extremely important

21. By using radiation protection best practices in x-ray exams, I will take longer to

complete exams.
unlikely 1 2 3 4 5 6 7 likely

22. Taking longer to complete exams is:
a serious problem -3 -2 -1 0 +1 +2 +3 not a serious problem

SOCIAL PRESSURE/NORMS–DIRECT (#23-27)

23. Most people who are important to me think that
I should not 1 2 3 4 5 6 7 I should
use patient radiation protection best practices in x-ray exams.

24. Most people in my role who are radiologic technologists, use patient radiation protection best practices in x-ray exams.
unlikely 1 2 3 4 5 6 7 likely

25. It is expected of me that I use patient radiation protection best practices in x-ray exams.
disagree 1 2 3 4 5 6 7 agree

26. I feel under social pressure to **not** use patient radiation protection best practices in x-ray exams.
disagree 1 2 3 4 5 6 7 agree

27. People who are important to me want me to use patient radiation protection best practices in x-ray exams.
disagree 1 2 3 4 5 6 7 agree

SOCIAL PRESSURES/NORMS–INDIRECT (#28-#37)
28-29–Patients
30-31–Patient's family
32-33–Rad Tech Peers
34-35–Radiology Manager
36-37-Radiologist

28. My patients who come in for an x-ray think I
should not -3 -2 -1 0 +1 +2 +3 should
use patient radiation protection best practices.

29. My patients' approval of my patient radiation protection best practices is important to me.
not at all 1 2 3 4 5 6 7 very much

30. The family of my patients think I
should not -3 -2 -1 0 +1 +2 +3 should
use patient radiation protection best practices in x-rays on their family member.

31. The approval of the patient's family is important to me.
not at all 1 2 3 4 5 6 7 very much

32. My radiologic technologist coworkers
disapprove -3 -2 -1 0 +1 +2 +3 approve
of my using patient radiation protection best practices in x-rays.

33. The approval of my radiologic technologists coworker's is important to me.
not at all 1 2 3 4 5 6 7 very much

34. My radiology manager
disapproves -3 -2 -1 0 +1 +2 +3 approves
of my using patient radiation protection best practices in x-rays.

35. The radiology manager's approval is important to me.
not at all 1 2 3 4 5 6 7 very much

36. The physicians who are Radiologists
disapprove -3 -2 -1 0 +1 +2 +3 approve
of my patient radiation protection best practices.

37. The Radiologist's approval is important to me.
not at all 1 2 3 4 5 6 7 very much

PBC–DIRECT (#38-#41)

38. I am confident in my own ability to use patient radiation protection best practices in x-ray exams.
strongly disagree 1 2 3 4 5 6 7 strongly agree

39. For me, using patient radiation protection best practices in x-ray exams is:
impossible 1 2 3 4 5 6 7 possible

40. Whether or not I use patient radiation protection best practices in x-ray exams is entirely up to me.
strongly disagree 1 2 3 4 5 6 7 strongly agree

41. Whether I use patient radiation protection best practices in x-ray exams is sometimes beyond my control.
strongly disagree 1 2 3 4 5 6 7 strongly agree

PBC–INDIRECT (#42-#57)
42-43–Rushed
44-45–Trauma/challenging situations
46-47–Lack of equipment–portables
48-49–Lack of equipment–main department
50-51–Policies
52-53–Reward
54-55–Continuing education
56-57–Safety culture

42. When I use patient radiation protection best practices in x-ray exams, I feel rushed.
unlikely 1 2 3 4 5 6 7 likely

43. Feeling rushed makes it more difficult to use patient radiation protection best practices in x-ray exams.
disagree -3 -2 -1 0 +1 +2 +3 agree

44. In trauma or challenging situations, getting the exam done takes priority over other considerations.
unlikely 1 2 3 4 5 6 7 likely

45. When getting the exam done takes priority over other considerations, it becomes difficult to use patient radiation protection best practices in x-ray exams.
disagree -3 -2 -1 0 +1 +2 +3 agree

46. Radiation protection equipment, such as lead shields/aprons, is sometimes <u>not</u> available on portable x-ray equipment.
unlikely 1 2 3 4 5 6 7 likely

47. Lack of radiation protection equipment, such as lead shields/aprons, on portable x-ray equipment, makes it difficult to use patient radiation protection best practices.
disagree -3 -2 -1 0 +1 +2 +3 agree

48. In the main Radiology Department, radiation protection equipment, such as lead shields, is available.
unlikely 1 2 3 4 5 6 7 likely

49. When radiation protection equipment, such as lead shields, is available in the main Radiology Department, it makes it easier to use patient radiation protection best practices.
disagree -3 -2 -1 0 +1 +2 +3 agree

50. The Radiology Department has clearly defined policies for radiographic techniques, the use of lead shielding, and ALARA.
unlikely 1 2 3 4 5 6 7 likely

51. Policies for the use of lead shielding and ALARA that are clearly defined makes it easier to use patient radiation protection best practices.
disagree -3 -2 -1 0 +1 +2 +3 agree

52. Where I work, radiologic technologists are rewarded for complying with patient radiation protection best practice policies.
unlikely 1 2 3 4 5 6 7 likely

53. Receiving rewards for complying with patient radiation protection best practice policies makes it easier to use these best practices.
disagree -3 -2 -1 0 +1 +2 +3 agree

54. Continuing education about how to lower patient exposure and increase patient protection is a regular and ongoing activity in the Radiology Department.
unlikely 1 2 3 4 5 6 7 likely

55. Receiving regular and ongoing continuing education about how to lower patient exposure and increase patient protection makes it easier to use patient radiation protection best practices.
disagree -3 -2 -1 0 +1 +2 +3 agree

56. The promotion of a safety culture is a regular and ongoing activity in the Radiology Department.
unlikely 1 2 3 4 5 6 7 likely

57. Working in a department that promotes a safety culture makes it easier to use patient radiation protection best practices.
disagree -3 -2 -1 0 +1 +2 +3 agree

DIGITAL: ATTITUDE–DIRECT (#58-#62)

Learning to use new digital equipment and new digital exposure techniques in order to lower patient dose is:

58. bad 1 2 3 4 5 6 7 good
59. unpleasant 1 2 3 4 5 6 7 pleasant

60. harmful 1 2 3 4 5 6 7 beneficial
61. punishing 1 2 3 4 5 6 7 rewarding
62. a waste of time 1 2 3 4 5 6 7 worth the time

DIGITAL: SOCIAL PRESSURE/NORMS–DIRECT (#63-#66)

63. Most people who are important to me think that
I should not 1 2 3 4 5 6 7 I should
learn to use the new digital equipment and new digital exposure techniques to lower patient dose.

64. Most people in my role, who are radiologic technologists, are learning to use the new digital equipment and new digital exposure techniques to lower patient dose.
unlikely 1 2 3 4 5 6 7 likely

65. It is expected of me that I learn to use the new digital equipment and new digital exposure techniques to lower patient dose.
disagree 1 2 3 4 5 6 7 agree

66. People who are important to me want me to learn to use the new digital equipment and new digital exposure techniques to lower patient dose.
disagree 1 2 3 4 5 6 7 agree

DIGITAL: PBC–DIRECT (#67-#70)

67. I am confident in my own ability to learn to use the new digital equipment and new digital exposure techniques to lower patient dose.
strongly disagree 1 2 3 4 5 6 7 strongly agree

68. Whether or not I learn to use the new digital equipment and new digital exposure techniques to lower patient dose is entirely up to me.
strongly disagree 1 2 3 4 5 6 7 strongly agree

69. Whether I learn to use the new digital equipment and new digital exposure techniques to lower patient dose is sometimes beyond my control.
strongly disagree 1 2 3 4 5 6 7 strongly agree

70. For me, learning to use the new digital equipment and new digital exposure techniques to lower patient dose is:
impossible 1 2 3 4 5 6 7 possible

DIGITAL: PBC–INDIRECT (#71-#80)
71-72–Revert
73-74–Policies
75-76–Continuing Education
77-78–Unprepared
79-80–Initial education insufficient

71. When I am under pressure (in a trauma or challenging situation) while using digital equipment, I sometimes revert back to using previously-learned exposure techniques that I was comfortable with.
unlikely 1 2 3 4 5 6 7 likely

72. It becomes easy revert back to using previously-learned exposure techniques that I was comfortable with, when I am under pressure (in a trauma or challenging situation) while using

digital equipment.
disagree -3 -2 -1 0 +1 +2 +3 agree

73. The Radiology Department has clearly defined policies for standardized radiographic techniques when using the new digital equipment.
unlikely 1 2 3 4 5 6 7 likely

74. Policies for the use of standardized radiographic techniques when using the new digital equipment that are clearly defined makes it easier to use patient radiation protection best practices.
disagree -3 -2 -1 0 +1 +2 +3 agree

75. Continuing education on the use of digital equipment and digital exposure techniques to lower patient dose is sufficient.
unlikely 1 2 3 4 5 6 7 likely

76. It becomes easy to use digital equipment and digital exposure techniques to lower patient dose when continuing education is sufficient.
disagree -3 -2 -1 0 +1 +2 +3 agree

77. When using new digital equipment and new digital exposure techniques to lower patient dose, I feel unprepared.
unlikely 1 2 3 4 5 6 7 likely

78. Feeling unprepared makes it more difficult to use new digital equipment and new digital exposure techniques to lower patient dose.
disagree -3 -2 -1 0 +1 +2 +3 agree

79. The initial training on the use of new digital equipment and new digital exposure techniques to lower patient dose was insufficient.
unlikely 1 2 3 4 5 6 7 likely

80. It becomes difficult to use new digital equipment and new digital exposure techniques to lower patient dose when initial training is insufficient.
disagree -3 -2 -1 0 +1 +2 +3 agree

APPENDIX E

TABLE OF SPECIFICATIONS FOR CONTENT VALIDITY

TABLE OF SPECIFICATIONS FOR CONTENT VALIDITY

Question # Based on Research Questions Order	Past Behaviors and Intentions	Attitudes	Social Norms and Pressures	Perceived Behavioral Control	Work Place Pressure	Availability of Equipment	Policy and Compliance	Education	Safety Culture	New Digital Equipment
1	R									
2	R									
3	R									
4	R									
5		R								
6		R								
7		R								
8		R								
9		R								
10		R								
11		R								
12		R								
13		R								
14			R							
15			R							
16			R							
17			R							
18			R							
19			R							
20			R							
21			R							
22			R							
23			R							
24			R							
25			R							
26			R							
27			R							
28			R							
29				R						
30				R						
31				R						
32				R						
33					R					
34					R					
35					R					
36					R					
37						R				
38						R				
39						R				
40						R				

Question # Based on Research Questions Order	Past Behaviors and Intentions	Attitudes	Social Norms and Pressures	Perceived Behavioral Control	Work Place Pressure	Availability of Equipment	Policy and Compliance	Education	Safety Culture	New Digital Equipment
41							R			
42							R			
43							R			
44							R			
45								R		
46								R		
47									R	
48									R	
49		R								R
50			R							R
51			R							R
52			R							R
53			R							R
54				R						R
55				R						R
56				R						R
57				R						R
58					R					R
59					R					R
60							R			R
61							R			R
62								R		R
63								R		R
64								R		R
65								R		R
66								R		R
67								R		R

APPENDIX F

TABLE OF ALIGNMENT FOR CONTENT VALIDITY

RESEARCH QUESTIONS	HYPOTHESIS	LITERATURE and INTERVIEWS
1. Is there a relationship among selected demographic variables (age, gender, years in practice, primary role, area of practice, place of practice) and a radiologic technologist's intention to use patient radiation protection best practices?	1. The demographic variables (age, gender, years in practice, primary role, area of practice, place of practice) are predictive of the intentions of a radiologic technologist's intentions to use patient radiation protection best practices.	
2. Do the intentions of radiologic technologists predict past behavior?	2. Intentions predict past behavior. 2a. A correlation exists between the intention "plan to use" (#7) with past behaviors (#10). 2b. A correlation exists between the intention "will make an effort" (#8) with past behaviors (#10). 2c. A correlation exists between the intention "intend to use" (#9) with past behaviors (#10). 2d. A correlation exists between the sum of intention (#7-#9) with past behaviors (#10).	theory of planned behavior: Intention is an indication of an individual's readiness to perform a given behavior. It is based on attitude toward the behavior, subjective norm, and perceived behavioral control, with each predictor weighted for its importance in relation to the behavior and population of interest (Ajzen, 1991). INTERVIEWS: Expert radiologic technologists have suggested that past behaviors indicate that radiologic technologists do have struggles in the workplace to perform patient radiation protection best practices. RESEARCH: Academic researchers have indicated that the past and current practices and behaviors of a radiologic technologist are contributing to the problem (Slechta & Reagan, 2008).
3. Do the direct and indirect attitudes of radiologic technologists predict intentions to perform patient radiation protection best practices?	3. Attitudes are predictive of intentions to perform patient radiation protection best practices. 3a. Direct attitudes are predictive of intentions to perform patient radiation protection best practices. 3b. Indirect attitudes are predictive of intentions to perform patient radiation protection best practices. 3c. Direct and indirect attitudes are predictive of behavioral intentions to perform patient radiation protection best practices.	theory of planned behavior: Ajzen (1985, 1991, 2001, 2002) suggests that the attitudes of people influence behavior. INTERVIEWS: Expert radiologic technologists have suggested that radiologic technologists have a varied attitude toward patient radiation protection best practices, but in general, technologists do have a high positive attitude toward patient care and best practices. In the interviews, the radiologic technologists also indicated attitudes toward ethics, taking longer in some exams, and the desire to reduce patient exposure when they do their job.
4. Do the direct and indirect social pressures/norms of radiologic technologists predict intentions to perform patient radiation protection best practices?	4. Social pressures/norms are predictive of intentions to perform patient radiation protection best practices. 4a. Direct social pressures/norms are predictive of intentions to perform patient radiation	theory of planned behavior: The social norms and pressures is the person's perception about the behavior as influenced by the judgment of significant others (Ajzen, 1991).

	protection best practices. 4b. Indirect social pressures/norms are predictive of intentions to perform patient radiation protection best practices. 4c. Direct and indirect social pressures/norms are predictive of behavioral intentions to perform patient radiation protection best practices.	INTERVIEWS: Expert radiologic technologists have observed that the influence of other technologists does influence behavior.
5. Do the direct and indirect perceived behavioral controls of radiologic technologists predict intentions to perform patient radiation protection best practices?	5. Perceived behavioral control is predictive of intentions to perform patient radiation protection best practices. 5a. Direct perceived behavioral controls are predictive of intentions to perform patient radiation protection best practices. 5b. Indirect perceived behavioral controls are predictive of intentions to perform patient radiation protection best practices. 5c. Direct and indirect perceived behavioral controls are predictive of behavioral intentions to perform patient radiation protection best practices.	theory of planned behavior: Perceived behavioral control is the person's perceived ease or difficulty of performing the particular behavior (Ajzen, 1991). Ajzen suggests that qualitative interviews be conducted to determine the variables involved in behavior INTERVIEWS: Expert radiologic technologists observe that technologists generally do have control over their behavior. Expert radiologic technologists observe that technologists experience workload pressure, such as in stressful situations, and that their behavior does change in these situations. Sometimes lead shields are not available on portable equipment. Marshall & Keene (2007) are suggesting that the need for increased speed when performing an exam is impacting how patient radiation protection best practices are demonstrated.
6. Do the direct attitudes of radiologic technologists predict intentions predict intentions to use digital equipment and digital techniques to lower patient dose?	6. Direct attitudes are predictive of intentions to use digital equipment and digital techniques to lower patient dose.	theory of planned behavior: Ajzen suggests that qualitative interviews be conducted to determine the variables involved in behavior (Ajzen, 1991).
7. Do the direct social pressures/norms of radiologic technologists predict intentions to use digital equipment and digital techniques to lower patient dose?	7. Direct social pressures/norms are predictive of intentions to use digital equipment and digital techniques to lower patient dose.	INTERVIEWS: We are aware of manufacturer suggested standard techniques and dose for the new digital equipment, but we're not sure that everyone is using them. We are not aware of specific policies and procedures for appropriate use of lead shielding. In an interview with a radiation safety office, it was indicated that specific policies and procedures and compliance measures in the department were not specifically evident.
8. Do the direct and indirect perceived behavioral controls of radiologic technologists predict intentions to use digital equipment and digital techniques to lower patient dose?	8. Perceived behavioral controls (direct and indirect) are predictive of intentions to use digital equipment and digital techniques to lower patient dose. 8a. Direct perceived behavioral controls are predictive of intentions to use digital equipment and digital techniques to lower patient dose. 8b. Indirect perceived behavioral controls are predictive of intentions to use digital equipment and digital techniques to lower patient dose.	
9. Do the components of Ajzen's theory of planned behavior (attitudes, social norms, perceived behavioral norms) predict intentions and past behavior of radiologic technologists regarding patient radiation protection best practices?	9. The components of Ajzen's theory of planned behavior will predict intentions and past behavior to perform patient radiation protection best practices when controlling for age, gender, years of practice, role, area of practice, and place of practice.	RESEARCH: Academic researchers have indicated that the practices of a radiologic technologist are contributing to the problem (Slechta & Reagan, 2008). Colangelo et al. (2009) have stated the continued need for continuing education regarding reducing patient radiation exposure, and compliance with radiation safety practices (Slechta and Reagan, 2010). The Joint Commission suggests to develop policies and protocols for proper radiographic techniques and dose and to develop policies for the appropriate use of lead shielding. theory of planned behavior: Ajzen suggests that qualitative interviews be conducted to determine the variables involved in behavior (Ajzen, 1991). INTERVIEWS: Training impacts the
10. Do the components of Ajzen's theory of planned behavior (attitudes, social norms, perceived behavioral norms) predict intentions and past behavior of radiologic technologists regarding the use of digital equipment and digital techniques to lower patient dose?	10. The components of Ajzen's Theory of Planned Behavior will predict intentions and past behavior to use new digital equipment and digital techniques to lower patient dose when controlling for age, gender, years of practice, role, area of practice, and place of practice.	

	appropriate use and none use of equipment. Initial training with the new digital equipment was minimal. INTERVIEWS: In general the radiologic technologists want to use the best practices for patient radiation protection, but we are not aware of a specific safety culture. In an interview with a radiation safety officer, it was indicated that a safety culture was more of a daily practice, but not necessarily a hospital initiative. This officer indicated an interest in learning more about the behaviors of radiologic technologists in order to improve safety at a hospital. RESEARCH: The Joint Commission suggests that standards be developed for promoting a safety culture. Academic researchers have indicated that the practices of a radiologic technologist are contributing to the problem (Slechta & Reagan, 2008). Colangelo et al. (2009) have stated the continued need for continuing education regarding reducing patient radiation exposure, and compliance with radiation safety practices (Slechta and Reagan, 2010). The Joint Commission suggests that training be provided on how to use new, complex equipment

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