



The Journal of Global Radiology

ENSURING MEDICAL IMAGING ACCESS FOR ALL

ORIGINAL RESEARCH

Radiology Education and the Quality of Care: Radiation Dose

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DOI: 10.7191/jgr.2020.1077

Published: 7/31/2020

Citation: Foster MRB. Radiology education and the quality of care: radiation dose. *J Glob Radiol.* 2020;6(1):1077.

Keywords: radiology, radiology education, patient care quality, radiation dosage, mAs, kVp, ARRT certification, American Registry of Radiologic Technologists

Word count: 3,464

Abstract

The purpose of this quantitative, quasi-experimental study was to analyze whether the education of radiology personnel mandated by the American Registry of Radiologic Technologists (ARRT) affects the quality of care delivered to radiology patients. One area of radiology quality of care was focused on the findings presented in this study: radiation dosage. Three groups of study participants were used. The participants were chosen and divided into groups based on their radiology background, non-radiology medical background, or lack of medical background. All study participants were required to complete an assessment asking participants what radiation dosage and shields they would use for a standard set of radiographic examinations. A training video was shown to those participants with no radiology background prior to the assessment. The data provided by each group was compared to determine similarities and variances between the groups and ANOVA calculations were completed. Differences were found between the assessments completed by members of all three groups. The results support the perception that ARRT-mandated education does affect radiation dosage chosen in the care of radiology patients.

Introduction

Radiology is a field of medicine that requires the use of ionizing radiation (1). If used improperly, ionizing radiation can cause significant harm to those administering and receiving the radiation (2). Since the discovery of this potential danger, international standards have been created and are constantly updated to ensure safe radiology practices (3). These standards include educational requirements of those practicing in the field of radiology or, as this study reviews, lack of educational requirements (3). This study compared the quality of care delivered by health care professionals in the United States who received ARRT-mandated radiology education to the quality of care delivered by individuals who received on-the-job radiology training.

Danger Revealed

Upon the initial discovery of x-rays, no damaging effects were known (4). X-ray machines became an attraction at traveling circuses and fairs, and were rented for parties (4).

The popularity of Roentgen's x-ray discovery also encouraged other researchers to become acquainted with x-rays and continue researching the phenomenon (1). American inventor Thomas Edison became part of the growing popularity of x-ray by researching the barium platinocyanide, originally used as the fluorescent material (1). Edison investigated the fluorescent capabilities of over 1,800 materials, including the two materials later used for x-ray, zinc cadmium sulfide and calcium tungstate (1). Unfortunately, Thomas Edison's research with x-ray ceased when he became one of the first to discover the damaging effects of x-rays (2). Edison used the hands of his assistant, Clarence Dally, to test the x-ray

capabilities of different fluorescent materials (2). During the testing, Dally suffered severe x-ray burn on both arms that eventually required bilateral amputation (2). Dally died in 1904 and is known as the first fatality because of x-ray in the United States (2). As research continued in x-ray, other fatalities similar to Dally's occurred (1). This eventually led to the recognition that frequent exposure to x-rays could be harmful (1). Knowing radiation causes tissue damage, it was further confirmed that the amount of damage can also be related to the mAs and kVp values, since both of these factors affect the dose and quality of radiation produced (3).

Researchers began investigating how x-rays damage tissues and determined that damage starts at the cellular level (2). As x-rays penetrate tissues, they come in contact with and damage the nucleus of cells where deoxyribonucleic acid (DNA) and genes are contained (5). If the genes are damaged or destroyed, the cell is missing the necessary components needed to develop and function properly (5). Damaged or destroyed genes can cause a cell to die or become mutated and function improperly (5). Some of the noted effects include, but are not limited to, radiation burn, malignancy, and fertility deficiencies (5). The relationship between diagnostic radiation and statistical risk of exposure are direct and many physicians are unaware of this correlation (6). Additionally, those imaging modalities using higher doses of radiation, such as computed tomography, will increase the patient's risk because of the higher diagnostic doses delivered during procedures (6). This supports the previously mentioned finding that the extent of the effect of the x-ray depends on the power of the x-ray (determined by the mAs and kVp) and the strength and sensitivity of the cell (7).

As ionizing radiation deposits energy throughout the tissues, chemical changes are induced that cause a variety of structural changes and breaks in both single and double DNA strands. These changes include but are not limited to hydrogen bond breaks, molecular degradation, intermolecular cross-linking and intramolecular cross-linking. The hydrogen bonds link DNA base pairs and breaking of these bonds can potentially lead to irreversible changes in the molecules structure that can ultimately affect genetic transcription. This damage can potentially lead to two types of effects: stochastic and deterministic. The probability of stochastic effects (such as cancer) occurring are proportional to the dose; however, the severity is autonomous. The severity of deterministic effects (such as infertility) does increase with dose (8).

With the discovery of harmful effects associated with x-ray, leaders in the radiology field decided mechanisms must be developed to maintain safe practices within the field (9). The American Registry of Radiologic Technologists (ARRT) took part in an initiative to maintain safe practices by developing the registry examination, establishing rules and regulations for radiologic technologists to follow, and establishing ethical guidelines specific to radiology (10). The ARRT developed a mission involving maintaining high standards of patient care for radiology services by recognizing qualified

individuals (10). To support the mission, the ARRT adopts and regulates standards for educational preparation prior to entry into the radiology field (10). The ARRT also continues to develop, maintain, update, and administer professional standardized examinations to assess the knowledge and skills of those wishing to enter the radiology profession (10). The ARRT also adapted the ALARA Principle and strictly enforces its use throughout the United States. ALARA stands for As Low As Reasonably Achievable (11).

ARRT Certification

The ARRT developed the certification examinations and competency requirements used to assess the knowledge and skills of those desiring to become radiography professionals (10). The certification examination is updated by the ARRT and includes questions on different areas pertaining to radiography (12). The certification examination currently has four categories: patient care, safety, image production, and procedures (13). In order to become certified, a candidate must earn a minimum score (currently 80) on the examination (14).

The ARRT also requires certain procedures to be competently completed (15). The completion of the competencies must be signed off by an ARRT registered technologist (15). The ARRT constantly updates the competencies based on the examinations ordered most frequently in each separate modality (15).

Certifications can provide validated proof of a person's education and skills, and training in a specific field (16). Maintaining current certifications also signifies the individual's effort to stay updated on the latest standards in regulations in the area of focus through required continued education credits (16).

The establishment of the ARRT, certification examinations, and competencies led to the development of radiologic science educational programs that are designed to educate students on the five areas evaluated by the ARRT examinations and to allow them to complete competencies through clinical rotations (17).

Although the ARRT has established a certification examination and competency requirements for individuals seeking to become Registered Technologists, the United States does not require ARRT certification to perform radiology examinations (18). The United States allows each state to determine how strict the regulations will be to work with radiology equipment and patients (18). Currently, 11 states do not require individuals to be certified to perform radiology examinations (noncertified states): Alabama, Alaska, Georgia, Idaho, Michigan, Missouri, Nevada, New Hampshire, North Carolina, North Dakota, and South Dakota (13).

The options used by the 11 noncertified states include limited licensure and on-the-job training. Limited licensure involves receiving a license to perform a limited scope of

radiologic examinations. For example, an individual working at a podiatrist office can receive a limited licensure stating he or she has been trained on how to perform x-rays involving only the feet and ankles. This type of licensure can be beneficial for offices practicing limited scopes like a podiatry office (19).

On-the-job training is another option used by many medical offices and facilities in the 11 uncertified states. The medical office will choose other medical professionals to receive on-the-job training to operate the x-ray equipment on staff to perform the examinations most ordered by the physicians. Sometimes this training is provided by ARRT certified x-ray technologists, and sometimes the training is provided by another medical professional who also underwent on-the-job training. These individuals may be required to complete competency examinations developed by the individual practice or facility (20).

The training offered during on-the-job training sessions is very brief and vague compared to the ARRT-mandated education and training (21). The two main physical measurements used in radiology, mAs and kVp, are not discussed in detail in most on-the-job training programs (21). Instead, trainees are told that the mAs and kVp correlate with the strength of the x-ray (22). Trainees are told thicker objects and patients will require more mAs and kVp to obtain quality images (22). Dr. W. Edwards Deming emphasized the importance of professional, standardized training versus on-the-job training (23). Deming underlined that new knowledge is best taught by experts in the field of study whose main focus is to teach the materials. Allowing others who only have experience and not textbook expertise to provide training creates opportunities for materials to be overlooked and neglected during training. On-the-job training decreases the quality of education provided to the trainee because an expert is not providing the information and the trainer's main focus is not on providing the trainee with a thorough knowledge of the subject but instead to provide trainees with the main necessities of information. ARRT-mandated education programs educate students on how x-rays are generated, and the calculations involved with determining the proper mAs and kVp to use for limiting the radiation dose (24).

Methods and materials

The aim of this quantitative, quasi-experimental study was to analyze whether ARRT-mandated education has any effects on the quality of care delivered to radiology patients.

Population and sampling

The study included a study population of 75 professional adults living and working in central North Carolina. Study participants included all ages, races, and genders. Study participants were selected randomly and targeted through flyers posted in hospitals, medical facilities, and non-medical public places. Potential participants contacted the head researcher through an e-mail provided on the flyer.

The study sample was divided into three groups based on professional and educational background as it relates to health care and radiology. Each group was required to complete a test containing questions about the mAs and kVp used for a series of common radiologic examinations. A description and photograph were provided of the test subject so that body mass/composition could be considered in the answer choices.

The first group, Group A, included 25 ARRT-certified radiologic technologists. All members of Group A were required to be graduates from ARRT-mandated radiography education programs, have current ARRT certification in radiography, a minimum of one year of experience as a radiologic technologist, and current employment as a radiologic technologist.

The second group, Group B, consisted of 25 medical professionals. The medical professionals were from varying entities within the health care industry except radiology. These individuals were required to have experience as a health care provider without any previous experience in the radiology field. These individuals included medical assistants, surgical technologists, and nurses.

The third group, Group C, consisted of 25 non-medical professionals. These individuals were professionals from different industries and disciplines that had no previous experience or education in the health care industry. These individuals included a high school English teacher, an aircraft inspector, and a police officer.

Data collection

In Group A, each individual radiologic technologist was required to complete the test provided. The test asked each participant to choose radiation doses for four common radiologic examinations: AP chest, KUB, AP knee, and lateral C-spine.

The members of Groups B and C were scheduled to arrive at a local university's campus to watch a 30-minute on-the-job training video. The training video was conducted by an experienced, ARRT-certified radiologic technologist with experience in providing on-the-job radiography training. After viewing the video, Groups B and C completed the same test.

Statistical methods

An analysis of variance test (ANOVA) was completed for each of the four examinations. ANOVA was chosen over a t-test because three data sets were involved, and t-tests are only recommended for studies involving two data sets (25). For each calculation, the mean for each group was used along with the mean square within value (MSw) from the ANOVA test results. Groups B and C were compared to the control group, Group A. The values between all comparisons showed statistical significance except for four data comparisons.

A post hoc Tukey test was also completed to compare the mean values for each exam between the control group, Group A, and the other two groups. The values for Tukey test results for Examination 4's kVp comparison of Groups A and B, Examination 3's kVp comparison of Groups A and B, Examination 2's kVp comparison of Groups A and B, and Examination 1's kVp comparison of Groups A and B showed statistical difference. The data shows both Group B and Group C used a higher mAs than the control group for all examinations. The data also shows both Group B and Group C used a lower kVp than the control group on all examinations.

The calculations were completed in a manner that established an overall mean for each group based on the averages of each individual examination. The standard deviation was also calculated, representing how much inconsistency is found between the numbers. A low standard deviation is desired.

Additionally, the minimum, maximum, mode, median, range, average, standard deviation, and variance for the mAs and kVp chosen for each exam were also calculated. After calculations for each set of data were complete, the results for each group were compared. The calculations used for the main data comparisons were average, standard deviation, and variance.

Results

Data analysis – mAs and kVp: Significant findings

The data for mAs and kVp were collected to test one set of hypotheses. The hypotheses were:

- **H10:** No differences are found in the radiation doses chosen to complete radiography examinations by those who receive ARRT-mandated radiography education and those who receive on-the-job radiography training.
- **H1a:** Differences are found in the radiation doses chosen to complete radiography examinations by those who receive ARRT-mandated radiography education and those who receive on-the-job radiography training.

The ANOVA test results for Examination 1's mAs values and Examination 1's kVp values rejected the null hypothesis. The ANOVA test results for Examinations 2, 3, and 4's mAs values and Examinations 2, 3, and 4's kVp values failed to reject the null hypothesis.

Table 1 presents the post hoc Tukey test results for each of the four examinations.

Table 1. Post hoc Tukey test results for all Examinations: mAs and kVp

EXAMINATION 1 - mAs		EXAMINATION 1 - kVp	
Group A & Group B	Group A & Group C	Group A & Group B	Group A & Group C
1.90	1.50	1.60	1.80

EXAMINATION 2 - mAs		EXAMINATION 2 - kVp	
Group A & Group B	Group A & Group C	Group A & Group B	Group A & Group C
1.40	1.90	0.97	2.00

EXAMINATION 3 - mAs		EXAMINATION 3 - kVp	
Group A & Group B	Group A & Group C	Group A & Group B	Group A & Group C
1.74	1.75	0.04	1.75

EXAMINATION 4 - mAs		EXAMINATION 4 - kVp	
Group A & Group B	Group A & Group C	Group A & Group B	Group A & Group C
0.68	1.97	0.49	1.90

Table 2 shows average mAs values for all groups for all examinations. Table 3 shows the differences between average mAs and kVp values for Group A (control group) and Groups B and C for all examinations.

For each comparison, the average and standard deviation of the four numbers were calculated. For the data sets comparing the average mAs of Group A to Group B and C the standard deviations were 8.64 and 3.62 respectively, which are both acceptable. For the data sets comparing the average kVp of Group A to Groups B and C the standard deviations were 28.45 and 14.97 respectively, which are both higher than desired.

The results comparing the data sets for mAs and kVp for Group A and Group C support hypothesis H1a. The results showed differences in the radiation doses chosen to complete radiography examinations by ARRT-certified radiologic technologists and non-medical professionals who received on-the-job radiography training.

Table 2. Average mAs and kVp values for all groups.

PROCEDURE	mAs			kVp		
	Group A	Group B	Group C	Group A	Group B	Group C
AP Chest	3.76	27.76	22.64	118.12	83.88	80.16
KUB	30.04	38.84	42.12	77.64	73.00	68.12
AP Knee	6.52	19.40	19.64	66.32	66.20	61.04
Lateral C-spine	19.40	23.08	30.00	74.64	13.46	64.40

Table 3. Difference between average mAs and kVp values for Group A to Groups B and C.

PROCEDURE	Difference in average mAs values		Difference in average kVp values	
	Group A vs Group B	Group A vs Group C	Group A vs Group B*	Group A vs Group C*
AP Chest	24.00	18.88	34.24	37.96
KUB	8.80	12.08	4.64	9.52
AP Knee	12.88	13.12	0.12	5.28
Lateral C-spine	3.68	10.60	61.18	10.24

*denotes significant finding

The data analysis process: mAs and kVp

Figures 1 and 2 provide a visualization for comparison of the data for the average, standard deviation, and variance calculations for both mAs and kVp.

The graphs and tables were used to make the final calculations for the mAs and kVp data including the ANOVA calculations. For the ANOVA calculations, the average and standard deviation values for each group on each of the four examinations were compared to determine if the null hypothesis was rejected and, if so, to what degree.

Study limitations

One major limitation of the study is it only involved radiography and medical personnel in central North Carolina. Although North Carolina is a state that does not require ARRT certification, 10 other states also do not require ARRT certification and the data could have different results if medical professionals from those areas had been included.

Validity of the study was limited because dependency was based on the truthfulness of the participant's reporting. Although ARRT-certified technologists could be verified online at the ARRT website, there was no way to know if members of Groups B and C had any radiography background or experience. This fact depended on their truthfulness in responding to the assessment.

Another limitation of the study involved the advantage the members of Group A had over members of Groups B and C based on experience. Although it was known all members of Group A had received ARRT-mandated education, one cannot ignore the work experience these individuals had also received by working in the field. Although the 30-minute on-the-job training video was presented by an ARRT-certified radiologic technologist who had decades of teaching experience, the work experience factor did give them some knowledge advantage over the members of Groups B and C who were seeing the information for the first time during the on-the-job training video. Additionally, it would be impossible to include all information from a degree program in a 30-minute video.

Lastly, although the on-the-job training video provided information that is commonly used by the certified technologist featured in the video, the inability to provide hands-on experience could potentially affect the knowledge comprehension and retention of the members of Groups B and C, especially kinesthetic learners.

Conclusion

The data collected for the set of hypotheses supported hypothesis H1a, showing a difference in the radiation doses chosen to complete radiography examinations by those receiving ARRT-mandated education and those receiving on-the-job radiography training. The ANOVA calculations

Figure 1. Average mAs values for all groups and all examinations along with standard deviation values represented by error bars.

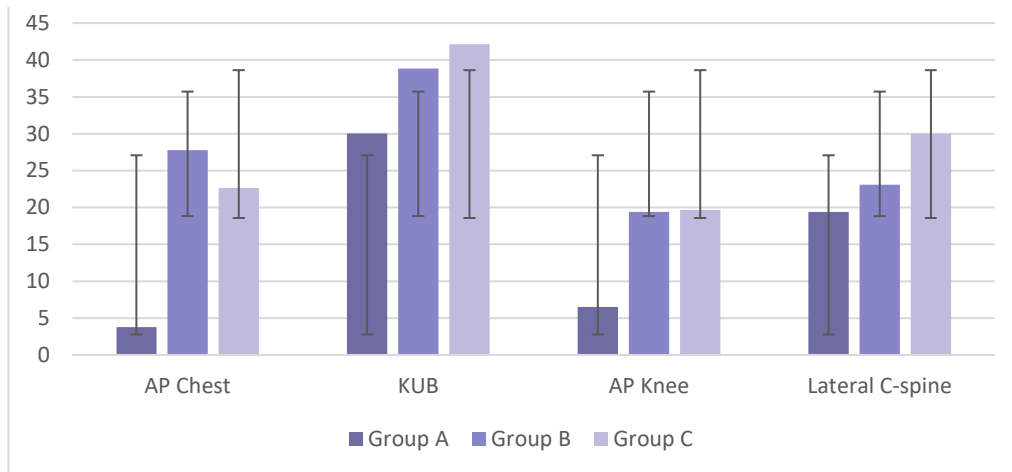
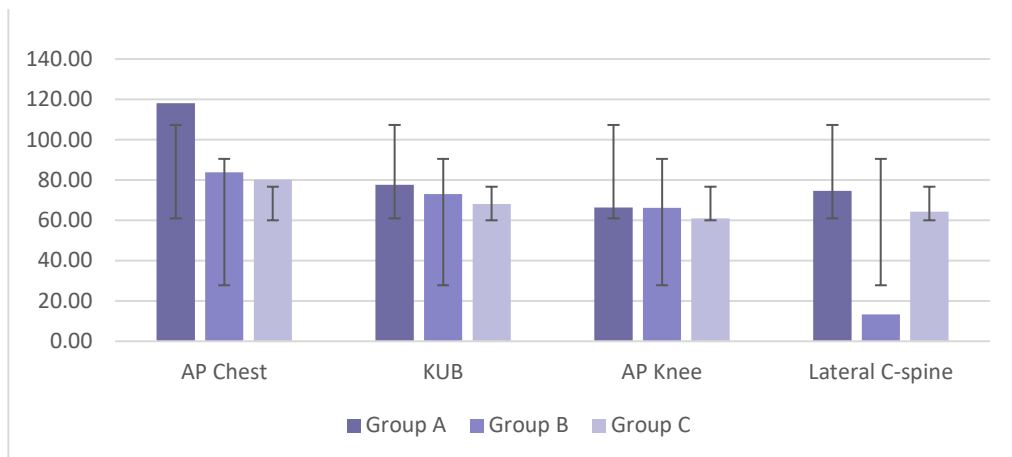


Figure 2. Average kVp values for all groups and all examinations along with standard deviation values represented by error bars.



completed for this data correlated with this finding by resulting in values non-significant for supporting the null hypothesis.

The results of the study implicate differences in the methods used by ARRT-certified technologists and those receiving on-the-job radiography training to complete radiography examinations. The differences found between the three groups were great enough to clearly show differences in the radiation doses chosen and the shielding techniques used.

Implications for leadership would involve the creation of universal operations for all radiography personnel. Another implication would involve the possibility of becoming a certified state. Employees fear change, and fear can cause them to fight new programs and changes being implemented in their organization (26). Explaining the positive benefits employees and patients can receive by requiring ARRT certification is one way that leaders and managers can ease the transition to becoming a certified state.

The requirement of ARRT certification for radiographic technologists is a controversial topic in noncertified states. Health care professionals throughout the noncertified states are divided on whether or not certification should be required. The findings of this study showed differences between the amounts of radiation used by ARRT certified technologists and those receiving on-the-job radiography training.

Acknowledgments

The author wishes to thank Dennis Bowman, for his support, encouragement, and continued reminder of the importance of research focused on quality patient care.

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