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Relationship between Patient Anatomical Thickness and Radiographic Exposure Factors for Selected Radiologic Examinations

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ABSTRACT
The most common cause of errors in radiographic examinations is inappropriate selection of exposure factors, which depends on the patient's anatomical thickness. Inappropriate selection of exposure factors could lead to either underexposed or overexposed radiographs and unnecessary radiation exposure to the patient. The study sought to assess the relationship between patient anatomical thickness and their corresponding radiographic exposure factors used in the selected examinations. Anatomical thicknesses of patients aged 18 years and above, who presented for chest, lumbar spine or pelvis radiographic examinations at the Korle-Bu Polyclinic, from April to May 2014, were measured and recorded using a calliper of least count 0.1cm. The corresponding exposure factors (kVp and mAs) used for each examination were recorded as well as the demographic data of the patients. The study established a correlation between patient anatomical thickness and exposure factors. The results revealed a positive correlation between kVp, mAs and anatomical thickness in almost all the examinations under study. A low-negative correlation between mAs and kVp was recorded for lumbar spine lateral examinations. As mAs increases, kVp reduced marginally.

KEYWORDS: kVp, mAs, anatomical thickness

1.0 INTRODUCTION

The production of high quality radiographs require appropriate positioning of the patient, selection of appropriate exposure factors and control of film processing conditions. These results in a good image quality and an accurate diagnosis of the resultant image (Shanahan, 2007; Spalding, 2003; Moores, 2002).

There is no safe dose of radiation, as in theory it takes only a single photon of particle to cause damage to DNA, resulting in a genetic alteration (Canon, 2010). The International Commission on Radiological Protection (ICRP) recommends the optimization of X-ray imaging in order to reduce radiation dose to patients in compliance with the 'as low as reasonably achievable' (ALARA) principle (International Commission on Radiological Protection [ICRP], 2007).

The selection of appropriate exposure factors based on patient anatomical thickness is one way of avoiding unnecessary radiation exposure to patients. Repeat radiographs pose potential harm to patients because of the unnecessary exposure to ionizing radiation. It is of high significance that cognizance is given on the selection of exposure factors, based on patient anatomical factors.

Whenever a film is rejected, that particular examination is repeated and these repetitions present various concerns, including unnecessary radiation exposure to the patient, increased costs, longer patient waiting time, additional workload for radiographers and reduced X-ray tube life (Andolina & Lillé, 2011).

A number of faults can occur during radiological examinations which are detrimental to the diagnostic value of the radiograph. Therefore, it is important to understand the exposure factors that affect the radiographic image quality.

Studies in Ghana and elsewhere show that the most common cause of poor image quality in radiographs is inappropriate selection of exposure factors (Ofori, *et al.,* 2013; Sheung-Ling et al., 2004; Wilson, 2000). Exposure factors influence and determine the quantity and quality of the x-radiation to which the patient is exposed (Langland et al. 2002).

The recommendation by the International Commission on Radiation Protection that all patients undergoing radiological examinations should be protected against unnecessary radiation (ICRP, 2011) is a laudable one.

In Ghana, generally, radiographers subjectively utilise the build of patients to select exposure factors for radiographic examinations. No objective evidence suggests that a particular exposure factor is set for a particular thickness of patient. Even though most imaging facilities in Ghana have automatic exposure control (AEC) devices, studies show that radiographers still rely on manual selection of exposure factors (Sheung-Ling, *et al.,* 2004; Wilson, 2000; Clark & Hogg, 2003).

Studies on reject analysis showed that approximately 50% of repeats were due to error in choosing exposure factors, resulting in underexposure or overexposure of radiographs In Ghana, it has been reported that the leading cause of repeats/rejects is exposure error, which accounts for 52.0% of the overall causes for film rejection (Ofori, *et al.,* 2013).

Due to the negative impacts of the repetition of radiographic examinations, such as increased radiation dose and waiting time, it is necessary that radiographers pay particular attention to the selection of exposure factors based on the patient's build in order to minimize the radiation effects to patients and staff.

2.0 LITERATURE REVIEW

2.1 INTRODUCTION

The leading contribution to man-made source of public exposure to ionising radiation comes from the extensive use of X-rays in medicine for diagnostic purposes (United Nations Scientific Committee on the Effects of Atomic Radiation [UNSCEAR], 2011). Patient radiation dose from conventional radiographic procedures ranges from 0.1 mSv to 10 mSv, resulting in a collective dose to the population which could be significant (UNSCEAR, 2011).

For diagnostic purposes, the optimisation of exposure involves the relationship of three core aspects of the imaging process which are: choice of radiographic technique, radiation dose to the patient and diagnostic quality of the radiographic image (Commission of the European Communities [CEC], 2002). Exposure parameters influence and determine the quantity and quality of the X-ray beam. The selection of the most adequate radiographic technique to each radiologic examination involves the selection of correct exposure parameters. It is the radiographer's responsibility to adequately select exposure parameters (CEC, 2002).

2.2 CHEST, LUMBAR SPINE AND PELVIS RADIOGRAPHY

The most frequently performed radiographical examination is chest radiography (Baert & Donoghue, 2010). The radiographic technique used for producing radiographs varies with the region of interest. Chest X-ray is an examination which requires high expertise because the entire thoracic cavity has a wide range; from low density air-filled lung tissues to the high density heart and mediastina structures (Coche, *et al.,* 2011). Demonstrating this wide range on a film without loss of detail is one technical challenge that most radiographers face. The high kVp technique is a radiographic technique which employs a tube potential voltage of 100kVp and above for diagnostic radiographic examinations (Carlton et al, 2014). Also, the X-ray beam has sufficient penetration to delineate structures in the denser mediastinum (Coche, *et al.,* 2011). The European Commission (1996) recommends a focus-film distance (FFD) of 180 centimetres for chest-PA examinations. This is recommended to minimize magnification of the heart and the mediastinal structures and also to minimalize radiation dose to patients.

Studies suggest that lumbar spine radiography is associated with the highest entrance skin dose (ESD) values (Visconti, *et al.*, 2013; Fosbinder & Orth, 2011). The abdominopelvic region comprises more soft tissue, as compared to the thorax. Therefore, a lower kVp and an increased mAs is used to accentuate image contrast (Vaden, *et al.,* 2011). The recommended focus –film distance (FFD) for both lumbar spine anterioposterior (AP) and lateral (LAT) is between 100cm-150 cm (European Commission, 1996). According to Brennan, McDonnell and O'leary (2004), increasing FFD from the traditional 100 cm but within the range recommended by the European Commission is an effective method of reducing dose whilst maintaining image quality.

The pelvis is like a cylinder of bone that contains many critical soft tissue structures and organs such as the bladder, the iliac vessels, prostate or vaginal vault, and the rectum (Swiontkowski & Stovitz, 2012). The pelvis also houses the male and female reproductive organs (Zill & Dewar, 2009). Radiography of the pelvis involves exposure of the gonads to ionizing radiation. The European Commission (1996) recommends a peak kilovoltage (kVp) range of 80-100 for pelvis-AP examinations. Also, an FFD between 100cm-150cm is suggested for pelvis-AP examinations when a high film-screen film of nominal speed class 800 is used (EC, 1996).

2.3 EXPOSURE FACTORS

The patient's anatomical thickness and density of body part to be examined affects the required patient exposure dose during radiographic examinations. These factors are determined by the patients (Whaites & Drage, 2013). Also, some factors are determined by the medical staff (radiographer and/or radiologist) in charge. Most factors that affect patient exposure dose also affect image quality. In most instances, when a specific exposure factor is changed, image quality is also altered (Bull, 2005). For example, when milliamperage is altered, the amount of X-rays produced changes, resulting in a change in density in the final radiograph. Also, altering the kVp changes the overall contrast of the final radiograph. Therefore, the objective in setting up most X-ray procedures is to select exposure factors which will provide a sufficient compromise between patient exposure and image quality (Bull, 2005).

During a radiographic examination, the X-ray beam is transmitted through the patient's body. The entrance surface near the centre of the beam receives the maximum exposure (Sprawls, 2008). This due to the fact that the primary X-ray beam has not yet been attenuated by the tissue at this point, and also, that area is exposed by some of the scattered radiation from the body. The amount of surface exposure produced by the deflection of x-radiation (backscatter) depends on the spectrum of the primary beam and the size of the exposed area. For typical radiographic procedures, scattered radiation can add at least 20% to the surface exposure produced by the primary beam (Sprawls, 2008).

The selection of appropriate exposure factors for each X-ray examination is essential to ensure a diagnostic image with minimal patient dose. Exposure Technique chart is used to compile the exposure settings for each specific projection. Exposure technique chart helps to prevent wrongly exposed radiographs and therefore avoid having to repeat exposures (Coumbe, 2008). Due to the variation of patient size, appropriate exposure factors must be selected for specific radiographic examinations and views. (Coumbe, 2008).

A good radiograph should have sufficient density to display anatomical structures, an appropriate level of subject contrast to differentiate among the anatomical structures, the maximum amount of special resolution, and a minimal amount of distortion (Visconti, *et al*., 2013).

2.3.1 MILLIAMPERAGESECOND (mAs)

The milliamperage controls the number of electrons in the electron cloud generated at the filament of the cathode (Sirois, 2012). Altering the mAs alters the overall film density (blackening). Increasing the mA increases the amount of radiographic density because more X-rays are generated and vice versa (Long et al 2012). The mAs should be set to produce a sufficient level of brightness, with black background and an acceptable range of greys (greyscale) in the image. By varying the exposure time, the number of X-rays generated is controlled. Using a longer exposure time allows the electrons more time to cross from the cathode to the anode, thus generating more X-rays (Sirois, 2012). Exposure time and mA are inversely related. As mA increases, the exposure time required to maintain the desired number of X-rays generated decreases (Campeau & Fleitz, 2009)

2.3.2 PEAK KILOVOLTAGE (kVp)

The peak kilovoltage (kVp) is the voltage applied between the cathode and the anode. It is used to accelerate electrons flowing from the cathode toward the anode side. Changing photon energy, by altering the kVp also alters the penetrating ability of the X-ray beam. Increasing the kVp increases the positive charge on the anode. This causes the electrons to move faster, increasing the force of the collision with the target, which produces an X-ray beam with a shorter wavelength and more penetrating power (Slipman, 2008). The kVp setting affects both the image density and the contrast. An increase in the kVp setting improves the penetrability of the X-ray beam through the tissues. If after a radiographic examination, the bone detail is too low or the tissues too white, the kVp must be increased. If however, there is evident of low contrast on a radiograph, with adequate blackening or too much scatter, the kVp must be reduced. Once the dose is deemed adequate, the kVp should be set to compromise between penetration, contrast and scatter (McKinnis, 2013). To improve contrast or penetration but preserve the right level of density, the kVp may be changed and the dose altered accordingly in the opposite direction (White & Pharoah, 2013). A higher kVp value produces a longer scale of contrast and more exposure latitude. Greater exposure latitude allows for more variation in exposure factors, which will still produce a diagnostic radiography (Thali et al., 1998).

The correct kVp setting is determined by the thickness of the part of the body being imaged; thus, the thicker the body part, the higher the required kVp setting, because more penetration is required (Fosbinder & Orth, 2011). The exposure to a specific organ or body part within the direct X-ray beam depends on its proximity to the entrance surface. The scatter exposure to the surrounding tissue is relatively low in comparison to the exposure levels within the primary beam (Jacobson, 2008).

2.4 MASS DENSITY/ TISSUE THICKNESS

Mass density or subject density refers to how closely packed the atoms are in a tissue, that is, the compactness of the structure (Thali, *et al*., 1998). X-ray photon attenuation is increased in dense tissue. Air or gas has the lowest density in the body with bones the highest (Fosbinder & Orth, 2011). Radiographers estimate the density of the tissues that was included in the radiographic field to be imaged. If the estimate is incorrect, the resulting radiograph was incorrectly exposed (Carlton & Adler, 2012).

Sprawls (2008) argues that exposure factors must be adjusted to compensate for different tissue thicknesses. Modern X-ray units have automatic exposure control (AEC) circuits designed to adjust the mAs to compensate for different patient thicknesses. Exposure factors used with portable units must be selected by the radiographer (Fosbinder & Orth, 2011).

In radiography, the automatic exposure control (AEC) is used as an automatic dose-rate (ADR) control. AECs are developed to minimise human error. They measure the amount of radiation required to produce the correct exposure for radiographic examination. It is first necessary to select a kVp that will produce satisfactory penetration of the part to be examined (Hertrich, 2005). Once the kVp is selected, either the radiographer or a photo timer must select the mAs that will produce a proper exposure. The goal is to produce a satisfactory radiograph with each attempt, and to reproduce this radiograph reliably each time another examination is required.

2.5 HALF-VALUE LAYER

The half-value layer (HVL) is defined as the amount of material required to reduce the X-ray beam intensity to one-half its original value (Khan, 2012). The HVL is affected by the amount of peak kilovoltage (kVp) and filtration in the beam (Dendy & Heaton, 2011). Twice the thickness of material does not produce twice attenuation because the average energy of the X-ray beam reduces as it passes through the body (Ghom, 2008). The lower energy, less penetrating X-ray photons are removed from the beam so the exit beam is more penetrating and has a higher average energy than the entrance beam (Fosbinder & Orth, 2011). This removal of "soft" X-ray photons results in hardening of the beam, which increases the ability of the X-ray photons to penetrate tissue (Dowsett et al. 2006). The HVL describes the X-ray beam quality or penetration of the beam. More penetrating X-ray beams have greater HVLs (Fosbinder & Orth, 2011).

3.0 METHODS

3.1 Study Design

The study was a quasi-experimental study which involved the measurement of the thickness of patients and therefore involved data from an environment which is similar to laboratory settings. This study design was utilised to investigate the influence of patient anatomical thickness on the selection of radiographic exposure factors.

3.2 Study Site

This study was carried out at the Polyclinic unit of the Korle-Bu Teaching Hospital. The hospital is the leading national referral centre in Ghana and also serves patients from neighbouring countries.

3.3 Sample size and Sampling Technique

The study included patients, 18 years and above who presented at the x-ray unit for chest, lumbar spine and pelvic x-ray examinations between April and May, 214. A non-probability convenient sampling method was used because of lack of an appointment system at the X-ray department. Data on 150 patients with who presented for the various examinations and corresponding exposure factors were measured and recorded. The number was selected conveniently due to lack of knowledge on the number of patients who present at the department for radiographic examination and also due to the limited time for the study.

3.4 Patient physical measurements

The thickness of the anatomical part under examination (in meters), gender, age (years), mass (in kilogram), height (in meters) and radiographic exposure factors (kVp and mAs) were the information gathered and/or recorded. A calliper of a minimum count of 0.1 cm was used to measure the anatomical thickness of the body part under examination. A tape measure, mechanically attached to the collimator box of the equipment, with minimum count 0.1cm was used to measure the focus-film distances (FFD). All FFD measurements were from the center of the X-ray tube to the table top. The anatomical thickness of the patient for each projection was measured at the following anatomical levels:

- Chest-PA projection: at the level of inferior angle of the scapula from the back to the same level in the anterior side of the body.
- Lumbar spine-AP projection: at the level of lower costal margin anteroposteriorly.
- Lumbar spine lateral projection: at the level of the lower costal margin from side to side of the patient.
- Pelvis-AP projection: at the level of the anterior superior iliac spines anteroposteriorly (Ofori, *et al.*, 2012a; Ofori, *et al.,* 2012b).

The selection of the above examinations was based on their frequencies and contribution to the collective dose to the population. In particular, chest-PA was included because it is the most frequent X-ray examination; pelvis-AP because during this examination critical organs that contribute to effective dose are irradiated; lumbar spine, particularly the lateral projection, was included in this study because literature has shown that it is associated with higher entrance surface dose (ESD) values than all other X-ray plain film examinations (Visconti, *et al.,* 2013; European Commission, 1999). The selected projections were posteroanterior (PA) for chest examinations; anteroposterior (AP) projection for lumbar spine and pelvis examinations and lateral (LAT) for lumbar spine examinations.

3.5 Inclusion & Exclusion criteria

All patients aged 18 years and above who presented for chest, lumbar spine or pelvic xray examinations were included in the study. Patients below age 18 years and those who refused to give informed consent were excluded from the study.

3.6 Data Analysis

Data collected from the study were analysed using the Statistical Package for the Social Sciences (SPSS) version 20. The statistical dependence between patient anatomical thickness and radiographical exposure factors was measured. The scales of measurement adopted in this study included nominal, interval and ratio. This enabled the use of inferential and descriptive statistics for the data analysis. The results were presented pictorially in the form of graphs and tables to aid in data summary.

4.0 RESULTS ANALYSIS AND DISCUSSION

A total of one hundred and fifty (150) participants were recruited for the study. Two hundred (200) projections with various radiographic exposure parameters were taken and recorded.
More females (60.7%) participated in the study than males. The average age of the participants was 43.05 ± 13.49 years. The females on the average, had higher body mass index from all the anatomical areas measured than their counterpart males. Also all the females had on the average, higher anatomical thickness than their counterpart males except for the lumbar spine lateral projection.

The highest mean kVp (107.60) was recorded for chest PA whereas the lowest (57.12) was recorded for lumbar spine AP. On the contrary, lumbar spine lateral and chest PA projections recorded the highest (51.33) and lowest (3.92) mean value of mAs respectively.

Pearson's correlation between patient anatomical thickness, tube potential (kVp) and mAs for the various projections were analysed.

The higher number of females than males reflects the demography in Ghana where females constitute about 51.2% of the population (Ghana Statistical Service, 2012). The mean BMI for all the participants was 28.48 ± 5.06 kgm^{-2}, which indicated overweight according to the WHO classifications (World Health Organisation [WHO] Classification, 2004).

4.1 Tube Potential And mAs

The study revealed a high kVp technique was used for chest-PA examinations with the view of reducing contrast between lung-fields and mediastinum on the film. This finding confirmed the study by Coche *et al*. (2011) which argued that there was the need to use high kVp technique for chest-PA examinations in order to reduce radiation dose to the patient.

The study further showed that an average kVp with a higher mAs technique was used for lumbar spine-AP and lateral examinations, as well as pelvis-AP procedures (Table 1.0). The application of these exposure parameters was as a result of the abdominopelvic region consisting of more soft tissues, hence the requirement of a lower kVp to improve image contrast. The higher kVp and mAs observed in lumbar spine lateral examinations, as compared to lumbar spine-AP was due to the increased attenuation from the increased body thickness in the lateral region of the human body as discussed by Gyekye *et al*. (2013).

It was observed that the mean kVp used for pelvis-AP examinations was far below that recommended by the European Commission (1996) and this might be due to the screen-film combination (speed class 400) used for the pelvis examinations. The outcome further could be due to the fact that the corresponding mAs used for the respective pelvis examinations was higher than recommended by the European Commission (1996).

4.2 *Relationship between tube potential (kVp), mAs and Patient Anatomical Thickness.*

The findings indicated that, for all four projections, there was a positive significant relationship between kVp and anatomical thickness, such that, as anatomical thickness increased, kVp increased. The positive correlation between tube potential voltage and patient thickness was due to the fact that thicker patients required more energetic X-rays to penetrate to form a good quality diagnostic image. Fosbinder and Orth (2011) highlighted that the utilisation of kVp depends on the patient's anatomical thickness. The results revealed that there was a positive relationship between kVp and mAs such that, as mAs increased, kVp is also increased. This was evident among all the projections except lumbar spine lateral projection. This means that, for increasing body part thicknesses, both kVp and mAs are increased. An increased body thickness required more penetrative (kVp) and higher quantity (mAs) of X-rays.

However the results revealed a low-negative correlation between mAs and kVp used for lumbar spine lateral examinations. As mAs increases, kVp reduced marginally. This is not in agreement with the assertion that both mAs and kVp should be utilized in relation to increased body thickness, and hence, should vary directly to each other.

The study also indicated a high positive relationship between mAs and anatomical thickness for chest-PA, lumbar spine-AP and lateral examinations. The mAs controls the quantity of X-rays emitted from the X-ray tube and hence, the radiation transmitted through the patient. Therefore, the density of the resultant radiographic image depends directly on mAs (Long, *et al.,* 2012). The selection of mAs is influenced by the patients' anatomical thicknesses. However, there was a low positive correlation between mAs and anatomical thickness for pelvis-AP examinations. This could be due to the fact that the gonads are very sensitive to radiation, hence the need to reduce the mAs.

Also, the study showed a positive correlation between kVp and anatomical thickness for all four projections.

Both kVp and mAs depends directly on anatomical thickness. There was generally varied positive correlation ranging from low to high among the various parameters. However, with the exception of the relationship between mAs and anatomical a high positive correlation(R=0.876) was recorded between mAs and anatomical thickness for lumbar spine-AP examinations. The varied level of correlation among the parameters was due to the fact that mAs and kVp also depends on the density of body part being examined. Tissue density varies directly proportional to tissue thickness. However, two tissue thicknesses may have different densities. For example, tissue 'A' may have the same tissue thickness as tissue 'B', but different tissue density. For instance, tissue 'A' may comprise predominantly muscle, whereas tissue 'B' contain fat. The attenuation of one cm of muscle is greater than the attenuation of one cm of fat. Therefore, tissue 'A' would require more penetrative and higher number of X-rays, in order to obtain a quality diagnostic image, whereas tissue 'B' would require a relatively low mAs and kVp.

5.0 CONCLUSION

Patient anatomical thicknesses and their corresponding radiographic exposure parameters were measured and recorded. All patients were aged 18 years and above, hence the study can be deemed applicable to adult patients. The relationship between anatomical thickness and exposure factors were assessed. The study showed that, regarding the exposure factors used for radiological examinations, there was a correlation among kVp, mAs and anatomical thickness. Generally, there was a positive correlation between kVp, mAs and patient anatomical thickness for all the projections understudied. However, a low-negative correlation was recorded between kVp and mAs for lumbar spine lateral projections.

6.0 LIMITATIONS

1. The study was restricted to a small sample size due to limited study time.
2. Also, only four body part projections were assessed in this study, with different correlation coefficients and significant values, hence the findings may not be generalised to include other body parts.

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Table 1.0: Descriptive statistics for kVp and mAs per projection

Examination	n	kVp				mAs				FFD(cm)
		Min	Max	Mean	SD	Min	Max	Mean	SD	
Chest PA	50	102	117	107.60	5.01	2.30	6.70	3.92	1.14	180
Lumbar Spine AP	50	57	60	57.12	0.59	13.00	57.90	39.81	15.71	100
Lumbar Spine LAT	50	57	66	62.70	1.84	20.20	58.60	51.33	12.29	100
Pelvis AP	50	52	66	59.02	5.00	13.60	58.00	33.42	15.13	100

Table 1.1: Correlation between anatomical thickness(m), kVp and mAs

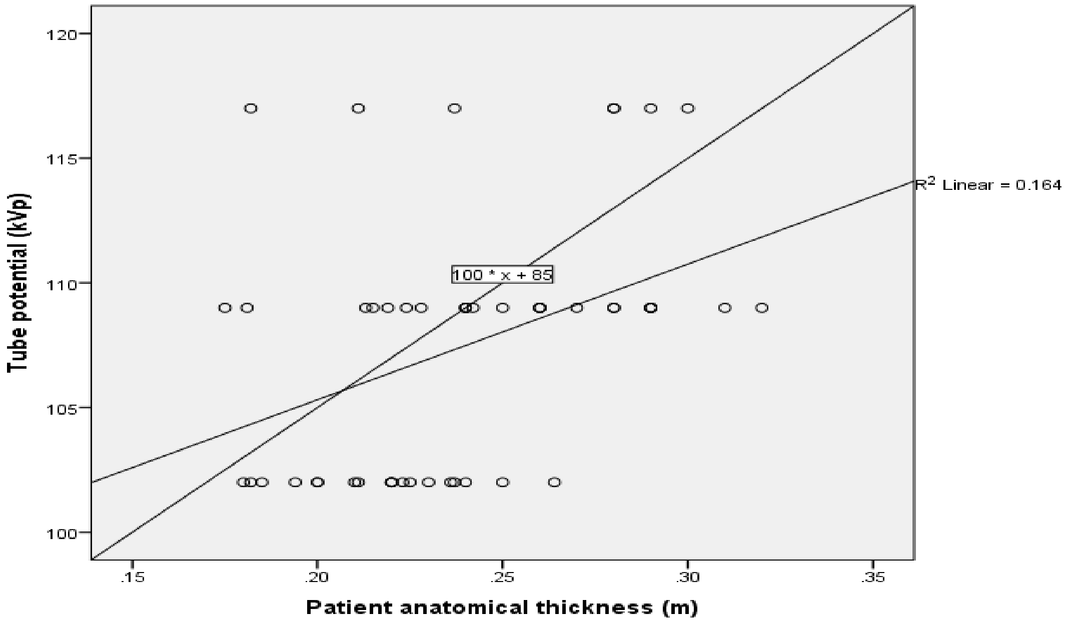
Variables	**Chest-PA**		**Pelvis-AP**		**Lumbar-AP**		**Lumbar lateral**	
	R Value	P-value	R value	P-value	R value	p-value	R value	p-value
Anatomical thickness(m) (kVp)	0.404 MPC	0.004	0.424 MPC	0.002	0.342 MPC	0.015	0.472 MPC	0.001
Anatomical thickness(m) and mAs	0.539 HPC	0.001	0.103 LPC	0.475	0.876 HPC	0.097	0.488 MPC	0.540
Tube potential (kVp) and mAs	0.284 LPC	0.045	0.379 MPC	0.007	0.237 LPC	0.000	-0.089 LNC	0.000

The table above shows a generally positive correlation from low to high among the measured variables. A low-negative correlation was recorded between kVp and mAs for lumbar spine lateral projection.

HPC- high positive correlation *MPC- Medium positive correlation*

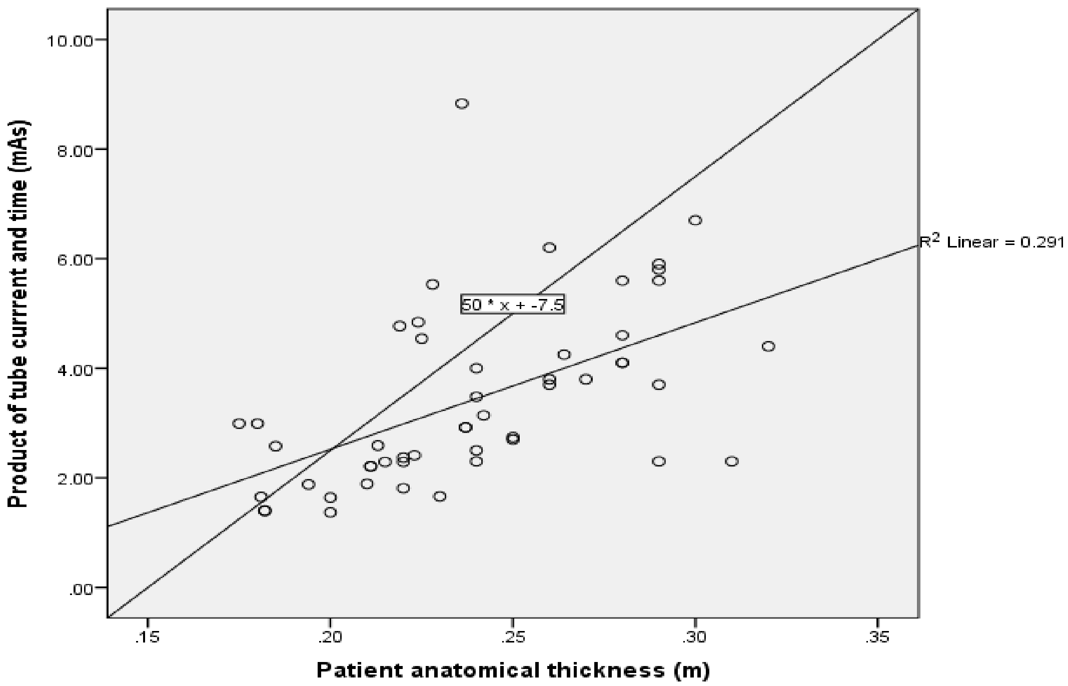
LPC- Low positive correlation *LNC- low negative correlation*

Figure 1.0: Scatter plot for kVp and anatomical thickness for chest PA examinations



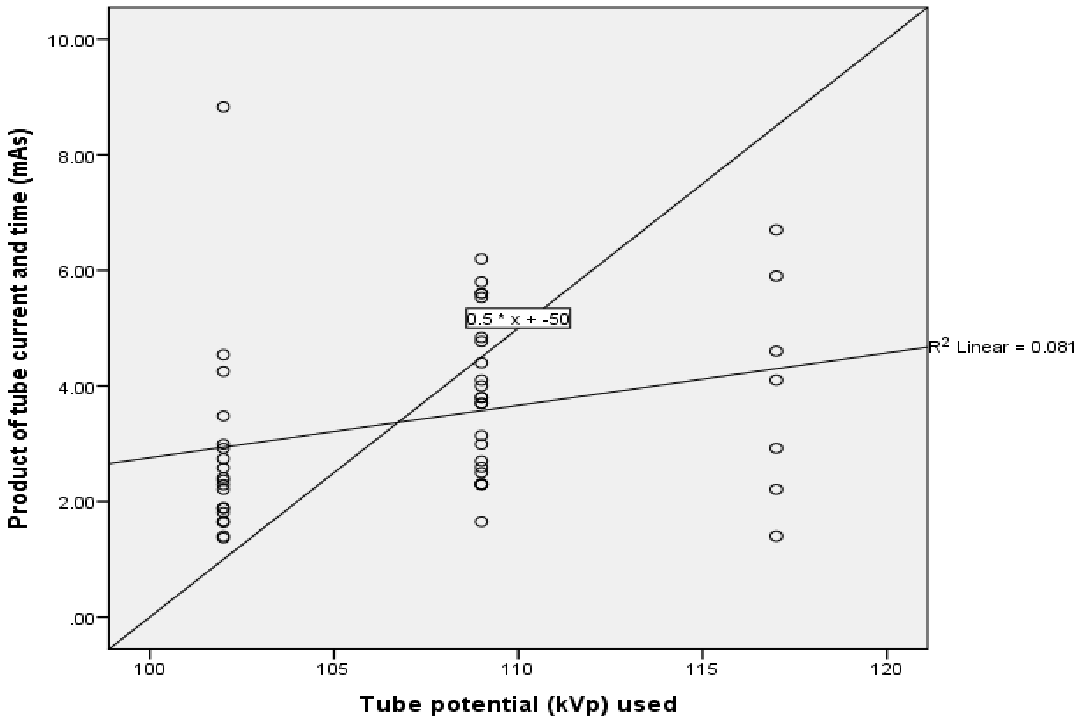
A medium-positive correlation (R) of 0.404 was recorded between kVp and anatomical thickness for chest PA projection.

Figure 1.1 Scatter plot for mAs and anatomical thickness for chest PA examinations



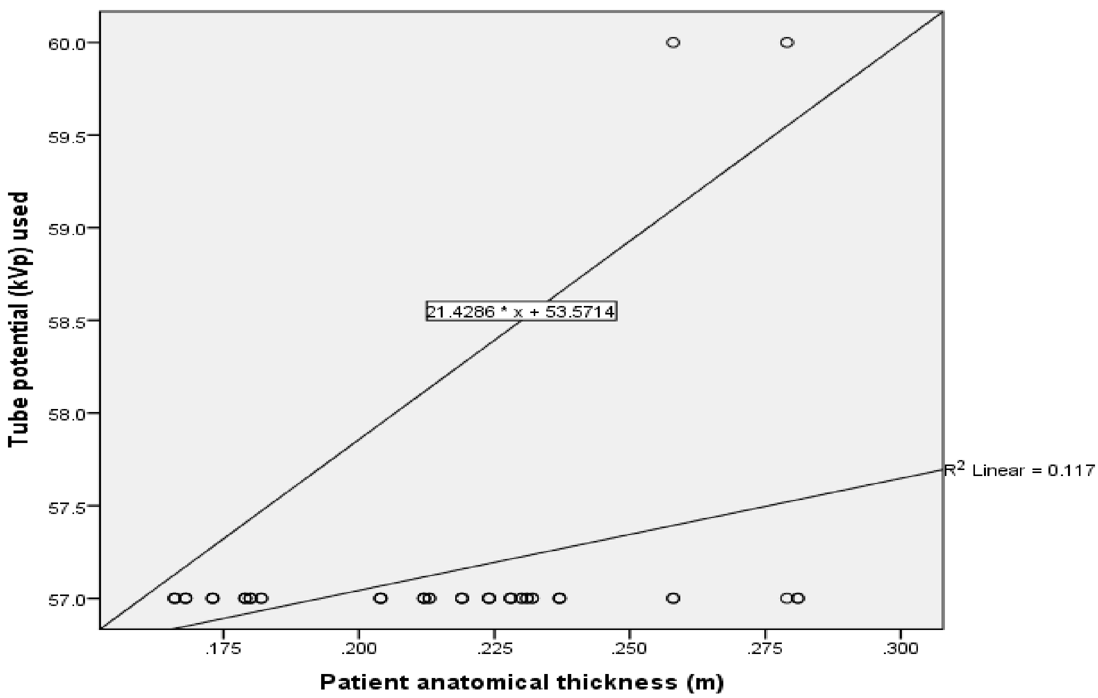
A high-positive correlation (R) of 0.539 was recorded between mAs and anatomical thickness for chest PA projection.

Figure 1.2: Scatter plot of mAs and kVp for chest PA examinations



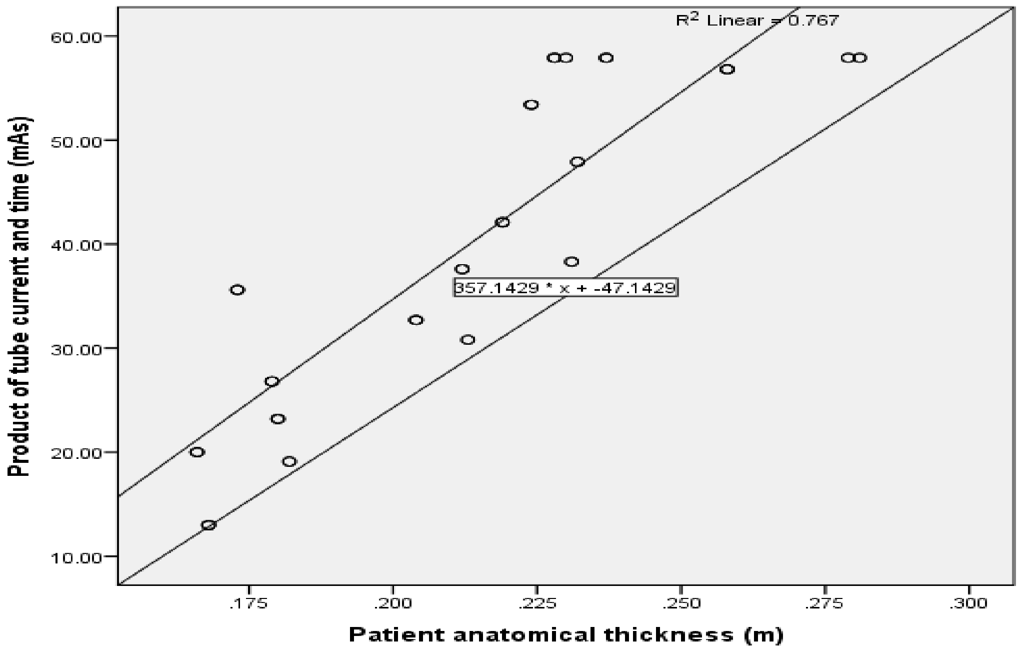
A low-positive correlation (R) of 0.284 was recorded between kVp and mAs for chest PA projection.

Figure 1.3: Scatter plot for kVp and anatomical thickness for lumbar spine AP examinations



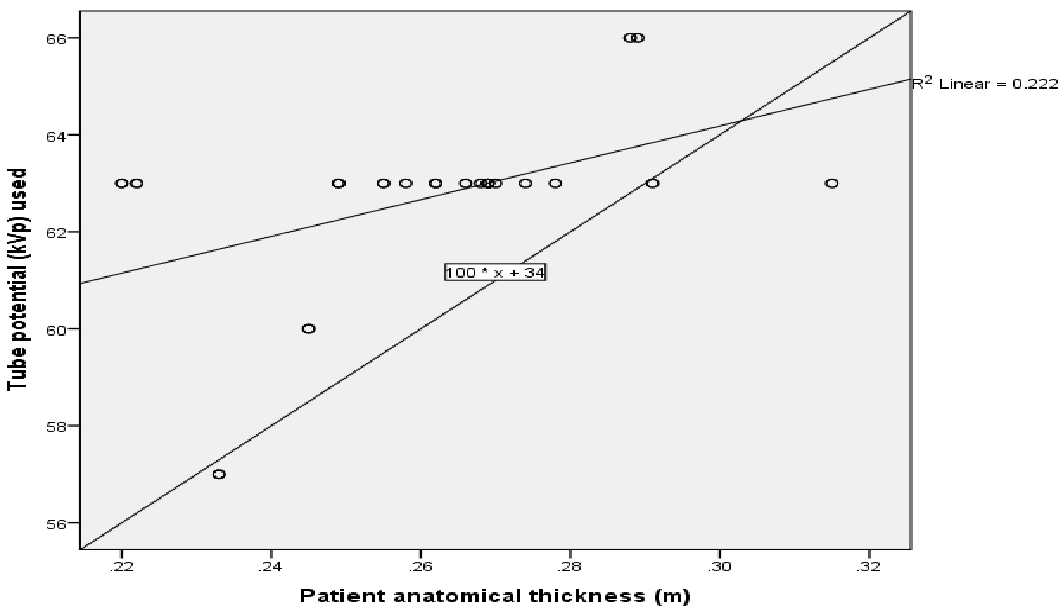
A medium-positive correlation (R) of 0.342 was recorded between kVp and anatomical thickness for lumbar spine AP projection.

Figure 1.4: Scatter plot for mAs against anatomical thickness for lumbar spine AP examinations



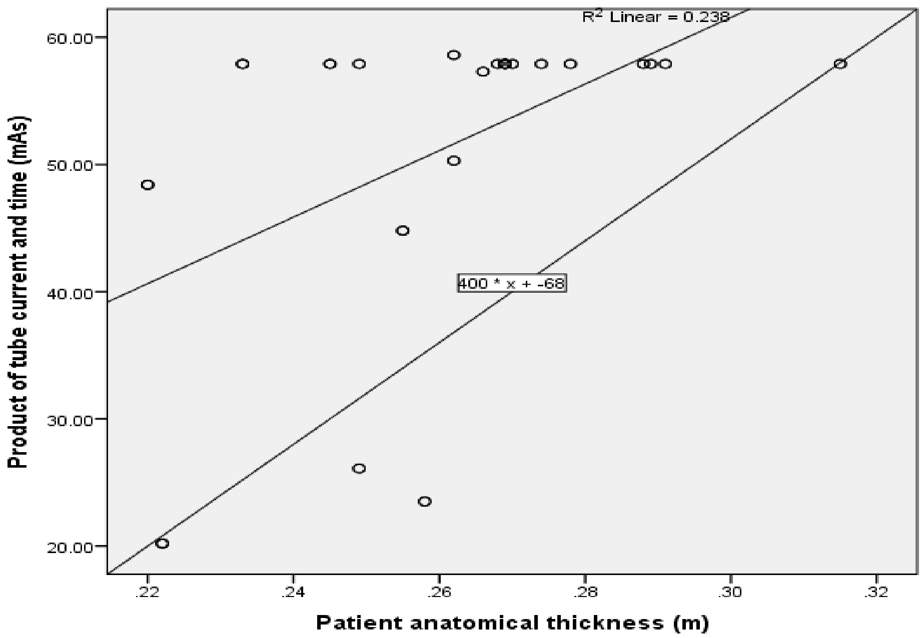
A high-positive correlation (R) of 0.876 was recorded between mAs and anatomical thickness for lumbar spine AP projection.

Figure 1.5: Scatter plot for kVp and anatomical thickness for lumbar spine lateral examinations



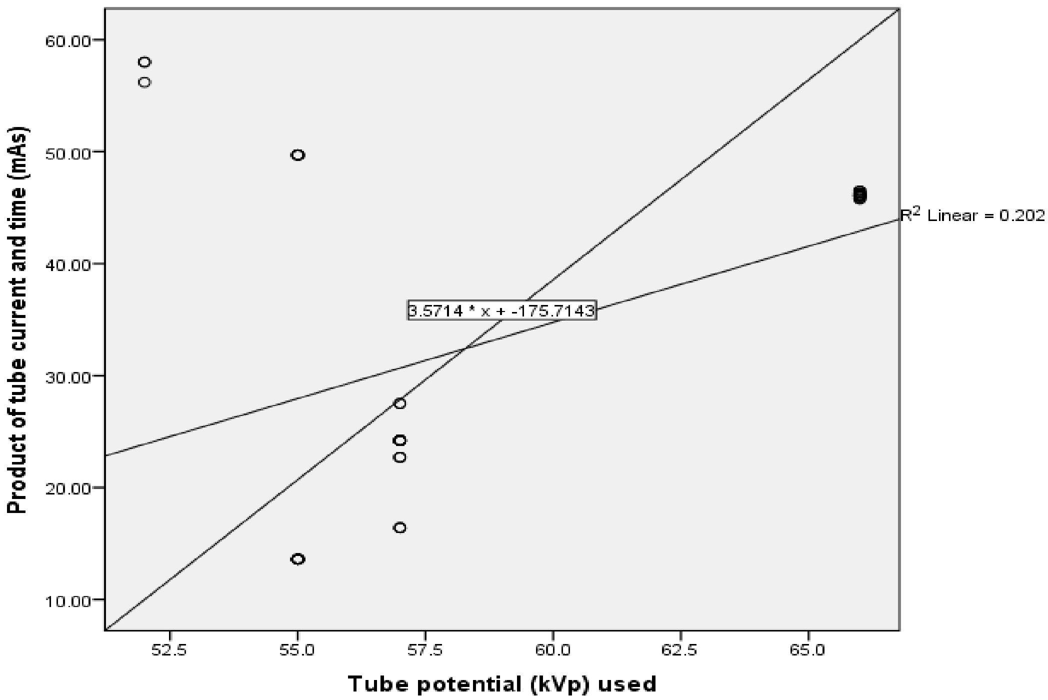
A medium-positive correlation (R) of 0.472 was recorded between kVp and anatomical thickness for lumbar spine lateral projection.

Figure 1.6: Scatter plot for mAs and anatomical thickness for lumbar spine lateral examinations



A medium-positive correlation (R) of 0.488 was recorded between mAs and anatomical thickness for lumbar spine lateral projection.

Figure 1.7: Scatter plot for mAs against kVp for pelvic AP examinations



A medium-positive correlation (R) of 0.379 was recorded between kVp and mAs for pelvic projection.

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