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Impact of Different Grids on the Quality of Abdominal Radiography Images

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ABSTRACT

Grids are additional accessory in radiography that absorb scatter radiation hoping to reduce blurriness on the image. Various type of grids is available in the market so the effect of those on image quality needs to be evaluated. The purpose of this study is to compare the quality of abdominal radiography images using three variations of grids (moving and stationary grid) and without using a grid in order to see the best type or grids to produce the greatest image quality. Abdominal radiography exposure factors were used to expose two phantoms. Pro-Fluo 150 phantom was used as the object to measure image quality such as Signal to Noise Ratio (SNR), Contrast to Noise Ratio (CNR), and spatial resolution. A survey of five radiologists was also performed to evaluate the contrast and the visibility of objects' boundaries in Anthropomorphic phantom images. The result of this study showed that the usage of various grids gave different values of SNR, CNR, and spatial resolution. The exposure factor of 70-75 kV in each mAs have the highest SNR value (52,64-78,31). Images obtained without a grid and exposure factor of 80-85 kV in each mAs have the highest SNR value (160,65-800,48). Images obtained from using moving grid also have the highest CNR and spatial resolution, with score of 3.72 – 7.62 and 3.7 lp/mm. The results of radiologists' survey showed that the average score for moving grid's images was 29.8 of 30 with a percentage of 99.33%. Therefore, it that can concluded that images obtained with moving grid have the best quality that can provides contrast and shows the boundaries between organs clearly in abdominal radiography. Based on this research, it's recommended to use moving grid for abdominal radiography examinations.

INTRODUCTION

X-ray radiography image qualities depend on many factors, such as beam energy and peak kilovoltage, tube current, focal spot size, collimation, and anti-scatter grids. One of the image quality parameters, SNR (Signal to Noise Ratio), depends on the scatter radiation present when obtaining the image (Gennaro et al., 2012). The presence of scatter radiation can affect object detectability because it will increase noise and reduce SNR (Boone et al., 2000; Singh et al., 2014). Reducing noise is an important process to improve image quality. Anti scatter grid is the component added to radiography modalities to absorb the scatter radiation produced in the patient's body before it reaches the image receptor (Larsson et al., 2018). Various types of grids are available on the market. Based on the movement, the grid is divided into two, the moving grid and the stationary grid (Priyono et al., 2020). Grid is characterized by its ratio, which is the ratio between the height and width of the interspaced material, and its frequency, which is the number of grid

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strips/cm. Therefore, the effects of grid usage on image quality need to be evaluated.

Image quality parameters, such as contrast, were affected by the presence of a grid, as they absorbed scattered X-rays (Zhou et al., 2020). The effect of grids on image quality is shown to be different in every type of radiography examination. A previous study showed that using a grid could increase the cervical radiography image contrast (Goode et al., 2019; Mekis et al., 2024, Moey & Ramlee, 2019). Other research showed that a stationary grid with a ratio of 8:1 increases vertebrae thoracal's image quality (K. Lee et al., 2015). Grids with ratios of 6 and 10 are also proven to improve SNR for ≥ 100 mm thickness objects (Kunitomo & Ichikawa, 2020). On the other hand, grids are not recommended to be used on high-resolution detectors as the CNR (Contrast to Noise Ratio) does not improve significantly and reduces the visibility of low-contrast objects (Singh et al., 2014).

Radiological assessment of the abdomen is still important to support the diagnosis of diseases such as bowel obstruction (Jaffe & Thompson, 2015), and abdominal malignancy (Porrello et al., 2023; Saha et al., 2022) , and urinary-related diseases (Mahmoud et al., 2021). High-quality radiographs could provide better diagnosis and contribute to patient care (Shettima et al., 2017). An abdominal radiograph is also one of the first diagnostic modalities for abdominal pain patients, therefore, imaging techniques also need to be evaluated for abdominal radiography (Alzyoud et al., 2022).

Three factors affecting the amount of scattered radiation are the use of high kV, the thickness of the object, and the area of irradiation (collimation) (Bushong, 2020; Suraningsih et al., 2023). Effective collimation reduces scattered radiation that reaches the image detector, therefore, reducing noise. Meanwhile the thicker the object, the more beams are scattered inside the object and can cause more scattered radiation to reach the image detector. The abdomen is one of the objects of examination with a thickness of 16-30 cm which usually uses 70-80 kV of tube voltage and the area corresponding to 35x43 cm^2 (Lampignano & Kendrick, 2020). The usage of a grid is recommended for objects with a thickness exceeding 15 cm (Alzen & Benz-Bohm, 2011). Therefore, the abdomen examination requires a grid to reduce scatter radiation.

Many studies showed the importance of anti scatter grid in abdominal radiography. Evaluation of the effectiveness of a grid on an anthropomorphic abdomen phantom using 70 kVp tube voltage showed that images acquired with a grid had better CNR and SNR compared to non-grid images (Sayed et al., 2024). The image quality figure (IQFinv) of burger phantom images acquired with a grid is significantly higher than without a grid (Ichikawa et al., 2019). The presence of a grid in dose reduction techniques for adult abdominal radiography also shows that there is a 36% image quality improvement potential (Kawashima et al., 2023).

Improving previous studies, a thorough evaluation of grid roles in abdominal radiography was performed using two phantoms, Pro-Fluo 105 and Anthropomorphic Phantom. Abdominal radiography exposure factors were used to expose the phantoms. The Pro-Fluo 105 phantom was used to provide image quality parameters such as Signal Noise Ratio (SNR), Contrast to Noise Ratio (CNR), and spatial resolution. Deeper analyses are also provided by performing a survey of five radiologists on Anthropomorphic phantom images to evaluate the contrast and the visibility of objects' boundaries. Besides, since there are many types of anti-scatter grids available in the market, evaluation of their performance in abdominal radiography image quality is needed. This study compares the quality of radiography images using various grids, and grid ratios, and without using any grid.

METHODS

The purpose of this research is to compare the quality of abdominal radiography images using variations of grids to see the best type or grids to produce the greatest image quality. To evaluate the effects of each grid thoroughly, two phantoms were used as imaging objects. The first one is Anthropomorphic phantom for anatomy evaluation (evaluate the effects of grids in anatomy visibility of the object) which will be carried out by radiologists using a questionnaire with a scoring system. The second one is the Pro-Fluo phantom to evaluate image quality parameters. A Stationer X-ray machine for general examination with 150 kV and 500 mA capacity available at our partner laboratory, was used as the imaging modality.

(a) (b)

Figure 1. (a). Anthropomorphic Phantom, (b) Pro-Fluo Phantom.

Each of these phantoms was exposed using abdominal exposure factors that are usually used in radiography examinations, which were set on 70 kV, 75 kV, 80 kV, 85 kV 16 mAs, 25 mAs, and 32 mAs. Three types of grids, moving grids with a ratio of 10:1, stationary grids with a ratio of 10:1 and 8:1, and without using any grid, were used, so a total of 48 images of each phantom were obtained. Parameters of image quality observed were the Signal to Noise Ratio (SNR), Contrast to Noise Ratio (CNR), and spatial resolution. ImageJ software was used to measure all the parameters.

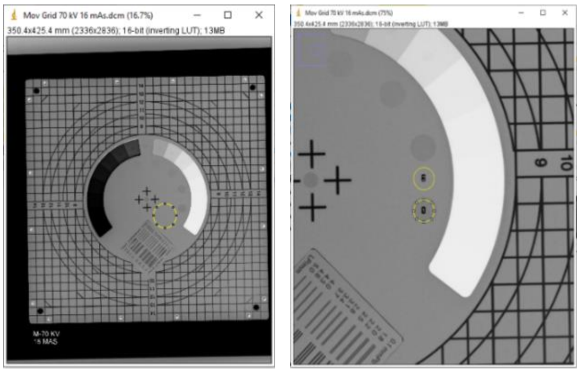
SNR is the ratio of mean signal value (μ_i), which is the mean of pixel value observed in Region of Interest (ROI), and noise, which is the standard deviation (σ_0) of pixel value in the ROI (Carroll, 2011; Goode et al., 2019; Kempski et al., 2020).

$$\mathrm{SNR} = \frac{\mu_i}{\sigma_o} \qquad (1)$$

CNR is an image quality parameter that measures the presence of contrast in a noise background. CNR is measured by dividing the difference of the mean signal on the object (μ_i) and background (μ_o) with the square root of the standard deviation on the object (σ_i^2) added by the background (σ_0^2). The third image quality parameter observed in this study is spatial resolution. Spatial resolution was measured in the bar pattern part of Pro-Fluo phantom with a unit of line pairs/mm (lp/mm).

$$\mathrm{CNR} = \frac{\mu_i - \mu_o}{\sqrt{\sigma_i^2 + \sigma_0^2}} \qquad (2)$$

The measurement process of each parameter is shown in Figure 2. The results of SNR, CNR, and spatial resolution on each grid were then compared at the same exposure factor. For example, images obtained from 4 grid varieties (3 grids and non-grid) were compared at 16 mAs and 70 kV.



(a) (b)

(c)

Figure 2. (a). Measurement of SNR, (b). CNR, and (c). spatial resolution

An additional survey of 5 radiologists was also performed to support the result of the image quality measurement. The questionnaire concerned was about images' contrast and the visibility of objects' boundaries in Anthropomorphic phantom images. Due to the lack of time, each radiologist only observed a random sample of 24 Anthropomorphic phantom images including all varieties, and gave a score range from 1-5, where a score of 5 means the image has a good contrast and can display objects' boundaries. So, if all 5 radiologists gave the highest score, a total score of 30 (100%) was obtained. The full workflow of this research is shown in Figure 3.

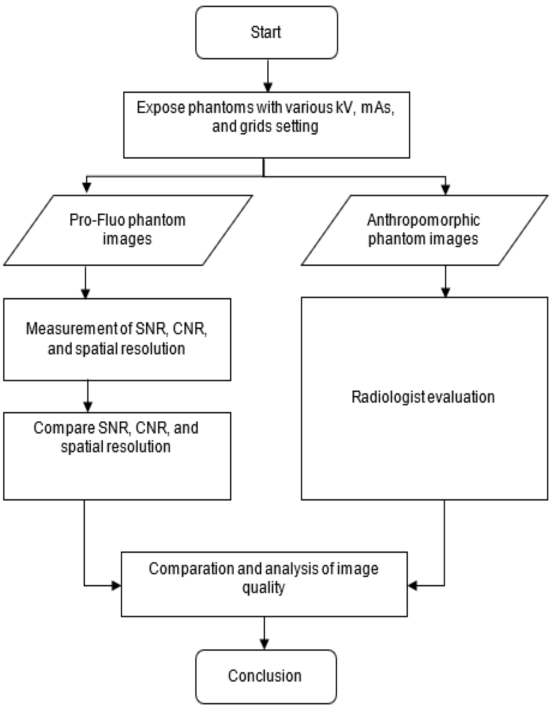


Figure 3. Research workflow

RESULTS AND DISCUSSION

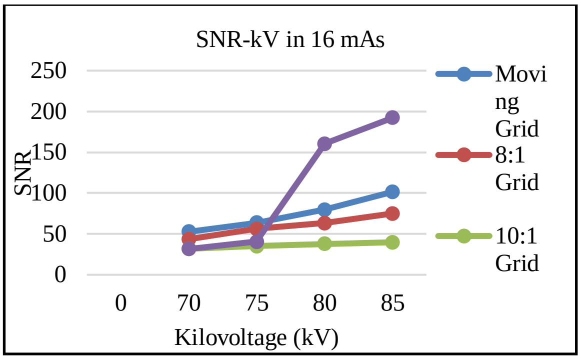
SNR Measurement

SNR measurement is carried out using ImageJ to make the ROI in the form of a circle to find out the mean value and standard deviation, then using the SNR formula. The results are shown in Table 1. The SNR value range of moving grid images is 52.64 – 172.38, while the stationary grid ratio of 10:1 images is 31.86-46.32, the stationary grid ratio of 8:1 is 43.55-93.24 and the non-grid is 31.53-800.48.

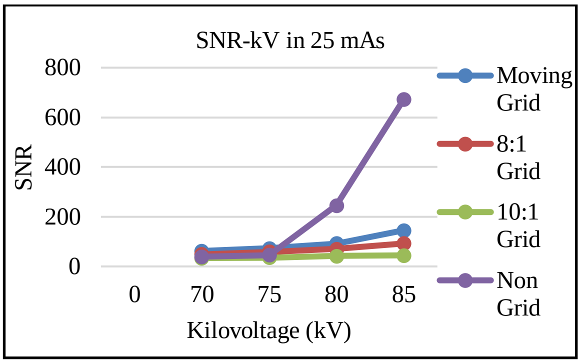
Table 1. SNR Value

mAs	kV	SNR			
		Moving Grid (10:1)	**Stationary Grid (8:1)**	**Stationary Grid (10:1)**	**Non-Grid**
16	70	52,64	43,55	31,86	31,53
	75	63,69	56,14	34,91	40,44
	80	79,78	63,34	37,96	160,65
	85	101,51	75,05	39,85	192,11
25	70	62,28	48,37	33,83	39,24
	75	72,56	58,15	35,82	45,27
	80	92,65	70,63	42,36	244,90
	85	145,42	92,36	44,66	672,22
32	70	66,40	50,02	34,45	42,14
	75	78,31	59,28	36,40	51,00
	80	96,70	79,00	42,47	547,94
	85	172,38	93,24	46,32	800,48

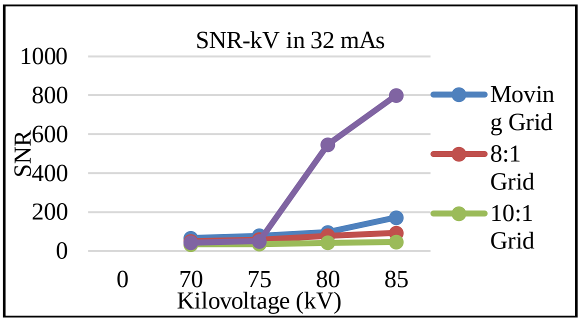
The result of SNR measurement in Table 1 and Figure 4 shows that images obtained without a grid and exposure factor of 85 kV in each mAs have the highest SNR value. It also shows that images obtained with a lower ratio of the stationary grid (8:1) have better SNR than the ones obtained with a higher ratio. Graphs in Figure 4 also show that the higher the kVp, the higher the SNR values on all grid types. A previous study on chest images and abdomen images using a modeling algorithm also showed the same result (Bor et al., 2016; Tanaka & Kuroyanagi, 2020). These results were due to the natural relation of the exposure factor (kV and mAs) and noise. Higher mAs cause more X-ray photons produced, thus reducing the noise and increasing the signal. On the lower kV, the moving grid shows effectiveness in decreasing noise, therefore increasing the SNR. On the higher kV, the absence of a grid and lower grid ratio caused more X-rays to go through the image detector thereby increasing the signal/mean pixel value (J. Lee et al., 2017). The actual purpose of an anti-scatter grid is to reduce scatter radiation, but the presence of a grid before the image detector can also cause primary X-rays to be attenuated therefore reducing the signal detected by the image detector. The higher the grid ratio means more X-rays to be absorbed by the grid materials, reducing signal acceptance in the detector.



(a)



(b)



(c)

Figure 4. SNR-kV graph of (a). 16 mAs, (b). 25 mAs, and (c). 32 mAs

CNR Measurement

CNR was measured by creating a circle ROI to find out the mean value and standard deviation on the object and background. CNR values for each image and each exposure factor are shown in Table 2. The CNR value range for moving grid images is 3.72 – 7.62, for 10:1 stationary grid is 3.36 – 6.64, for stationary grid ratio 8:1 is 3.20 – 5.77 and without the use of Grid 1.95 – 8.99.

Table 2. CNR Value

		CNR			
mAs	**kV**	**Moving Grid (10:1)**	**Stationary Grid (8:1)**	**Stationary Grid (10:1)**	**Non-Grid**
16	70	3,72	3,20	3,36	1,95
	75	4,90	3,64	3,97	2,22
	80	5,40	4,22	4,44	6,54
	85	5,99	5,06	5,19	7,82
25	70	4,23	3,75	3,85	2,17
	75	5,83	4,20	4,64	2,60
	80	6,22	4,59	5,62	8,99
	85	7,00	5,28	6,23	6,59
32	70	4,98	3,94	4,16	2,37
	75	6,30	4,55	4,89	2,82
	80	6,78	5,00	6,05	6,45
	85	7,62	5,77	6,64	5,16

From Table 2 and Figure 5, we can see that, in general, images obtained from using a moving grid have the highest CNR in all exposure factors which means they can visualize objects better. The CNR results in stationary grid images also show that the higher the grid ratio, the better the CNR is. This result is supported by previous research (Goode et al., 2019) which mentions that more high-contrast objects of the Leed Test Tool were visualized on the image obtained with the moving grid. It is also seen that a higher ratio of stationary grid produced images with the highest CNR too. This result was also seen with vertebrae thoracal radiography (Shimbo et al., 2018) These show that scatter grids improve objects' contrast in images and also absorb scatter radiation thus reducing the noise (Irsal & Winarno, 2020; Masayoshi, Mizuta; Shigeru, Sanada; Hiroyuki, Akazawa; Toshifumi, Kasai; Shuji, Abe; Yasuhiro, Ikeno; , Shigeki, 2012; Omondi et al., 2020). The process of noise removal was even more effective by using a high ratio stationary grid and moving grid. The movement of the grid makes more scatter radiation being absorbed therefore more primary X-rays reach the image detector producing high CNR images.

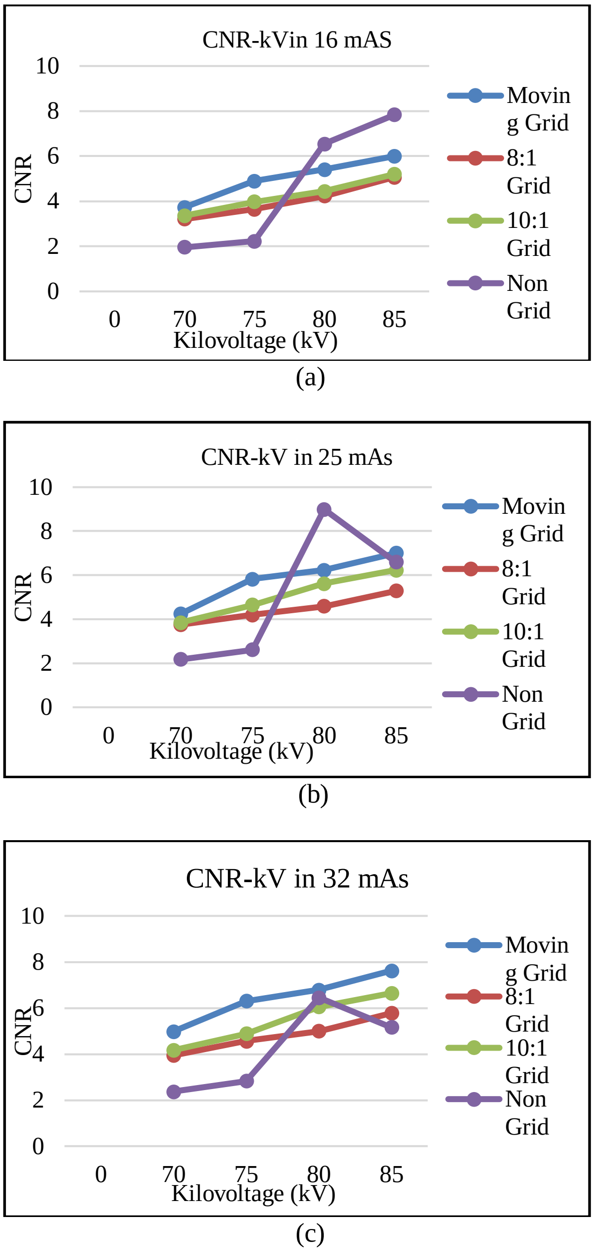


Figure 5. CNR-kV graph of (a). 16 mAs, (b). 25 mAs, and (c). 32 mAs

Another thing that can be observed is that the higher the exposure factor, the better the CNR is. The main contributor of noise in radiographic images is quantum noise which is due to the fluctuations in the number of X-rays captured by the image detector (Irsal & Winarno, 2020), therefore adding more beams (more X-ray photons) and increasing the exposure factor could decrease the image's noise. On the other hand, images obtained without a grid have the lowest CNR, even though they have the highest SNR as stated in Table 1. The absence of a grid causes all X-rays, the primary and scatter, absorbed by the image detector, therefore it increases the SNR but decreases the contrast (Bushong, n.d.; Fangqin Kong, 2008). Gean4 based simulation also showed that anti scatter grid is an effective technique for removing the scatter radiation (Alyassin et al., 2024).

Spatial Resolution Measurement

The spatial resolution was measured by making line plots on the bar pattern as shown in Figure 2(c) and observing which patterns are still distinguishable. The results of spatial resolution for each image are shown in Table 3.

Table 3. Spatial Resolution Value

mAs	kV	Spatial Resolution (lp/mm)			
		Moving Grid (10:1)	**Stationary Grid (8:1)**	**Stationary Grid (10:1)**	**Non-Grid**
16	70	3,7	3,4	3,4	3.1
	75	3,7	3,4	3,4	3,4
	80	3,7	3,4	3,4	3,4
	85	3,7	3,4	3,4	3,4
25	70	3,7	3,4	3,4	3,4
	75	3,7	3,4	3,4	3,4
	80	3,7	3,4	3,4	3,4
	85	3,7	3,4	3,4	3.1
32	70	3,7	3,4	3,4	3,4
	75	3,7	3,4	3,4	3,4
	80	3,7	3,4	3,4	3.1
	85	3,7	3,4	3,4	-

The result of spatial resolution measurement shows images produced with moving grids have the highest spatial resolution which means those images have better resolution and can distinguish two or more objects that are close together. A stationary grid especially one with a higher grid ratio can leave grid artifacts therefore disturbing small details visualization on images (Rana et al., 2016; Singh et al., 2014). It is also seen that changing the exposure factor and grid ratio doesn't affect the spatial resolution of the image. Previous research has also shown that lateral cervical spine images obtained with moving grids have better resolution than stationary and without grid (Moey, 2020). This result also supports the previous result on CNR that moving grid images have the best image quality.

Radiologists' questionnaire

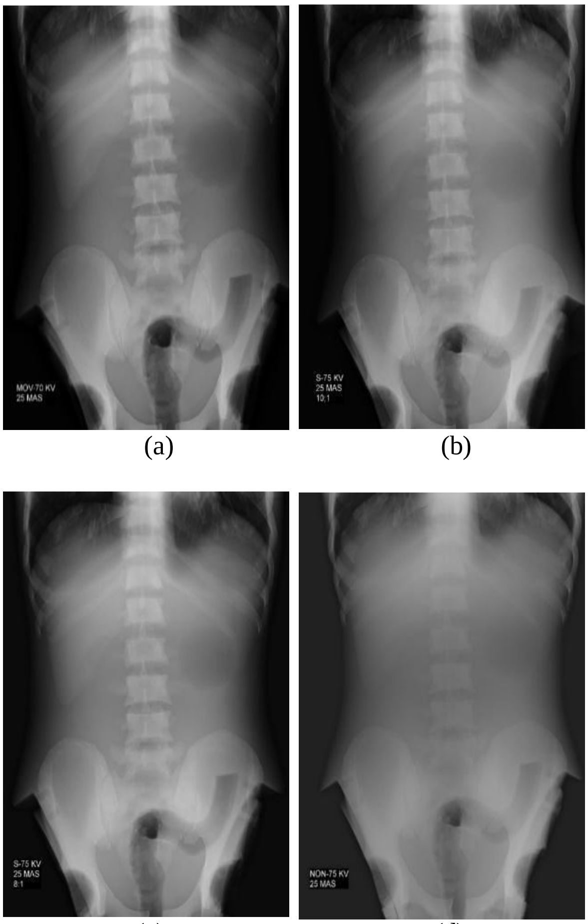
The questionnaire was distributed to the radiologist to evaluate and compare contrast and the visibility of organ boundaries in anthropomorphic phantom images. The total score obtained from 5 radiologists is presented in Table 4.

Table 4. Radiologists Questionnaire Scoring

Grid Types	∑ Score	Maximum Score	Percentage (%)
Moving Grid	29,8	30	99.33
Stationary Grid 8:1	21,6	30	72
Stationary Grid 10:1	25,2	30	84
Non-Grid	13,48	30	46

Radiologists' questionnaire results in Table 4 show that moving grid images have the highest score of 99,33% which means moving grid images have the best contrast and can display organ boundaries. Radiologist scores also show that images obtained with a higher ratio on a stationary grid have better contrast than the one obtained with a lower ratio grid and without a grid. This result supports the previous results of CNR and spatial resolution measurement.

There are several differences in anatomical visibility between images obtained using 4 grid types, as seen in Figure 6.



(a) (b) (c) (d)

Figure 6. Anthropomorphic phantom images were obtained with (a) moving grid (75 kV and 25 mAs), (b) stationary grid 10:1 ratio (75 kV and 25 mAs), (c) stationary greed 8:1 ratio (75 kV and 25 mAs), and (d) without grid (75 kV and 25 mAs)

Images obtained using a moving grid (Figure 6(a)) show great visibility in the boundaries of the liver, liver are more clearly visible, the visibility of air in the stomach is more defined and the joint gaps between the vertebrae bones are more visible. Images obtained using a stationary grid with a ratio of 10:1 (Figure 6(b)), the same ratio as the moving grid, have lower contrast, due to the influence of the grid lines. Figure 6(c), which was obtained with an 8:1 stationary grid, shows inferior contrast and object visibility compared to Figure 6(b), which was obtained using a higher ratio grid. The image obtained without any grid, shown in Figure 6(d), has the worst contrast and object visibility. It displays a blurred view of the vertebrae. Gridless images of skeletal radiography have significantly worse quality than the ones obtained with the grid (Lisson et al., 2019). Knee radiography images obtained with anti-scatter grids also show better image quality based on the VGC (Visual Grading Characteristics) (Abela et al., 2022). Similar research performed on chest radiography also showed that images obtained with a moving grid were able to visualize objects (vascular pattern of lungs, trachea, etc) (Grid et al., 2019).

CONCLUSION AND SUGGESTION

At lower kV, the highest SNR value (52,64-66,40) was obtained from moving grid-produced images. Images obtained without a grid and higher exposure factor have the highest SNR value. Those results are related to the fact that the higher kV, the more X-rays the detector captures. The absence of a grid, of course, caused more X-rays to reach the detector and reduced noise. Images produced with the existence of a moving grid have the greatest CNR (3,72-7,62), which means a moving grid is effective in removing scatter radiation, therefore increasing contrast. Spatial resolution measurement also showed that images obtained with moving grids are superior to others, with a value of 3,7 lp/mm. Radiologists' questionnaire results also agree that moving grid-assisted images have the best anatomical visibility. They show great visibility in the boundaries of the liver, the liver is more clearly visible, the visibility of air in the stomach is more defined and the joint gaps between the vertebrae bones are more visible. There are still some limitations of this study such as only one stationary X-ray machine used as the imaging modality and only some sample images reviewed by radiologists. Further research can be conducted to evaluate the effects of anti-scatter grids in other examinations such as thorax, pelvis, and extremities examinations.

AUTHOR CONTRIBUTIONS

SB contributed to this article as the one who performed the research, including the jobs of exposing phantoms with different grids to get radiographic images, measuring image qualities, and collecting questionnaire data. NL is the one giving an idea of the research, guiding how to conduct the research, assisting how to measure the image qualities, giving suggestions regarding radiologist questionnaires, assisting in how to analyze the result, and writing this article. PH contributes to suggesting how to process the data and visualizing the result. DM contributes as the peer reviewer who reads this article before it gets submitted, helps to correct the vocabulary and grammar errors of the article, and contributes by adding references that are related to this article.

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