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Original Research Paper

The role of virtual grid to increase contrast-to-noise ratio in thorax radiography

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Abstract
Thorax is a dense object, necessitating the use of a grid. However, hospitals use physical grids, which have drawbacks such as increased doses, appearance of artifacts, and a lack of ergonomics. To address these issues, virtual grid technology has been developed. This study aims to describe the thorax radiographic examination using a virtual grid and to compare the CNR of thorax radiographs using physical and virtual grids. This study uses a mixed-methods experimental, conducted at the Radiology Laboratory of 'Aisyiyah University Yogyakarta from November 2023 to May 2024. Data were collected through observation and experiments with a thorax phantom, physical and virtual grids, and CNR measurements at 5 points on images using ImageJ. The sample is thorax radiographic was tested in 5 trials each. Data analysis was performed using the paired samples T-Test. The results of thorax radiographic imaging using the virtual grid showed that after exposure, the image appeared on the monitor. Activating the virtual grid feature (ON) with 8:1 grid ratio, CNR were measured at each ROI. CNR with the physical grid were average of 27.22. With the virtual grid, the CNR were average of 40.81. These results indicate that the image quality using the virtual grid is superior. Statistical analysis showed a significant difference, with a p-value of 0.018. These findings suggest that the virtual grid not only improves image quality but also enhances workflow efficiency and operational ergonomics examinations. Future studies should explore the broader applicability of virtual grid technology in different radiographic modalities.

Keywords: contrast to noise ratio; thorax; virtual grid

1. Introduction

In the medical field, various supporting examination areas are needed to help establish the diagnosis of a disease, one of which is radiology. Radiology is a branch of medical science that studies the process of creating images of human body organs using X-ray radiation (Bushong, 2016). One such examination utilizing X-rays is thorax radiography.

The thorax is a cone-shaped cavity, with the lower part being larger than the upper part, and the posterior portion longer than the anterior. It is located between the neck and the abdomen. The thoracic cavity contains the lungs and the mediastinum (Pearce, 2009). Thorax radiography is the most frequent and routine examination conducted in every radiology department, especially in radiodiagnostics (WHO, 2016). According to (Bequet et al., 2020), thorax radiography is a significant diagnostic method for evaluating the airways, parenchyma, and pulmonary vessels, as well as the mediastinum, heart, pleura, and thoracic wall. This study examines the comparison between physical and virtual grids in thorax radiography as an effort to identify methods that can enhance diagnostic quality and efficiency in this procedure.

According to (Adler et al., 2022) objects with large and complex volumes increase the amount of scattered radiation. Scattered radiation that reaches the film interferes with the diagnostic value of the image due to the scattering effect and low signal. For adult thorax objects with standard patient size and high thickness (>10cm), a grid is needed to reduce scattered radiation incidence and improve image quality. Thorax radiographs using a grid tend to have lower density and higher contrast because the grid absorbs scattered radiation, allowing differentiation between soft tissue, bone, and mediastinum. In contrast, thorax radiographs without a grid have high density and high contrast because all radiation from the X-ray tube is absorbed by the image receptor, resulting in images that are too dark and less optimal in differentiating soft tissue, bone, and mediastinum (Utami et al., 2019).

So far, the grid used in radiology examinations is a physical grid. A physical grid is a radiology examination tool consisting of high atomic number metal strips (usually lead) arranged in parallel and separated by interspace material (usually aluminum and plastic fiber) that can be penetrated by X-rays (Mukhtar & Sutanto, 2015). However, the use of a physical grid also has several drawbacks, such as the reduction in the number of X-ray photons reaching the film or detector, leading to increased noise in radiographic images. To compensate for the reduction in the number of X-ray photons, exposure factors (tube current) are usually increased, resulting in a higher radiation dose received by the patient. The higher the grid ratio, the greater the exposure factor needed (Priyono et al., 2020). Additionally, lines on the radiograph can interfere with the radiologist's expertise. Another disadvantage of physical grids is that when X-rays penetrate at an oblique angle, uneven density appears in the resulting image. This issue is particularly notable in mobile X-ray examinations where the grid is often tilted. Therefore, the use of physical grids is currently considered not fully effective (Kawamura et al., 2015).

In 2016, FujiFILM Holdings Corporation developed a modality in the form of the FDR D-EVO II C35 digital radiography detector to enhance radiographic image quality and optimize radiographic results because it features a virtual grid. The virtual grid is an image processing technology that improves image quality by reducing the effects of scattered X-rays (Kawamura et al., 2015).

Kawamura et al. (2020) state that the virtual grid can enhance contrast degradation and granularity caused by scattered X-rays, thereby improving image quality. The broad application of technologies like the virtual grid can contribute to enhancing image quality and increasing procedural workflow efficiency in radiographic examinations. The virtual grid is believed to address all the shortcomings of the physical grid.

Research directly comparing the use of physical grids and virtual grids in thorax radiography is still limited. Although the drawbacks of physical grids, such as increased radiation dose, noise, and image artifacts, have been widely discussed, the effectiveness of virtual grids in addressing these issues, particularly in terms of diagnostic accuracy and operational efficiency, has not been thoroughly explored. Therefore, further research is needed to evaluate the advantages of virtual grids in improving image quality and enhancing radiographic procedures. The aim of this study is to investigate thorax radiography procedures and the contrast to noise ratio (CNR) of thorax radiographs using physical grids and virtual grids.

2. Research Methods

This study employs a mixed methods approach with an experimental design to evaluate thoracic radiography procedures utilizing both virtual and physical grid technologies to enhance the contrast-to-noise ratio (CNR). The research was conducted at the Radiology Laboratory of 'Aisyiyah University Yogyakarta, using an anthropomorphic thoracic phantom as the imaging subject to ensure consistency and control. The tools and materials used include the FDR D-EVO II C35 detector, the BMI Jolly 30 Plus mobile X-ray machine, a physical grid with an 8:1 ratio, shielding, a computer console, and writing instruments.

The procedure involved two exposures: one with the physical grid and one with the virtual grid. For the virtual grid, this feature was activated through the detector's software by setting the function to "ON" and adjusting the grid ratio to 8:1. The phantom was positioned following standard radiographic techniques, with care taken to remove any metal objects around it to avoid imaging artifacts. Both radiographs were processed using ImageJ software to select five Regions of Interest (ROIs)—the ribs, lung fields, sternum, clavicle, and scapula—where the Signal-to-Noise Ratio (SNR) values were calculated. These values were then statistically analyzed using a Paired Sample T-Test to identify significant differences in image quality between the two grid technologies.

The Contrast to Noise Ratio (CNR) is a parameter used to measure how well the desired signal can be distinguished from the background noise. The higher the contrast value, the easier it is for the signal to be differentiated from the background, which improves the overall image quality. A high-contrast image allows lesions and other anatomical details to be clearly visible, as lower noise and higher contrast facilitate the separation between the desired structures and the background (Huda & Abrahams, 2015). Therefore, a high CNR is crucial in producing high-quality radiographic images.

CNR can be calculated based on ROI measurements from the radiographic images. These measurements are particularly useful in optimizing radiation dose and ensuring that the desired signal remains clearly visible despite the background noise (Kempski et al., 2020). To calculate CNR, five ROI points on the background and five ROI points on the object were selected, including the ribs, lung fields, sternum, clavicle, and scapula. The placement of these ROIs aims to provide a representative view of the image quality and the differences between the virtual and physical grids used in this study (Asriningrum et al., 2021).

3. Results and Discussion

3.1. Procedure for thorax radiography examination with the FDR D-EVO II C35 modality using a physical grid and virtual grid technology

Thorax radiography examinations using physical and virtual grids were conducted in the Mobile Radiology Lab at 'Aisyiyah University Yogyakarta using a BMI brand mobile X-ray machine. According to (Kawamura et al., 2015), the exposure factors used were 80 kV and 4.0 mAs, and the detector was the FujiFilm FDR D-EVO II C35. Images were taken twice: first using a physical grid with an 8:1 ratio, and second using a virtual grid with an 8:1 ratio.

The thorax examination using the FDR D-EVO II C35 detector with both physical and virtual grid technology required no special preparations, as a thorax phantom was used. The only necessary step was ensuring that there were no metal objects around the phantom. As noted by (Lampignano & Kendrick, 2024), thorax examinations typically do not require special preparation other than ensuring that patients remove metal objects that may interfere with the radiographic results. This was especially applicable in this case, as the use of a thorax phantom (an inanimate object) meant that the only concern was avoiding interference from any metallic objects.

The preparation of the tools and materials for the thorax examination included the BMI brand mobile X-ray machine, thorax phantom, physical grid, FDR D-EVO II C35 detector, laptop as a computer console, and shielding. (Lampignano & Kendrick, 2024) describe the necessary equipment for thorax examination as including an X-ray machine, gonad shield, 35 x 43 cm cassette, and grid. The preparation of these tools in this study is consistent with the standard procedure, except that the use of a mobile X-ray machine meant that additional shielding was required to protect the researcher from direct radiation exposure, as no dedicated operator room was available. This shielding was crucial, particularly because the phantom was used in place of a patient, and there was no need for extra protective equipment for the phantom itself.

This methodological approach helps underline the effectiveness of using both physical and virtual grids in radiographic examinations. The absence of interference from metallic objects and the controlled use of the phantom provide a solid foundation for comparing the performance of the two grid types.

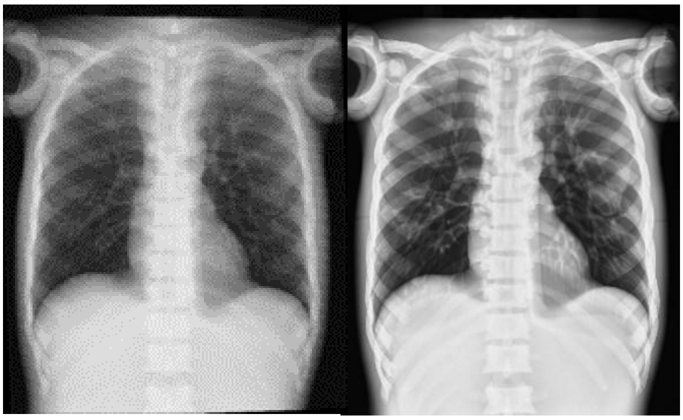
Furthermore, the use of shielding reflects a practical adaptation to ensure safety while also reinforcing the legitimacy of the results obtained. The comparison between the two grid types thus becomes not only a scientific inquiry into image quality and operational efficiency but also a practical assessment of the feasibility of using advanced radiographic technologies in mobile settings.

The object position for thorax radiography using the physical grid and the FDR D-EVO II C35 detector with a virtual grid included placing the phantom on top of the detector, and the 35x43 cm physical grid with an 8:1 ratio was used specifically for the physical grid in the Anteroposterior (AP) position, with the central point on Thoracic 7 or between the inferior angles of the scapulae. Collimation was adjusted to fit the object size, with the upper boundary at the apex of the lungs and the lower boundary at the diaphragm. The exposure factors used were 80 kV and 4.00 mAs, with an FFD of 120 cm. According to (Long et al., 2016), in the AP projection for thorax examination, both arms are placed beside the body, the MSP is centered on the cassette, the upper cassette boundary is 4–5 cm above the shoulder joint, the central point is on Thoracic 7 or between the inferior angles of the scapulae, with a 120 cm FFD and collimation matching the object size, using a high kV method. Exposure is performed during inspiration with breath-hold. The author agrees that the object position for thorax examination using a physical grid and the FDR D-EVO II C35 detector with a virtual grid is appropriate, as the phantom was placed on the detector or flat panel, and the physical grid size matched the collimation boundaries. Since the object was a phantom, breath-hold during exposure was unnecessary.

The results of thorax radiography using a physical grid appear immediately on the screen. In contrast, with the FDR D-EVO II C35 detector and virtual grid, after exposure, the image appears on the computer screen, and then QA and VGP are clicked to activate the virtual grid feature, set to ON, and the grid ratio is adjusted to 8:1. The FDR D-EVO II C35 detector offers various grid ratios, including 3:1, 6:1, 8:1, 10:1, 13:1, and 16:1. The grid ratio affects the grid's ability to enhance contrast, with higher ratios being more effective in absorbing scattered radiation compared to lower ratios, as the scatter angle is less than what is allowed by lower ratio grids. However, higher ratio grids require higher exposure factors for sufficient X-ray penetration to the image receptor, increasing the patient's dose (Bushong, 2016).

According to Bushong (2016), the 8:1 grid ratio is commonly used for general radiography. In virtual grid mode, the device processes images to simulate the appearance of those taken with a physical grid, resulting in better contrast and clarity. Based on research by Priyono et al., (2020), using a physical grid can reduce the number of X-ray photons reaching the film or detector, leading to increased noise in radiographic images. To address this, the tube current is usually increased, resulting in a higher radiation dose for the patient (Priyono et al., 2020). Lines on radiographs can also interfere with the radiologist's analysis. Another drawback of physical grids is uneven image density when X-rays penetrate at an oblique angle, especially in mobile X-ray examinations where the grid is often tilted. Therefore, physical grid usage is currently considered not fully effective (Kawamura et al., 2015). Conversely, virtual grids can enhance procedural workflow efficiency in radiographic examinations, making them more effective (Kawamura et al., 2015).

The author believes that thorax radiography using the FDR D-EVO II C35 detector with a virtual grid is easier and does not require adjusting the physical grid. If the physical grid is not correctly positioned on the cassette, it can tilt and be misaligned. The virtual grid simplifies workflow in radiographic examinations, increases work efficiency, and saves time. The results of both radiographs can be seen in Figure 1 below.



(a) (b)

Figure 1. Thorax Radiograph Results with Physical Grid (a) and Virtual Grid (b)

3.2. Contrast to Noise Ratio (CNR) values in Thorax radiographs with the FDR D-EVO II C35 modality using Physical Grid and Virtual Grid technology

The calculation results and normality test results of the Contrast to Noise Ratio (CNR) values in thorax radiography examinations using physical and virtual grids on 2 samples from each ROI are shown in Table 1 and Table 2 below.

Table 1. Calculation of CNR Values

Gambar	Nilai CNR					Rata-Rata CNR
	1	2	3	4	5	
Thorax Physical Grid	26,09	12,52	27,86	36,62	33,01	27,22
Thorax Virtual Grid	43,98	23,57	35,55	61,64	39,35	40,818

Source: Primary Data, 2024

Table 2. Shapiro-Wilk Normality Test Results

Gambar	p-Value Shapiro Wilk	Keterangan
Thorax Physical Grid	0,537	Data is normally distributed
Thorax Virtual Grid	0,871	Data is normally distributed

Source: Primary Data, 2024

The highest CNR value is for the virtual grid at 40.818, while the value for the physical grid is 27.22. A normality test was conducted to determine whether the data were normally distributed. The results indicated that the data were normally distributed with p-values greater than 0.05, with the physical grid at 0.537 and the virtual grid at 0.871. A Paired Samples T-Test was performed, yielding a significance level or p-value of 0.018. This indicates that the null hypothesis (Ha) is accepted, meaning there is a significant difference in image quality in terms of CNR between thorax images using different grid types.

This finding is consistent with the study by Kawamura et al. (2015), which states that virtual grid technology can influence the Contrast to Noise Ratio (CNR). The CNR for images exposed with a virtual grid is higher compared to images exposed with a physical grid. This is due to the virtual grid's ability to account for scattered X-rays according to the thickness of the object and its effectiveness in enhancing contrast to a level comparable to that of a physical grid. A low Signal-to-Noise Ratio (SNR), which occurs when low signal (low mAs) is accompanied by high noise, causes soft tissue details to appear blurred, rough, or mottled, resulting in a decreased contrast in the radiograph. This indicates that both SNR and CNR play an important role in affecting radiographic image quality, particularly in terms of contrast and image detail (Abhinaya, LM & Arvind, 2021). Thoracic radiography requires high image quality to clearly depict the lung fields and bronchial structures within the lung tissue to aid in diagnosis, which requires high tube voltage exposure and the use of a grid (Mukhtar & Sutanto, 2015).

According to the author, the CNR value in thorax radiographs using the FDR D-EVO II C35 modality with virtual grid technology is higher than that with physical grid technology, resulting in better image quality. This is in line with Kawamura et al., (2015) statement that without a grid, radiographs often show significant noise. The physical grid addresses this issue by absorbing scattered radiation and enhancing image contrast. The thicker the object being examined, such as the thorax in this study, the more important the use of a grid for producing clearer and more accurate images. Virtual grids offer features that can provide better image quality compared to physical grids, as they can account for X-ray scatter according to object thickness. The author recommends using virtual grid technology for examining thick objects, such as the thorax, and suggests that future research should employ phantoms with high image quality.

4. Conclusion

The research concludes that thorax radiography using physical and virtual grids with the FDR D-EVO II C35 modality can be performed without special preparation, though image processing differs. The virtual grid is more ergonomic, eliminating manual adjustments and improving workflow efficiency. The Contrast to Noise Ratio (CNR) values for the virtual grid (average 40.818) are significantly higher than for the physical grid (average 27.22), indicating better image quality. Statistical testing shows a significant difference with a p-value of 0.018, confirming the superior performance of the virtual grid. Further research should investigate related image information from thorax radiography using both virtual and physical grids.

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