An Analysis of Certification Exam Rates Among Varying Degree Levels in Radiation Therapy and Medical Dosimetry Educational Programs

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Abstract

The fields of radiation therapy and medical dosimetry have experienced advancements in recent years. One of the advancements has been in the educational requirements experienced by radiation therapists and medical dosimetrists. Certification is required to practice radiation therapy and medical dosimetry. This study will seek to determine if degree level has an impact on certification exam pass rates in radiation therapy and medical dosimetry.

Objectives*:* This study sought to determine if degree level, geographic location, number of examinees, and JRCERT accreditation status are significant predictors of radiation therapy and medical dosimetry certification exam pass rates.

Methodology: This study is a quantitative-correlational-retrospective study. The target population was all JRCERT accredited radiation therapy and medical dosimetry programs in the United States. Data was collected from the JRCERT, OMB, and programmatic websites. Multiple linear regression tests were used to analyze the data which was done by the statistical program SAS version 9.4.

Results: The results showed that none of the parameters analyzed for medical dosimetry were significant predictors of medical dosimetry certification pass rates. For radiation therapy, accreditation status was found to be a significant predictor (p= 0.001) of radiation therapy certification exam rates.

Conclusions: This study found that degree level, geographic location, and number examinees were not significant predictors of radiation therapy or medical dosimetry certification exam pass rates. For radiation therapy, it was determined that accreditation length was a significant predictor of radiation therapy certification exam pass rates and accounts for 15.16% of the variability of certification exam rates. None of the parameters analyzed for this study were significant predictors of medical dosimetry certification exam pass rates, however 21.93% of the variability of JRCERT accredited medical dosimetry programs is attributed to number of examinees.

Keywords: radiation therapy, medical dosimetry, certification exam

Dedications

This doctoral project is dedicated to my husband, my mother, my mother-in-law, father-in-law, and all of my family and friends. I would also like to dedicate this doctoral project to all past, current, and future cancer patients. There is one particular cancer patient who I would like to dedicate this doctoral project to, my godmother, the late Jacqueline Highter. Your cancer journey inspired me to pursue a career as a radiation therapist and medical dosimetrist. The knowledge that I have acquired through obtaining this degree and the previous degrees I have earned, I use to educate future radiation therapists and medical dosimetrists. It is my sincere hope that the passion and dedication I have for radiation oncology along with the knowledge and experience that I have gained over the years is conveyed to my students. It is that passion, dedication, and knowledge that I hope my students convey to the cancer patients they treat and is demonstrated in the treatment plans they create. I hope that I have made everyone proud.

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List of Abbreviations

AAMC………..Association of American Medical Colleges

AAMD……….American Association of Medical Dosimetrists

AAPM……….American Association of Physicists in Medicine

ABMP……….American Board of Medical Physics

ABR…………American Board of Radiology

ACGME…......Accreditation Council for Graduate Medical Education

ACR…………American College of Radiology

AMA………...American Medical Association

APTA……......American Physical Therapy Association

ARRT……......American Registry of Radiologic Technologists

ASCP BOC….American Society for Clinical Pathology Board of Certification

ASRT………..American Society of Radiologic Technologists

BSN…………Bachelor's of Science in Nursing

BSRS………..Bachelor's of Science in Radiologic Sciences

CAMPEP……Commission on Accreditation of Medical Physics Education Programs

CAPTE……...Center of Accreditation for Physical Therapy Education

CBCT……….Cone Beam Computed Tomography

CCPM………Canadian College of Physicists in Medicine

CHEA………Council for Higher Education Accreditation

CT…………Computed Tomography

DMLC……...Dynamic Multileaf Collimator

DPT………...Doctor of Physical Therapy

EMS………..Emergency Medical Services

FDA………..Food and Drug Administration

FDG………..Fluorine-18-Fluorodeoxyglucose

HLC………..Higher Learning Commission

IGRT……….Image Guided Radiation Therapy

IMRT………...Intensity Modulated Radiation Therapy

JRCERT……..Joint Review Committee on Education in Radiologic Technology

KV…………...Kilovoltage

MBA/MPH…..Master's of Business Administration/Master's of Public Health

MDCB……….Medical Dosimetry Certification Board

MLC…………Multileaf Collimator

MLS…………Medical Laboratory Sciences

MRI………….Magnetic Resonance Imaging

MSN………....Master's of Science in Nursing

MV…………..Megavoltage

NAACLS……National Accreditation Agency for Clinical Laboratory Sciences

NASEMSO…. National Association of State Emergency Medical Services Officials

NBCOT……...National Board for Certification in Occupational Therapy

NDRA……….Nelson Denny Reading Assessment

NLN…………National League for Nursing

NLN CNEA…National League on Nursing Commission for Nursing Education Accreditation

NP…………...Nurse Practitioner

NPTE………..National Physical Therapy Exam

NRC…………Nuclear Regulatory Commission

NREMT……..National Registry of Emergency Medical Technicians

OBI………….On Board Imaging

OMB………...Office of the Management of the Budget

OJT………….On the Job Training

OT…………...Occupational Therapy

OTR…………Occupational Therapist Registered

PET………….Positron Emission Tomography

PTA…………Physical Therapy Assistant

QMP………...Qualified Medical Physicist

RF…………........Radiofrequency

RN……………...Registered Nurse

SACSCOC……..Southern Association of Colleges and Schools Commission on Colleges

SBRT…………..Stereotactic Body Radiation Therapy

SCT…………….Social Cognitive Theory

SLT…………….Social Learning Theory

SRT…………….Stereotactic Radiation Therapy

TBR……………Tennessee Board of Regents

TEAS…………..Test of Essential Academic Skills

THEC………….Tennessee Higher Education Commission

TPS…………….Treatment Planning System

USDE………….United States Department of Education

VET……………Vroom's Expectancy Theory

VMAT…………Volumetric Arc Therapy

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Chapter 1

Introduction

The introduction of this study includes the background and significance of the study, purpose of the study, and the research questions and hypotheses. There has not been a study done on this topic in radiation therapy or medical dosimetry. This study will contribute needed research regarding radiation therapy and medical dosimetry education levels and certification exam pass rates.

Background and Significance

As the field of radiation oncology has become more technologically advanced, it has become necessary that radiation therapists and medical dosimetrists obtain more training and education. In 2015, a new educational mandate was established by the American Registry of Radiologic Technologists (ARRT). The educational mandate requires that individuals seeking to obtain certification in radiation therapy must either already possess an associate's degree or complete at minimum an associate's degree level radiation therapy educational program. In 2017, there was also an educational mandate implemented for medical dosimetry. The Medical Dosimetry Certification Board (MDCB) mandate requires that individuals seeking to obtain certification in medical dosimetry must possess at least a bachelor's degree and have completed a Joint Review Committee on Education in Radiologic Technology (JRCERT) accredited medical dosimetry educational program.

This study will be particularly beneficial for radiation therapy and medical dosimetry educators. Educators will be able to obtain a broader and more precise picture of how their program certification pass rates compare to other programs. This study aligns with Boyer's model of scholarship discovery. This study also aligns with the Radford University Carilion (RUC) Doctorate of Health Science outcome of critiquing and evaluating research related to improving healthcare or educating health professionals (JCHS, 2018). Scientific research should be grounded in theory, this study is no exception.

Purpose of the Research

The purpose of this study is to determine if the degree level makes a difference in certification exam pass rates for radiation therapy and medical dosimetry. The increased educational mandates are recent; therefore, little research on the effects of these new requirements is available. This study will contribute to the body of knowledge of radiologic sciences because the preliminary the literature review shows that a study such as this has not been completed.

Research Questions and Hypotheses

This study includes detailed information from published research about radiation therapy and medical dosimetry. The question of degree level and its possible effect on certification exam rates in radiation therapy and medical dosimetry has not been answered. There are numerous questions that could be raised as a result of researching this topic.

There are two questions that this study is seeking to answer:

Question	Alternative Hypotheses/Null Hypotheses
Are degree level, geographic location of the program, number of individuals who took the certification exam, and current JRCERT accreditation status significant predictors of radiation therapy certification exam pass rates?	**Null Hypothesis:** When controlling for other variables, degree level, geographic location of the program, number of individuals who took the certification exam, and current JRCERT accreditation status are not significant predictors of radiation therapy certification exam pass rates.

	Alternative Hypothesis 1: When controlling for other variables, degree level of the radiation therapy program is a significant predictor of exam pass rates. **Alternative Hypothesis 2:** When controlling for other variables, geographic location of the radiation therapy program is a significant predictor of exam pass rates. **Alternative Hypothesis 3:** When controlling for other variables, the number of individuals who took the certification exam for the radiation therapy program is a significant predictor of exam pass rates. **Alternative Hypothesis 4:** When controlling for other variables, the current JRCERT accreditation status of radiation therapy programs is a significant predictor of exam pass rates.
Are degree level, geographic location of the program, number of individuals who took the certification exam, and current JRCERT accreditation status significant predictors of medical dosimetry certification exam pass rates?	**Null Hypothesis:** When controlling for other variables, degree level, geographic location of the program, number of individuals who took the certification exam, and current JRCERT accreditation status are not significant predictors of medical dosimetry certification exam pass rates. **Alternative Hypothesis 1:** When controlling for other variables, degree level of the medical dosimetry program is a significant predictor of exam pass rates. **Alternative Hypothesis 2:** When controlling for other variables, geographic location of the medical dosimetry program is a significant predictor of exam pass rates. **Alternative Hypothesis 3:** When controlling for other variables, the number of individuals who took the certification exam for the medical dosimetry program is a significant predictor of exam pass rates.

	Alternative Hypothesis 4: When controlling for other variables, the current JRCERT accreditation status of medical dosimetry programs is a significant predictor of exam pass rates.

Chapter 2

Review of the Literature

The literature review of this study contains information regarding the theory, evolution of radiation therapy and medical dosimetry education, practice, and its potential effects on certification exam rates in these professions, as well as information on certification exam rates and accreditation in other fields of allied health and nursing. Radiation therapy and medical dosimetry have experienced vast technological and educational advancements in recent years. The literature review will provide detailed and scholarly information regarding these topics.

Vroom's Expectancy Theory (VET)

The theoretical framework that will guide this study is Vroom's expectancy theory (VET). VET is comprised of three main principles; force, valence, and expectancy. Force relates to the amount of effort a person will expend to reach their goal (Gyurko, 2010). Valence refers to how appealing or unappealing the goal is to obtain (Gyurko, 2010). Expectancy is the perception that the goal will be obtained (Gyurko, 2010). The purpose of this study is to determine if the degree level improves the likelihood of obtaining certification in radiation therapy and medical dosimetry. There are not many theories that are focused on factors attributed to successful certification exam rates in health careers. However, the main principles of VET are highly applicable to the factors that lead to successful certification exam rates.

Victor Vroom developed the expectancy theory in 1964. Vroom developed this theory after studying organizational behavior as a professor at the Yale School of Management (Yale School of Management, n.d.). According to VET, motivation to achieve something is a comprised of the perceived attractiveness of future outcomes and the possibility that a person's efforts will lead to these outcomes (Geiger & Cooper, 1995). Likewise, students' motivation to put forth the effort needed to be academically successful depends on students' perceptions of the benefit of academic performance (Geiger & Cooper, 1995). VET also states that a student's belief that exerting effort will lead to positive outcomes (Geiger & Cooper, 1995).

Valence and expectancy are partially reflected when a student chooses a college or university to attend. Consequently, a full description of Vroom's theory should include the components theoretically involved in the college selection. The Chapman model of college choice (1984) suggests that overall student expectations of college experiences and choices are comprised of a combination of individual student attributes and external factors (Gyurko, 2010). "Student characteristics can include socioeconomic status, scholastic aptitude, aspirations, and academic performance" (Gyurko, 2010, p.507). External forces are identified as significant others/partners, cost, location, programs offered by the college, as well as the marketing efforts (Gyurko, 2010).

Both valence and expectancy have cognitive and social facets, which may be explained by the social cognitive theory (SCT). Bandura, the originator of (SCT), asserts that SCT is grounded in social learning theory (SLT), which dates back to the late 1800s (Gyurko, 2010). SCT is also rooted in behaviorism, which explains why people behave the way they do (Gyurko, 2010).

Force

The force principle of expectancy theory associates motivational force and outcome expectancy with their individual valences (Malloch & Michael, 1981). The force model implies that a student's motivation to be academically successful is explained by the attractiveness of academic success and the likelihood that increased effort will result in the desired outcome (Malloch & Michael, 1981). In theory, motivated radiation therapy and medical dosimetry students that put forth their best effort in both their didactic and clinical coursework should successfully complete their educational program and subsequent certification exam.

Valence

The valence principle of VET attempts to capture the perceived attractiveness of an outcome by aggregating the attractiveness of all associated resultant outcomes (Malloch & Michael, 1981). Valence relates to what the student would gain or lose from pursuing a career as a radiation therapist or medical dosimetrist. Some of the benefits would be earning a degree and credential in a field that helps people in addition to earning higher than average wages for most professions with the same degree level. The potential drawbacks could be concerns of how to pay for the training, the amount of time it takes to get the training, and the amount of time it takes away from other aspects of life.

Expectancy

The expectancy principle of VET is quite simple. In regards to VET, radiation therapy and medical dosimetry students ultimately expect to successfully complete their respective educational programs, pass their certification exam, and obtain the associated benefits. VET suggests that an individual's motivation in a given circumstance depends on how strongly the individual expects a given level of effort to result in a certain outcome (Gyurko, 2010). As a certified radiation therapist and medical dosimetrist, I can speak to the amount of time and effort it takes to obtain these degree and certifications. It is indeed an arduous task, but is extremely rewarding.

Vroom's Expectancy Theory and Hypotheses of the Study

In terms of an equation, VET is force=valence x expectancy. Student outcomes correspond to Vroom's theory with regard to valence and expectancy in that student characteristics such as personal goals and academic performance directly influence expectancy that the outcome will be achieved (Gyurko, 2010). The expected outcome may also vary with the degree level that a student chooses to pursue in radiation therapy and medical dosimetry. As stated previously, students pursuing degrees in radiation therapy and medical dosimetry have multiple degree options.

Radiation therapy students have the option of certificate, associate's degree, or bachelor's degree programs. Dosimetry students have the option of a certificate, bachelor's, or master's degree. Many factors could play a part in which type of radiation therapy or medical dosimetry degree a student chooses to pursue. Some of the factors that could affect the educational program that a student chooses include: accessibility, cost, length of program, programmatic reputation/outcomes, and accreditation status. Accreditation status is particularly important for medical dosimetry as students seeking to become medical dosimetrists in 2017 and beyond must complete a JRCERT accredited medical dosimetry program (American Association of Medical Dosimetrists, n.d.).

As radiation therapy and medical dosimetry students have a variety of programs they can choose from, the amount of effort and time that a student may need to expend to be accepted and subsequently complete the program may vary as well. In general, the amount of time, effort, and money it takes to complete an associate's degree is less than it is for a bachelor's degree. An associate's degree is less coursework than a bachelor's degree which also equates to less time and effort to complete an associate's degree program in comparison to a baccalaureate level program. It takes more time, effort, and money to complete a baccalaureate degree level program in comparison to an associate's degree or certificate. It would also be fair to assume that the programmatic outcomes, specifically certification exam pass rates would be higher in baccalaureate level degree programs than certificate and associate degree level programs. Degree level relates back to the components of VET which are force, valence, and expectancy. With regard to the formula for VET, (force=valence x expectancy), it would be true to suspect that the effort (force) required to obtain a higher level degree is greater than for lower degree levels. It is also reasonable to assume that the attractiveness of obtaining a higher degree (valence) and the rewards that come from it (expectancy) are also higher.

There are also some other considerations that should be accounted for. Professional organizations, accrediting bodies, and educational institutions should consider VET when making decisions regarding the required degree level for a certain profession. If the valence and expectancy are not strong, then students will likely decide it is not worth the force. Therefore, health professions education programs must consider the force and valence required to earn a higher degree to determine if students will perceive the expectancy is sufficient. The purpose of this study is to determine if degree level makes a difference in certification exam pass rates.

History of Radiation Therapy

After the discovery of x-rays by Wilhelm Conrad Roentgen in 1895, the field of radiation therapy blossomed. One year later (1896), Antoine Henri-Becquerel discovered that certain elements randomly emitted subatomic particles and rays, which later became known as radioactivity (Radiation Therapy Alliance, n.d.). Subsequently, while conducting research with radium, Pierre and Marie Curie noticed that radium killed abnormal cells. That was the first indication that radiation could not only help diagnose conditions through x-rays, but could also be used as a method of treatment for abnormal cells.

Mostly due to the work of Antoine-Henri Becquerel, Marie Curie, and Pierre Curie, the field of radiation therapy began its evolution in the early 1900’s. In the primitive days of radiation therapy, physicians applied radiation exposure in experiments based on their observations in clinical practice. Although not completely understanding the mechanism of action, physicians reported cases of stability or regression of cancers due to radiation exposure (Radiation Therapy Alliance, n.d.). The medical community was confident in the potential medical benefits of the use of radiation. It was recognized that radiation could be harmful if improperly applied.

World War I was a pivotal event in which “Roentgenology” became more evident. American and French soldiers were trained to take x-rays, perhaps becoming the first radiologic technologists (Radiation Therapy Alliance, n.d.). Between World War I and II, physicists and biologists further researched how radiation worked, and how to measure radiation doses accurately. The limitations of the x-ray machines were their inability to produce high energy, deeply penetrating x-ray beams making it difficult to treat tumors deep within the body. In the 1960’s, linear accelerators emerged that were capable of producing deeply penetrating, high energy x-ray beams which permitted treatment of deep-seated tumors without extra damage to surrounding skin and normal tissue (Radiation Therapy Alliance, n.d.).

Based on the historical use of radiation and the technological advances in the 1970’s and 1980’s, modification on the use of radiation has allowed for the delivery of higher doses of radiation to tumors, and lower dose to the surrounding healthy tissue. These approaches have produced better treatment outcomes for patients, more organ conservation, and fewer treatment side effects. Today, more than 50% of all cancer patients receive radiation therapy during their treatment course (Radiation Therapy Alliance, n.d.). As approximately 50% of cancer patients receive radiation therapy, it is paramount that the people who are administering their treatment are properly trained.

Radiation Therapy Treatment Delivery Equipment

As the education of the radiation therapist has evolved, so has the equipment used for treatment delivery. The equipment used by radiation therapists to deliver radiation treatments is called a linear accelerator. Linear accelerator means “that charged particles travel in straight lines while they gain energy for an alternating electromagnetic field” (Washington & Leaver, 2015, p. 135). Inside the linear accelerator x-rays and electrons are created and used to treat various types of tumors. The linear accelerator is the most common treatment machine used in radiation oncology. The linear accelerator has evolved to have the capability to deliver multiple types of x-ray beams in numerous ways (Washington & Leaver, 2015).

The majority of radiation treatments today are given using electrons, protons, and x-rays. The beam energies used to treat cancers can be in the kilovoltage (KV) range, which are low energy to megavoltage (MV), which are high energy (Washington & Leaver, 2015). Most radiation treatments today are delivered with MV x-ray beams in the 4-25 MV range (Washington & Leaver, 2015). The technology used to deliver radiation treatments has evolved drastically over the last 60 years. There are several generations of linear accelerators: early accelerators, second generation accelerators, and third generation accelerators.

Early linear accelerators were large and bulky compared to today’s current linear accelerators. The first linear accelerator was used to treat patients at the Hammersmith Hospital in London (Washington & Leaver, 2015). These linear accelerators were limited in the x-ray beam energies produced as well as motion. The design and capabilities increased over the next several years, and the first linear accelerator was used in the United States at Stanford University in 1956 (Washington & Leaver, 2015).

Second generation linear accelerators can also be referred to as older 360-degree rotational units. The early linear accelerators did not have this rotational capability. The 360-degree rotational ability offers the capacity to improve the accuracy of treatment delivery (Washington & Leaver, 2015). Many of these units are still operational today, but are likely not used to treat patients due to the advancements in treatments and technology these machines are not capable of performing.

Third generation linear accelerators are what most radiation oncology centers use to treat cancer patients today. These machines are vastly more technologically advanced than the early and second-generation linear accelerators. Third generation linear accelerators account for more than 80% of the linear accelerators used worldwide (Washington & Leaver, 2015). Third generation linear accelerators are computer-driven with various options for patient treatment. These options include multiple x-ray and electron beam energies, numerous electronic features used to modify treatment as needed, as well as real-time imaging used to verify patient position among many other features (Washington & Leaver, 2015). The two most common manufacturers of radiation therapy linear accelerators used to treat patients today are Varian and Elekta.

Imaging

Imaging has become a key component to accurate radiation treatment delivery and treatment planning. As previously mentioned, patients are imaged with CT for simulation, however, patients are also imaged during the course of their radiation treatments. Patient images are taken daily or weekly. The frequency and type of image that is obtained depends upon the radiation oncologist's orders. The common types of images that a patient receives during the course of their radiation treatment are megavoltage (MV) imaging, kilovoltage (KV) imaging, cone-beam computed tomography scan (CBCT), or a combination of imaging.

MV imaging was traditionally used to verify the treatment target and treatment fields, as it was the only imaging method available. Early MV images were of poor image quality and resulted in difficulty identifying anatomy (Washington & Leaver, 2015). The MV image quality on the most current linear accelerators is far superior in comparison to older linear accelerators. It is challenging to distinguish soft tissue, and certain bony anatomy on MV images (Washington & Leaver, 2015). However, MV images are great for treatment localization of prominent anatomical landmarks and treatment verification.

KV imaging provides better image contrast, detail, and high-resolution soft tissue images (Washington & Leaver, 2015). KV imaging is also referred to as on-board imaging (OBI) as the imaging source is connected to the linear accelerator. The KV imaging system can provide two dimensional images, fluoroscopy as well as three dimensional images (Washington & Leaver, 2015). Two-dimensional imaging permits visibility of the front or back of the patient as well as from the side. Fluoroscopic imaging permits visibility of motion. Three-dimensional imaging permits visibility of the patient from the front, side, and rotation. These aspects permit better visualization of anatomy, which results in more accurate treatment delivery.

CBCT permits 180 degree and 360-degree image acquisition of the patient. CBCT also permits a three-dimensional view of a patient's anatomy. "CBCT is a volume image obtained during a period of time while the gantry rotates around the patient" (Washington & Leaver, 2015, p.126). CBCT is available on linear accelerators with both KV and MV capabilities.

In regards to MV, KV, and CBCT imaging, these imaging options are technologies that are available on modern linear accelerators. Images are performed on the linear accelerator by radiation therapists. Imaging is an integral part of accurate treatment delivery. Imaging does increase dose to the patient, but it is minimal (Washington & Leaver, 2015).

Computed Tomography (CT) Simulation

Before treatment delivery can occur, a patient must have a simulation performed. In many instances, the ultimate success of the treatment is directly related to the effectiveness of the simulation (Washington & Leaver, 2015). In the early years of radiation therapy treatments, simulations were performed on the linear accelerator. While technology advanced, the demand for more accurate treatments grew. Due to the advancements in treatment, conventional simulation was developed.

Conventional simulation implies the use of x-ray equipment with mechanical capabilities of a linear accelerator. As simulation software continued to advance, electronic transmission of patient information became available. Further advancement of simulation became possible via the use of computed tomography (CT). During current simulation procedures, images are acquired by CT by a radiation therapist. Those images are used to localize the treatment target and other important organs and tissues that are used to create the treatment plan by the medical dosimetrist (Washington & Leaver, 2015). The CT machines used for patient simulations are produced by four main manufacturers: Philips, Siemens, General Electric (GE), and Toshiba.

Imaging Modalities Incorporated in Treatment Planning

Creating a radiation therapy treatment plan is a very detailed, complex process that requires accurate information. Imaging information obtained is used to develop the treatment plan. There are three primary imaging modalities used by the medical dosimetrist to create a radiation therapy treatment plan which consists of CT, magnetic resonance imaging (MRI), and positron emission tomography (PET).

Computed Tomography

As discussed previously, CT is used in multiple aspects of the treatment planning and delivery process. Godfrey Hounsfield (a physicist and engineer) and Alan Cormack (a medical physicist) developed CT and shared the 1979 Nobel Peace Prize in Physics (Washington & Leaver, 2015). The development and use of CT scanners have provided a new method of viewing human anatomy, which has transformed how disease is treated and diagnosed (Washington & Leaver, 2015).

A CT scanner is comprised of an x-ray tube that rotates around the patient. As the x-ray tube rotates around the patient, multiple radiation detectors measure the amount of radiation entering and exiting the patient (Washington & Leaver, 2015). While the CT scanner rotates around the patient, the x-rays travel through different types of tissue such as bone, soft tissue, and air-filled cavities (Washington & Leaver, 2015). Every area of the body has varying densities that the CT scanner can detect and calculate the various doses to. Of all the imaging modalities used for radiation therapy treatment planning and delivery, CT is the only imaging modality that can be used to calculate the dose to a patient (Pereira, Traughber, & Muzic, 2014). As CT is the only imaging modality with that capability, it is instrumental in treatment planning.

Magnetic Resonance Imaging (MRI)

Unlike CT scanners, which uses radiation to obtain an image, MRI uses a large magnet and radiofrequency (RF) waves to produce an image (Washington & Leaver, 2015). In 2000, Paul Lauterbur and Sir Peter Mansfield were awarded the Nobel Peace Prize in Medicine for their discoveries related to MRI (Washington & Leaver, 2015). The human body is comprised of several natural elements such as carbon, hydrogen, and oxygen. Hydrogen and oxygen combine to make water, which comprises 60-80% of the human body. When the hydrogen atoms of the human body are combined with the magnetic fields and RF waves, an image is produced (Washington & Leaver, 2015).

In terms of appearance, the MRI machine closely resembles a CT scanner. However, the MRI bore (opening) is typically deeper and smaller than a CT scanner (Washington & Leaver, 2015). As the magnetic coils produce a large amount of heat, they need to be cooled. MRI machines have liquid nitrogen and liquid helium that runs through the magnetic coils to cool them down so they can function (Washington & Leaver, 2015). Patient positioning and stability are also major factors of an MRI scan. In contrast to a CT scan, any type of movement can negatively affect the entire MRI scan (Washington & Leaver, 2015). Patient positioning and the ability of the patient to maintain position during an MRI scan is paramount to obtaining clear MRI images which are used by the medical dosimetrist for treatment planning.

MRI displays detailed anatomic information in multiple planes of the body. MRI shows the presence and extent of tumors, as well as the shape of normal structures near the target, and permits the ability to make the distinction between recurrent disease and necrosis (Washington & Leaver, 2015). MRI use in radiation therapy treatment planning has grown quickly in recent years. MRI information can be used in the treatment planning process alone or in combination with other imaging modalities.

Positron Emission Tomography (PET)

Positron Emission Tomography (PET) is a form of imaging in which physiology, metabolic activity, and biochemistry are displayed as an image as opposed to anatomy (Washington & Leaver, 2015). Physiology describes how a tissue or organ may function. PET imaging involves using the body's natural metabolic process and having it interact with a radioactive nuclide (Washington & Leaver, 2015). The radioactive nuclide commonly used in

PET imaging is simply described as a radioactive sugar, which is fluorine-18-fluorodeoxyglucose (FDG).

Malignant (cancerous) cells use more glucose to obtain their energy needs (Washington and Leaver, 2015). The use of FDG to image during a PET scan permits visualization of tissue metabolism. PET can be helpful in determining if a patient has malignant activity occurring in the body and the specific location. PET imaging has drastically altered the diagnostic tests that cancer patients receive, which has also positively affected treatment planning (Washington & Leaver, 2015). PET images like MRI and CT images can be used alone or together with other imaging modalities for radiation therapy treatment planning.

Image Fusion

Image fusion is commonly done in radiation therapy treatment planning. Image fusion consists of combining two images of the same or different modality into one image. In radiation therapy, it is common to fuse PET and CT, and CT and MRI. Image fusion permits better visualization of the target as well as the surrounding anatomy. Image fusion permits increased accuracy of the treatment plan created by the medical dosimetrist. For example, combining PET and CT provides detailed structural information from the CT scan and functional information from the PET scan, which results in better target delineation and the subsequent treatment plan (Washington & Leaver, 2015). PET/CT has become an important and commonly used imaging modality to detect tumors, plan radiation therapy treatment, and evaluate responses to treatment (Kawakami et al., 2015).

Treatment Planning Systems (TPS)

As discussed previously, there are select manufacturers of linear accelerators and CT machines. There are also a select few treatment planning systems (TPS) that are used by medical dosimetrists to create patients' treatment plans. Those TPS's are Brainlab, XiO, Monaco, Pinnacle, Panther, RayStation, and Eclipse.

Brainlab TPS is useful to develop treatment plans for patients with brain, bone, head and neck, and spinal tumors (Fornell, 2013). The XiO and Monaco TPS's were designed to be compatible with Elekta linear accelerators. The Pinnacle TPS was created by Philips and is designed to be used in centers with no more than three linear accelerators (Fornell, 2013).

The Panther TPS is designed to be used with Siemens linear accelerators (Fornell, 2013). Siemens decided to stop producing linear accelerators in 2011 (Brown, 2019). Although Siemens is committed to providing replacement parts for 10 years, many centers have opted to acquire newer technologies (Brown, 2019).

The RayStation TPS was created by a proprietary company called RaySearch. RayStation is used in approximately 2,000 radiation oncology centers across the world (Brown, 2019). The Eclipse TPS was designed to be compatible with Varian linear accelerators (Brown, 2019).

Advances in Technology

There has been an extensive number of technological advances in radiation oncology, specifically as it pertains to treatment delivery and treatment, with which the radiation therapist and medical dosimetrist are most involved. Radiation therapy treatment delivery and planning has become more technological than physical in comparison to previous years. Some of the technological advances that have occurred in treatment delivery and planning in recent years is intensity modulated radiation therapy (IMRT), image guided radiation therapy (IGRT), volumetric arc therapy (VMAT), MRI linear accelerators, proton therapy, stereotactic radiation therapy (SRT), and stereotactic body radiation therapy (SBRT).

Intensity Modulated Radiation Therapy

As the radiation beam cannot differentiate between what needs to be treated and what does not, there must be mechanisms in place to do so. Before technology advanced, to treat the specified target and protect the unaffected area, a block was used. The block was made from a material called cerrobend, which is a combination of several metals that can withstand radiation (Washington & Leaver, 2015). The cerrobend block was used for daily treatment and is custom made for each patient's various treatment areas as needed.

As technology advanced, radiation treatments were able to be delivered with the same protective features as the cerrobend blocking. Now blocking is able to be done electronically through the treatment machine with IMRT. IMRT is delivered with multileaf collimators (MLC's), which act as the cerrobend block but is electronically designed by the medical dosimetrist. The MLC's are then used in the linear accelerator that the radiation therapist uses to deliver the radiation treatment.

IMRT can be delivered in multiple ways. The methods of IMRT treatment delivery are step and shoot, dynamic MLC (DMLC), or sliding window technique. In step and shoot IMRT treatment delivery, the radiation is delivered partially, the beam turns off, and the MLC's change shape and treatment resumes (Washington & Leaver, 2015). That process is done for every treatment area that the patient has. Dynamic MLC or sliding window technique is when the MLC's are constantly moving across the treatment field while the radiation beam is being administered (Washington & Leaver, 2015). Both the step and shoot and DMLC techniques permit the maximum dose to be delivered to the target while reducing the dose to the unaffected areas.

Image Guided Radiation Therapy (IGRT)

Direct integration of imaging on the linear accelerator allows for daily monitoring of patient positioning, tumor position, and changes in patient anatomy (Sterzing et al., 2011). "Any imprecision in positioning can be instantly corrected, and anatomic alterations that require modification of the irradiation procedure can be recognized as soon as they occur and the necessary measures taken" (Sterzing et al., 2011, p.274). Imaging permits the ability to immediately adjust and make changes from the imaging findings at the planning stage (Sterzing et al., 2011).

As a patient goes through radiation treatments, multiple changes can occur to the patient that can affect treatment. Common examples of changes are weight loss/gain, and fluid retention. These factors can affect the treatment target and should be accounted for and corrected to deliver optimal treatment. When discussing IGRT, those changes are interfraction and intrafraction uncertainties. Interfraction uncertainties refer to changes that occur between each treatment (Washington & Leaver, 2015). Intrafraction uncertainties are changes that occur during treatment (Washington & Leaver, 2015). In regards to IGRT, an image is obtained at the time of treatment and compared to the image obtained during the treatment planning process. The images are then registered or fused together that allows for changes to be made prior to radiation being delivered ensures accurate treatment delivery.

Volumetric Arc Therapy (VMAT)

Volumetric arc therapy (VMAT) "is the delivery of radiation from a continuous rotation of the radiation source and allows the patient to be treated from a full 360-degree beam angle" (Teoh et al., 2011, p.968). Arc therapies are capable of achieving highly conformal dose distributions to the target and are essentially an alternative form of IMRT (Teoh et al., 2011).

VMAT was first introduced in 2007 and described as a novel radiation technique that allowed the simultaneous variation of three parameters during treatment delivery, gantry rotation speed, movement of MLC leaves and dose rate (Teoh et al., 2011). More recent VMAT techniques have allowed the whole target volume to be treated using one or two arcs, although complex cases may require more. Common cancers that are being treated with VMAT are prostate, gynecological, and colorectal cancers (Teoh et al., 2011).

Tomotherapy

Tomotherapy also known as ‘‘slice therapy’’ machines are considered to be a combination of a CT scanner and a linear accelerator that can deliver radiation in a fan-shaped distribution (Teoh et al., 2011). Similar to CT imaging, a tomotherapy machine continuously emit radiation while it rotates, as the patient is moved through the machine (Teoh et al., 2011). Tomotherapy techniques can be subdivided into axial or serial tomotherapy. Tomotherapy delivers radiation slice by slice or in a helical fashion where the radiation is delivered in a continuous spiral (Teoh et al., 2011).

The first prototype of a tomotherapy machine was completed in 2001 at Wisconsin University and the first patients were treated a year later (Piotrowski et al, 2012). The first helical tomotherapy machine was installed at the Greater Poland Cancer Center in 2009 (Piotrowski et al., 2012). Any type of cancer can be treated with tomotherapy. However, cancers of the brain, head and neck, bone, and pelvis have shown good treatment outcomes when treated with tomotherapy in research trials (Piotrowski et al., 2012).

Stereotactic Radiation Therapy/Stereotactic Body Radiation Therapy

Stereotactic radiation treatments were first reported to be used for patient treatments in 1951 (Washington & Leaver, 2015). In recent years, the amount and types of patient treatments has significantly expanded. Stereotactic radiation therapy is used to treat malignant and benign conditions (Washington & Leaver, 2015).

The first stereotactic radiation treatments were of the brain. Hundreds of radiation sources made of cobalt-60 are directed to the target for treatment. Cranial stereotactic radiation therapy (SRT) involves surgical fixation of markers and a frame in the skull, which remain on the patient for the entire treatment planning and delivery process which can be up to 8 hours (Washington & Leaver, 2015).

Stereotactic body radiation therapy (SBRT) is defined as “radiation therapy treatment method to deliver a high dose of radiation to the target utilizing either a single dose or a small number of fractions with a high degree of precision within the body” (Washington & Leaver, 2015, p.317). The goal of SBRT is to deliver radiation to fully encompass the target with extreme accuracy and allow for minimal dose to the surrounding tissue. SBRT treatments are given by using up to five treatments in comparison to conventional radiation therapy, that is on average thirty treatments (Washington & Leaver, 2015). The amount of radiation given for SBRT treatments and conventional radiation therapy are comparable, however, with SBRT larger radiation doses are given in a shorter amount of time. As SRT and SBRT involves administering large doses of radiation at one time, the simulation, treatment planning, and treatment delivery procedures for these treatments are also much more stringent and detailed than with conventional radiation therapy.

Proton Therapy

While a vast majority of radiation treatments are delivered with megavoltage photons and electrons, radiation treatments can also be delivered with protons. Protons are heavy charged particles that are 2000 times heavier than electrons (Washington & Leaver, 2015). Due to their heavy mass, protons are more damaging than photons and electrons but have a limited range in the body. Using protons for radiation treatments is advantageous because the largest majority of the radiation is given to the target with little to no dose to the surrounding area (Washington & Leaver, 2015).

Proton therapy has also proved to be a large benefit to pediatric cancer patients due to the reduced short term and long term toxicities they experience as they become older in comparison to children treated with photons or electrons (Washington & Leaver, 2015). While there are a limited number of proton therapy treatment centers in the United States, the numbers have increased in recent years. Proton therapy facilities are expensive to build, with their cost 10 times than of a photon/electron facility (Washington & Leaver, 2015). Proton therapy can also be delivered intensity modulated in a similar fashion as IMRT. It is called intensity modulated proton therapy (IMPT).

MRI Linear Accelerators

The MRIdian system, created and manufactured by ViewRay, is one of the newest treatment machines in radiation oncology. It combines cobalt-60 treatment sources with magnetic resonance (MR) imaging to visualize soft tissue tumors during simulation and radiation therapy treatments (Feirn, 2015). The MRIdian is capable of IGRT, SRT, stereotactic radiosurgery (SRS), 3-D conformal radiation therapy, and IMRT (Feirn, 2015). While the MRIdian system can treat any area in the body, it is most beneficial to treat tumors that have significant movement (Feirn, 2015). Examples of these tumors are thoracic, abdominal, and pelvic tumors.

“MR imaging is provided in real time during the simulation and the entire treatment, allowing the radiation therapy team to visualize, track, and make adjustments as the patient is being treated" (Feirn, 2015, p.207). Before the development of the MRIdian, patient tumors could not be visualized during treatment. In 2011 the U.S. Food and Drug Administration (FDA) approved the MRIdian treatment planning and delivery software. The FDA approved use of the MR-guided radiation therapy treatment machine in 2012 (Feirn, 2015). The first patient was treated with the MRIdian system on January 15, 2014, at the Siteman Cancer Center in St. Louis, Missouri (Feirn, 2015).

Technological advancements in radiation oncology have been vast and frequent in recent years. These advancements have greatly influenced the role of radiation therapists and medical dosimetrists. The technological advancements are likely to be a major contributing factor of the recent increased educational requirements for radiation therapists and medical dosimetrists.

Individuals Involved with Treatment Delivery

There are three individuals who are directly involved with radiation treatment delivery: radiation therapists, medical dosimetrists, and medical physicists. Radiation therapists' duties include properly positioning and immobilizing patients' prior treatment delivery, which is called *simulation.* Radiation therapists also administer the radiation treatments to patients. Medical dosimetrists plan the patients' radiation treatments. Medical dosimetrists decipher how the radiation beams enter the patient and calculate the treatment dose per the radiation oncologist's prescription. Medical physicists have the responsibility of ensuring that the radiation therapy equipment is functioning and calibrated correctly for treatment delivery. Medical physicists also verify that the radiation therapy treatment plan parameters are correct prior to implementation. This study focuses on radiation therapists and medical dosimetrists.

Radiation Therapists

Radiation therapists are the allied health professionals that administer a cancer patient's radiation treatment. Before a patient's treatment can be administered, there are several important steps that must occur: diagnosis, consultation, simulation and treatment planning, and treatment administration. A patient must have a specific cancer diagnosis before any treatment can begin. After a diagnosis has been made, the next step is the consultation. During the patient's consultation, the radiation oncologist discusses the patient's diagnosis, treatment options and which treatment options are best suited for the patient's cancer (Washington & Leaver, 2015). The next step after consultation is the simulation.

When cancer patients come into the radiation oncology department for their simulation, this is the initial step in the treatment planning process. During a simulation, cancer patients are positioned in the manner in which they will be positioned for treatment by radiation therapists. The simulation includes using existing immobilization devices or creating immobilization devices that will be used for the patient's daily treatment setup. Radiation therapy treatment setups need to be as reproducible as possible for daily treatments. Images are taken of treatment fields, patient measurements are acquired and creation of treatment fields are also done (Washington and Leaver, 2015). Once the simulation has been completed the treatment planning process can begin. Administration of radiation treatments are patient-specific. Each patient has a specific treatment prescription and treatment plan that the radiation therapist is to administer (ASRT, 2018a). The equipment and technology used to administer these treatments are highly technical and require an extensive amount of education and training to be able to operate. "The general education courses combined with the radiation therapy specific courses required for an academic degree provide a foundation that supports the evolving role of the technologist and the lifelong learning abilities necessary to address continuing technological changes" (ARRT, n.d., par.2). The quantitative skills, communication skills, and understanding of human behavior that are acquired through general education courses help shape and advance a radiation therapist's role in health care (ARRT, n.d.).

Development of Radiation Therapy Educational Guidelines

Like most other health care professions, education of radiation therapists began in the hospital, and evolved into institutions of higher education. After Roentgen's discovery of x-rays in 1895, physicians trained x-ray technicians on an as-needed basis to help them with their research. Based on the direct interaction of radiologists and on-the-job trained x-ray technicians, it was recognized that formal training programs were needed (JRCERT, 2012). Initially, these training programs were hospital-based programs. At the time of the establishment of hospital-based programs, the American Medical Association (AMA) was the only recognized accrediting agency. The AMA did not have the required resources to evaluate programs, they solicited the American College of Radiology (ACR) to take the responsibility of surveying x-ray training programs (JRCERT, 2012).

In 1944, x-ray technology, the predecessor of radiologic technology, joined medical records, clinical laboratory sciences and occupational therapy as the fourth health occupation to develop standards of education and requirements for accreditation (JRCERT, 2012). The first educational standards "Essentials of an Acceptable School for X-ray Technicians" was the result of negotiation between the American Society of X-ray Technicians, now known as the American Society of Radiologic Technologists (ASRT), and the Council on Medical Education and Hospitals of the AMA (JRCERT, 2012). The ASRT later contributed to the establishment and advancement of educational standards for radiologic technology in the areas of curriculum and instructor development. By 1950, approximately 125 schools in the United States offered training programs in x-ray technology (JRCERT, 2012).

The education of radiation therapists has truly evolved over the last century. Initially established in 1969, the JRCERT is the only entity recognized by the United States Department of Education (USDE) and the Council for Higher Education Accreditation (CHEA) for the accreditation of traditional and distance delivery of radiography, radiation therapy, magnetic resonance and medical dosimetry programs (JRCERT, 2012). The JRCERT currently accredits approximately 750 radiologic science educational programs in the United States.

Prior to delineated practice standards, radiation therapists were radiologic technologists formerly known as x-ray technicians or registered nurses (RN), who were trained on the job to administer radiation treatments. It was not until 1964 that radiation therapy was recognized as a separate discipline from radiologic technology and the first certification exam was administered by the American Registry of Radiologic Technologists (ARRT) (JRCERT, 2012). During that time, radiation therapy training consisted of one-year certificate programs. The ARRT is the credentialing organization for radiologic technologists and radiation therapists. They certify and register technologists as well as establish the certification examination and ethical requirements. The ARRT also administers the various imaging modalities certification examinations.

It was not until the 1970s that associate and baccalaureate degrees were offered in radiation therapy. Students at that time had multiple choices regarding what degree path they wanted to pursue. Students had the option of one-year certificate (which required training as a radiologic technologist), two-year associate’s degree or four-year baccalaureate degree. Graduates who were certification eligible took the same certification exam regardless of the degree path.

There has been a push for increased educational requirements for several years by the ASRT. The ASRT is the professional organization for radiologic technologists and is deemed as the premier professional association for medical imaging and radiation therapy (ASRT, 2020). The ASRT established practice standards for medical imaging, radiation therapy, and medical dosimetry (ASRT, 2020a). The ASRT has also developed educational curricula that radiation therapy and medical imaging programs are encouraged to follow.

The ASRT has strongly encouraged that entry level technologists should be at the baccalaureate degree level. The ASRT developed the Bachelor of Science in Radiologic Sciences (BSRS) core curriculum (ASRT, 2018). The initial BSRS curriculum was developed in 2003 revised in 2008, and 2013, and adopted in 2018 (ASRT, 2018a.). Effective January 1, 2015, the ARRT mandated that all entry level technologists must have a minimum of an associate's degree to be eligible for primary certification (ARRT, 2015). While radiation therapists are the individuals most involved with treatment delivery and have experienced educational and technological changes in recent years, medical dosimetrists have encountered similar changes.

Medical Dosimetrists

Medical dosimetrists are the members of the radiation oncology team who create the cancer patient's treatment plan. Treatment plans consist of the treatment prescription, patient setup information, beam arrangements, dose distributions and treatment parameters. The treatment plan is created using a treatment planning computer that has sophisticated treatment planning software that allows the medical dosimetrist to plan the treatment and calculate radiation dose (American Association of Medical Dosimetrists, n.d.a.). The medical dosimetrist is given a treatment planning directive by the radiation oncologist, which includes the treatment prescription and dose information to various organs/areas including dose limits (American Association of Medical Dosimetrists, n.d.a.).

The medical dosimetrist creates a radiation treatment plan from the treatment planning directive according to the specifications of the radiation oncologist. Once the treatment plan has been created, it is reviewed by a radiation oncologist and approved. The approved treatment plan is sent through a computer system called a “plan checker” and it is also checked by the medical physicist prior to implementation (American Association of Medical Dosimetrists, n.d.a.).

As this process demonstrates, cancer treatments have become significantly more complex due to the technological advances of the equipment used to deliver radiation treatments. Due to these advances in radiation oncology, the amount of knowledge and training required has also increased in the radiation oncology treatment process. Medical dosimetrists have traditionally been trained on the job. Individuals who study to become medical dosimetrists have been radiation therapists, physicists, or mathematicians (Medical Dosimetrist, n.d.).

Medical Physicists

As discussed previously, radiation therapists and medical dosimetrists are not the only professionals involved with radiation treatment delivery. Medical physicists are an integral part of cancer patients’ care and treatment delivery. Medical physicists have experienced increased educational requirements in recent years comparable to radiation therapists and medical dosimetrists. Medical physicists have the responsibility of maintaining all aspects of radiation sources and equipment, developing and implementing a radiation safety program, assuring the accuracy of cancer patients’ treatment, development of new treatment techniques or protocols, planning for resource allocation and professional interaction with the medical physics community (AAPM, 2016).

Radiation sources and the equipment used in correlation with these sources are key in delivering a patient's treatment. The medical physicists' role is to assure that the radiation equipment used to deliver the treatment is calibrated correctly. During the calibration process, the medical physicist tests the radiation sources and equipment to assure that the measurements are within the manufacturer's specifications (AAPM, 2016). Calibration is paramount for accurate treatment delivery. There are also federal regulations mandated from the Nuclear Regulatory Commission (NRC) as well as state regulations that must be followed. Medical physicists have the responsibility of developing and implementing radiation safety programs for their respective departments. The radiation safety programs at minimum must follow state and federal regulations.

Medical physicists also have the responsibility of assuring the accuracy of cancer patients' treatment plan (AAPM, 2016). Accuracy of individual treatment plan parameters are verified in addition to machine calibrations specific to the patient's treatment plan. Verification of accuracy assures that the patients' treatments are being delivered according to the radiation oncologist's prescription and the approved treatment plan. Each treatment plan and prescription are patient specific, which requires the medical physicist to check these parameters for every patient's treatment prior to treatment delivery (AAPM, 2016). The development of new treatment techniques and protocols is instrumental for the advancement of radiation oncology. Medical physicists are involved with this process as well. As medical physicists are part of the treatment planning and delivery process, they see firsthand how this process works and how it can be improved. Due to this exposure, the medical physicist is always involved with process improvement which leads to the development of new techniques and protocols (AAPM, 2016).

A person who chooses to pursue medical physics as a career has a choice to become certified in diagnostic imaging, radiation therapy or nuclear medicine. A qualified medical physicist (QMP) has earned a masters or doctoral degree in a specified type of physics or equivalent field of study from an accredited college or university and has been certified by the proper certifying body (AAPM, n.d.). Certifying bodies for therapeutic medical physics include the American Board of Radiology (ABR), American Board of Medical Physics (ABMP), and the Canadian College of Physicists in Medicine (CCPM).

There have been changes to the qualifications to become a medical physicist in recent years. Effective as of 2012, individuals must complete or be enrolled in a Commission on Accreditation of Medical Physics Education Programs (CAMPEP) recognized program or residency (AAPM, n.d.). To be certification eligible in 2014 and beyond, individuals must have completed or be enrolled in a CAMPEP recognized program (AAPM, n.d.). These requirements are for clinical physicists. Medical physicists can also pursue non-clinical careers such as research, policy, scientific writing, radiation safety or health physics (AAPM, n.d.). The role of the medical physicist is crucial to radiation therapy treatment delivery. They, too have experienced increased educational requirements in recent years, however, this study will focus on radiation therapists and medical dosimetrists. While there have been educational advancements that have affected various members of the radiation oncology team, there have also been educational advancements in other healthcare fields such as physical therapy and nursing.

Additional Health Professions that have Experienced Increased Educational Requirements

Physical Therapists

Another field in allied health that has experienced increased educational requirements is physical therapy. Physical therapy education has moved from the master's degree level to the doctoral degree level in recent years. The doctor of physical therapy (DPT) has now become the entry level degree for an individual who desires to become a physical therapist (American Physical Therapy Association, 2019).

The increasing complexity of healthcare in the United States requires healthcare providers to become experts in multiple aspects of health care. A combination of clinical skills, public health knowledge, and business/administrative aspects are now required of health care providers, including physical therapists. Those skills provide the ability for a physical therapist to effectively manage and navigate the changing health care environment and become a leader in their field (Kapasi et al., 2016).

A few universities have implemented combined/dual master's of business administration or master's of public health and doctorate of physical therapy (DPT/MBA and DPT/MPH) degrees, one of which is Emory University. At Emory University, the combined DPT/MBA and DPT/MPH programs were created to provide students with the required clinical, business, administrative, policy analysis, and public health perspectives needed to be successful as leaders in a constantly evolving health care system (Kapasi et al., 2016).

In addition to promoting interprofessional education, the combined degree programs at Emory have shown positive outcomes. "All graduates indicated that their dual degree positively impacted their careers, and the majority reported specifically using their dual degree in their career" (Kapasi et al., 2016, p.31). The graduating grade point average (GPA) and first-time pass rate on the national physical therapy exam (NPTE) of the combined degree students in the DPT program is comparable to that of the overall DPT class graduating the same year (Kapasi et al., 2016). The research suggests that the additional coursework (MBA/MPH) did not adversely affect the students' performance in the DPT program (Kapasi et al., 2016).

Nursing

Fields outside of allied health have also experienced the same increased educational requirements such as nursing. As nursing has evolved, so has the amount of education and training nurses have had to obtain (Nurse.com, 2012). Most people in healthcare are familiar with Florence Nightingale who pioneered the field of nursing. In the early years, nursing was not regarded as a respected profession. As the nursing profession advanced in the nineteenth and twentieth centuries perceptions of the field of nursing began to change (The Sentinel Watch, 2016). Like radiation therapists and medical dosimetrists, nurses were also traditionally trained on the job. According to Karen Egenes, Ed. D., R.N., nursing historian, nursing students were an unpaid labor source who received minimal clinical supervision and worked 12 hour shifts during their training (Nurse.com, 2012).

As the field of nursing advanced, formal educational programs began. Nursing training programs began in the nineteenth century when there were not established standards for nursing education. The programs ranged from 6 months to 2 years (The Sentinel Watch, 2016). During the early 1900s, schools of nursing were recommended to be offered at colleges and universities due to the advancement of the field even though there was significant resistance until the 1950s when major technological and scientific progress in healthcare was made (Nurse.com, 2012). It was during that time that associate degree nursing programs were developed. In the 1960s and 1970s there was a decline in the number of certificate programs as associate degree programs were being offered. In the 1980s the National League of Nursing (NLN) made the push for a Bachelor of Science in Nursing (BSN) to be the minimum education level for entry level nurses (The Sentinel Watch, 2016). As the push for the BSN to be the entry level minimum for nurses, research studies were showing that patient outcomes were improved due to nurses having BSNs and a report by the Institute of Medicine distributed in 2010 called for 80% of nurses to hold a BSN by the year 2020 (The Sentinel Watch, 2016).

Nursing education has grown substantially since the profession began. There has been tremendous growth in the numbers and types of programs offered (Beogo et al., 2015). Due to the nursing shortage, there have also been fast track nursing programs that have been developed. There were fast track programs for BSN programs and Nurse Practitioner (NP) programs. The NP programs were implemented in 1965 to help with the shortage of physicians. The fast track programs were so successful in the United States that other countries developed them. Fast track nursing programs were developed in New Zealand, Australia, United Kingdom, Ireland and Canada (Beogo et al., 2015). The changes that have occurred in physical therapy and nursing education are comparable to the educational changes that have occurred in radiation therapy and medical dosimetry. Evaluating the educational reforms that have occurred in these fields in addition to radiation therapy and medical dosimetry, further shows how the educational requirements needed to practice in various areas of healthcare have increased due to the constantly evolving field of healthcare. As the educational requirements in the various fields of healthcare have increased, it is also important to discuss the certification and licensure exams needed to practice in these fields.

Certification Exam in Radiation Therapy and Medical Dosimetry

To become a certified radiation therapist or medical dosimetrist is no simple task. These two professions require that students meet certain requirements which include but are not limited to education (both didactic and clinical) as well as certain ethical requirements. Students are not eligible to take the certification exam in radiation therapy or medical dosimetry until they have successfully completed their educational program and fulfilled all established requirements by the respective certifying body. The entities that administer the certification exams for radiation therapy and medical dosimetry are the American Registry of Radiologic Technologists (ARRT) and Medical Dosimetrists Certification Board (MDCB). Both the ARRT radiation therapy exam and the MDCB exam are developed by psychometricians who receive information and data from job task and current practice analyses surveys in the respective professions (ARRT, 2017; MDCB, n.d.a.).

Radiation Therapy Certification

To be eligible for the ARRT certification exam in radiation therapy, students must have earned an associate’s degree or higher, completed an ARRT recognized radiation therapy educational program, and have met the required ethical qualifications (ARRT, n.d.c.). The associate’s degree or higher requirement became a requirement by the ARRT in 2015. An ARRT recognized program is a program that is recognized as a programmatic accrediting agency, regional accrediting agency, national accrediting agencies, and international accrediting agencies (ARRT, n.d.a.). The most commonly recognized programs are those that are programmatically accredited, such as the JRCERT and regionally accredited programs that are recognized by organizations such as the Higher Learning Commission (HLC) or the Southern Association of Colleges and Schools Commission on Colleges (SACSCOC).

The ARRT radiation therapy certification exam is a computerized exam in which students have 3.5 hours to complete the exam. The exam is 220 questions in total; 20 of those questions do not count for or against the examinee, but may be used on subsequent examinations (ARRT, n.d.d.). The examinee will not know which questions those are. The scoring scale ranges from 1-99 and examinees must achieve an overall scaled score of at least 75 to pass (ARRT, n.d.e.). The scoring scale does not require examinees to obtain at least a 7.5 on each section to pass, but the overall scaled score of 75 is required to pass (ARRT, n.d.e.). Each section of the exam are varying lengths and are weighted differently, that is why the score is a scaled score. Effective 2019, examinees will have to answer more questions correctly to achieve the minimum cut score of 75 (ARRT, 2019).

Upon submission of the exam, examinees are given preliminary scaled score. However, this is not the final score. Within 4 weeks of the exam date, passing examinees will receive an examination results packet with an official score report and registration results (ARRT, n.d.e.). The score report shows total score and relative performance by content area (ARRT, n.d.e.). This information is valuable to examinees if they should need to retest as it will help them to identify weak areas so they can better prepare for subsequent exam attempts.

Most examinees pass the certification exam on the first attempt. However, some applicants do need to retest and there are some caveats. The ARRT has a three year /three attempt rule. Examinees have 3 attempts within 3 years to pass the radiation therapy certification exam (ARRT, n.d.b.). The 3-year period begins with the starting date of the initial ARRT exam attempt. After 3 unsuccessful exam attempts or three years, whichever comes first, an examinee’s eligibility expires (ARRT, n.d.b.). To regain eligibility, an examinee must re-enroll in an educational program, complete an advancement placement option, or repeat the clinical competency requirements (ARRT, n.d.b.).

Medical Dosimetry Certification

To be eligible for the MDCB exam, students must have completed at minimum a bachelor's degree and have completed a JRCERT accredited medical dosimetry program that is at minimum 12 months (MDCB, n.d.). This policy applies to all candidates who are United States residents and became effective in 2017. International candidates are also eligible to take the MDCB exam but have slightly different requirements than United States applicants. In addition to the bachelor's degree requirement, international candidates must also have received a grade of "C" or higher in specified courses and have completed a minimum of 1000 clinical hours in medical dosimetry treatment planning (MDCB, n.d.).

The MDCB exam contains 155 multiple choice questions. Examinees are allowed 3 hours and 50 minutes to complete the exam and it is only administered in English. "A small percentage of randomly imbedded un-scored items are included on the exam to obtain and evaluate statistical information for new items" (MDCB, n.d.a., par.5). These items are not included in the score calculation. Beginning 2020, for the first time, a small number of performance-based test (PBT) questions will be included in the MDCB exam (MDCB, n.d.a). Performance-based questions can assess an examinee's ability to apply learned skills and knowledge (MDCB, n.d.a).

The MDCB exam consists of seven content areas and are varying in percentage of the total amount of the exam (MDCB, n.d.d.). The MDCB exam is a pass/fail exam; actual scores are not given to examinees (MDCB, n.d.c.). "Each candidate's ability is measured against a determined cut score identified by the cut score study, a recognized industry practice" (MDCB, n.d.c., par. 4). As a result, each examinee is compared to the same standard. Candidates are not required to have a passing score in each of the content areas of the exam to pass.

If an examinee is unsuccessful, a fail report with details are provided to the examinee so that they can assess their performance in each of the content areas (MDCB, n.d.c.). Exam results are made available to examinees approximately six weeks after the examination attempt (MDCB, n.d.c.). Examinees are notified by e-mail when scores are available. While detailed score reports are not provided, they can be requested. The detailed score reports confirm the score and the accuracy of the exam outcome (MDCB, n.d.c.). Raw or scaled scores are not provided.

All examinees are allowed three attempts for the MDCB exam. An examinee who has failed the exam on the third attempt is not be eligible for re-examination for two calendar years (MDCB, n.d). After an unsuccessful attempt, examinees may sit for the two successive exams based on the eligibility criteria for which they were approved (MDCB, n.d). “If the exam is offered more than once in any calendar year, candidates may sit for each administration” (MDCB, n.d., par.2). There is no specified time limit in which a candidate must complete the three exam attempts. After the 2-year waiting period preceding the last unsuccessful attempt, the candidate may apply to retest (MDCB, n.d.).

Exam Reporting for Radiation Therapy and Medical Dosimetry

Certification exam reporting for educational programs recognized by the ARRT, MDCB, and JRCERT determine an educational program’s certification pass rates by the first exam attempt. As the passing score for the ARRT radiation therapy exam is 75, the JRCERT requires that all accredited programs have a 5-year credentialing exam average of 75% (JRCERT, n.d.). The MDCB does not provide a specific score; the exam is scored as pass or fail. Both radiation therapy and medical dosimetry programs report certification exam pass rates by calculating the number of successful attempts divided by the number of overall attempts (JRCERT, n.d.).

Gaps in the Literature

There are minimal published studies that discuss radiation therapy or medical dosimetry certification exam rates. This study would be one of the first that compares degree level and certification exam pass rates. While there is minimal literature about this topic in radiation therapy and medical dosimetry, there are other health professions that have published studies regarding certification exam rates and the methods employed to improve certification exam pass rates. Those health professions include medical laboratory science (MLS), physical therapy assistant (PTA), occupational therapy (OT), nursing, and paramedics.

Certification Exams in Allied Health Professions and Nursing

Most health professions require formal education and certification to practice, it is imperative that students receive proper preparation for the respective certification exam they will need to take. Credentialing exam rates of health professionals is a topic that has received increased attention in recent years (Ebiasah et al., 2002). Multiple methods have been used as preliminary measures of exam success and to prepare students for certification exams in various fields of healthcare. Although there is no literature about exam preparedness and predictability in radiation therapy or medical dosimetry, scholars from other fields of healthcare such as MLS, PTA, OT, nursing, and paramedics have published literature on this topic. The methods evaluated regarding certification exam rates in the various health professions and nursing were tests, coaching programs, programmatic accreditation, and students' admissions criteria on certification exam success rate.

Methods Evaluated regarding Certification Exam Rates

Tests

The American Society for Clinical Pathology (ASCP) Board of Certification (BOC) is the entity that administers the certification exam for MLS. In 2017, Pelton studied the use of a comprehensive programmatic examination as a predictor of how well students would perform on the ASCP certification exam. In this study, Pelton not only studied overall scores, but content area scores as well. The study showed that there was a correlation between a passing score on the comprehensive programmatic exam and successful ASCP certification exam results (Pelton, 2017).

The ASCP certification exam incorporates adaptive computer technology, in which questions are presented at increasing difficulty levels until the examinee fails to answer correctly, upon the occurrence the difficulty level is reduced (ASCP, 2016). The exam is scored by the weight of the question which is based on assigned difficulty rankings. An examinee must score at least 400 out of a possible 999 to pass the exam (Pelton, 2017).

In Pelton's (2017) study, the exam scores of the 152 students of the study program ranged from 35-86% (percentage of correct answers) for students completing both exams (comprehensive programmatic exam and national certification exam) from 2006-2015. The BOC exam scores ranged from 287-755. All students scoring above 67% on the comprehensive programmatic exam passed the certification exam. Pelton did not examine the direct relationship between the two exams.

PTA's are also required to take a certification exam to practice. Easley (2016) studied the results of the Nelson Denny Reading Assessment (NDRA) taken by PTA students in a Tennessee community college to determine if it could be a predictor of completing the PTA program and passing the certification exam. The NDRA is a diagnostic exam developed in 1929 by M.S.

Nelson and E.C. Denny and is used by many community colleges to assess the reading level of incoming college students (Brown et al., 2015). The NDRA consists of reading comprehension and vocabulary questions in which each section is scored independently, then integrated to produce a composite score. The target score for a high school graduate is 12, and that was the score used to determine the validity of the NDRA for the study (Easley, 2016).

At the time of the study, there were six Tennessee Board of Regents (TBR) community colleges that offered PTA programs. The sample population were 135 students who were conveniently selected from one PTA program. “A non-random sample was best suited for this study, as it ensured that the multitude of intervening variables that could influence the results of the study was eliminated” (Easley, 2016, p.76). The study found that the NDRA is a strong predicting variable of both retention and first time pass rate success on the NPTE exam (Easley, 2016). As found in the review of the literature about MLS programs, no literature examining the relationship between degree level and NPTE pass rates was identified. The lack of literature may be due to PTA programs are required to be at the associate’s degree level and that there are not many programs that are not at this degree level.

Occupational therapists, like other health science professionals, have to pass a certification exam to work in the field. The purpose of occupational therapy educational programs is to produce graduates that are clinically competent to practice at the entry level (Avi-Itzhak, 2015). “Consequently, a body of literature has begun to emerge examining variables predicting student success in health professions educational programs using first-time pass rates on national or regional certification exams as an outcome measure for student success” (Avi-Itzhak, 2015, p.2). Ari-Itzhak (2015) measured the ability of the National Board for Certification in Occupational Therapy (NBCOT) Occupational Therapist Registered (OTR) practice test to predict first-time pass status on the NBCOT OTR national certification exam in a sample of students in an occupational therapy educational program in a public urban higher education institution.

The purpose of Avi-Itzhak's (2015) study was to assess the relationship between performance on each of the four NBCOT practice test domains and first-time pass status on the NBCOT exam. The aim was to apply the outcomes of the four content areas of the NBCOT practice test to develop a logistic regression model for estimating the probability of first-time pass status on the NBCOT exam. The study also looked to identify the exam content areas that have a significant predictive effect on this probability. Of the 71 students who completed the program during 2010–2013, 65 (92%) for whom information was available were used in the study. Of these students, 41(63%) passed the practice test, whereas 24 (37%) did not (Avi-Itzhak, 2015).

Avi-Itzhak (2015) concluded that the logistic regression model for estimating the probability of passing the NBCOT OTR exam on the first attempt show that the model with all four predictors are the most accurate. The variance in NBCOT first time pass rates ranged from 22% to 29%. The study showed that passing the NBCOT practice exam was an accurate predictor of passing the NBCOT OTR exam in 80% of examinees. The NBCOT practice exam was also more effective in predicting successful first-time exam attempts. These findings have educational implications because they can assist educators in identifying effective curricular models to incorporate into their programs to help their students pass the NBCOT OTR exam on the first attempt (Avi-Itzhak, 2015). While Avi-Itzhak's (2015) study demonstrated promising results with practice tests improving certification exam rates, online coaching programs is another method that has been found to be effective in this area as well.

Online Coaching Programs

Of all the published literature regarding health professions certification exam pass rates, nursing by far has the most. Nursing program faculty have the difficult task of creating and delivering curricula that permits graduates to be successful on the NCLEX-RN exam as well as comply with the requirements of state and national regulatory agencies (NLN CNEA, 2016). Nursing accrediting bodies require programs to produce comprehensive plans of assessment and evaluation that include targets for national licensure examination success to maintain the program's accreditation status (Opsahl et al., 2018).

In a recent study by Opsahl et al. (2018), methods implemented in a BSN program to improve the scores on the NCLEX-RN were evaluated. Opsahl et al. (2018), found positive effect of the implementation of an online coaching program with Appreciative Advising and Emotional Intelligence education as combined educational methods to increase student learning outcomes. The online coaching programs included supplemental learning activities which provided an increased level of complexity throughout the nursing curriculum that incorporates a comprehensive examination to predict performance on the student's NCLEX-RN examination first attempt (Killingsworth et al., 2015).

The online nursing coaching systems require frequent interactions between the Master of Science in Nursing (MSN) prepared nurse coach and the student (Opsahl et al., 2018). The goal is that the mentoring from the MSN prepared nurse coach along with the newly incorporated teaching strategies will be a comprehensive predictor to gauge students' success with the national board examination and program completion (Opsahl et al., 2018). Appreciative Advising was used as the theoretical framework/design in creating and maintaining relationships with students. Appreciative Advising is a student-centered approach that involves purposeful collaboration to support students in optimizing their educational experiences and achieving the best possible outcome (Bloom et al., 2013).

The advisors work with students to highlight their qualities and to create a specific plan for their success. After the 2013 pass rate scores, the nursing program faculty of the study decided that all senior BSN students would receive a 12-week, personalized, online support program with an MSN- prepared coach (Opsahl et al., 2018). The advisor and student would meet weekly and focus on areas related to the NCLEX-RN examination. The convenience sample comprised all students who completed the baccalaureate program at the university and took the NCLEX-RN from May 2013 to August 2016 (Opsahl et al., 2018).

Once the students completed the 12-week online program, they received approval to take the NCLEX-RN exam from their online coach when the student passed each section of the practice tests with satisfactory marks (Opsahl et al., 2018). Before the implementation of the online coaching program, the program's NCLEX-RN first attempt examination pass rate in 2013 was 66% (Opsahl et al., 2018). During the time of the implementation of the online coaching program which was 2014-2016, the NCLEX-RN first attempt examination pass rates ranged from 89%-95% (Opsahl et al., 2018). Findings indicated a marked increase in pass rates when comparing the first-time NCLEX-RN pass rates before the implementation of the new program approach which included the added online coaching and student academic support (Opsahl et al., 2018). Of all health professions, nursing by far has the most published literature regarding certification exam pass rates and methods to improve them. Nursing literature also has the most information regarding admissions criteria that students are evaluated on.

Admissions Criteria

In response to the call to train a more diverse healthcare workforce, allied health and nursing programs have begun a process of evaluating factors that influence the composition of the students that apply to their programs (Wambuguh et al., 2016). Many programs that train health professionals have adopted components of a "holistic assessment" in their admissions processes. Holistic assessment takes into consideration life experiences of applicants as well as scholastic strengths (Wambuguh et al., 2016). Educators and nursing school admissions offices have indicated there is a correlation among the academic and non-academic factors involved and programmatic outcomes. Students who perform well in pre-requisite science courses and attain specific scores in entrance tests like the Test of Essential Academic Skills (TEAS) have demonstrated increased likelihood of successfully completing the nursing program curriculum with an above average GPA and passing the NCLEX-RN on first attempt (Wambaugh et al., 2016).

Wambuguh et al. (2016) studied five areas of admissions criteria: preadmit science GPA; TEAS score; healthcare experience; previous baccalaureate degree; and pre-admission university enrollment versus college transfer as predictors of three desired outcomes: graduation; nursing program GPA; and passing NCLEX-RN. The results showed that the TEAS scores and pre-admit science GPA were a predictor of nursing program outcomes. Students' TEAS scores that were greater than or equal to 82 had an 8 % greater probability of completing the program, 13% greater probability of a GPA greater than or equal to 3.25, and 9% greater probability of passing NCLEX-RN, compared to students with TEAS scores less than 82. Students that had pre-admissions science GPAs greater or equal to 3.8 had 11 % greater probability of successfully completing the NCLEX-RN and 14 % greater probability of a GPA greater than or equal to 3.25 compared to students with pre-admissions science GPAs less than 3.8.

Programmatic Accreditation

As students' admissions criteria are important factors related to programmatic outcomes, so is accreditation. Accreditation is a peer-reviewed process of educational organizations' programs (internally and externally) to verify the quality of the educational program and ensure public protection (Council for Higher Education Accreditation, 2010; Eaton, 2006). In the United States, accreditation of educational programs that lead to students' certification or licensure to practice is the standard for many allied health and nursing programs (Accreditation Council for Graduate Medical Education, 2015; Association of American Medical Colleges, 2012; Mims et al., 2015; Swing et al., 2013). Programmatic accreditation helps to ensure academic integrity and that current industry standards for entry level practice are incorporated into the curriculum, and facilitates students' accessibility to federal funding (JRCERT, n.d.a). Programmatic accreditation for allied health and nursing programs can be mandatory or voluntary. Regarding the health professions discussed in this study, programmatic accreditation is required for MLS, PTA, OT, paramedics, and medical dosimetry. Programmatic accreditation is voluntary for radiation therapy and nursing.

For most accredited health professions programs the graduates' certification pass rates can factor into a program receiving or maintaining accreditation. Accredited programs are also held to certain standards that non-accredited programs are not. For example, the National Accrediting Agency for Clinical Laboratory Sciences (NAACLS) uses the ASCP Board of Certification (BOC) exam pass rates as an outcome measure for accredited MLS programs. The NAACLS requires a 3-year average pass rate of 75% for graduates that take the exam within 1 year of program completion (Pelton, 2017). Due to this accreditation requirement, MLS programs must identify students who may be at risk of failing the certification exam and variables that may contribute to this (Pelton, 2017). Educational programs accredited by the JRCERT such as radiation therapy and medical dosimetry also have a similar certification exam pass rate requirement to MLS. JRCERT accredited programs are required to achieve and maintain a 5-year credentialing exam average of 75% for graduates that take the exam within 6 months of program completion for radiation therapy and 1 year after program completion for medical dosimetry (JRCERT, n.d.b.)

Accreditation status of a program may be a factor in a graduate's ability to pass their respective certification exam. Rodriguez et al. (2018) compared the certification pass rates of accredited and non-accredited paramedic educational programs. Well-trained, competent emergency medical services (EMS) professionals are needed to ensure that qualified professionals are available to meet the needs of the communities that they serve. To ensure quality preparation of all EMS students prior to clinical practice is the initial step to protecting the public during an emergency (Rodriguez et al., 2018). The EMS *Education Agenda for the Future* from the U.S. National Highway Traffic Safety Administration (NHTSA) spotlighted universal accreditation of EMS programs as a method to ensure program quality and compliance to national standards and guidelines (NHTSA, 2000).

Effective January 1, 2013, the National Registry of Emergency Medical Technicians (NREMT) and National Association of State Emergency Medical Services Officials (NASEMSO) mandated that students must complete accredited paramedic educational programs to be eligible to sit for National EMS Certification (NASEMSO, n.d.; NREMT, n.d.). Institutional and program accreditation has been the norm for quite some time for physician and nursing education, paramedic program accreditation was not mandated in the United States until recently (Rodriguez et al., 2018).

The objective of the study was to evaluate if programmatic accreditation was correlated with higher certification pass rates and cognitive ability performance on the NREMT paramedic certification (Rodriguez et al., 2018). In 2012, 8,404 paramedic educational program graduates sat for the cognitive examination. Of the total number of examinees, 1,093 (13%) of the examinees graduated from non-accredited programs (Rodriguez et al., 2018). The first-attempt pass rate for accredited program graduates was 75.6% compared to 67.3% of graduates from non-accredited programs. The summative pass rate after three exam attempts also was higher for accredited program graduates (88.9%) than for non-accredited graduates (81%). The graduates of accredited paramedic programs demonstrated higher cognitive ability in all clinical content areas of the exam. Graduates of accredited paramedic programs had greater success on the National Paramedic Certification examination with 51% greater odds of passing the exam on the first attempt (Rodriguez et al., 2018).

Challenges

Another factor that was commonly addressed in the literature regarding certification exam rates was GPA (Amankwaa, Agyemang-Dankwah, & Boateng, 2015; Macomber & Sanders, 1984; Sloas, Keith, & Whitehead, 2013). A study by Lanier and Lambert (1981) showed that higher GPA for science courses taken prior to being in the program were associated with higher scores on the ASCP certification exam and a comprehensive exam. In addition to science GPA, overall GPA and programmatic GPA were associated with a significant impact on variation in certification exam scores in radiologic technology, physical therapy assistant, and nursing programs.

Many allied health and nursing programs are associate degree level programs. These programs are commonly housed at community colleges, which presents some benefits and setbacks. Some of the challenges that community colleges face are meeting the Complete College Agenda, outcomes-based funding, open-enrollment policies and high attrition rates (Easley, 2016).

The Complete College Agenda was created by President Barack Obama. This initiative asked community colleges to educate an additional five million students by the year 2020 (Easley, 2016). While this is excellent in theory, it does pose several challenges. Unlike their 4-year counterparts, community college students are not required to take standardized tests such as the SAT or ACT to be accepted. “As a result, many students, including those interested in Allied Health programs, are not prepared to meet college-level coursework requirements” (Easley, 2016, p.72).

In addition to being underprepared for college-level coursework, allied health students enrolled in community colleges also face the challenge of passing a state or federal credentialing exam to be able to practice in their profession (Easley, 2016). A PTA student, for example, is not considered successful until a degree has been earned and the student has passed the National Physical Therapy (NPTE) exam. “In fact, the Tennessee Higher Education Commission (THEC), the Center of Accreditation for Physical Therapy Education (CAPTE), and the American Physical Therapy Association (APTA) will only consider first-time pass rates on the NPTE as successful” (Easley, 2016, p.73). As the first exam attempt is what is reported, this puts a tremendous amount of stress, not only on the student, but also on the program directors and faculty members to ensure that the students are successful. First time pass rates are also what are used to report radiation therapy and medical dosimetry certification exam statistics.

The degree level that a student chooses to pursue can be related to Vroom's expectancy theory (VET). As mentioned previously, some allied health and nursing programs are housed at community colleges which offer associate degrees or certificates. However, these programs can also be offered at higher degree levels such as a bachelor's or master's degree. VET is based on the principle of force (effort)=valence (attractiveness) x expectancy (reward). The level of degree a student chooses to pursue and subsequently the GPA earned relates to the amount of force (effort) the student puts forth. The perceived prestige of being a health care professional may be the valence (attractiveness) and obtaining certification and subsequent position is the expectancy (reward) of the force (effort) exerted.

This literature review provides detailed information about the theory, evolution of radiation therapy and medical dosimetry education, practice, and its potential effects on certification exam rates in these professions. Information on certification exam rates and accreditation in other fields of allied health and nursing are also discussed. The theory that drives this research is VET. VET is composed of three principles: valence, expectancy, and force. These principles can be related to a radiation therapy or medical dosimetry student's motivation to perform well in their respective program and the subsequent results of that motivation. One of those results is hopefully passing their respective certification exam. The history of radiation therapy provides information regarding the discovery of x-rays and their use in cancer treatment. The section on radiation therapy treatment delivery equipment discusses the equipment that radiation therapists use to administer patients' radiation treatment and how they have advanced over the years.

Imaging ensures accurate radiation treatment delivery. The sections of the literature review that discuss imaging and the imaging modalities incorporated into treatment planning describe the types of imaging that are used in delivering radiation treatment by the radiation therapists. The various imaging modalities discussed provides information regarding the various types of imaging used in creating a radiation treatment plan by the medical dosimetrist. The various treatment planning systems are discussed as well which are the computer systems that the medical dosimetrists use to create patients' radiation treatment plans.

As the educational requirements for radiation therapists and medical dosimetrists have increased in recent years, the technology that is used by these individuals has also advanced. The section that discusses the advances in technology discusses the recent technological advances that have occurred in recent years and how it has affected treatment delivery and treatment planning. There are multiple health professionals involved with a cancer patient's treatment and care which are discussed in this study. The key individuals involved with treatment delivery are the radiation therapist, medical dosimetrist, and the medical physicist. This study focuses on the radiation therapist and medical dosimetrist.

There are other health professions that have experienced increased educational requirements outside of radiation oncology. Two of those professions are physical therapy and nursing which are discussed in this study in the section titled "Additional health professions that have experienced increased educational requirements". Most health professions require certification or licensure. The certification exams in radiation therapy and medical dosimetry are discussed in this study as well as the certification exams in other allied health professions and nursing. This section also includes information on the methods employed to help increase certification exam rates for the professions discussed. Although many health science disciplines are increasing their educational requirements for licensure or certification, no studies were found that explored the relationship between degree level and pass rate on certification exams. There were also no studies that examined the geographical location, number of individuals testing, or current accreditation status of the program as factors contributing to success on the exams.

Chapter 3

Methodology

The methodology section of this study includes the study design, target population, and how data will be collected and analyzed. As previously mentioned, a study of degree level impacting success on certification exams has not been done in radiation therapy or medical dosimetry. It is informative and beneficial to know what insight the data provides as this study is a novel approach to this topic.

Study Design

The study design for this research is a quantitative-correlational-retrospective study. Quantitative studies rely on the collection and analysis of numerical data to describe, explain, predict, or control variables (Gay, et al., 2009). Quantitative studies can help describe the relationship between variables and explain causal relationships between variables. Correlational studies use population-level data to look for associations between two or more group characteristics (Jacobsen, 2012). Retrospective studies establish baseline information from previously established or published data and how it relates to current data (Jacobsen, 2012). The data collected was from 2014-2018 or 2015-2019. This study incorporated many of the aspects of a quantitative-correlational-retrospective study and thus is the best research design for this type of data.

Target Population

The target population included all JRCERT accredited radiation therapy and medical dosimetry programs in the United States. The JRCERT currently accredits educational programs in radiography, radiation therapy, magnetic resonance, and medical dosimetry. The JRCERT accredited radiation therapy programs are offered at the certificate, associate, and baccalaureate degree levels. The JRCERT accredited medical dosimetry programs are offered at the certificate, baccalaureate, and master's degree levels "within the United States, its territories, commonwealths, and possessions" (JRCERT, 2020, par.3). All degree levels will be studied. The data acquired for the study was obtained from individual programmatic websites and the JRCERT website. Five years of specific programmatic and accreditation related data were obtained (2014-2018 or 2015-2019).

Inclusion/Exclusion

There are 71 radiation therapy programs and 17 medical dosimetry programs that are JRCERT accredited and were examined for inclusion. Programs that were awarded initial accreditation were not included as those programs have limited to no data acquired and published. There is one program that was awarded a 3-year accreditation award. That program was combined with programs that have received a 5-year accreditation award. Most of the programs were awarded the full accreditation award of 8 years.

Sample Size

A priori power analysis was conducted using G*Power to determine suggested sample size for each of the two disciplines. Given that analyses similar to these have not yet been completed until now, there is not prior literature to use to inform an appropriate effect size. Thus, a liberal medium to large effect size was selected. Using an effect size of $f^2 = 0.25$, a type 1 error rate of $\alpha = 0.05$, and a power of 0.80, the suggested sample sizes are 40. After data were collected, there were 71 radiation therapy programs (due to missing values, 67 programs were used in analysis) and 17 medical dosimetry programs (due to missing values, 14 programs were used in analysis). This resulted in actual powers of .9566 and .0503; respectively for the full models.

Data Collection

Data were obtained from three sources: the JRCERT website, the programmatic website, and the Office of the Management of the Budget (OMB) website. The JRCERT website contains the current accreditation status, award, degree type offered, and geographic location. The programmatic website contains the 5-year average certification exam pass rates and the number of examinees. The size of the geographic location was obtained from the United States OMB website.

JRCERT Website

The researcher began the data search on the JRCERT website located https://www.jrcert.org/find-a-program/. The researcher clicked on “Accredited programs” and selected type of program as radiation therapy. A list of all the JRCERT accredited radiation therapy programs was displayed. The visible results displayed were the type of program, program name, city, state, and zip code the program is located in, and the degree level. After the following information was gathered for all of the radiation therapy programs, the process was repeated for all of the medical dosimetry programs.

Each program displayed was selected by clicking on “view” which was on the right of the screen. Once the researcher was on that screen, which is “accredited program details” the researcher obtained the type of program, degree level, most recent accreditation award, and geographic location. The researcher entered this information for each radiation therapy and medical dosimetry program into an Excel spreadsheet using the variable designation listed in Table 1. The researcher input the following information for each radiation therapy and medical dosimetry program in an Excel spreadsheet: the type of program, degree level, most recent accreditation award, and geographic location.

The most recent accreditation award is a 5-year or 8-year accreditation award. The programs that received an 8-year accreditation award have demonstrated more compliance with the accreditation standards than programs that received a 5-year award. The researcher based the program's geographic location on where the program is housed. In the program details, some programs were described as having "Alternative Learning: Distance Education." This refers to the program offering their entire program or a certain number of courses in an on-line or hybrid fashion. The list of the program's approved clinical sites is also on this webpage which could be in any city and state in the United States. The researcher based the program's geographic location on the where the program is housed. The clinical settings were not a factor that was included for analysis. Each program was assigned a unique identifier and was not identified by name.

Programmatic Website

The programmatic website was found from accessing the JRCERT website under "accredited program details". Once the researcher was on the programmatic website the researcher found the tab that says "program effectiveness data", "JRCERT data", "outcomes data" or "program outcomes" or something equivalent to obtain the certification exam pass rates and the number of individuals who took the exam. The JRCERT requires that programmatic statistics are publicly available, however programs may not have the data labeled or displayed in the same exact fashion.

The researcher obtained the 5-year average certification exam pass rates and the number of examinees was collected from the specific programmatic website. The 5-year averages collected were from 2014-2018 or 2015-2019 for both radiation therapy and medical dosimetry programs. This is the latest data available at the time of data collection. The certification exam pass rates and number of individuals who sat for the exam may or may not have a total or an average on the website. In some cases, the researcher had to combine the percentage pass rates for each year and take an average to obtain the 5-year certification exam rate average. The researcher also had to add the total number of examinees for each year for a combined sum for some programs. This was due to some programs not having the 5-year certification exam rate pass average displayed. The researcher input the following into the spreadsheet for each radiation therapy and medical dosimetry program: five-year certification exam pass rate and number of individuals who took the certification exam.

OMB Website

The size of the geographic location was obtained from the United States OMB website at https://www.census.gov/programs-surveys/metro-micro.html. As previously mentioned, the radiation therapy and medical dosimetry programs reviewed are located throughout the United States. “The OMB delineates metropolitan and micropolitan statistical areas according to published standards that are applied to Census Bureau data” (United States Census Bureau, n.d., par. 1). Once on the website, the city and state of the program was entered into the “search” box at the top of the page and the researcher hit enter. This provided the population data about the city. The programs’ geographic location was characterized into two categories: metropolitan and micropolitan.

The U.S. Census Bureau and the OMB defines an area as metropolitan if the population is over 50,000 (U.S. Census Bureau, 2019). Micropolitans are defined as areas that have a population of 10,000-50,000 (U.S. Census Bureau, 2019). Rural areas have a population of 10,000 or less (U.S. Census Bureau, 2019). As the majority of the programs are in metropolitan areas, the researcher combined programs in micropolitan and rural areas for data analysis. The researcher input the following into a spreadsheet for each radiation therapy and medical dosimetry program regarding location: micropolitan or metropolitan.

Data Input

All of the data collected from the JRCERT website, programmatic website, and the OMB website were put into an Excel spreadsheet which was used to run the appropriate statistical tests. The statistical tests completed on the collected data were F-tests and T-tests as further explained in the Data Analysis section. All of the websites from which the data were obtained are publicly accessible. Table 1 provides an overview of the variables analyzed in this study. The raw data is included in Appendix B (Table 16). The variable designations are listed in Table 1:

Table 1

Variable designations

Variable	IV or DV	Data Type	Levels (if categorical)	Overall Statistical Test	Post-Hoc (if applicable)
Discipline[1]	N/A	Categorical	Radiation Therapy; Medical Dosimetry	N/A	
Certification Exam Pass Rate	DV	Continuous		Regression F-test	
Number of Examinees	IV	Continuous		Regression F-test	
Degree Type	IV	Ordinal	0 = Certificate (ref[2]) 1 = Associates 2 = Bachelors	Regression F-test	Multiple T-tests

			3 = Masters		
Accreditation Length	IV	Ordinal	0 = 5-year (ref[2]) 1 = 8-year	Regression F-test	T-test
Location	IV	Nominal	0 = Micropolitan (ref[2]) 1 = Metropolitan	Regression F-test	T-test

*** each row of data will represent one program

[1]Discipline is a column in the variable designation table however it is neither an independent nor dependent variable. Rather there are two separate research questions one for each discipline. [2]ref indicates that the specified level was set as the reference group in the statistical procedures for analysis.

Data Analysis

Parameters that were collected and statistically analyzed were geographic location of the program (United States), number of individuals who took the certification exam, certification exam pass rate percentage, degree level, and current JRCERT accreditation award. These parameters were analyzed separately for the two disciplines (radiation therapy or medical dosimetry). The data were statistically analyzed by multiple linear regression. The data were analyzed by the statistical program SAS version 9.4.

The statistical analysis was conducted from the data collected and entered into the Excel spreadsheet. A statistician ran the statistical tests to ensure that the data were entered correctly and the correct tests have been properly performed. Multiple linear regression was the statistical test used to analyze the data. The multiple linear regression test produced an overall F-test for the entire model and individual F-tests for each parameter. Each parameter's F-test determined whether the parameter is a statistically significant predictor of certification exam pass rates (Minitab, 2016). For any of the factors that were significant, post-hoc analysis T-tests were used to determine the differences between the factor's levels (Trochim, 2020).

As previously mentioned, the parameters that were collected and statistically analyzed are geographic location of the program (United States), number of individuals who took the certification exam, certification exam pass rate percentage, degree level, discipline (radiation therapy or medical dosimetry), and current JRCERT accreditation award. Each program has a unique identifier and will not be identified by name. The geographic location has two categories analyzed; metropolitan and micropolitan/rural. The number of individuals who took the exam includes a combined number of examinees for 5 years (2015-2019 or 2014-2018) for each program included in the analysis. The certification exam pass rate percentage included was each program's 5-year certification exam rate average. Degree level was analyzed in four categories: certificate, associate's degree, bachelor's degree, and master's degree. Lastly, the final category of analysis is the current accreditation award which has two potential awards: 5 year or 8 year.

Backwards selection was used to arrive at a final model. The selection criterion was significance level, such that the parameter with the least significant (or largest) p-value was removed from the model and then the model was re-run with the remaining effects. This process was repeated until effects with a significance level of .10 or less remained in the model. Each parameter was assessed using the Type III Sums of Squares output from SAS and p-values of less than .05 were considered statistically significant. Post-hoc T-tests were performed for the radiation therapy data as accreditation length met the criteria for backwards selection which necessitated a Post-hoc T-test.

Institutional Review Board

This study does not require Institutional Review Board (IRB) approval. This was further verified by the Radford University research compliance officer (see Appendix A). The data that was collected and analyzed is published information that was obtained from programmatic, and accreditation websites. As a result, IRB review and approval were not required.

While this study does not require IRB approval, the same safeguards regarding ethical research standards were still followed. Those standards included minimizing risks, equitable selection of various factors, minimizing coercion, protecting privacy, and ensuring data confidentiality (Grand Valley State University, 2016). Programmatic names were not used in this study, so there is no risk to the individual students or programs as a result of collecting and analyzing the data. The researcher gathered data on all JRCERT accredited radiation therapy and medical dosimetry programs, so the data sample is equitable. This study did not involve contact with the program officials or students, so the potential for coercion is zero. The information that was obtained and analyzed for this study is published on publicly accessible websites and will have no known identifiers, so there is no risk of jeopardizing privacy. While the information obtained is publicly accessible, it has to be appropriately stored. All data obtained was stored on the researcher's personal thumb drive. It will remain in the researcher's personal home or work office, which is locked and only accessible by the researcher. Now that the study is complete, the data will remain on the researcher's thumb drive and stored in the researcher's office or personal home.

Limitations

There are some limitations that should be addressed for this study. This study has a small sample size (71 radiation therapy programs and 17 medical dosimetry programs). There were also considerably more radiation therapy programs than medical dosimetry programs thus the findings for radiation therapy are more reliable. Lastly, there have not been any studies published to date that address certification exam rates among varying degree levels in radiation therapy or medical dosimetry, making it impossible to compare the results of this study to previous studies in the fields.

Delimitations

There are some delimitations associated with this study. The researcher sampled JRCERT accredited radiation therapy and medical dosimetry programs. There are other radiation therapy programs that are not JRCERT accredited that could have been included for analysis. However, the researcher decided against it due to the potential of not being able to readily access needed data. Medical dosimetry students are required to complete a JRCERT accredited medical dosimetry program, so this is not a factor for medical dosimetry programs. The researcher also combined programs in micropolitan and rural areas for data analysis due to a large proportion of programs being in metropolitan areas. In regards to programs that were listed to have an online track, the researcher based the program's geographic location on where the program is housed. This is due to the high likelihood that this is where the program's curriculum was developed and resources are located.

In conclusion, the methodology described allowed the researcher to explore factors impacting radiation therapy and medical dosimetry certification exam pass rates. Several of the factors (degree type and certification exam pass rates) that were statistically analyzed are directly related to the theory selected for this study, VET. It is reasonable to assume that it requires more time, effort, and financial resources to complete a bachelor's degree in comparison to an associate's degree or certificate. It would also be reasonable to assume that certification exam pass rates would be higher in baccalaureate level degree programs than certificate and associate degree level programs. Degree level and certification exam pass rates correlate to the key aspects of VET which are force, valence, and expectancy.

Chapter 4

Results

This study examined factors influencing certification exam pass rates in radiation therapy and dosimetry program in the United States. There were two hypotheses that are guiding this study: "When controlling for other variables, degree level, geographic location of the program, number of individuals who took the certification exam, and current JRCERT accreditation status are not significant predictors of radiation therapy certification exam pass rates." and "When controlling for other variables, degree level, geographic location of the program, number of individuals who took the certification exam, and current JRCERT accreditation status are not significant predictors of medical dosimetry certification exam pass rates." These hypotheses were tested using multiple linear regression F-tests for the entire model and then individual F-tests for each parameter. Factors found to be statistically significant were tested by post-hoc analysis T-tests to determine the differences between the factor's levels.

This section provides the statistical results of the data collected for this study. Tables 2 and 3 provides the descriptive statistics on the radiation therapy and medical dosimetry programs. Tables 4-8 provides data on the radiation therapy programs. Tables 9-13 provides data on the medical dosimetry programs. There are terms used in the tables and the explanations for each are described in this paragraph and the subsequent paragraphs. *Source* refers to the variation of the dependent variable (UCLA Statistical Consulting, n.d.). The source contains three parts; model, error, and corrected total. The number associated with *model* is the variance of the full model. *Error* is variation not explained by the model and the corrected total is the variance of the full model and the error (UCLA Statistical Consulting, n.d.). *Degrees of freedom* (DF) are related to the respective source of variance (UCLA Statistical Consulting, n.d.).

The s*ums of squares* (SS) correlate to the three sources of variation (UCLA Statistical Consulting, n.d.). The model sum of squares is the squared difference of the predicted value and the total mean combined over all observations. The error sum of squares is the squared difference of the observed value from the predicted value combined over all observations. The corrected total sum of squares is the squared difference of the observed value from the total mean combined over all observations (UCLA Statistical Consulting, n.d.).

The *mean square* (MS) is defined as the SS divided by the DF (UCLA Statistical Consulting, n.d.). *F-value* tests the null hypothesis and is computed as MS_{Model} / MS_{Error}. The *type III sum of squares,* which are referred to as partial sum of squares, for a certain variable, is calculated with respect to the other variables in the model (UCLA Statistical Consulting, n.d.).

Sample

The sample of this study includes JRCERT accredited radiation therapy and medical dosimetry programs in the United States. Information regarding each program's certification pass rates, current accreditation status, geographic location, and number of certification examinees were examined for this study. The timeframe of data that was collected was from 2014-2018 or 2015-2019.

Recruitment Strategies

This study did not use human subjects or IRB, so there were not any specific recruitment strategies used for this study. All of the data obtained was collected from publicly accessible websites which included the JRCERT, programmatic, and OMB websites. Each program will have a unique identifier and will not be identified by name.

Demographics

The sample population of this study is 71 radiation therapy programs and 17 medical dosimetry programs. All of these programs are accredited by the JRCERT. Of the radiation therapy programs, there are 17 associate's degree programs, 18 certificate level programs, and 36 baccalaureate degree level programs. In terms of geographic location of the radiation therapy programs, 56 (78.87%) are located in metropolitan areas and 15 (21.13%) are located in micropolitan/rural areas. The average number of radiation therapy certification examinees for all degree levels was 43.6 for the timeframe collected and the 5-year certification exam rate average for all programs was 89.96%.

There are 17 JRCERT accredited medical dosimetry programs. Of these programs, there are 10 certificate level programs, 3 baccalaureate degree level programs, and 4 master's degree level programs. Twelve (70.59%) of the medical dosimetry programs are located in metropolitan areas, while 5 (29.41%) are located in micropolitan/rural areas. The average number of medical dosimetry certification examinees was 37.5 for all degree levels for the timeframe collected and the 5-year certification exam rate average for all programs was 92.8%.

Table 2

Descriptive Statistics – Quantitative

Discipline	Certification Exam Pass Rate		
	n	M	SD
Medical Dosimetry	17	92.80	6.4
Radiation Therapy	71	89.96	10.0

Table 3

Descriptive Statistics - Categorical

Independent Variable	Discipline	
	Medical Dosimetry % (n)	Radiation Therapy % (n)
	Accreditation Length[a]	
3 or 5 years	11.76% (2)	11.43% (8)
8 years	88.24% (15)	88.57% (62)
	Geographic Location	
Metropolitan	70.59% (12)	78.87% (56)
Micropolitan/Rural	29.41% (5)	21.13% (15)
	Degree Type	
Certificate	58.82% (10)	25.35% (18)
Associates	0% (0)	23.94% (17)
Bachelors	17.65% (3)	49.30% (35)
Masters	23.53% (4)	1.41% (1)

[a]The accreditation length was not specified for one radiation therapy program

Radiation Therapy Results Tables

Table 4

Radiation Therapy (Entire Model F-test containing all parameters before backward selection)

Source	DF	Sums of Squares	Mean Square	F	P-value	R^2
Model	6	.1171	.0195	2.41	.0375*	.1941
Error	60	.4860	.0081			

Corrected total	66	.6031

**p* < .05*

Table 5

Radiation Therapy (Entire Model Type III Sums of Squares containing all parameters before backward selection)

Variable	DF	Type III SS	Mean Square	F	P-value
Number of examinees	1	0.0010	0.0010	0.12	0.7282
Accred. len.	1	0.0976	0.0976	12.05	0.001**
Deg Type	3	0.0249	0.0083	1.03	0.3875
Geo loc.	1	0.0012	0.0012	0.14	0.7057

$^{**}p<.01$

Table 6

Radiation Therapy (Final Model F-test containing only parameters that met the backward selection criterion)

Source	DF	Sums of Squares	Mean Square	F	P-value	R^2
Model	1	.0914	.0914	11.62	.0011**	.1516
Error	65	.5117	.0079			
Corrected total	66	.6031				

$^{**}p<.01$

Table 7

Radiation Therapy (Final Model Type III Sums of Squares containing only parameters that met the backward selection criterion)

Variable	DF	Type III SS	Mean Square	F	P-value
Acc. Len.	1	.0914	.0914	11.62	0.0011**

***p<.01*

Table 8

Radiation Therapy (Parameter Estimates & Post-Hoc containing only parameters that met the backward selection criterion)

Variable	Beta	Standard Error	T	P-value
Acc. Len 8 years	.1208	.0354	3.41	0.0011**
Acc. Len. 3 or 5 years (ref)	0.000			

***p<.01*

The model containing number of examinees, accreditation length, degree type, and geographic location was significant (p = .0375) (Table 4), indicating the model is useful in predicting radiation therapy certification exam pass rates. The type III sums of squares table (Table 5) shows that accreditation length is a significant (p=.0010) predictor of certification exam pass rate while number of examinees, degree type, and geographic location, were not (p=0.7282, 0.3875, and 0.7057 respectively). Thus, as explained in the methods, backward selection was used, resulting in only accreditation length remaining in the final model (p=.0011) (Table 6). The type III sums of squares table (Table 7) shows that accreditation length is significant in predicting certification exam pass rate (p=.0011). Table 8 shows the parameter estimates and t-test comparing the two levels of accreditation length. Radiation therapy programs with an accreditation length of 8 years have, on average, a .1208 higher certification exam pass rate than do radiation therapy programs with an accreditation length of 3 or 5 years. The R-square value for the final model was .1516, indicating that the accreditation length explains 15.16% of the variation in radiation therapy certification exam pass rates. The researcher will reject the null hypothesis. There is statistically significant evidence to show that when controlling for other variables, the current JRCERT accreditation status of radiation therapy programs is a significant predictor of radiation therapy certification exam pass rates. The number of examinees, degree type, and geographic location did not show statistically significant evidence to be significant predictors of radiation therapy certification exam rates.

Medical Dosimetry Results Tables

Table 9

Medical Dosimetry (Entire Model F-test containing all parameters before backward selection)

Source	DF	Sums of Squares	Mean Square	F	P-value	R^2
Model	5	0.0221	0.0044	1.19	0.3936	.4261
Error	8	0.0297	0.0037			
Corrected total	13	0.0518				

Table 10

Medical Dosimetry (Entire Model Type III Sums of Squares containing all parameters before backward selection)

Variable	DF	Type III SS	Mean Square	F	P-value
Number of examinees	1	0.0114	0.0114	3.37	0.0913
Accred. len.	1	0.0030	0.0030	0.79	0.3989

Deg Type	2	0.0021	0.0011	0.28	0.7607
Geo loc.	1	0.0026	0.0026	0.71	0.4249

Table 11

Medical Dosimetry (Final Model F-test containing only parameters that met the backward selection criterion)

Source	DF	Sums of Squares	Mean Square	F	P-value	R^2
Model	1	0.0114	0.0114	3.3700	0.0913	.2193
Error	12	0.0405	0.0034			
Corrected total	13	0.0518				

Table 12

Medical Dosimetry (Final Model Type III Sums of Squares containing only parameters that met the backward selection criterion)

Variable	DF	Type III SS	Mean Square	F	P-value
Number of examinees	1	0.0114	0.0114	3.37	0.0913

Table 13

Medical Dosimetry (Parameter Estimates (containing only parameters that met the backward selection criterion)

Variable	Beta	Standard Error	T	P-value
Number of examinees	-0.0009	0.0005	-1.84	0.0913

The model containing number of examinees, accreditation length, degree type, and geographic location was not significant (p = .3936) (Table 9), indicating the model is not useful in predicting medical dosimetry certification exam pass rates. The type III sums of squares table (Table 10) reiterates this insignificant p-values (0.0913, 0.3989, 0.7607, and 0.4249) for number of examinees, accreditation length, degree type, and geographic location respectively. Thus, as explained in the methods, backward selection was used, resulting in only number of examinees remaining in the final model (p=0.0913) (Table 11). The Type III sums of squares table (Table 12) shows that the number of examinees is not a significant predictor of the Medical Dosimetry Certification Exam pass rate, at the $\alpha = .05$ significance level. Table 13 shows the parameter estimate of number of examinees and implies that as the number of examinees increases by one examinee, the medical dosimetry exam pass rate is expected to go down by .0009 on average, however this was not statistically significant. The R-square value for the final model was .2193, indicating that the number of examinees explains 21.93% of the variation in medical dosimetry certification exam pass rates. The researcher will fail to reject the null hypothesis. There is not statistically significant evidence to show that number of examinees, accreditation length, degree type, and geographic location are significant predictors of medical dosimetry certification exam pass rates.

This research examined potential predictors of certification exam pass rates for two disciplines, radiation therapy and medical dosimetry. The hypothesized predictors investigated were degree type, accreditation length, geographic location, and number of examinees. There were 71 radiation therapy programs and 17 medical dosimetry programs. There was not statistically significant evidence to show that accreditation length was a significant predictor of certification exam pass rate for medical dosimetry programs. Degree type, number of examinees, and geographic location were not statistically significant predictors of certification exam pass rate for either program type. There was statistically significant evidence ($p=.0010$) to show that accreditation length is a significant predictor of certification exam pass rate for radiation therapy programs. Accreditation length explains 15.16% of the variation in certification exam pass rates for radiation therapy programs. Radiation therapy programs with an accreditation length of 8 years have, on average, a .1208 or 12.08% higher certification exam pass rate than do radiation therapy programs with an accreditation length of 3 or 5 years.

Chapter 5

Discussion

This study analyzed the effect of accreditation length, geographic location, number of examinees, and degree level on certification exam pass rates in radiation therapy and medical dosimetry. For medical dosimetry, none of these parameters were significant predictors of certification exam pass rates. However, for radiation therapy it was found that accreditation length is a significant predictor of radiation therapy certification exam pass rates. None of the other parameters (geographic location, number of examinees, or degree level) were significant predictors of radiation therapy certification exam pass rates.

Discussion of the Results

This study investigated two different disciplines; radiation therapy and medical dosimetry, and how various parameters predict certification pass rates. For radiation therapy, the variables: number of examinees, degree type, and geographic location were not statistically significant. Accreditation length was significant ($p = .0011$) in predicting certification pass rate, such that programs with accreditation lengths of 8 years have a higher average pass rate (by 12.08%) than do programs with accreditation lengths of 3 or 5 years. Given the small number of programs with accreditation lengths of 3 years, they may be underrepresented in this interpretation.

$$Cert.\, exam\, pass\, rate \;=\; .7953 \;+\; .1208(AccLen) \;+\; error \qquad \text{(eq. 1)}$$

$$8\, year = 1;\; 3\, or\, 5\, year \;=\; 0$$

$$Cert.\, exam\, pass\, rate \;=\; .7953 \;+\; .1208(1)\, \_error \leftarrow 8\, year\, length \qquad \text{(eq. 2)}$$

The above regression equation (eq. 1) can be used to predict the certification exam pass rate for radiation therapy programs of either 8 or fewer years of accreditation. For example, a radiation therapy program with an accreditation length of 8 years is predicted to have a certification exam pass rate of .9161. As seen above in equation 2, this was calculated by entering into the equation the number 1, representing 8-years of accreditation.

For medical dosimetry, none of the parameters were found to be significant, at the alpha = .05 level, predictors of exam pass rate. However, this very well may be due to the very small sample size (n=14), resulting in an under-powered test. The variable number of examinees came close with a p-value less than .10 (p=.0913), indicating that with a larger sample size, it may be warrant further research in the future. It should be noted that while the parameters were not significant in predicting certification exam pass rates for medical dosimetry, number of examinees actually explains 21.93% of the variation ($R^2 = .2193$) in certification exam pass rates. While for radiation therapy, accreditation length explains 15.16% of the variation ($R^2 = .1516$) in certification exam pass rates. This further supports the researcher's assumption that with a larger sample size, more interesting and significant results may be gleaned for medical dosimetry.

Relationship of the Findings to Prior Research

There are not studies yet published regarding degree level and certification exam pass rates in radiation therapy and medical dosimetry. However, there are published statistics regarding the certification exam rates for both of these disciplines. Implications of the findings of this study on certification exam rates are discussed below.

Radiation Therapy Certification Exam Data and Statistics

The ARRT annually publishes certification exam statistics and results on its website. This information is publicly accessible. The ARRT radiation therapy certification exam data and statistics is from all first-time examinees in the United States from 2015-2019. The information available on the website includes examinees completing JRCERT accredited and non-accredited programs and is not differentiated by degree level or accreditation status. Results are summarized in Table 14.

2015 Exam Data and Statistics.

In 2015, there were 878 examinees who sat for the radiation therapy certification exam from 39 states. The average number of all examinees per state was 22.5. The mean exam score was 82.5, and 763 (86.9%) examinees passed the exam (ARRT, 2015a).

2016 Exam Data and Statistics.

In 2016, 828 examinees sat for the radiation therapy certification exam from 39 states. This is 50 less examinees than for 2015. The average number of all examinees per state was 21.8. The mean exam score was 82.5, and 732 (88.4%) examinees passed the exam. While there was a decline in the number of examinees from 2015 to 2016, the percentage of examinees who passed increased by 1.5% (86.9% vs. 88.4%) (ARRT, 2016).

2017 Exam Data and Statistics.

There were 807 examinees who sat for the radiation therapy certification exam from 37 states in 2017. This represents a small decline of 21 examinees and the number of states with examinees (39 vs. 37) in comparison to 2016. The average number of all examinees per state was 21.8. The mean exam score was 82.4, and 710 (88.0%) examinees passed the exam (ARRT, 2017a).

2018 Exam Data and Statistics.

In 2018, there were 793 radiation therapy certification examinees from 36 states (ARRT, 2018). The number of examinees and number of states with examinees was the lowest in of all the previous years. The percentage difference in examinees was 9.7% (2015 vs. 2018), 4.3%

(2016 vs. 2018), and 1.7% (2017 vs. 2018). The number of states with examinees also was the lowest for 2018. There were 39 states with examinees in both 2015 and 2016, and 37 states in 2017 compared to 36 in 2018. While there was a decline in number of examinees and states represented, the average number of examinees and mean score was comparable to previous years with 22.0 examinees and mean score of 82.1. There were 686 or (86.5%) of examinees who passed the exam which is a slight decline from 2016 (88.4%) and 2017 (88.0%). The certification exam pass rates for 2015 was 86.9%, which is almost identical to 2018 (86.5%).

2019 Exam Data and Statistics.

There were 823 radiation therapy certification examinees in 2019 from 36 states (ARRT, 2019a). This number represents an increase from 2017 and 2018 and is comparable to the average number of examinees for 2015-2019 which is 825.8. The average number of examinees per state is also the highest of all years analyzed at 22.9. However, the mean score was the lowest of all years analyzed which was 81.9. This was the year that the ARRT changed the scoring criteria which required examinees to answer more questions correctly to achieve the cut score to pass. This may explain the slight decline in the mean score for 2019 in comparison to 2015-2018. While the exam scoring changed, 713 (86.6%) of examinees passed the exam which was comparable to previous years.

Table 14

Radiation Therapy Certification Exam Statistics 2015-2019

Year	Total # of examinees	Avg. # of examinees	Mean Score	% pass (n)
2015	878	22.5	82.5	86.9% (763)
2016	828	21.8	82.5	88.4% (732)

2017	807	21.8	82.4	88.0% (710)
2018	793	22.0	82.1	86.5% (686)
2019	823	22.9	81.9	86.6% (713)

In summary, the 2015-2019 radiation therapy certification exam data and statistics shows that the average number of total examinees was 825.8, the average number of examinees per state was 22.2, the mean exam score was 82.28, and the percentage of examinees who passed the exam on the first attempt was 87.28%. Table 14 shows that the 2015 had the highest number of overall examinees (878) and 2018 had the lowest (793) which is a difference of 85 examinees between the 2 years. This is most likely due to the continued effects of the associate's degree mandate in 2015. The year with the highest number of examinees per state was 2019 with 22.8, the years with the lowest are 2016 and 2017 with 21.8. This is most likely due to the associate's degree mandate as well. Due to the mandate being in effect for a few years, students have been able to complete a program that meets the certification eligibility requirement. The exam years with the highest average mean exam score of 82.5 was 2015 and 2016, the year with the lowest was 2019 which was 81.9. While the difference is small (0.6), it is most likely attributed to the change of the cut score instituted in 2019 which required examinees to answer more questions correctly to pass the exam. Examinees in 2016 had the highest number of individuals to pass the exam which was 88.4%. The year with the lowest percent exam pass rate was 2018 at 86.5%. While 2018 had the lowest pass rate of all the years examined, it was only 1.9% lower than the highest pass rate and 0.78% lower than the 5-year average pass rate.

Upon further analysis of the JRCERT accredited radiation therapy programs' certification pass rates of this study it was determined that bachelor's degree program pass rates were 85.2%, associate's degree programs were 89.6%, and certificate programs were 92.3%. This is a difference of 4.4% when comparing bachelor's programs and associate's programs and 7.1% difference of bachelor's degree versus certificate programs. While the bachelor's (85.2%) and associate's degree programs (89.6%) had lower exam pass rates than the certificate programs (92.3%) the results are comparable to the ARRT's exam statistics for all programs (87.28%).

The average number of examinees for the timeframe that this study analyzed was 41.79. This number is indicative of a 5-year average or 8.36 examinees annually for JRCERT accredited radiation therapy programs. In comparison to the ARRT data which encompasses all programs to include JRCERT accredited and non-accredited programs, the average number of annual examinees is 22.2. This indicates that the majority (62.3%) of radiation therapy certification examinees during the timeframe examined are graduates of non-JRCERT accredited radiation therapy programs.

This study found that the number of examinees was not a significant predictor of radiation therapy certification exam rates ($p = 0.7282$; see Table 5). This difference (8.36 vs. 22.2) indicates that further research should be done on JRCERT accredited radiation therapy programs and non-accredited radiation therapy programs as the total number of examinees of all programs as whole may be a significant predictor of radiation therapy certification exam pass rates. Regarding certification exam pass rates, this study found that JRCERT accredited radiation therapy program had an average 5-year pass rate of 89.96%. This study also found that accreditation length was statistically significant ($p=0.001$) and explains 15.16% of the variability of radiation therapy certification exam pass rates. The ARRT data shows that for all programs, the 2015-2019 certification exam pass rate average was 87.28%. This represents a 2.68% lower difference when comparing all radiation therapy programs to JRCERT accredited radiation therapy programs. While the 5-year average percentage difference in certification exam rates in

JRCERT accredited and all radiation therapy programs may be small (89.96% vs 87.28%), the variability of exam scores was found to be 15.16% and is worth further researching for all radiation therapy programs.

Medical Dosimetry Certification Exam Data and Statistics

The MDCB publishes the medical dosimetry certification exam results on its website. The information is publicly accessible. The certification exam information presented below are the results from 2014-2020. Each year, there are two exam administrations. In 2019, the MDCB certification exam was only administered once in April. The results encompass all examinees regardless of degree level or accreditation status. These results are summarized in Table 15.

2014 Exam Data and Statistics.

The two exam administrations in January and August 2014 had 154 and 167 examinees respectively. This is an average of 160.5 examinees for 2014. There were 91 (59%) successful examinees for the January administration and 80 (48%) successful examinees for the August administration (MDCB, n.d.b.). This is an average of 53.5% for both administrations. The certification exam pass rates for 2014 was the lowest for all years reviewed for this study.

2015 Exam Data and Statistics.

The exam administrations in 2015 were in February and August. There were 132 examinees and 118 examinees respectively for each administration with an average of 125 examinees. There were 88 (67%) successful examinees for the February exam and 91 (77%) successful examinees for the August exam (MDCB, n.d.b.). This is an average of 72% for both administrations and an 18.5% increase from 2014.

2016 Exam Data and Statistics.

The January and August exam administrations had 135 and 174 examinees respectively with an average of 154.5 examinees. There were 104 (77%) successful examinees for the January administration and 122 (70%) successful examinees for the August administration (MDCB, n.d.b.). This is an average of 73.5% for 2016. The exam pass rate percentage increased 20% when comparing 2014 (53.5%) and 2016 (73.5%). There was also a small increase noted from 2015 (72%) to 2016 (73.5%) of 1.5%.

2017 Exam Data and Statistics.

The February and August exam administrations had 126 and 86 examinees respectively with an average of 106 examinees. In comparison to 2014, 2015, and 2016, this is a lower number of examinees. There were 91 (72%) successful examinees for the February administration and 66 (77%) successful examinees for the August administration (MDCB, n.d.b.). This is an exam pass average of 74.5% which is the highest when comparing 2014 (53.5%), 2015 (72%), and 2016 (73.5%).

2018 Exam Data and Statistics.

The January and August exam administrations had 104 and 90 examinees respectively with an average of 97 examinees. In comparison to 2014, 2015, 2016, and 2017 where there were two exam administrations, 2018 had the lowest number of examinees. There were 80 (77%) successful examinees for the January administration and 72 (80%) of successful examinees for the August administration with an average pass rate of 78.5% (MDCB, n.d.b.). The primary researcher for this study was a successful examinee for the August administration. While in 2018 the exam had the fewest examinees of the previous years, the exam pass rates were the highest.

2019 Exam Data and Statistics.

The 2019 exam only had one administration which was in April and had 174 examinees. The exam pass rate was 83% or 144 successful examinees (MDCB, n.d.b.). The 2019 exam pass rate was the highest pass rate achieved when comparing the exam rates of 2014-2018.

2020 Exam Data and Statistics.

The January and September exam administrations had 124 and 105 examinees respectively with an average of 114.5 examinees. There were 107 (86%) successful examinees for the January exam administration which is the highest published MDCB exam pass rate ever (MDCB, n.d.b.). There were 78 (74%) successful examinees for the September exam administration.

Table 15

Medical Dosimetry Certification Exam Statistics 2014-2020

Year	# of examinees	% pass (n)
2014 (Jan.)	154	59% (91)
2014 (Aug.)	167	48% (80)
2015 (Feb.)	132	67% (88)
2015 (Aug.)	118	77% (91)
2016 (Jan.)	135	77% (104)
2016 (Aug.)	174	70% (122)
2017 (Feb.)	126	72% (91)
2017 (Aug.)	86	77% (66)
2018 (Jan.)	104	77% (80)
2018 (Aug.)	90	80% (72)

2019	174	83% (144)
2020 (Jan.)	124	86% (107)
2020 (Sep.)	105	74% (78)

In summary, the average number of medical dosimetry certification examinees has decreased since the educational mandate requiring examinees to have a bachelor's degree and successfully complete a JRCERT accredited medical dosimetry program was implemented in 2017. In 2017-2020, this number decreased to an average of 115.57 examinees. During 2014-2016, the average number of examinees was 146.67. The reduced number of examinees is most likely due to fewer individuals who meet the eligibility requirement for certification.

One of the factors examined in this study was the impact of JRCERT accreditation. In 2013, medical dosimetry certification candidates had two options: graduate of JRCERT accredited program or bachelor's degree in any field with ARRT certification. Then, in 2015, the regulations changed to require that medical dosimetry examinees have a bachelor's degree to be eligible to sit for the exam. Effective in 2017, there is only one standard for medical dosimetry exam certification. Candidates must have a bachelor's degree and have graduated from a formal dosimetry program accredited by the JRCERT. These changes impacted the number of examinees taking the exam and the pass rate.

The average number of examinees from JRCERT accredited programs was 37.5. The variability in number of examinees may be explained by the changes in certification exam eligibility in 2013 and 2015. While the average number of examinees decreased in 2017-2020, the certification exam pass rates increased. The certification exam pass rate average for 2014-2016 was 66.3%. The certification exam pass rate average for 2017-2020 was 78.4%. This is a 12.1% overall increase in certification exam pass rates. This increase in certification exam pass rates is likely attributed to the mandate implemented in 2017 requiring formal education from a JRCERT accredited program.

The 5-year certification exam rate pass average for JRCERT accredited programs was 92.8% versus 72.35% pass rate during 2014-2020 for all programs. Graduates from JRCERT accredited programs have 20.45% higher certification pass rates in comparison to all examinees. When degree level is examined, graduates of certificate programs have the highest average certification pass rates (96.7%) in comparison to bachelor's degree graduates (90%), and master's degree graduates (88%). This demonstrates an 8.7% decrease in pass rates between certificate (96.7%) and master's degree graduates (88%) and a 6.7% decrease between certificate (96.7%) and bachelor's degree graduates (90%). While degree level and certification exam rates were not found to be statistically significant for this study, there are currently only 17 accredited medical dosimetry programs. As there are so few programs, degree level and certification exam pass rates in medical dosimetry should be further explored.

Accreditation length was not found to be a significant predictor of medical dosimetry certification exam pass rates. While none of the parameters analyzed for this study: number of examinees ($p = 0.0913$), accreditation length ($p = 0.3989$), degree type ($p = 0.7607$), or geographic location ($p = 0.4249$) were found to be significant predictors of medical dosimetry certification pass rates. It should be noted that the statistical p-value of number of examinees was close to being a significant predictor of medical dosimetry certification exam pass rates. Also, the number of examinees explains 21.93% of the variability of medical dosimetry certification exam pass rates (Table 12). Due to this variability and the small number of medical dosimetry programs, the number of examinees effect on exam pass rates should be further researched.

Research in Medical Dosimetry and Paramedics Regarding Certification Exam Pass Rates

There have been no studies published to date that analyzed degree level and certification exam pass rates in medical dosimetry or radiation therapy. There is a study by Lenards (2020), that was recently published regarding comparing medical dosimetry students that are certified in radiation therapy and students that are not which analyzed the MDCB exam results and other parameters. Another study by Rodriguez (2018), regarding paramedic graduates of accredited and non-accredited programs and the effect of accreditation of paramedic certification exam pass rates was published. Both of these studies will be discussed further.

Medical Dosimetry.

In the study by Lenards (2020), certification exam pass rates were evaluated comparing medical dosimetry students who had a radiation therapy degree versus students who did not. As previously mentioned, to be eligible for medical dosimetry certification in 2017 and beyond, examinees must complete a JRCERT accredited medical dosimetry program and possess at minimum a bachelor's degree. The researcher reviewed the archived records of 127 medical dosimetry graduates of a large, midwestern university who completed the program between 2010 and 2018. The study found that of 127 graduates who sat for the MDCB exam within 12 months of completing the program resulted in 114 graduates passing on the first attempt which resulted in a 90% overall program exam pass rate (Lenards, 2020). Of the students that did not pass on the first attempt, seven had radiation therapy degrees and nine did not (Lenards, 2020). Education for medical dosimetrists has substantially changed in recent decades. Traditionally, radiation therapists were trained on the-job (OJT) to become medical dosimetrists. In previous years, medical dosimetry training emphasized clinical education customized to each individual without a formal education requirement (Lenards, 2020). OJT focused on acquiring knowledge from peers, practical application, and tracking progress of the trainee (Romi & Schmida, 2009; Rothwell & Kazanas, 1990). OJT medical dosimetry training was specific to the individual employer; however, the training was guided by the instruction from the staff.

As formal medical dosimetry programs were developed and programmatic accreditation followed, OJT was eliminated. Today, medical dosimetry education is measured and assessed resulting in a level of accountability that now exists in the field (Romi & Schmida, 2009). Formal education, specifically undergraduate degrees, is an important predictor of success in medical dosimetry. A study by Baker et al. (2016), found that individuals entering medical dosimetry without an undergraduate degree were 77.4% less likely to complete their respective medical dosimetry program.

Medical dosimetrists who completed formal education also exhibited superior critical thinking skills and performed better on the national certification exam (Lenards, 2020). In the dissertation by Greener (2013), it was found that allied health professionals who completed formal education in their respective disciplines traditionally scored higher on certification exams than individuals who did not receive formal education. This may also explain the 12.1% average lower MDCB certification exam rates during 2014-2016 as formal education was not mandated until 2017. The MDCB certification exam data showed that OJT medical dosimetrists did not pass the certification exam at the same rate compared to examinees who obtained formal education (Pusey et al., 2005). Additionally, participants of the Greener (2013) study who had prior radiation therapy certification (RTT) background had weaker critical thinking skills compared to non-RTT medical dosimetrists. This is most likely due to non-RTT medical dosimetrists having a degree in a natural science such as biology, chemistry, or physics which requires a significant amount of critical thinking regarding various scientific concepts.

Paramedics.

This research found that accreditation length is a significant predictor of certification exam pass rates in JRCERT accredited radiation therapy programs. It was also found that radiation therapy programs with an accreditation length of 8 years have on average a 12.08% higher certification exam pass rate than radiation therapy programs with an accreditation length of 3 or 5 years. This study also determined that accreditation length explains 15.16% of the variation in radiation therapy certification exam pass rates. While the parameters analyzed in this study (degree level, number of examinees, geographic location, and accreditation length) have not been studied in radiation therapy or medical dosimetry, other fields of allied health have studied some of these parameters.

In the study by Rodriguez et al. (2018), the researchers evaluated if programmatic accreditation was correlated with higher certification pass rates and cognitive ability performance on the National Registry of Emergency Medical Technicians' (NREMT) paramedic certification. Effective January 1, 2013, the National Registry of Emergency Medical Technicians (NREMT) and National Association of State Emergency Medical Services Officials (NASEMSO) mandated that students must complete accredited paramedic educational programs to be eligible to sit for National EMS Certification (NREMT, n.d.; NASEMSO, n.d.). In 2012, 8,404 paramedic educational program graduates sat for the cognitive examination. Of those examinees 1,093 (13%) of the examinees graduated from non-accredited programs (Rodriguez et al., 2018). The first-attempt pass rate and summative pass rate for accredited program graduates was 75.6% and 88.9% respectively compared to graduates from non-accredited programs who had pass rates of 67.3% and 81% respectively (Rodriguez et al., 2018). The graduates of accredited paramedic programs demonstrated higher cognitive ability in all clinical content areas of the exam (Rodriguez et al., 2018). Graduates of accredited paramedic programs had greater success on the National Paramedic Certification examination with 51% greater odds of passing the exam on the first attempt (Rodriguez et al., 2018).

Implications for Future Practice, Research, and Policy

As a study such as this has never been done in radiation therapy or medical dosimetry, it is a novel approach to researching certification exam pass rates. This study yielded interesting results regarding accreditation length for radiation therapy and number of examinees for medical dosimetry. Accreditation length was a significant predictor ($p= 0.001$) of radiation therapy certification exam rates. Radiation therapy programs with an 8-year accreditation length had on average a 12.08% higher certification exam pass rate than programs with a 3 or 5-year accreditation length. The programs that received an 8-year accreditation award have demonstrated more compliance with the accreditation standards than programs that received a 3-year or 5-year award. Also, accreditation length explained 15.16% of the variation of radiation therapy certification exam pass rates. As this study only analyzed JRCERT accredited radiation therapy programs, it may be worth analyzing JRCERT accredited and non-accredited radiation therapy programs to determine if accreditation status is a significant predictor of radiation therapy certification exam rates overall.

While this study did not find that the other parameters analyzed (degree level, certification exam pass rates, and geographic location) were statistically significant, it may be worth further researching degree level and certification exam pass rates. The data collected regarding JRCERT accredited radiation therapy certification exam pass rates and degree level showed that certificate program graduates had the highest certification exam pass rates (92.3%) in comparison to associate’s degree (89.6%) and bachelor’s degree graduates (85.2%). The educational mandate that went into effect in 2015 requires a minimum of associate's degree for entry level practice. Further research on degree level and certification exam pass rates should be investigated in the future to determine if the associate's degree mandate is necessary for entry level radiation therapy practice.

This study found that none of the parameters analyzed for this study were significant predictors of medical dosimetry certification exam pass rates. However, the number of examinees explains 21.93% of medical dosimetry certification exam pass rates. In further analysis of the JRCERT accredited medical dosimetry programs, it was found that the number of examinees by degree level was comparably different. For master's degree programs the 5- year average number of examinees was 78.5 or 15.7 annually, bachelor's degree programs had 43.7 examinees or 8.74 annually, and certificate programs had 14.75 or 2.95 annually. While degree level and the number of examinees was not found to be statistically significant, this should be further researched along with the percentage of variation in medical dosimetry certification exam pass rates. Considering that JRCERT accreditation and a bachelor's degree was mandated in 2017 and there are few medical dosimetry programs that are currently JRCERT accredited, the number of programs will need to increase. If the number of programs increases, this further substantiates that the number of medical dosimetry certification examinees and the effect on exam pass rates should be studied in the future. Future findings may also determine the number and type (degree level) of medical dosimetry programs that may possibly be implemented which may later necessitate a master's degree for entry level practice if master's degree programs consistently produce more graduates than other degree levels as shown in this study (Appendix B).

Conclusion

As technology in the field of radiation oncology continues to advance, the level of knowledge and education required for individuals working in this field will also continue to increase. The recent educational mandates in both radiation therapy and medical dosimetry have necessitated individuals who want to pursue careers in these fields to obtain additional education and graduate from JRCERT accredited programs. These aspects relate back to this study's theory of VET, which has three main principles; force, valence, and expectancy.

As graduates of radiation therapy and medical dosimetry programs are now required to have a certain level of education and complete a JRCERT accredited program (medical dosimetry), it is fair to assume that radiation therapy and medical dosimetry graduates are more educated than previous graduates. As these graduates are more educated, it also fair to assume that there was more effort (force) put into obtaining the respective degree. It is also reasonable to assume that the attractiveness of obtaining a higher degree (valence) and the potential rewards obtained (expectancy) are also higher for recent and future radiation therapy and medical dosimetry graduates.

Certification in radiation therapy and medical dosimetry is a requirement to practice in these respective disciplines. It is imperative that radiation therapy and medical dosimetry programs are graduating competent students who can pass their respective certification exam to help combat the workforce shortage that is occurring in radiation oncology. This study found that degree level, geographic location, and number examinees were not significant predictors of radiation therapy or medical dosimetry certification exam pass rates. For radiation therapy, it was determined that accreditation length was a significant predictor of radiation therapy certification exam pass rates and accounts for 15.16% of the variability of certification exam rates. JRCERT accreditation is not required for radiation therapy programs currently, this may change in future as it is required now for medical dosimetry as the two disciplines are highly related. None of the parameters analyzed for this study were significant predictors of medical dosimetry certification exam pass rates, however 21.93% of the variability of JRCERT accredited medical dosimetry programs is attributed to number of examinees. Also, upon further analysis of these programs, the number of examinees varied greatly among degree level. As the educational mandates for radiation therapy and medical dosimetry are recent (2015 and 2017 respectively), future research will need to be done to determine the impact of these mandates.

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Appendix A

E-mail from Radford University research compliance manager

This is the e-mail sent from the Radford University research compliance manager (Anna Marie Lee) on April 30, 2020. See below.

LeShell,
Thank you for your follow-up.
As long as the source is truly publicly available (i.e., available to anyone on request, without qualification or restriction) and stripped of any identifiers, you should not need IRB review and approval.
If you are receiving a restricted version dataset or a dataset not considered publicly available, then review may be required if the data is considered identifiable or potentially identifiable. Materials are considered individually identifiable when the identity of the participant is or may readily be ascertained by the investigator or the investigator's staff, or associated with the information.

I hope that helps.

Best regards,

Anna Marie

Anna Marie Lee, MHA, CPIA
Research Compliance Manager
Buchanan House
540.831.5290
https://www.radford.edu/content/research-compliance/home.html

Appendix B

Table 16

Raw data

Program	Deg type	Discipline	Accred. length	Certification exam_pass_rate	Location	# of examinees
1	A	RT	8	97%	Metropolitan	33
2	B	RT	8	100 %	Metropolitan	18
3	B	RT	8	89%	Metropolitan	35
4	B	RT	3	66%	Metropolitan	30
5	B	RT	8	.	Micropolitan	.
6	B	RT	8	84.4%	Metropolitan	25
7	B	RT	8	70%	Metropolitan	4
8	A	RT	8	98%	Metropolitan	46
9	C	RT	8	97.6%	Micropolitan	34
10	A	RT	8	90.54%	Metropolitan	65
11	C	RT	8	100%	Metropolitan	7
12	C	RT	8	97%	Metropolitan	34

13	C	RT	5	82%	Metropolitan	66
14	C	RT	8	93%	Metropolitan	14
15	C	RT	8	87%	Metropolitan	75
16	C	RT	8	98%	Micropolitan	52
17	A	RT	8	82%	Metropolitan	56
18	A	RT	8	90%	Metropolitan	58
19	C	RT	8	95%	Metropolitan	20
20	A	RT	8	91%	Metropolitan	32
21	C	RT	5	58.3%	Metropolitan	7
22	A	RT	5	73.2%	Metropolitan	34
23	A	RT	8	93%	Metropolitan	29
24	B	RT	8	74%	Metropolitan	46
25	C	RT	5	94%	Metropolitan	49
26	B	RT	8	81%	Metropolitan	86
27	B	RT	8	76%	Micropolitan	49
28	A	RT	8	93.75%	Metropolitan	88

29	B	RT	.	64%	Metropolitan	23
30	B	RT	8	84%	Metropolitan	47
31	B	RT	8	89%	Metropolitan	59
32	A	RT	8	92%	Metropolitan	32
33	B	RT	8	94%	Micropolitan	51
34	A	RT	8	79%	Micropolitan	24
35	B	RT	8	82%	Micropolitan	38
36	A	RT	8	100%	Metropolitan	17
37	C	RT	8	100%	Metropolitan	27
38	B	RT	8	77%	Metropolitan	57
39	C	RT	8	96%	Metropolitan	32
40	A	RT	8	91%	Micropolitan	22
41	A	RT	5	96%	Micropolitan	48
42	B	RT	8	96%	Metropolitan	62
43	A	RT	8	77%	Micropolitan	27
44	A	RT	8	.	Metropolitan	.

45	C	RT	8	100%	Metropolitan	27
46	B	RT	8	94.4%	Metropolitan	36
47	C	RT	8	82%	Rural	71
48	B	RT	8	100%	Metropolitan	53
49	B	RT	8	99%	Micropolitan	81
50	C	RT	8	92.3%	Micropolitan	27
51	B	RT	8	100%	Metropolitan	33
52	B	RT	8	82%	Metropolitan	22
53	A	RT	3	.	Metropolitan	.
54	B	RT	8	100%	Metropolitan	55
55	B	RT	8	97%	Metropolitan	66
56	B	RT	8	100%	Metropolitan	48
57	B	RT	8	88%	Metropolitan	99
58	M	RT	8	97%	Metropolitan	20
59	B	RT	8	94%	Metropolitan	69
60	B	RT	8	100%	Metropolitan	33

61	B	RT	8	89%	Metropolitan	37
62	B	RT	8	100%	Metropolitan	32
63	C	RT	8	100%	Metropolitan	18
64	B	RT	8	96.4%	Metropolitan	28
65	B	RT	8	78%	Metropolitan	32
66	B	RT	5	87.2%	Micropolitan	39
67	B	RT	8	100%	Metropolitan	90
68	B	RT	8	98%	Metropolitan	60
69	C	RT	8	89%	Metropolitan	171
70	B	RT	8	86%	Metropolitan	42
71	C	RT	8	100%	Micropolitan	20
72	B	MD	8	94%	Metropolitan	12
73	M	MD	8	85%	Metropolitan	34
74	C	MD	8	.	Metropolitan	.
75	M	MD	8	79%	Metropolitan	81
76	C	MD	5	.	Micropolitan	9

77	C	MD	8	89%	Rural	18
78	M	MD	8	97%	Micropolitan	90
79	C	MD	8	89.5%	Metropolitan	19
80	C	MD	8	95.8%	micropolitan	24
81	C	MD	5	100%	Metropolitan	11
82	B	MD	8	87%	Metropolitan	74
83	B	MD	8	89%	Metropolitan	45
84	C	MD	8	100%	Metropolitan	5
85	C	MD	8	100%	Metropolitan	7
86	C	MD	8	100%	Metropolitan	.
87	C	MD	8	96%	Metropolitan	25
88	M	MD	8	91%	Micropolitan	109