Fall 2010

Milliamperage-seconds, kilovoltage and patient dose in computed radiography

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Recommended Citation

Stewart, Grace, "Milliamperage-seconds, kilovoltage and patient dose in computed radiography" (2010). *Master's Theses*. 183.
https://scholars.fhsu.edu/theses/183

MILLIAMPERAGE-SECONDS, KILOVOLTAGE AND PATIENT DOSE IN COMPUTED RADIOGRAPHY

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A Thesis Presented to the Graduate Faculty
of the Fort Hays State University in
Partial Fulfillment of the Requirements for
the Degree of Master of Liberal Studies

by

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ABSTRACT

Radiographic techniques were applied to a human simulation pelvis phantom with evaluations of the resultant image analyzed by a designated radiologist. Results indicate that a lower patient dose is received when coupled with an increase in the tube voltage. Images analyzed demonstrated little noise variation between images, which indicates the ability to lower patient dose while maintaining quality images.

ACKNOWLEDGEMENTS

This thesis was made possible through the help, advice and support of many individuals. A very special thanks to Dr. Arthur Morin, my advisor, who had the expertise and patience to guide me through many difficult situations. Thanks also to the members of my graduate committee, Professor Brenda Hoopingarner and Professor Christa Weigel. Thank you to my Uncle, Daniel Dotson, who encouraged and guided me through the aspects of radiation measurement.

I would like to extend a sincere thank you to White-Wilson Medical Center and the imaging staff for allowing me to conduct research at their very busy facility. A special thanks to the facility radiologist, Dr. Norman Clinkscales, for taking the time to evaluate the radiographic images. Thanks also to the PACS administrator, Mr. Terry Foster, for setting up the computer parameters for the research project.

Last, but not least, I would like to thank my family and friends who have assisted me, whether through proofreading, sharing thoughts and ideas, or just being there during this long process: Stew, Carol, Doyle, Beth, Emory, John, Becky, Joan, Roslyn, Marie, Chelsea, Haley and Aubrey. Thank you!

TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

CHAPTER 1: INTRODUCTION TO THE STUDY

Overexposure in imaging departments can be commonplace. The International Commission on Radiation Protection (ICRP) has published a document addressing technique and patient dose indicating the –potential to increase patient dose with digital imaging" (International Commission on Radiation Protection, 2004). Technologists are not always held accountable for maintaining standard quality control measures. This leads to over-radiation and unnecessary repeat exposures. The research hypothesis is that radiation exposure is not dependent on specific radiation technical factors, but that a wide range of exposures produce equally diagnosable radiographic images. This lends itself to utilizing the lowest amount of radiation for the greatest protection to the patient. In addition, the index numbers given during an exposure should not be utilized to determine if an image is acceptable. Instead, the radiologist and a quality control team should make the decision of whether the image is of diagnostic quality.

The literary sources available for the thesis support the scientific basis for the organization and comprehension of radiation exposure. As radiologic technology is an evolving science, the literature used included scientific journals, peer-reviewed articles, and radiologic textbooks within the past eight years. The thesis is organized into six chapters: Introduction to the Study, Introduction to the Profession of Radiography, Proposal Question, Methods, Results, and Discussion.

CHAPTER 2: INTRODUCTION TO THE PROFESSION OF RADIOGRAPHY

This chapter provides a brief history of radiography, including information about the profession of radiography, the history of radiography and the science involved with radiography. This chapter also gives a brief glimpse into the regulation of radiation and practitioners in the field.

Introduction to Radiography

Radiography is both an art and a science (American College of Radiology (ACR), 2007). Radiographers are artists, performing a symphony of positioning and patient care. This orchestrated –dance” is fluid and dynamic and can be filled with emotion and compassion. Radiography is a science due to the nature, history, and advancement of the processes of radiation exposure. Radiography is the –making of permanent records of the internal structures of the body” (Adler & Carlton, 2007, p. 5). This is accomplished by utilizing x-rays that penetrate the body and are absorbed at varying levels by human tissue and bone. The resultant radiation is captured or detected by an imaging system and processed. A radiologic technologist is specially trained to position the human body and adjust radiation levels to produce optimal images for interpretation. The technologist or radiographer (as commonly known) –administers contrast agents, assists radiologists, and performs many duties critical to the health and well-being of patients” (ibid**,** p.11).

The radiographer has many responsibilities related to imaging. The technologist must be able to practice time-management, patient assessment and advocacy, and critical thinking skills. The technologist must perform these duties while interacting with patients and staff from diverse backgrounds and socio-economic experiences (Ehrilch & Daly, 2009). The student technologists spend approximately two years learning their skills. Their training includes an in-depth education concerning the rules and ethics of this profession (Adler & Carlton, 2007).

As Low As Reasonably Achievable (ALARA)

The governing organization for radiographers is the American Registry of Radiologic Technologists (ARRT). The ARRT enforces the laws, regulations and ethics set forth by the government, including the Nuclear Regulatory Commission (NRC). One such rule and ethical principle is the standard As Low As Reasonably Achievable (ALARA). This specific rule is the foundation of education in radiography programs. ALARA, as it relates to patient dose, assures that the least amount of radiation will be utilized in order to perform a diagnostic exam (American Registry of Radiologic Technologists, 2009). Radiography students and technologists must understand that litigation is possible if they do not uphold these standards. Students and technologists may be sued for any number of malpractice issues, including patient over-exposure due to incorrect setting of technical factors (Towsley-Cook & Young, 2007). In order to understand the basics of radiography, one should be familiar with the history of radiography.

History of Radiography

The founder of modern-day radiography is Wilhelm Conrad Roentgen, who was a scientist and professor in Germany in the late 1800s. His research and discovery of x-rays made a huge impact on the scientific community and the world. Scientists quickly began to imitate Roentgen‘s experiment, which allowed them to continue the research. The general public took an immense interest in the x-ray. This attention and excitement changed medical procedures forever (Bushong, 2004). Within months after the announcement of Roentgen‘s discovery, x-rays were being utilized in the United States. The first documented diagnostic x-ray in the United States was performed at Dartmouth College and showed the fractured wrist of a pediatric patient (Adler & Carlton, 2007).

As x-rays were studied and utilized by scientists around the world, the negative effects of radiation became apparent. Scientists working continually with radiation contracted very serious health problems attributed to their exposure to radiation. Researchers began studying the damaging effects of radiation on the cellular level. This research lead to specific radiation limits so that medical, scientific, and industrial uses of radiation may continue at levels of risk no greater than, and frequently less than, the levels of risk associated with any other technology (Robertson, 2005). To evaluate the risk involved with radiation, one should realize how x-rays are generated.

The Generation of X-rays

X-rays are created in a vacuum tube. The tube contains two electrodes; a negatively charged electrode, called the cathode, and a positively charged target, called the anode. The electrodes are attached to a source of direct current, creating a potential difference (tube voltage) between the cathode and anode. When the current is turned on, electrons are ejected from the cathode. They travel through the glass tube and strike the target anode. The energy released when the electrons hit the target is emitted in the form of x-rays. The wavelength of the x-rays is determined by the specific metal used for the target and the energy of the electrons released from the cathode. The focal spot is that area on the anode that the electrons strike. Focal spot size and angle affect the detail of the resultant image. The small focal spot concentrates the electrons into a narrow beam. The large focal spot spreads the electrons into a wider target area beam (Bushong, 2004). Small focal spots are usually selected for detailed anatomical extremities, such as the hand and wrist; large focal spots for all other parts of anatomy (Bushong, 2004). Figure 2.1 shows a side view of a cathode and anode and the area of the anode that is bombarded with electrons.

After the x-radiation leaves the tube housing, it interacts with the patient being imaged. The beam interacts with various bodily tissues or passes completely through the patient. The radiation is attenuated, or absorbed, at different rates depending on the chemical makeup of the body part (Bushong, 2004). Calcium in bones absorbs x-rays the most, so bones look white on the radiographic image. Fat and other soft tissues absorb less radiation, and look gray. Air absorbs the least, so lungs look black on a radiographic image (Bushong, 2004).

Since the discovery of x-rays, various types of analog and digital receptor devices have been used, from paper-coated film to radiographic film glass plates utilized during World War I, to film screen imaging, and finally to the computed and direct digital radiography imaging that is used today (Bushong, 2004). The evolution in patient protection was catapulted by the desire to engineer a receptor that would still result in diagnostic images, but allow for decreased patient dose. The updated receptor came in the form of a double emulsion film housed inside a cassette that has intensifying screens on either side of the film. Intensifying screens are thin sheets, or layers, of fluorescent materials. The screens are mounted in the cassette and the film is placed inside (Adler & Carlton, 2007). The x-ray energy is absorbed by the intensifying screen material and converted into light. The light, in turn, exposes the film. Intensifying screens are used because film is much more sensitive to light than to x-radiation. Different types of intensifying screens are available for clinical use. The selections of a screen for a specific procedure is usually based on the requirements for image detail and patient exposure, and are expressed numerically as screen speed. A slow screen speed requires more radiation to expose it than does a faster screen speed. This is due to the chemical composition of the screens and films. Usually the speeds are 200 (extremities) and 400 (thorax, pelvis, etc.) (Slovis, 2002).

Processing analog films is similar to photographic film. They both have silver-based emulsion. Incoming photons of light, created by the x-rays, are able to excite the crystals holding the silver in place. This causes a rearrangement of electrons. This process results in the latent image. The final image is produced from this latent image through a series of chemical reactions known as processing. The film must be developed, fixed, washed and dried (Adler & Carlton, 2007). Originally, each step was done manually. Automatic processing has allowed this chemical process to occur in about 90 seconds (Bushong, 2004).

Computed radiography (CR) was the next development in radiographic imaging. CR technology is 20 years old, but has only recently become mainstream (Warren-Forward et al., 2007). Like film screen, the CR system uses a cassette with a phosphor plate. The CR cassette is approximately equal to a 200-speed film-screen combination, although this speed can vary by manufacturer (Bronson & Gunn, 2002). The CR cassette generally requires more radiation exposure than what would be used during conventional screen radiography. The cassette is exposed to radiation and then processed through a reader where it is scanned and eventually turned into a digital image. The scanner houses a laser that is directed to a specific area on the phosphor. When the low energy light (laser beam) strikes the phosphor, it stimulates the release of light. The amount of light that is released on the cassette is proportional to the amount of x-ray radiation to which that location was exposed during the acquisition. This light is then converted from an analog image to a digital image. This entire scanning process takes up to one minute per cassette (Bushong, 2004). The digital image is available after the scanning and is presented to the technologist on a preview computer monitor for image quality review and acceptance.

While the conversion from film-screen to computed radiography may sound like an easy transition, this is not entirely accurate. Most of the technologists practicing in the field today were trained on conventional methods of film development and exposure technique. The transition is easier for current student technologists, since they are taught digital imaging in the radiographic curriculum. Experienced technologists who have been in the field prior to formal classroom instruction are expected to learn digital processes ―in house.” This ―in-house” education creates a learning curve among established technologists as well as other healthcare professionals (Bronson & Gunn, 2002). The education of established technologists should include the knowledge of radiation exposure required for each exam.

Exposure

All x-ray medical image receptors, whether film-screen or computed radiography, depend on milliamperage seconds (mAs) and kilovoltage (kV) settings to produce an image. These manual settings (mAs and kV) that the technologist selects on the control panel are what create the radiation in the x-ray tube (Bushong, 2004).

In film-screen radiography, the mAs settings are used to control the density of the image. Density is the overall darkening of the radiographic image. The mAs control the quantity of electrons that are released from the cathode side of the x-ray tube. As the mAs go up (which means the quantity of electrons increase), the overall darkening of the image occurs. As the mAs go down, the overall darkening of the image decreases. The kV controls the force of the electrons that travel from the cathode side of the x-ray tube to the anode side of the x-ray tube. The kV setting is used to control the contrast of the image. With higher or increased kV there is more force, or penetration, of the x-ray beam through a body part. With a decreased amount of kV there is less force, or penetration, through the body part. Unlike film-screen radiography, the computed radiography factors of kV and mAs are not as critical to the contrast and density of the image. Processing codes applied to the image data now determine the radiographic contrast and density. This is because the computer will utilize predetermined algorithms to produce the most diagnostic image (Bronson & Gunn, 2002).

Radiologic technologists are taught that different body parts require a specific range of kV and specific focal spot size (see Table 2.1). Usually, there is a range of 5 kV for each part. For example, the range for the abdomen is 75 +/-5 kV. Theoretically, one could set a kV of 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, or 80. The premise is that one would utilize a higher kV for thicker, denser anatomy and less kV when the anatomy is not as thick or dense. For patient protection, it is recommended to utilize the highest kV in the range and then lowering the quantity (mAs) of the x- rays. This will decrease patient radiation dose (Bontrager & Lampignano, 2010).

Dose is also dependent on the exposure latitude of the equipment. The exposure latitude is the difference between the minimum and maximum acceptable signal levels, which are influenced by mAs and kVp. Due to the wide exposure latitude of the digital imaging system, varying levels of radiation exposure produce acceptable images. This ability to utilize such a wide exposure range can result in using an excessive amount of exposure for a part of the anatomy of the patient. With over-exposure of radiation, the resultant image will appear sharp and of an excellent quality. Over-exposure is common among radiologic technologists (Hoaglin, 2006). Over-exposure means that the patient is subject to higher levels of radiation. The protection of the patient is sacrificed in order to get a clearer image. Under-exposure can result in a loss of quality or mottling of the image. The purpose of this thesis is to demonstrate that clear images can be rendered even when exposure may seem too low.

The CR cassette readout algorithms (mathematical computations) make adjustments to the digital image specific to the anatomy. The method for determining the useful signal range for most CR systems requires the automatic construction of a histogram of the image. The general shape of a histogram graph is dependent on the anatomy and the amount of radiation used in the image acquisition. The histogram from the scanned cassette is compared and adjusted to match the template histogram stored in the computer. Varying radiation levels are adjusted to produce the desired, predetermined histogram. What this means is the computer will try and compensate for any radiation exposure errors (mAs and kV) and try to correct the errors using the histogram and look up tables. The pixel values will automatically change to predetermined display characteristics even when an undesired amount of exposure is used to create the image (Bushong, 2004).

The digital signal of a CR image is produced after x-ray exposure and during processing of the latent image. The signal is influenced by the number of x-rays that strike the detector. Noise is the grainy appearance of scatter radiation that is not overcome by the signals (Lancaster, 2008). Signal to noise ratio (SNR) is important in radiography. Generally, as the mAs are increased, the SNR is also increased. Noise on a CR image interferes with the ability to distinguish differences between anatomical areas. Radiographers want a high SNR, while at the same time honoring the ALARA principle. One way to keep a high SNR without increasing patient dose is for facilities to purchase high detective quantum efficiency (DQE) imaging plates. Expressed as a function of object detail, or spatial frequency, DQE combines noise and contrast performance into a single parameter that is widely accepted as the measure most representative of digital image quality and object detection (ACR, 2007). The overall radiation exposure, whether by conventional or CR, must remain as low as possible. This is due to the effects of radiation on the human body.

Biological Effects of Radiation

It is not possible to remove oneself from radiation; it is inherent to life. Radiation is in the food we consume, the water we drink, and in the places we live. There is terrestrial (ground) radiation, cosmic (space) radiation, and radiation inside each person (Nuclear Regulatory Commission, 2009). Humans have little to no control over natural radiation. Radiation from diagnostic imaging is a form of radiation exposure that is controllable, to some extent. What must be established first is the need for the exam versus the potential risk of radiation exposure from the x-rays during the exam (Gallet, 2007).

It is well documented that x-ray exposure is harmful. The effect of radiation on living creatures is the result of ionizing radiation interactions at the cellular level (Bushong, 2004). At times, the effects of radiation can be overcome and are repairable. Sometimes, however, we are not able to recover from the effects. The radiosensitivity of the cell depends on ―maturation and metabolism" of the tissue (Bushong, 2004). In the United States, radiation absorbed dose, dose equivalent, and exposure are often measured and stated in units called rad, rem, or roentgen (R), respectively. For x-rays, these units of measure for exposure or dose are considered equal. There are strict guidelines that limit the occupational dose as well as give yearly dose equivalent for non-occupational workers. The radiation limit for occupational workers is 5 rem per year, and the yearly limit for non-occupational workers is 0.1 rem (Nuclear Regulatory Commission, 2009). Diagnostic medical procedures account for about 40 millirem (mrem) of exposure per person each year via ionizing radiation (Nuclear Regulatory Commission, 2009).

Ionizing radiation simply means that there is enough energy to remove an electron from atoms and change the molecular structures of cells. Ionizing radiation absorbed by human tissue has enough energy to remove electrons from the atoms that make up molecules of the tissue. When ionizing radiation interacts with cells, it may or may not strike a critical part of the cell (Henry Ford Health System, n.d.). According to the Washington State Department of Health (2000), one of the following interactions will occur when ionizing radiation interacts with the body:

1. The radiation may pass through the cell without doing damage
2. The radiation may damage the cell, but the cell may be able to repair the damage before it produces new cells
3. The radiation may kill the cell
4. The radiation may damage the cell in such a way that the damage is passed on when new cells are formed.

The Linear Non-Threshold (LNT) theory indicates a cancer risk exists with even the lowest amount of exposure. The National Academies uphold this non-threshold model and define low-dose exposure as “those ranging from nearly zero to about 100 millisievert (mSv)—units that measure radiation energy deposited in living tissue” (The National Academies, 2005, ¶ 3). The article just cited lists the exposure of a routine chest x-ray examination at 0.1 mSv, clearly within the National Academies definition of risk. If one is to believe the LNT theory, then it makes sense to utilize the least amount of radiation possible during radiographic procedures. However, there are studies which contradict the LNT theory. Studies by Robertson (2005) indicate that cells can recover from radiation.

According to Robertson (2005), many scientists believe the linear non-threshold (LNT) theory of radiation exposure and dose. This theory is based on the understanding that there is no safe level of radiation, that all radiation is dangerous (NRC, 2009). Robertson (ibid) does not agree with this theory. His theory is that there is a repair mechanism inherent to each cell. The repair mechanism inherent to each cell is determined by the amount of damage sustained. Robertson states the following:

> The first complication to the LNT mechanism is that nature has provided all DNA with a repair mechanism. This seems only reasonable since normal processes occurring in all our bodies result in about 10,000 DNA lesions in each cell nucleus every hour. Without a repair mechanism none of us would survive for long. Of the 10,000, about three are due to the ambient level of radiation to which we are all exposed from natural sources. Further exposure to the annual limit would result in just over one more. Thus, as long as the dose is not delivered at a rate too fast for the repair mechanism to keep up, residual damage would not be expected to be detected. (Robertson, ¶ 2, 2005).

Robertson (ibid) suggests the LNT theory is inaccurate, and that the repair mechanism inherent to each person compensates for radiation exposure.

There is a theory that small amounts of x-rays cause a decrease in the cancer rate. According to Wagner (2004), the premise is that the ―additional radiation given at lower doses does cause some genetic damage, but also stimulates the cells to fix the naturally occurring genetic damage at an earlier stage” (p. 1). ―A naturally occurring deoxyribonucleic acid (DNA) abnormality that might later lead to development of a cancer could be repaired because the additional radiation damage triggered the repair mechanism” (Wagner, 2004, p. 1). Regardless of the LNT theory or the repair theory, radiographers must remain vigilant in the proper use of radiation doses to prevent under- and over-exposures.

Under-and Over-Exposure

It is well documented that digital imaging technologies can compensate for under- and over-exposure during radiographic examinations. According to the International Atomic Agency (IAEA) training manual, "for digital detectors, higher doses result in a better image quality (i.e., a less-noisy image) in a certain range of dose” (IAEA, 2010, p. 33). Low radiation exposures increase the amount of quantum mottle (noise) visible on the image. Radiologists ―complain about the noise in computed radiography (CR) images exposed at one quarter to one half of an appropriate level” (Willis, Thompson, & Shepard, 2004, p. 12). CR inherently has wide exposure latitude, which means that final images appear acceptable with both low and high exposures. CR‘s ability to compensate for exposure errors is more than ―100 to 1000 times greater than that of film-screen imaging,” resulting in decreased repeat images (Don et al., 2007). However, this wide exposure latitude of CR has led to the realization that radiographers may not be as precise in selecting optimal exposure techniques (Hoaglin, 2006). In addition, Hoaglin (2006) believes that the increase in exposure latitude of the digital imaging system makes it more difficult to recognize overexposure or underexposure. This may lead technologists to overexpose patients. This is because the CR computer automatically adjusts chosen technical factors and manipulates them into an acceptable image. The technologist may not realize that he/she is over-exposing the patient, because the resultant image is accepted.

Researchers Warren-Forward, Arthur, Hobson, Skinner, Watts, Clapham, Lou, and Cook submitted analyses of exposure indices for chest and lumbar exams at various hospitals to determine whether radiographers were selecting exposure techniques within the manufacturers‘ recommended guidelines. Their research found both under -and over-exposures occurred frequently at all facilities (Warren-Forward et al., 2007). This indicates a real need to educate technologists about the science of CR. The education of technologists must not be overlooked; it is vital to the health and well being to the patients in medical imaging.

Training

An article by Forrest (2007) discussed differences between film-screen, computed radiography, and digital radiography radiation exposures. Forrest described research of standard radiographic procedures and found that CR generally resulted in higher effective skin dose than did film-screen radiography: ―It is not surprising that average doses increased for some examinations when CR was introduced" (Forrest, 2007, ¶ 3). Forrest‘s article again emphasized training, because it is apparent that technologists were still prone to mistakenly using low kilovolt peaks to boost image contrast, as well as short source-to-skin distance (SSD), even after their CR and digital imaging training" (Forrest, 2007, ¶ 7). If the technologist utilizes a low kV when he/she could be utilizing a high kV, the technologist has increased patient dose due to the amount of mAs that is used to compensate for the low kV. Source-to-skin distance is the distance that the tube is from the patients' skin. The closer the tube is to the patient, the higher dose the patient will receive. There are strict guidelines for the SSD. Failure to follow guidelines can lead to radiation injury (Bontrager & Lampignano, 2010). The guidelines for radiation exposure are stated in any positioning or radiographic physics book. As emphasized by the ARRT, it is imperative that operators of ionizing radiation-emitting equipment become better educated to meet the demand for quality radiographic images with the lowest possible exposure to the patient (ARRT, 2009). Radiographers must adhere to the ALARA principle to ensure that the benefit of patient radiation exposure outweighs the risk (Gallet, 2007). The need for exact doses and practices is especially crucial for pediatric patients, due to their developing systems.

Pediatric Exposure

Concerns regarding overexposure in pediatric imaging have been emphasized in diagnostic literature. According to Gallet (2007), any time ionizing radiation is used for imaging children, special care must be taken to ensure the lowest possible ionizing dose for the diagnostic imaging task requested. This is due to the increased cell division inherent to a child. CR and all x-ray procedures create ionizing radiation. As with all ionizing radiological procedures, the benefit of the procedure (immediate and future) should outweigh its potential risks" (p. 2). Following the ALARA principle, the least amount of radiation should be used in order to provide the diagnostic value intended. The experiment conducted to test the basic claim of this thesis indicates the ability (and thus necessity) of utilizing low dose without compromising the integrity of the radiographic images. The basic claim of this thesis is that it is possible to expose patients to lower doses of radiation (thus honoring the ALARA principle) without compromising the integrity of the radiographic images. The following chapter will state the hypotheses and explain the methodology used to test this claim.

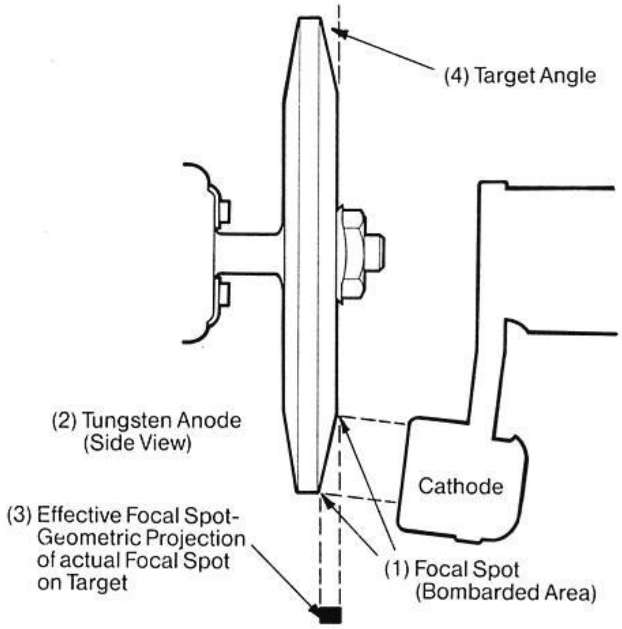

Figure 2.1 The Cathode and Anode. (Odnall, n.d., p. 3).

Table 2.1

Kilovoltage Range and Focal Spot Size

Body habitus	kV range	Focal spot
Chest	125	Large
Abdomen	75 + -5	Large
Pelvis	75 + -5	Large
Lumbar spine lateral	80 +-5	Large
Shoulder	70 + -5	Small

Table 2.2 Actual Exposure

Exposure	mAs	kV	SI Number	Dosimeter readout
Exposure 1	125	75	155	24.9 mrem
Exposure 2	100	75	197	18.4 mrem
Exposure 3	80	75	243	15.5 mrem
Exposure 4	64	75	328	12.7 mrem
Exposure 5	50	75	484	7.7 mrem
Exposure 6	40	75	577	6.3 mrem
Exposure 7	32	75	841	5.0 mrem
Exposure 8	25	75	937	3.0 mrem
Exposure 9	20	75	1402	2.6 mrem
Exposure 10**	12.5	75	1405	5.3 mrem
Exposure 11**	10	75	1788	4.2 mrem
Exposure 12**	10	80	1334	4.2 mrem
Exposure 13**	12.5	80	978	5.4 mrem
Exposure 14	20	80	959	2.3 mrem
Exposure 15	25	80	734	2.8 mrem
Exposure 16	32	80	555	4.8 mrem
Exposure 17	40	80	451	6.1 mrem
Exposure 18	50	80	317	7.3 mrem
Exposure 19	64	80	214	12.1 mrem
Exposure 20	80	80	165	15.0 mrem
Exposure 21	100	80	194	11.8 mrem

Note. **Small focal spot utilized.

CHAPTER 3: PROPOSAL QUESTION

As previously documented, utilizing the least the amount of radiation necessary follows the ALARA principle for medical radiography. This means that the smallest amount of dose should be utilized when performing medically necessary radiographic procedures on patients. It is widely accepted that radiation associated with diagnostic imaging is of the LNT type, in which it is proposed that

> The risk of harm (fatal and non-fatal cancers and genetic defects) is linearly proportional to the dose, e.g., halve the dose and the risk is halved, but with some adjustment for the period over which the exposure occurs; and that there is no threshold dose below which the harm is zero. (Robertson, 2005, ¶5).

There is no amount of medical radiation that can be proven to be safe 100% of the time. Most radiation doses are assumed to be cumulative. Although some cells may be able to repair themselves with seemingly little effects, this is not a guarantee (Wiley-Blackwell, 2008). This LNT theory is one that ~~in~~volves the least amount of mathematical assumptions and is thereby consistent with the ancient principle of scientific philosophy known as Okam's razor (the simplest explanation which describes a phenomenon is the best)" (Henry Ford Health System, n.d., ¶ 1). Since the technical factor of mAs is the major contributor of patient dose, it makes sense to try to limit the exposure time to only that which is absolutely necessary to produce a diagnosable image.

Computed radiography inherently has wider latitude of acceptability than film-screen technology. This latitude enables a wide range of exposures to produce equally acceptable images. This results in the potential abuse of radiation technique (higher than necessary mAs). This is less of a problem with film-screen radiography because ―over-exposure” produces a dark film and is immediately recognized as overexposed. However, an overexposed *digital* (CR) image is visually appealing and will not be recognized as one made with unnecessary exposure. The ability to mask exposure errors occurs because of the manufacturer‘s preset algorithms inherent to each digital system.

What is not generally appreciated by technologists is that unlike film-screen radiography, with CR the use of the mAs and kV settings are not as critical for the resultant image to display density and contrast. Instead, these factors can be enhanced digitally. In an attempt to regulate and control overexposure in CR, radiation equipment manufacturers have established numerical representations or suggested ―parameters” that are an approximation of the exposure on a radiographic image. Each system has its own unique ―exposure indication” with a mathematical algorithm (formula) inherent to it. Different systems are known by different exposure numbers (see Table 3.1). For example, Kodak named its exposure representation the exposure index or ―EI.” Fuji‘s and Konica‘s system of exposure representation is known as sensitivity or ―SI” values (Warren-Forward et al., 2007). Each system is unique and its numerical representation of data is either directly proportional or indirectly proportional to exposures. A directly proportional system means that when an image is over-exposed the index number will be higher than suggested; when under-exposed, lower than suggested. An indirectly proportional system means that when an image is over-exposed, the index number is lower than suggested and when under-exposed, the index number is higher than suggested.

Although these indices are provided by manufacturers to assist in providing a suitable image, it has been found that these can also be used as an indicator of patient dose levels. If the amount of radiation reaching the imaging plate is higher than recommended by the manufacturer, this could imply that the patient is receiving too much radiation or that the index recommended is too low -or too high, depending on the system in use (Warren-Forward et al., 2007). While the suggestions of monitoring patient dose according to the index numbers may indicate over-exposure or under-exposure, there are inherent disadvantages to utilizing CR.

Computed Radiography (CR) Noise

Patients who are radiographed utilizing CR systems are already at a disadvantage when technical factors are utilized. The reason for this is that most CR systems are based on 200 film-screen speed systems (ACR, 2007). For instance, if a film-screen 400-speed image of a pelvis requires 20 mAs and 75 kV to be an optimal radiograph, then the 200 comparable CR image automatically requires more technique to compensate for the slower imaging system. Thus, the CR pelvis radiograph requires more mAs. It is necessary to use 40 mAs and 75 kV on CR systems, effectively doubling the dose. Sometimes, if underexposed, these images appear noisy or grainy and this effect is known as –quantum mottle” (Bushong, 2004). These –noisy” images are undesirable to radiologists, though some of these may be of diagnostic quality (Slovis, 2002). It is expected that increasing the dose (mAs) will produce overexposed images, which appear crisp without any noise or grainy appearance. CR technologists may overexpose for fear that the study will be repeated due to appearance of noise. This may result in a reprimanded from the radiologist. This intentional increase of mAs is known as the ―exposure factor creep” phenomenon (Willis et al., 2004). The only guaranteed way of eliminating exposure creep is by having knowledge about radiographic techniques and the impact they have on the dose.

Technique

This study assumes that a variety of exposure techniques (mAs and kV) will produce optimal images. This hypothesis will be tested by utilizing a wide range of mAs exposures with the intent of producing diagnostic images for the radiologist to interpret. It is theorized that low mAs exposures will be of diagnostic quality when performed in conjunction with the increase in kilovoltage (tube potential) and that this will decrease the exposure of radiation to patients. The research will demonstrate that when compared to the manufacturer‘s recommendation of exposure, the experimental sensitivity number will represent an inaccurate representation of exposure values. It is expected that a more acceptable range of values can be established. Furthermore, the research will establish that some amount of noise on an image may be acceptable. This would substantiate the ability to lower patient dose. What this research potentially will confirm is at the increased levels of radiation, many steps above quantum mottle, the mAs will be of diagnostic quality, although at unnecessary levels of radiation.

Process

This study employed a design to identify variation in mAs and CR index numbers that were combined with a change in kilovoltage (kV). The radiation measuring device (a dosimeter), displayed the entry dose given to an anthropomorphic radiopaque phantom. The phantom used was an accurate life-size anatomical model of a human pelvis. The soft tissue substitute and the synthetic bones have x-ray absorption (tissue-equivalent material) rates similar to those of human tissue and bones (Winslow et al., 2009). The reason the pelvis phantom was chosen was due to the proximity of gonadal region to the radiation. All exposures were taken at a source-to-image distance of forty inches.

The first experimental method utilized exposures (mAs) of the phantom at varying quantities with a set tube potential (quality or kV). The second experimental method utilized exposures (mAs) of the phantom at varying quantities with varying tube potential (quality or kV). During both methods, the exposure index, or its equivalent, was documented. This information was stored and ―blind images” were forwarded to the radiologist. The radiologist was not provided any information about the techniques chosen (kV or mAs), nor the exposure index or sensitivity numbers associated with the images. The radiologist was required to identify which of the images were of diagnostic quality and which were not, as well as the ―preferred” image and the most ―noisy” image, which was still of diagnostic quality. Careful analysis of this information would demonstrate whether a decrease in patient dose was possible in computed radiography while maintaining a usable diagnostic image.

Hypotheses

The hypotheses are as follows:

Hypothesis 1. Increasing radiation dose is not always necessary during computed radiography pelvis exams.

Hypothesis 2. SI numbers do not give an actual representation of a diagnostic image.

Hypothesis 3. Some amount of noise on radiographic images is acceptable and diagnosable.

The three hypotheses must have a way to be tested, to verify if the predicted results will occur. This is accomplished as described on the previous page.

Table 3.1

Acceptable Exposure Ranges According to Manufacturer

Manufacturer range	Exposure
Agfa	2.05-2.35 (logM) logarithmic median
Fuji/Konica	200-300 (SI-value) sensitivity index
Kodak	1850-2150 exposure index

(Eastman, 2006)

CHAPTER 4: METHODS

Design

A design was used in the research study to investigate the effect of varying the quantity of radiation exposure on CR image quality. The dependent variable was the amount of radiation incident on the CR image plate (IP). The radiation quantity was varied by changing the time of exposure to increase or decrease the mAs. The independent variable (i.e., radiographic quality-kV) was evaluated by the exposure indicator and was documented by the sensitivity index (SI) value provided during CR image processing. The second phase of the experiment increased the dependent variable (kV) to the limit suggested by radiographic positioning literature (Bontrager & Lampignano, 2010). This design and the results were affected by the type of radiographic equipment utilized in the testing phase of the experiments.

Equipment

A General Electric MVP 60 3-phase routine radiography generator was used to expose the IPs. State radiation inspectors had previously verified that the imaging system was functioning properly and at the time of the experiment the equipment was registered with the state of Florida. A Konica Minolta Regius Model 190 was used to process the exposed computed radiography image receptors. The CR equipment was installed at the medical facility in 2008.

An anthropomorphic radiopaque pelvis phantom was used due to the similarities of a human pelvis. An electronic pocket dosimeter, with instant readout, was utilized to measure surface entry doses. The dosimeter was placed in a transverse manner on the radiopaque pelvis phantom (see Figure 4.1). This dosimeter has the capability of recording energy responses between 30 kV and 3 MeV (megaelectron volt). This experiment utilized a 75 and 80 kV tube current.

Research/Experiment

Twenty-one images of an Anterior-Posterior (AP) simulated pelvis were taken. A dosimeter was placed on the pelvis as previously indicated, and was zeroed out and activated prior to each exposure of radiation. The image receptor was a 14” x 17” computed radiography cassette. Collimation was equal to the image receptor cassette dimensions of 14” x 17”. The source to image distance (SID) was locked vertically to the x-ray table at a distance of 40 inches to the bucky (IP holder) for each exposure. The kilovoltage was set at 70 for the first 10 images, and then adjusted to 80 for the remaining images (see Table 2.2). After each exposure, the image receptor was processed and the exposure number documented. After each exposure, the dosimeter readout was documented (see Table 2.2). On exposures 10-13, the small focal spot size was selected for radiographic detail. All other exposures utilized the large focal spot.

Radiologist Interpretation

The exposed images were sent via the Picture Archiving and Communications System (PACS) to the radiologist. The images were numbered 1-21. The radiologist did not know any of the technical factors, dosimeter readouts, or index numbers. The radiologist‘s assignment was to evaluate the images on the monitors and indicate which ones were ―noisy” and which ones were not. In addition, the radiologist was to communicate if the ―noisy” images were of diagnostic quality in spite of the noise, or due to lack of noise. The radiologist was given the task of interpreting the phantom images. The results of the radiologist's interpretation were used to see whether the hypotheses were substantiated. The results are reported in Chapter Five.

Figure 4.1 Phantom and Dosimeter.

CHAPTER 5: RESULTS

Interpretation

Table 5.1 demonstrates the actual exposures taken during the experiment. The first column lists the exposure, followed by the mAs and kVs utilized during the exposure. The fourth column lists the ―S' number, and the final column lists the dosimeter readout. All of the exposures are listed in this chart, as well as an indication of which images utilized a small focal spot.

Tables 5.2 – 5.6 give more detailed information about the experiment. In the far left column of tables 5.2-5.6 the exposures are labeled 1-21. The first column lists the specific image. The second and third columns list the mAs and kVs, respectively. The fourth column lists the focal spot size (either large or small). Column five lists the specific SI for each exposure. The sixth column lists the dosimeter readout taken during the radiation exposure. The ‗yes' or ‗no' in the seventh column indicates whether the radiologist found that the image had noise. The radiologist scanned each image looking for any type of artifact or noise that could hinder a correct diagnosis. If there was no noise visible, the radiologist marked N for no noise. If there is noise the radiologist marked Y for yes, there is noise. The eighth column lists whether the image was acceptable by the radiologist. The final column lists the radiologist's comments concerning the images.

As stated earlier in this thesis, the Konica system utilized in the experiments is an inversely proportional readout system. This means that as the radiation decreases, the SI number will increase and conversely, as radiation decreases, the SI number will increase.

This inverse relationship is documented in tables 5.1-5.6. The range of acceptability for this system is 200-300; anything higher or lower than the number is deemed unacceptable.

Expected results pertaining to tables 5.2-5.6 include the acceptability of visible noise on the radiographic image**.** The radiologist reviewed the image on the computer monitor and decided if the image had visible noise. If so, the radiologist determined if the noise was at an acceptable level or exceeded it. Visible noise appears as mottle or grainy anatomy. This expectation was met as the radiologist did find noise on images 7-13. The radiologist accepted all of the images that displayed noise. In other words, the radiologist believed that the noisy images were good enough to allow him to give a diagnosis. Typically, noisy images are repeated. These findings suggest that it may not be necessary to repeat the image, thereby preventing an unnecessary exposure to the patient. It was expected that using SI numbers as a quality control tool may not be effective. The radiologist‘s diagnosis leads to the conclusion that using SIs is not effective. As demonstrated on Images 1, and 3-18, the SIs are all out of range. According to the manufacturer all of the images should have been repeated. Instead, all of the images were accepted by the radiologist. It was also expected that the SI numbers will remain outside of the range of the manufacturer‘s recommended acceptability, yet still produce a radiograph image of good quality. Again, this expectation was met by the radiologist‘s ability to ―read” the images that were deemed unacceptable according to the manufacturer‘s standards.

Finally, it was expected that radiation increases, common to computed radiography, are not always necessary. This expectation was demonstrated by the dosimeter readouts captured during increased radiation exposure to the phantom. As shown in the charts, increasing technique increases the dosimeter readout, which indicates an increased dose to the patient. However, increasing technique is not necessary to produce an acceptable image. The radiologist accepted all but two of the images. This indicates the wide range of acceptability of radiographic images, regardless of the technical factors chosen. When a group of resultant images are accepted that have varying technical factors, in practice, the lowest mAs technique should be utilized to maintain ALARA principles of radiation protection.

Of the 21 images sent to the radiologist, only images 20 and 21 were deemed too noisy for interpretation (see tables 5.2-5.6). It was not expected that the images taken at a higher mAs (80 and 100) would be the images deemed unacceptable. Usually, higher mAs decreases the visible noise on a resultant image. The lack of detail and noise on the images identified by the radiologist could have several implications for the hypothesis. First, the tube could have an output fluctuation, which means the x-rays were not as powerful as they should have been. Second, the interpretation of x-ray images is subjective; another radiologist could have accepted the radiographs. Third, there could have been a processing malfunction, which could lead to improper readout. Fourth, the phantom is not a reliable substitute for a human body part.

Image No. 15 was regarded as the preferential image (see table 5.5). This particular exposure was taken at 25 mAs at 80 kV. The dosimeter readout was 2.8 mrem, which clearly demonstrates a lower dose in comparison to most other exposures. The SI value was at 734, well above manufacturer‘s recommendation of 200-300. The 734 value represents (according to the manufacturer) an underexposed anatomical body habitus, and therefore should be repeated. However, according to the radiologist, this was the most defined image out of the group, the best for interpretation. The radiologist‘s identification of this image as the —preferred image” is instrumental to this thesis. The findings clearly demonstrate the ability to lower patient dose and that clear images can be produced with lower levels of radiation exposure.

The ALARA concept grew out of the principle that any radiation exposure carries with it some risk. Medical procedures that include radiation exposures are sometimes necessary, and ALARA must be a key factor in balancing the exposure risks to the benefit of diagnosis. To err on the side of caution, it is assumed that medical radiation doses accumulate over a lifetime. In this particular set of exposures, 25 mAs at 80 kV, the SI was higher than the recommended range. The image was still acceptable, and in this case preferable. The realization that SI numbers can be outside of the manufacturer‘s recommendation, yet still produce acceptable images, is vital to this thesis. Images with index numbers outside of the accepted range may not make it to the radiologist for interpretation. The images are repeated, giving the patient an unnecessary medical radiation dose.

Results from the experiments indicate that SI numbers cannot be utilized as a reliable means of determining appropriate radiation exposure. If one were expected to follow the manufacturer‘s guideline, then 19 out of the 21 images in this experiment would require a repeat image, leading to unnecessary radiation to the patient. Yet, of the 19 images that were outside of the acceptable range, 17 of the images were acceptable, according to the radiologist.

As previously stated, the kV and the mAs contribute to the amount of radiation that a patient receives for any given procedure. The kV is the ―quality” or penetration of the x-rays on the image. When the kV is fixed, the radiographer does not incrementally adjust this factor. In this experiment the kV for the pelvis was 75 and 80 kV. The mAs were varied. The mAs are the quantity of x-rays during each exposure. The x-rays produced during an exam increases the exposure of radiation to the patient. Using varied mAs during this experiment demonstrated the wide range of radiation quantity that produced equally acceptable radiographs.

Focal spot selection is important when performing radiographic procedures. Choosing a focal spot depends on the body part being imaged, as well as technical factors selected. The large focal spot accepts a wider physical area of electrons from the anode. This larger area allows for more heat to dissipate from within the tube, which leads to a longer life of the x-ray tube. This is one of the reasons that a large focal spot is chosen during pelvis x-rays. Another reason is that the pelvis image does not usually require as much visible detail as does an extremity, which requires a small focal spot. When the x-rays hit the larger focal spot on the anode there is more chance for unsharpness, or penumbra, around the edges of the image. Conversely, when the small focal spot is selected, a narrower beam of electrons interacts with a physical area on the anode. This produces a more concentrated and narrow beam that interacts with the patient. Smaller focal spots are usually chosen when bony detail is important. In this experiment, both small and large focal spots were utilized to document acceptability or non acceptability of detail by the radiologist. The large focal spot was selected on 17 images and the small focal spot was selected on four images**.** The results in this experiment indicate that, compared to the use of the large focal spot, the use of the small focal spot did not demonstrate an improvement in noise or detail. This indicates acceptability of either focal spot for this body part (pelvis), with the understanding that the lowest technique should be utilized for maximum patient protection.

Exposure 1 used the most radiation of all of the images: 125 mAs at a fixed kV of 75. The large focal spot was selected. After the exposure and processing of the CR plate it was noted that the SI number was below the recommended manufacturer‘s range of 200-300. According to the manufacturer this image is over-exposed and unacceptable. The dosimeter readout was 24.9 mrem. The radiologist read this image as having no visible noise and deemed an acceptable image. At higher mAs exposures such as this, one expects little noise, because the overall amount of radiation is higher than the amount of inherent noise in the system. Technologists would be happy to send an image with little noise to the radiologist. However, higher mAs mean the patient is subject to higher levels of radiation exposure. Because other images with lower levels of mAs could be read by the radiologist, Exposure 1 was a misuse of radiation.

Exposure 2 had a decrease in mAs, while keeping the kV the same as the original exposure. Exposure 2 had an SI of 197, still below the manufacturer‘s guidelines. Once again, this indicated an overexposure and unacceptable image according to the manufacturer. The dosimeter readout was 18.4 mrem, less than the original dose of 24.9. Again, the radiologist read the image as having no noise and also commented that images 2-6 were virtually identical. From the perspective of the radiologist, there is no difference in the quality of the images. This result implies that radiographers can utilize low mAs, which in turn lowers radiation dose, and still have diagnostic images for the radiologists.

The decrease in dose from image 1 to image 6 is greater than 75 percent. With a decrease in patient dose, the risks of radiation-induced injury decrease and the cumulative dose to the patient decreases as well. The SIs for images 4-6 were above the manufacturer‘s recommendations, with exposure 6 exceeding the recommendation by almost twice the allowable recommendations. This reinforces the hypotheses that SIs should not be utilized as an indicator of technique acceptability, and that increasing radiation is not necessary in computed radiography.

Images 7-11 were virtually indistinguishable from each other, according to the radiologist. As radiation utilized to make exposures decreases, the amount of radiation that reaches the imaging plate also decreases. As stated earlier, the Konica system utilized in the experiments is an inversely proportional readout system. This is related to the amount of amplification required during processing by the photomultiplier tube to adjust the digital image to the predetermined histogram. This means that as the radiation decreases, the SI number will increase. Again, according to the manufacturer, if the SI number exceeds the recommended range of 200-300, the image is under-exposed. If the SI number falls below the 200-300 range, the image was over-exposed. None of exposures 7-11 met the recommended exposure guidelines; images exceeded the guidelines, implying under-exposure, yet they were deemed acceptable. This again reinforces the hypothesis that the SI range should not be utilized for determining acceptable images.

Images 7-11 displayed a minimal amount of noise. This noise, however, was not a deterrent to diagnosing the image. The radiologist specified that the noise amount was not excessive. This finding supports the hypothesis that some noise is acceptable on an image. Therefore, noise alone cannot be utilized to determine if an image is unacceptable. Comprehension of this principle is necessary to prevent repeat exposures on patients.

Images 7-9 show the dosimeter readout gradually decreases as the technique decreases. The results show that lower levels of radiation exposure do not mean the quality of the image is unacceptable. The use of lower levels of radiation exposure that resulted in acceptable images means the ultimate goal of patient protection and usable images were produced. The combination of low levels of radiation and usable images are the most preferred combination. Images 10 and 11 demonstrate a gradual increase in dosimeter readout, yet the image with less exposure is acceptable. This is as affirmation of the ALARA principle of radiation protection. As previously stated, the ALARA principle is one of the most important guidelines technologists are expected to follow. Most philosophies concerning radiation protection are conservative in nature and indicate that all doses contribute to an increased risk of biological effects to the person exposed to the radiation. The principle of ALARA as it relates to radiologic technologists means they are required to protect the patient from unnecessary radiation exposures. Overexposure in any amount results in unnecessary radiation to the patient. The implication is simple, but clear – the increase in the dosimeter readout means the patient has been unnecessarily subjected to an increase in exposure**.**

Images 10 and 11 were the first to be taken utilizing a small focal spot (see table 5.4). The dosimeter readout increased from exposure 9 to exposure 10. The dosimeter readout decreased from exposure 10 to 11 (see table 5.4). The reason for the increase in dosimeter readout from image 9 to image 10 may be due to the use of the small focal spot that concentrates the beam. Normally, a large focal spot should be selected for the pelvis and other similar anatomical parts because they are generally larger. A large focal spot ensures adequate radiation exposure**.** As a rule, when utilizing a large focal spot there is some loss of detail due to the wider exposure angle, but this loss of detail does not usually impact the quality of an image of larger body anatomy such as the pelvis. Noise differences during this experiment demonstrated that the only noise prevalent was with the utilization of the large focal spot at higher mAs and kV. Additional testing may be required to verify the radiation and noise based on comparisons of large and small focal spots.

Images 12 and 13 were taken utilizing small focal spots, with 10 and 12.5 mAs, respectively. However, both images had SIs above of the manufacturer‘s recommendations. This implies that the images were underexposed, not acceptable, and repeat exams are necessary. Both images displayed minimal noise and were both considered acceptable images by the radiologist. This confirms the hypothesis that SI numbers should not be utilized when approving exams.

Images 14-19 utilized an 80 kV selection, with a large focal spot and a gradual increase in mAs (see table 5.4). As the mAs increased, the SIs for images 14-18 decreased but were still above the manufacturer's suggested guidelines. Image 19 was within the acceptable range with an SI of 214. The recorded doses increased with each exposure from 14-19. Image 19 had an almost six-fold increase in dosimeter readout when compared to image 14. All images were deemed acceptable by the radiologist. This gives credibility to the argument that readable images can be produced with lower radiation exposure. As pointed out previously, one should utilize the least amount of radiation possible for any given exam.

Images 16-19, according to the radiologist, were identical. With little distinction between them, they could have been the same exposure. This means that an increase in mAs is not necessary, and therefore overexposure is not necessary, further supporting the thesis. The radiologist thought that all of the images, 14-19, were acceptable. It stands to reason that the lowest mAs (lowest dose) should be utilized.

Images 20 and 21 utilized an 80 kV, with increased technical factor selections of 80 and 100 mAs. The large focal spot was selected. Contrary to the expectation, the radiologist deemed these images unacceptable, due to the lack of detail. Some loss of detail was expected, due to the use of the large focal spot. However, the need for a repeat exposure due to focal spot size was not expected. Other images that utilized the large focal spot were deemed acceptable. The reason for this unexpected result could be an output flux problem with the tube, or it could be a normal readout for this system. However, as stated earlier, the equipment utilized had been verified and certified operational. The processing could have had an impact on the result. The unacceptability could also have been a subjective decision by the radiologist. Neither exposure was within the manufacturer‘s recommended range. The SIs are below the manufacturer‘s guidelines. The SIs are close to the acceptable range, reinforcing the need to evaluate these numbers overall and the relationship to exposure acceptability. One area to also be considered is whether the use of a small focal spot would have made a difference in the visibility of the image when utilized with the same mAs and kV factors. The implication is that additional testing is necessary to ensure confirmation of the findings.

Chapter six will include a discussion of the hypotheses of this experiment as well as provide recommendations and a conclusion.

5.1 Grace Stewart Experiment 2010

Actual Exposure

Exposure	mAs	kV	SI Number	Dosimeter readout
Exposure 1	125	75	155	24.9 mrem
Exposure 2	100	75	197	18.4 mrem
Exposure 3	80	75	243	15.5 mrem
Exposure 4	64	75	328	12.7 mrem
Exposure 5	50	75	484	7.7 mrem
Exposure 6	40	75	577	6.3 mrem
Exposure 7	32	75	841	5.0 mrem
Exposure 8	25	75	937	3.0 mrem
Exposure 9	20	75	1402	2.6 mrem
Exposure 10**	12.5	75	1405	5.3 mrem
Exposure 11**	10	75	1788	4.2 mrem
Exposure 12**	10	80	1334	4.2 mrem
Exposure 13**	12.5	80	978	5.4 mrem
Exposure 14	20	80	959	2.3 mrem
Exposure 15	25	80	734	2.8 mrem
Exposure 16	32	80	555	4.8 mrem
Exposure 17	40	80	451	6.1 mrem
Exposure 18	50	80	317	7.3 mrem
Exposure 19	64	80	214	12.1 mrem
Exposure 20	80	80	165	11.8 mrem
Exposure 21	100	80	194	15.0 mrem

Note. **Small focal spot utilized.

Table 5.2

Radiologist Findings Images 1-6

Exposure	mAs	kV	Focal Spot	SI Number	Dosimeter readout	Noise (Y/N)	Acceptable (Y/N)	Radiologist comments
Exposure 1	125	75	Large	155	24.9 mrem	N	Y	No difference
Exposure 2	100	75	Large	197	18.4 mrem	N	Y	No difference
Exposure 3	80	75	Large	243	15.5 mrem	N	Y	No difference
Exposure 4	64	75	Large	328	12.7 mrem	N	Y	No difference
Exposure 5	50	75	Large	484	7.7 mrem	N	Y	No difference
Exposure 6	40	75	Large	577	6.3 mrem	N	Y	No difference

Table 5.3

Radiologist Findings Images 7-9

Exposure	mAs	kV	Focal Spot	SI Number	Dosimeter readout	Noise (Y/N)	Acceptable (Y/N)	Radiologist comments
Exposure 7	32	75	Large	841	5.0 mrem	Y	Y	Minimal noise 7-11 comparable
Exposure 8	25	75	Large	937	3.0 mrem	Y	Y	Minimal noise 7-11 comparable
Exposure 9	20	75	Large	1402	2.6 mrem	Y	Y	Minimal noise 7-11 comparable

Table 5.4

Radiologist Findings Images 10-13

Exposure	mAs	kV	Focal Spot	SI Number	Dosimeter readout	Noise (Y/N)	Acceptable (Y/N)	Radiologist comments
Exposure 10	12.5	75	Small	1405	5.3 mrem	Y	Y	Minimal noise 7-11 comparable
Exposure 11	10	75	Small	1788	4.2 mrem	Y	Y	Minimal noise 7-11 comparable
Exposure 12	10	80	Small	1334	4.2 mrem	Y	Y	Minimal noise 12-13 comparable
Exposure 13	12.5	80	Small	978	5.4 mrem	Y	Y	Minimal noise 12-13 comparable

Table 5.5

Radiologist Findings Images14-19

Exposure	mAs	kV	Focal Spot	SI Number	Dosimeter readout	Noise (Y/N)	Acceptable (Y/N)	Radiologist comments
Exposure 14	20	80	Large	959	2.3 mrem	N	Y	Less noise than image 13
Exposure 15	25	80	Large	734	2.8 mrem	N	Y	Subtle improvement in detail from 13-19 ―Preferred Image”
Exposure 16	32	80	Large	555	4.8 mrem	N	Y	No difference 16-19
Exposure 17	40	80	Large	451	6.1 mrem	N	Y	No difference 16-19
Exposure 18	50	80	Large	317	7.3 mrem	N	Y	No difference 16-19
Exposure 19	64	80	Large	214	12.1 mrem	N	Y	No difference 16-19

Table 5.6

Radiologist Findings Images 20-21

Exposure	mAs	kV	Focal Spot	SI Number	Dosimeter readout	Noise (Y/N)	Acceptable (Y/N)	Radiologist comments
Exposure 20	80	80	Large	165	11.8 mrem	N	N	Image too smooth, detail blurred
Exposure 21	100	80	Large	194	15.0 mrem	N	N	Image too smooth, detail blurred

CHAPTER 6: DISCUSSION

Hypotheses

This chapter includes recommendations and the conclusion of the paper.

Hypothesis 1: Increasing radiation dose is not always necessary during computed radiography pelvis exams.

Given the wide range of acceptable exposures for the pelvis image**,** this hypothesis was substantiated. The hypothesis was validated by the radiologist who accepted all but two images, suggesting the ability to utilize low dose radiation.

Hypothesis 2: SI numbers do not give an actual representation of what is a diagnostic image.

This hypothesis was substantiated. The radiologist‘s interpretation of images clearly demonstrated that relying on a specifically identified range of values to indicate image acceptability is not a good practice. The acceptable range of 200-300 SI rarely occurred during the entire experiment, except for images 1-3 and 19-21. Fifteen images (4-19) were outside of the manufacturer‘s recommendation of acceptable index ranges, yet results demonstrated that when the SI number was out of range, the images were still acceptable for diagnostic purposes.

Hypothesis 3: Some amount of noise on radiographic images is acceptable and diagnosable.

In this experiment, noise was not an overriding factor. Noise did not occur where predicted (lower mAs range). Instead, noise occurred at a much higher increment, but was still deemed acceptable. Images 7-14 had noise, but were acceptable radiographs.

This hypothesis was substantiated by suggesting noise is acceptable at certain exposure levels. This hypothesis was not substantiated in the suggestion that noise would occur at the lowest exposures. Normally, low mAs will not produce enough photons to overcome the inherent noise in the computer system. Thus, the image will appear grainy, or –noisy.” Conversely, at higher levels of mAs, the noise is usually not an issue due to the photon energy compensating for the inherent noise in the computer system. The noise which occurred at much higher mAs could indicate a flux in the CR system. However, the technologists and administrators stated the equipment was working properly, and was within parameters.

Conclusion

The results of the research indicate that a technologist could expose a patient‘s gonadal area to mAs of 20 or mAs of 100, and either one would result in a satisfactory image. The difference would be the amount of radiation to the patient. Dependence on SIs could result in improper radiographic exposures with over-exposure being masked. The over-exposure is not identified as excess radiation because the image –turned out.”

The wide range of exposures is a double-edged sword. The post-manipulation ability of CR allows over-exposed images to be adjusted so as to make the image acceptable. This allows manual compensation for over-radiation. The over-exposed but acceptable image would be repeated at some facilities due to the strict compliance to the SI numbers. The confusion and misunderstanding between technologists, radiologists and system engineers concerning exposures must be eliminated. There must be consistency of radiation exposures to patients with respect to equipment, techniques and SI numbers.

Radiologic technologists have a professional and ethical duty to protect their patients from harm. Training remains the front line defense for the safe practice of radiation protection and is crucial for the technologists, radiologists, and manufacturers of medical radiation equipment. Education is paramount to ensure compliance with protective standards and practices. This training should include updated, equipment specific, quality assurance practices and procedures.

Radiologic technologists are encouraged to increase their knowledge and expertise in these protective practices and policies. Technologists should know institutional policies and practices, and verify that they are in compliance with standards and recommendations set by the ACR and other organizations and agencies. Technologists should be encouraged to use protective equipment and procedures, or held accountable if they do not. In addition, radiologic technologists should hold themselves to a high standard of care and continue to raise that standard by fully protecting themselves and the patients they serve.

One way to assist technologists and students in the pursuit of decreased patient dose is through the utilization of manual technique charts. Technologists measure the patient‘s body part to be imaged utilizing calipers. The technique is set based on the caliper measurement. This measurement and setting of manual techniques can be done for all anatomical parts and body types. While the process of establishing a technique chart based on body measurement can be a daunting task, it is a way to reduce patient overexposure to radiation.

It is also recommended that additional field research would enhance the radiographic findings. Collimation, focal spot size, source to image distance and other variables also contribute to patient safety in regards to radiation exposure. A wider range of equipment could be tested to verify if results are facility specific or equipment specific. Multiple anatomical phantoms could be utilized to determine if the findings are anatomically specific. In addition, other radiologists could evaluate collected images in order to substantiate the initial results. Perhaps on the doctoral level, these additional questions can be submitted, researched, and answered.

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