AJMB
eISSN: 2600-8173

https://doi.org/10.37231/ajmb.2023.1.S.680
https://journal.unisza.edu.my/ajmb

PENERBIT
Universiti Sultan Zainal Abidin

Asian Journal of Medicine and Biomedicine

Image Quality Comparison between 10kvp Technique and 15 Per Cent Rule on AP Supine Abdominal X-Ray Examination

Qashrina Nadhirah Yaakob, Fairuz Mohd Nasir*, Azlinawati Ali

Faculty of Health Sciences, Universiti Sultan Zainal Abidin, Kampus Gong Badak, 21300 Kuala Nerus, Terengganu, Malaysia

Corresponding author: fairuznasir@unisza.edu.my

Received: 1st August 2023 Accepted: 5th December 2023 Published: 24th December 2023

Abstract

The abdomen is one of the thickest parts of the human body and there are challenges in obtaining good images due to the thickness and pathology of the patient during an abdominal X-ray. The 15% rule and the 10 kVp technique are used as exposure manipulation methods in abdominal radiography, however, theoretically, the 15% rule is preferred. The 15% rule provides optimal exposure while the 10 kVp technique is simpler in terms of calculating the exposure factor. These two techniques have their advantages; therefore, this study aims to compare the image quality between the 15% rule and the 10 kVp technique of X-ray supine anteroposterior (AP) abdominal radiography image quality and evaluate whether 10 kVp could be an exposure replacement technique for the 15% rule. Five abdomen radiographic images were taken based on both techniques and evaluated quantitatively using ImageJ software and qualitatively based on scoring by two radiographers. Based on the result of the experimental study, the SNR (signal-to-noise) ratio, CNR (contrast-to-noise ratio) and image mean score had no significant differences (p-value>0.05) between the 10 kVp and 15% rule. In conclusion, the 10 kVp technique is a possible substitution for the 15% rule in obtaining valuable diagnostic image quality during AP abdominal X-ray projection and is more suitable to be implied in clinical settings compared to the 15% rule.

Keywords

15% rule, 10kVp technique, exposure factor selection, image quality

Introduction

The selection of the exposure factor is very important to produce a quality image. The exposure factor is usually chosen according to the thickness of the patient's body and this is important to avoid film rejection if the image obtained has no diagnostic value. This led to repeat examination and give an unnecessary dose to the patient [1]. Thicker patients require a higher tube voltage (kVp) and lower tube current (mAs) in order to increase the penetrating power and obtain an optimal image [2]. Previous study shows that kVp has a positive correlation and the anatomical thickness of the patient [3].

It is essential to have the skills to modify the exposure setting as patients vary in terms of shape, size and pathology. There are a few methods of exposure manipulation if it involves different thicknesses of the patient's body, for example, the high kVp exposure technique, 10 kVp technique and 15% rule technique [1]. The application of the 10 kVp technique and 15% rule could be to increase or lower the exposure factor according to patients. The 10 kVp technique refers to an increase of 10 kVp where the mAs will be halved, and it is claimed to be equivalent to the image quality of doubling the mAs [4]. As for the 15% rule, the tube voltage will be increased by 15 per cent which will be equivalent to achieving the same exposure and image quality as the standard exposure [5]. When the 15% rule is applied, the image density will change by a factor of 2 which means the radiographic density will be doubled if increased by the 15% rule [6].

The abdomen is the part that varies the most in size from person to person, therefore, the selection of the exposure factor is very crucial according to the thickness of the patient's body. In standard abdominal radiographic studies, the field of view must include the diaphragm to the inferior pubic rami, including the abdominal musculature laterally [7]. It was imperative to include all of the organs and muscles to prevent any misdiagnosis. The most vital part of the radiograph is the diaphragm and the psoas muscles [8]. The correct sufficient exposure and contrast will visualize both lumbar vertebral columns and the right and left psoas muscle [8]. Other than that, radiographs should visualize the lumbar vertebrae transverse process, the lower border of the liver margin, and especially the kidneys outline on smaller average-sized patients. There are problems raised in imaging the abdominal area as it is one of the thickest parts of the human body and consists of many organs such as the kidney, liver and reproductive systems. The X-ray photon has higher attenuation in thicker tissues resulting in low photon energy detected by the detector, thus reducing image quality.

This study involves evaluating the image quality of the abdominal X-ray examination based on 15% rules and the 10kVp technique. Theoretically, the 15% rule is the preferred method for exposure manipulation due to patient thickness, however, the 10 kVp technique is more suitable to be applied in the clinical setting as it has quicker calculation compared to the 15% rule [9]. This leads to confusion in the selection of exposure factors especially among beginners or radiographer students, therefore, this study is to compare the quality of the image between the 15% rule and the 10kVp technique to ensure a good image.

Materials and Methods

Study design

This is an experimental study design carried out at the X-ray laboratory, Universiti Sultan Zainal Abidin (UniSZA).

Ethical statement

This study involves radiographers to evaluate the radiographs for qualitative image analysis. Therefore, the ethical approval was obtained from the UniSZA Human Research Ethics Committee (UHREC) [UniSZA/UHREC/2021/306].

Experimental setup procedures

This study was done on Kyoto Kagaku PB-31 whole body phantom; consisting similarly to the human tissue weighting factor and representing human anatomy and attenuation characteristics. The phantom was set up in an anteroposterior (AP) abdomen supine position and exposed using Siemens Polydoros IT 55 General Radiography System. The source-to-image distance (SID) was set up to 102cm. First AP abdomen radiographic images were taken as a standard with an exposure factor of 70 kVp and 32 mAs; standard hospital practice. Then, two radiographic images were taken using exposure factor for the 10 kVp technique and another two images were taken using exposure factor for 15% rules. The exposure factor for all exposures made is summarized in Table 1. For the 10 kVp technique, the tube voltage value is supposed to be increased by 10 for each exposure, however, because there is no option for manual selection 80 kVp, and

79 kVp have been chosen for the next exposure. For the 15% rule, the tube voltage value was increased by 15% for each increment.

Table 1: Exposure factors for standard exposure, 10kVp technique and 15% rules

	kVp	mAs
Standard exposure	70	32
10 kVP technique	79	16
	90	8
15% rules	81	16
	93	8

Quantitative Assessment

The quantitative image quality was assessed in terms of signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) using ImageJ software that had been developed and recognized by the National Institutes of Health (NIH) [10]. This software has been recognized for image processing used in biological and life science that is appropriate for amateur and professional researchers or developers. This method of image assessment was also demonstrated in a previous study [11]. All radiographs are saved in JPEG format, analysed by the software, calculated the SNR and CNR of each radiograph. SNR is the measurement of the image signal to a certain region of the background. Equation 1 is the formula to calculate SNR, where μ is the mean value of the image pixels that represent the expected signal and σ is the standard deviation of the pixel value that represents the estimated noise. SNR was evaluated by placing three regions of interest (ROI) and measuring the mean pixel value three times for each ROI (left flat side of iliac wing, left side of 5th lumbar spinous process and right side of 11th rib) as in Figure 1a. The placement of ROIs was based on the image evaluation criteria on exposure [8]. The size of each ROI was kept constant throughout the process and kept as small as possible to obtain the most accurate data.

$$SNR = \frac{mean\ pixel\ value\ in\ ROI}{Standard\ Deviation\ of\ Background\ ROI} \qquad (1)$$

Equation 2 is the formula to calculate CNR. The CNR refers to the ratio of the contrast between the signal in a given region and the background. To find the value of CNR to evaluate the contrast between two adjacent areas. Then, three ROIs were included in the same radiograph to find the CNR as shown in Fig. 1b.

$$CNR = \frac{(Avg.Signal\ ROI - Avg.Background\ ROI)}{Standard\ Deviation\ of\ Background\ ROI} \qquad (2)$$

The SNR and CNR values obtained from ImageJ software were evaluated using the Statistical Package for Social Science (SPSS) software for Windows Version 21. A non-parametric test, the Wilcoxon Signed Rank test was carried out to see the differences between the 10 kVp and 15% rule technique in comparing the image quality by evaluating the value of SNR, CNR and mean image score of each image.

Qualitative Assessment

The qualitative image analysis was evaluated by a randomized blinded method from two radiographers. The scoring chart is shown in Table 2. The radiographers assessed the image quality for AP supine abdominal X-ray for both exposure techniques based on criteria scoring adapted from previous studies [8, 12]. The total scoring was made between 0 to 15 for each radiograph. A higher image scoring will indicate better image quality. The image scored ≥12 will also indicate an acceptable image at the rate of 80% and above.

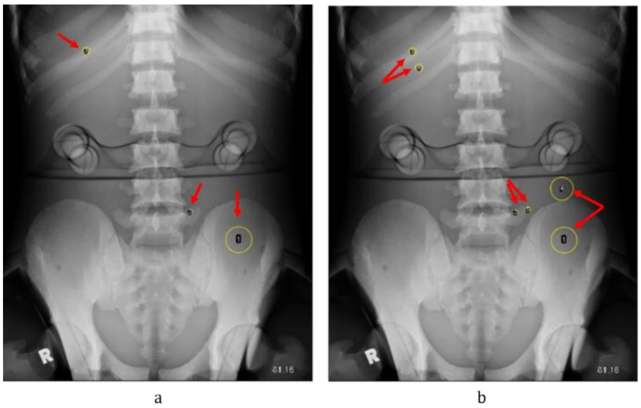

Figure 1: a) Three ROIs marked on the radiographs in ImageJ software to calculate the SNR. b) Another added three ROIs, placed adjacently to the previous ROI to calculate the CNR. The red arrow shows the ROI in the images.

Table 2: Image quality evaluation score.

Item	Image criteria
1	There is visually reproduction of right and left flanks
2	There is visually reproduction of the pubic symphysis
3	There is visually reproduction of the lumbar transverse process
4	Iliac wings and ischial spines appear symmetrical
5	Sharp visualization of ribs

Results and Discussion

SNR and CNR values were obtained using ImageJ software based on each ROI in each radiographic image (Fig. 1a, 1b). The SNR and CNR values of each ROI were then averaged and presented in Table 3. From the result, during the 1st and 2nd increments; the value of SNR for the 15% rule was higher than the 10 kVp technique. The SNR is the ratio of the image signal over noise and greater SNR values indicate more significant signals and lower noise. As tube voltage increases, higher energy X-ray is produced and increases the penetrating power, therefore, increasing signal reaches the image receptor [3,13]. This explains why the SNR for the 15% rule was higher than the 10 kVp technique. However, the difference in SNR value between both techniques is less than 1 and the Wilcoxon Signed Rank test shows there is no significant difference between the SNR of the 10 kVp technique and the 15% rule (p-value>0.05, Z= -1.342).

As for the CNR value, both techniques show close values for all exposure factor settings, as the differences are less than 0.15. However, the result shows as the kVp increases and lower mAs, the CNR value reduces. Higher kVp leads to a higher number of photons emitted, the higher the number of X-rays transmitted through patients. Higher kVp also leads to a higher energy of X-rays and increases the penetration power of the X-ray beam. However, this will also cause a higher amount of scatter radiation and decrease differential absorption, resulting in reduced radiographic contrast [13]. Previous study also shows the CNR decreases as increasing the tube voltage [14]. This is due to the scattered radiation from Compton interaction which is predominant at higher energy X-rays [15]. The CNR value is influenced by the background noise level; the lower the noise, CNR increases. The noise is influenced by the mAs value. mAs is the amount of radiation produced over a certain amount of time (in seconds) [16]. During the 2nd increment, the mAs are reduced and lowering the mAs will reduce the signal, and increase the noise which results in lower CNR [16]. Changing the mAs affects image quality; increasing the mAs increases the beam intensity which leads to better noise and contrast [15]. However, the difference in CNR value between both techniques is less than 1 and the Wilcoxon Signed Rank test shows there is no significant difference between the CNR of the 10 kVp technique

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and the 15% rule (p-value>0.05, Z= - 0.447). Thus, the result from the test shows there are no significant differences between the 10 kVp and 15% rule in affecting image quality in terms of SNR and CNR.

Table 3: The SNR and CNR value of the images for the 10kVp technique and 15% rule.

	Exposure factor	SNR	CNR
Standard Exposure	70 kVp, 32 mAs	21.80	4.12
10 kVP technique	79 kVp, 16 mAs	23.14	3.57
	90 kVp, 8 mAs	24.16	3.03
15% rule	81 kVp, 16 mAs	23.22	3.43
	93 kVp, 8 mAs	25.21	3.05

The scoring result for qualitative image assessment is summarized in Table 4. The mean score for all exposure settings is between 12 and 13.5. The highest and lowest score is obtained from 15% rule images; the highest score is 13.5 (81kVp, 16mAs) while the lowest score is 12.5 (93kVp, 8mAs). A Wilcoxon Signed Rank test was done to compare the image quality of 10 kVp and the 15% rule technique for the image score. The image score of the 10 kVp technique and 15% rule also had no significant differences (p-value >0.05, Z= 1.000).

Table 4: The image criteria scoring by the observers.

	Exposure factor	Observer (Radiographer)		Mean Score
		1	2	
Standard Exposure	70 kVp, 32 mAs	13	12	12.5
10 kVP technique	79 kVp, 16 mAs	13	12	12.5
	90 kVp, 8 mAs	14	11	12.5
15% rule	81 kVp, 16 mAs	15	12	13.5
	93 kVp, 8 mAs	14	10	12

The selection of 10 kVp and 15% technique for the abdominal needed extra care due to higher mAs values tend to be used in those examinations to preserve image quality [13]. It is essential to have high image quality for abdominal X-ray examination while reducing patient dose [17]. A previous study showed a slight decrease in contrast and higher image noise when using high kVp and low mAs (10 kVp and 15% rule), however, their result was evaluated by two radiologists who accepted the image regardless of the slight decrease in image contrast and noise as the diagnostic value could still be interpretable [17]. In this study, the result shows that when using either one technique; the 15% rule or 10kVp technique (high kVp with lower mAs) the image quality was slightly degraded in contrast (CNR value) compared to the standard exposure. However, based on the statistical test done and qualitative evaluation by two radiographers did not identify the images as unacceptable. No significant differences were found in comparing the image quality SNR and CNR value for the 10 kVp and 15% rule. Even though the statistical test shows there are no significant differences in image quality between the 15% rule and the 10kVp technique, the manipulation of kVp and mAs plays a massive role in achieving the desired exposure for the patient. Pathology that is involved with water retention or ascites and by increasing the kVp will higher the dose thus the contrast will be better [18].

There were some of the limitations on the 10 kVp and 15% rule. The 10 kVp and 15% rule technique was optimal between the ranges of 60 kVp to 100 kVp [1, 19, 20]. Both exposure techniques show some limitations on the range of kVp used. As for our experiment, using higher kVp for abdominal X-ray projection might be challenging to achieve the best valuable image quality. Therefore, future research needs to be done on whether the exposure techniques could be applied when using a higher kVp increment than 100 kVp on abdominal X-ray projection. The other limitation of this study is using only one size phantom as the 10 kVp and 15% rule technique should be applied when dealing with thicker body patients. Different thicknesses of the body lead to differential absorption and scattering of photons within the body, and this influences the SNR and CNR values as well.

Further research on using the 10 kVp and 15% rule on the abdomen with a larger amount of data to evaluate the effect on image quality for extensive research using quantitative and qualitative measurement is highly recommended as it will allow us to study the effect of high kVp and low mAs in abdomen X-ray and it will increase the strength of statistical analysis results. Lastly, widen the range of X-ray examinations such as the skull or lower extremities to see the effect of the 10 kVp and 15% rule on different parts of the body.

Conclusion

From this study, the image quality of the 15% rule and 10kVp technique applied in abdominal radiographic projection varies depending on the kVp and mAs setting. However, the differences are not significant and the image is acceptable. In conclusion, the 10 kVp technique is a possible substitution for the 15% rule in obtaining valuable diagnostic image quality during AP abdominal X-ray projection and is more suitable to be implied in clinical settings compared to the 15% rule due to less calculation involved.

Funding

The author(s) received no specific funding for this work.

Conflict of Interest Disclosure

None to declare

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