INVESTIGATION OF DIFFERENT EXPOSURE SETTINGS FOR IMAGE QUALITY AND ENTRANCE SKIN DOSE

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ABSTRACT

Introduction: The ideal imaging system that is providing a good quality image of minimal radiation dose. There are many parameters that influenced image quality and radiation dose on clinical radiography. This study has identified some of the problems whereby there are practitioners do not select the proper size of image receptor (IR) and collimation during the examination. The re-usable of the IR and imaging plate also need to be concerned whether multiple exposures may affect the image quality or not. The purpose of this study is to investigate the effect of different exposure settings; kVp, mAs, collimation field sizes and different IR' sizes for image quality and radiation dose. **Methods:** The wall-mounted x-ray machine act as a sources of radiation which exposed the acrylic cylinder that placed over the IR. The examination is repeated with different kVp, mAs, collimation field sizes and IR's sizes. The source to image distance (SID) is fixed to 100 cm distance and put Nano dot dosimeter similar level with the top of acrylic to measure the dose. The result analysed by using software ImageJ to measure the Contrast to Noise Ratio (CNR). **Results:** The percentage of CNR1 and CNR2 reduced as the kVp is increased from (CNR1=77.25, CNR2=64.45), (CNR1=73.47, CNR2=61.22) and (CNR1=62.80, CNR2=57.32) for 50 kVp, 75 kVp and 100 kVp respectively and fluctuate when mAs increased. The CNR and entrance skin dose (ESD) shows higher when x-ray beam collimate according to IR's size. **Conclusions:** Overall, the manipulative effect of exposure settings on image quality and ESD shows some positive results. The result also shows inconsistent readings in the CNR and ESD. The percentage of CNR decreased when kVp increases and slightly fluctuate when mAs increased. The ESD reading depicts higher when the kVp and mAs increase as well as when x-ray beam collimated according to IR's sizes.

KEYWORDS: Entrance skin dose, Image quality, Contrast-to-Noise Ratio, collimation

INTRODUCTION

The ideal imaging system that is allowing a better quality image of minimal radiation dose. Each x-ray machine and equipment need to be monitored periodically under QA and QC to ensure it operated at optimum level. Jones et al, (2015) explained that, QA is simply understood as a process to prevent flaws in products or deliverables while QC is the process to identify flaws in the products. In the computed radiography (CR) system, technological solutions for data acquisition consist of imaging receptor with imaging plates (Photostimulable phosphor –PSP), CR reader, and workstation with monitors to display digital images. There are several tests should be done in ensuring image quality for CR imaging receptor, including CNR (Oborska-Kumaszyńska & Wiśniewska-Kubka, 2010).

The selection of parameter and technical settings affect the amount of radiation experienced by the patient as well as image quality (Huda & Abrahams, 2014). Some of the radiographer or physician does not use a proper selection of image receptor size, which is not suitable for the region of interest (Pongnapong, 2005). For example, during peak hours, the IR are running out and the radiographer tends to use larger imaging receptor to examine the extremities such as wrist or hand, but using smaller collimation according to the anatomy of interest. This is to ensure the workflow is run smoothly in the department.

Some radiographer does not practice radiation protection by inadequately collimate x-ray beam during the procedure. According to the study done by Okeji et al. (2010) stated that, about 52% and 59% of the radiographs evaluated in the teaching hospitals and specialist hospitals depicted inadequate collimation. The percentage of poor beam collimation in lumbosacral x-rays is 55.6%, which the highest reported. Pongnapang (2005) explained that, when proper collimation do not practice in lumbosacral examination, the image KUB will be made. Thus, image processing will eventually fail to process because the input information is different. Therefore, poor collimation also give high unnecessary radiation exposure to the patient.

The CR image receptor and imaging plate is reusable (LeBlanc, 2015). It is mean that, the similar imaging receptor and imaging plate can be re-used for multiple times and multiple exposure to examine the body part of interest in clinical radiography. The CR reader will erase the IR allowing them to be used for the next exposure. Hence, this study tends to measure whether the consistency of image quality produced by that image receptor is affected or not (either maintained or reduced) after multiple exposure.

The main objective of this study is to investigate the manipulative effect of image quality and ESD with different exposure settings; kVp, mAs, collimation field sizes and three different size of image receptors, and to measure the Contrast to Noise Ratio (CNR) and ESD for acrylic block on the CR system with different exposure settings.

The hypothesis of this study that there should be a significant effect of the image quality and ESD when different exposure settings (kVp, mAs, collimation field sizes and IR's sizes) being used.

METHODS

Figure 1 below shows how the materials and equipment is setup. The x-ray tube of wall mounted x-ray machine is used as a source of x-ray beam. The smallest (18×24cm) imaging receptor is being placed on the top of x-ray table and aligned the x-ray tube perpendicular with the IR on the table. Then adjust height to 100cm source of image distance (SID) from IR by using measuring tape. The cylindrical acrylic block is then placed at the centred of the IR and central ray. Collimate the x-ray field to 13 cm × 13 cm to the IR surface. Then, Nano dot dosimeter is being placed similar level with the top of the acrylic cylinder to measure the ESD throughout the experiment. Make sure that the Nano dot dosimeter is held firmly using adhesive tape to maintain the correct positioned and give acceptable results. After set up all the materials and equipment, exposed the cylindrical acrylic block with 50kVp and 4 mAs and read the Nano dot dosimeter.

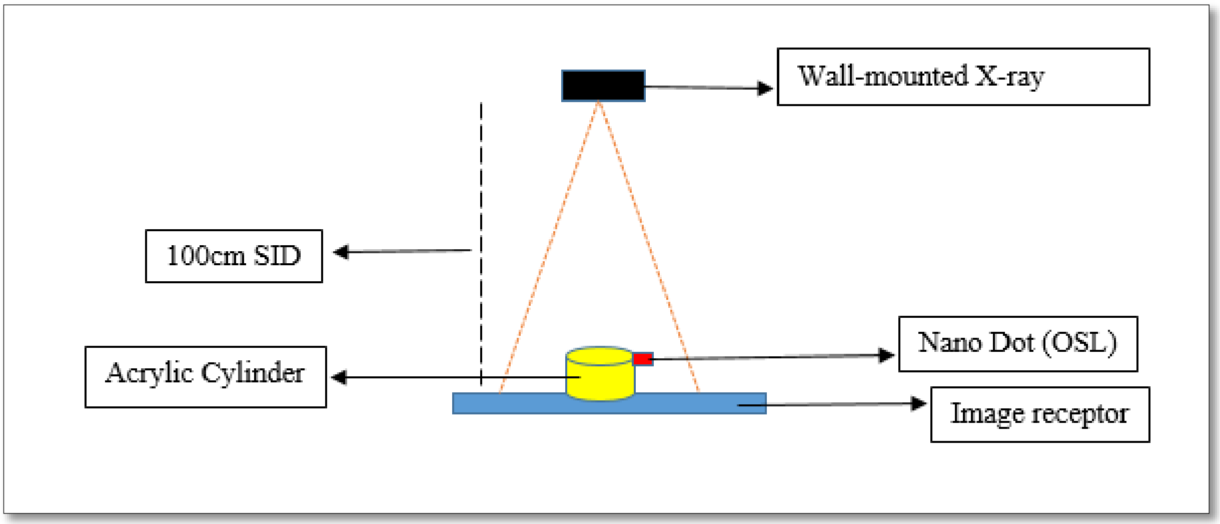

Figure 1. *The materials and equipment is setup.*

Then, replaced the IR with the different size of IR (24×30cm and 35×43 cm) with similar exposure setting (kVp, mAs). The different size of IR used to evaluate the consistency of the image produced on the different IR's size as well as dose with given exposure setting. The procedure is repeated with different exposure in Table 1, on three different size of imaging receptors. All three sizes of image IR is fixed which are (18×24) cm with a bar code (A49948462C), 24×30 cm (A49648140C) and 35×43 cm (A51036195C). Noted the bar code so that, the similar IR is being used and prevent from by picking others IR. The imaging receptors are from similar vendor which is Carestream/Kodak. This is to confirm whether image quality is showed better in small IR or not. By using previous exposure factors (kVp, mAs), repeat the examination with the collimation field size according to IR's sizes.

Table 1. The exposure kVp and mAs used during the experiment.

mAs	kVp
4	75
	100
8	50
	75
	100
12	50

	75
	100

Data Analysis

The image grayscale or (CNR) is analysis by using ImageJ software and doing graph by using the Microsoft Excel. The percentage of CNR is measured by the following equation:

Contrast-to-Noise Ratio (CNR) (%) = $\frac{y}{x} \times 100\%$ (Equation 1)

The CNR is to measure the differences in signal intensities between the object (acrylic cylinder) to the background image. The data then is recorded in the table.

The ESD also been evaluated during exposure indirectly by placing the dosimeter same level with the object. The size of dosimeter is equal to 1cm^2. The reading of ESD at point source need to be calculated by using the equation 2 to measure the ESD according to collimation field sizes.

Entrance Skin Dose (mGy) = $\frac{Collimation\ Field\ sizes\ (cm^2)}{1cm^2} \times OSL\ reading\ (mGy)$ (Equation 2)

RESULTS AND DISCUSSION

Image quality

Image quality is very important in medical imaging in order to provide accurate diagnosis. There are many factors that need to be considered to evaluate the image quality of the radiograph. One of them is Contrast to Noise Ratio (CNR). CNR is defined as the differences of X-ray beam intensity relative to the background image (Nadzri, 2011). A good CNR able to differentiate the grayscale boundaries between object and the background image clearly. The ability of visual detection of an object in an image also depend on the Contrast to Noise Ratio (CNR).

CNR in relation to increase kVp

The tube voltage is functioning in controlling the energy of the x-ray beam striking the target for any given mAs. Figure 2 shows the relationship between CNR and kVp. The 13×13cm collimation, 4 mAs and small IR size are kept constant. From the Figure 1, the bar chart shows the percentage of CNR1 and CNR2 reduced as the kVp is increased. The percentage of CNR1 and CNR 2 for 50 kVp, 75 kVp and 100 kVp are (CNR1=77.25, CNR2=64.45), (CNR1=73.47, CNR2=61.22) and (CNR1=62.80, CNR2=57.32) respectively.

As mentioned by the Vladimirov (2010), the sources of energy and physical properties of the imaged object are affecting the image contrast. According to the study by Huda & Abrahams (2015) explained that, increasing tube potential or kVp will reduce the CNR of the resulting image due to scatter radiation. In addition, this is may be because increase kVp caused increased the amount of scattered radiation due to the Comptom effect which predominates at higher energies (Radiology Key, 2016). Scattered radiation is one of the major factors that reduce the sensitivity of contrast and degrade image quality in x-ray imaging. Thus, increasing kVp should be used together with small collimation to improve image contrast.

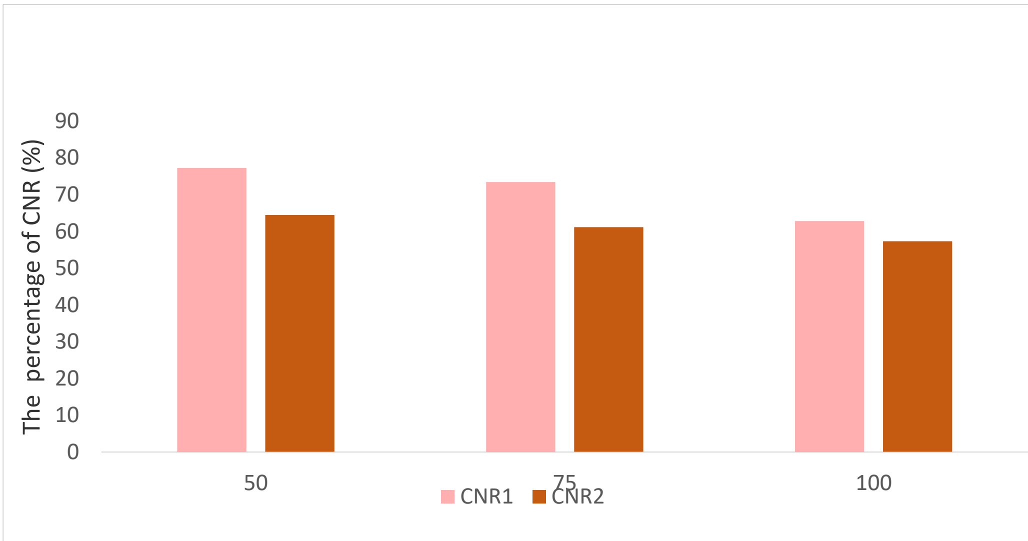

Figure 2. *The relationship between the CNR (%) with increasing kVp.*

CNR in relation to increase mAs

Milliamperage-seconds or mAs is defined as the quantity or amount of the x-ray photon given during exposure. When mAs increases, the number of x-ray photons and image density also increased (Carlton & Adler, 2013). Figure 3 depicts the percentage of CNR is slightly fluctuate when mAs is manipulated while other exposure settings are constant. The percentage of CNR1 and CNR2 for 4 mAs, 8 mAs and 12 mAs are (CNR1=77.25, CNR2=64.45), (CNR1=67.45, CNR2=63.12) and (CNR1=73.36, CNR2=68.69) respectively.

The product of tube current and exposure time or mAs is less direct effect to the image contrast because it will alters the image density, therefore affects contrast. The fluctuation of the CNR may cause by other parameters such as collimation field sizes or inconsistency of the x-ray system, resulting in the fluctuation of x-ray photon and energy. Hence, do not depend on the exposure settings (kVp and mAs) selection solely and ensure x-ray machine undergo a quality control. The equipment need to undergo some quality control so that the diagnostic value of the image is maintained as well as minimum radiation dose (Lessa, 2008).

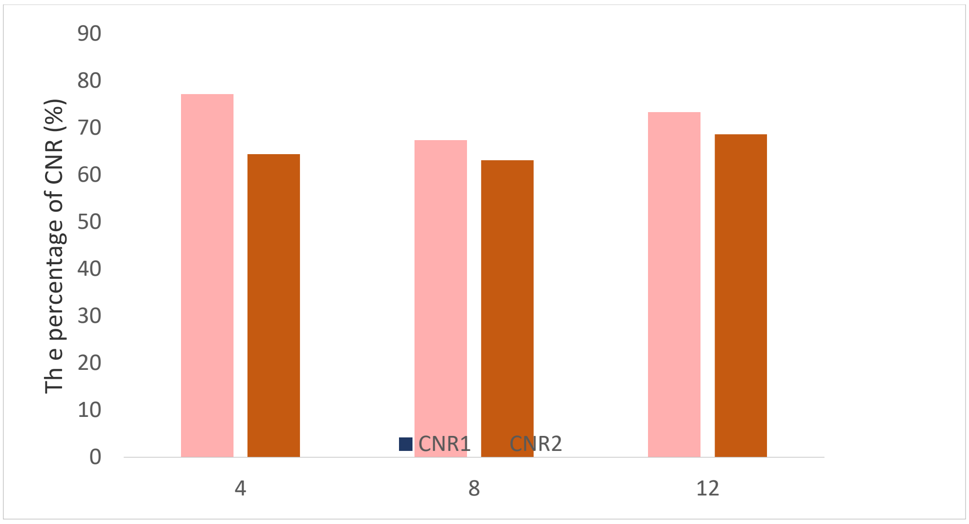

Figure 3. *The relationship between the CNR (%) with increasing mAs.*

CNR in relation to collimation and different IR's size

Collimation and IR size are two important components that influenced image quality, specifically in image contrast. Referring to the Figure 4 demonstrates, the percentage of CNR produced in the experiment by using different collimation field sizes and different IR' sizes. The other exposure settings are constant. There are three different of IR's sizes used which were small (18×24 cm), medium (24×30 cm) and large (35×43 cm). There are two sizes of collimation which are 13×13 cm collimation and collimation according to IR's sizes. The bar chart showed that the percentage of CNR1 when x-ray beam is collimates 13×13 cm decreased with increasing the IR's sizes from 77.25%, 58.68% to 54.39 %. However, the percentage of CNR1 for three different IR sizes, small, medium and large is quite constant which 75.35%, 74.02%, 74.83% respectively. Meanwhile, the percentage of CNR2 for both collimation sizes decrease gradually in three different IR's sizes. The percentage of CNR2 for small, medium and large IR sizes is 64.45%, 52.4 and 46.78% respectively for 13×13 cm collimation whereby 71.16%, 57.84% and 43.36% in small, medium and large IR respectively when x-ray beam collimate according to IR's size.

In term of IR's sizes, the small IR depicts higher CNR compared to others size for given exposure settings. The small IR showed better in differencing between object and background image regardless the collimation sizes. This may also due to the pixel and matrix sizes that caused the percentage of CNR increased.

When x-ray beam is collimate according to IR size, the percentage of CNR1 is increased on three different IR's sizes in Figure 4. These results contradicted to the study done by Bomer et al. (2013). This study stated that, a proper collimation improves the image quality by reducing the production of scattered radiation reaching the IR. This may due to the acrylic (attenuator) that are thinner, which only 24 mm in thickness and do not give much in terms of scatter radiation. The thickness or the amount of the irradiated area of the patient or object is a factor that contributed to the formation of scattered radiation (Sprawls, 1995). The larger the irradiated area or patient thickness, the increase the amount of the scatter radiation production and reduce the image contrast.

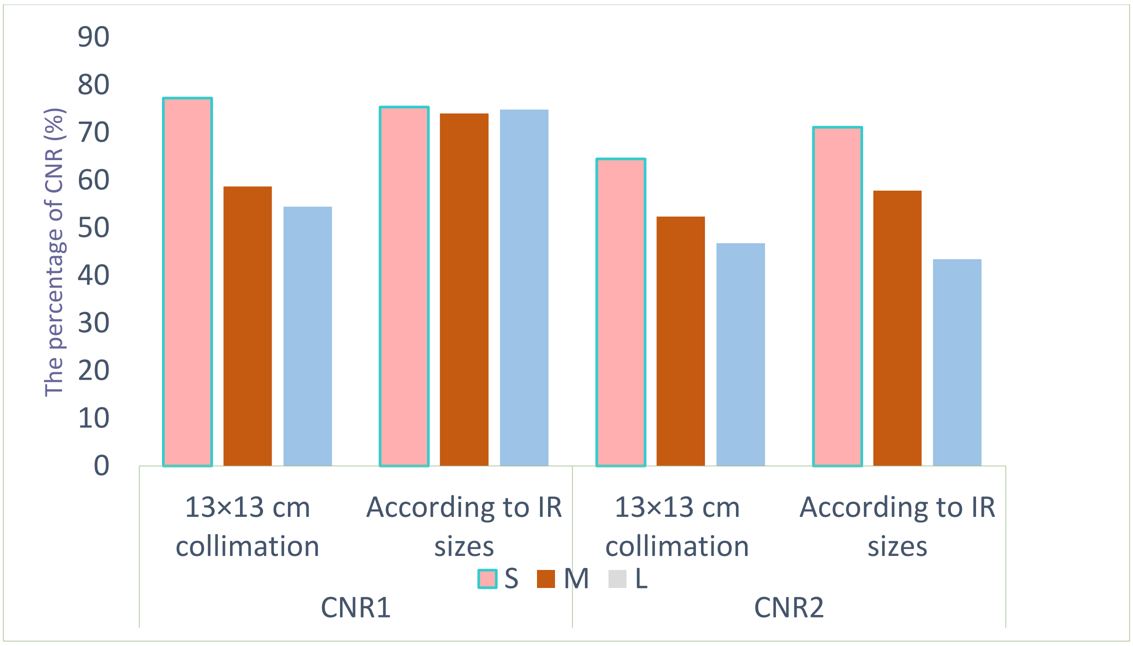

Figure 4. *The bar chart illustrates the relationship between CNR (%), collimation field sizes and IR's sizes.*

From the Figure 2, 3 and 4 depicts that, the percentage of CNR1 has been always higher as compared to CNR2 in any situations. This is due to the anode heel effect during the exposure. Anode heel effect is a process and formation of x-ray beam in x-ray tube which produce higher intensity of x-ray photon at cathode side and less intensity at anode side (Buissink et al., 2006). The reading of CNR1 is higher because it's positioned at the anode side while the CNR2 positioned at anode side of the x-ray tube.

The anode heel effect has more pronounces when the large x-ray beam field was used and exposed on large imaging receptor's size Fung & Gilboy (2000). However, the anode heel effect is less prominent when the x-ray beam collimate to smaller beam and exposed on small IR's size. Hence, the practitioners should identify the accurate tube potential selection and proper collimation before exposing the patient to obtain a better quality image as well as the lowest possible dose given to the patient.

Entrance Skin Dose (ESD)

ESD in relation with increasing mAs and different collimation sizes

Entrance skin dose (ESD) is a measure of the radiation dose that absorbed by the skin for a given exposure (Parry et al., 1999). Figure 4 shows the reading of ESD (mGy) with increasing mAs and it compare with two different collimation sizes which are 13×13cm collimation and collimation according to IR's sizes. The reading of ESD is increasing when mAs increased from 4, 8 and 12 on both collimation sizes. The 50 kVp and small IR's sizes are constant.

The reading of ESD gradually increased when mAs increases due to increase the quantity of the photons that reach the patient. mAs is controlling factor for image density. However increasing mAs will increase the radiation dose received by the patient (Carlton & Adler, 2013). Thus, mAs should be chosen accordingly so that optimum image quality produced at minimal dose.

A proper selection of collimation is very crucial in order to minimize unnecessary radiation exposure to the patient. Figure 5 depicts the ESD reading lower when x-ray beam collimated 13×13 cm collimation as compared to collimate according to IR's size. This is due to the increase the amount of irradiated area exposed to the radiation. This was supported by the study done by Karami et al. (2016) which larger collimation will increase the amount of irradiated area and exposed unnecessary patient exposure. Hence, a proper collimation should be applied by the practitioner in order to minimize radiation risks exposed to the patient.

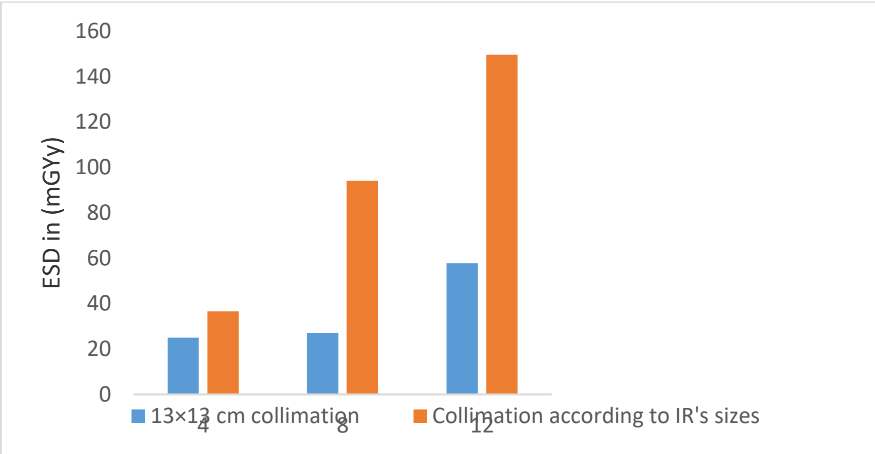

Figure 5. *The reading of ESD in (mGy) with increasing mAs.*

ESD in relation with an increasing kVp

Referring to the Figure 6 illustrates, the reading of ESD (mGy) increase gradually when increase kVp being used. The 4 mAs and 13×13cm collimation sizes are constant. The kVp is control the energy of electron striking the object for any given mAs. It is also means, increasing kVp will increasing the penetrating power for the given quantity of photon to reach the patient. This is supported by Joseph (2006) which increasing the kVP with all other exposure settings remaining the same also increase the intensity of the radiation. Hence, increasing kVp will increase the energy as well as increase in number of photon reach the patient. Thus, increased the ESD received by the patient. So, high kVp should be used with lower mAs in order to produce image with minimal radiation dose.

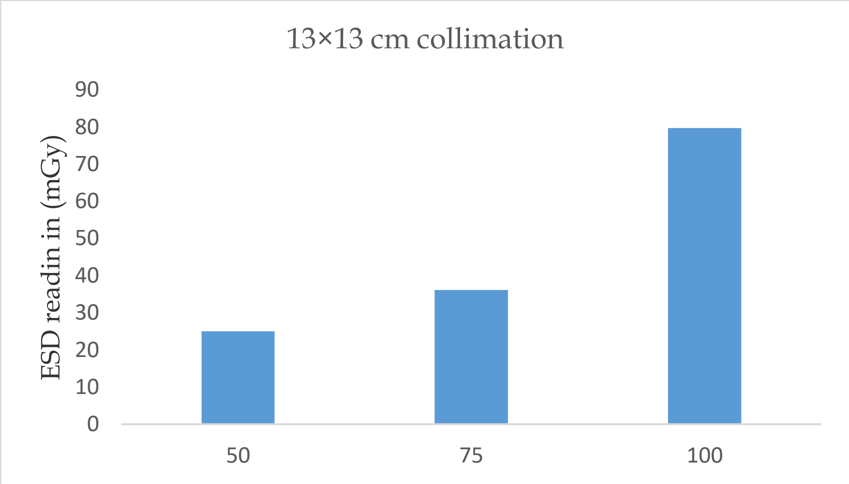

Figure 6. *The reading of ESD in (mGy) with an increasing kVp.*

CONCLUSION

As conclusion, there are effects on image quality and ESD when exposure setting; kVp, mAs, collimation field and IR's sizes manipulated. However, there are also inconsistencies of the CNR and ESD that may be due to the x-ray system which do not comply with the parameter selections. The percentage of CNR1 and CNR2 reduced as the kVp is increased. The percentage of CNR1 and CNR 2 for 50 kVp, 75 kVp and 100 kVp are (CNR1=77.25, CNR2=64.45), (CNR1=73.47, CNR2=61.22) and (CNR1=62.80, CNR2=57.32) respectively. However, the percentage of CNR is slightly fluctuate when mAs is manipulated while other exposure settings are remained constant. The percentage CNR shows higher when small IR size and large collimation being used. In term of ESD, the reading depicts higher when the kVp and mAs increase as well as when x-ray beam collimated according to IR's sizes. Therefore, the practitioners should have knowledge regarding the effect of exposure settings when manipulated on image quality and radiation dose.

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