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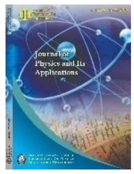

Comparison of Image Quality Between Virtual Grid And Physical Grid At A Ratio of 10:1 Using Digital Radiography (DR)

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A B S T R A C T

Virtual Grid (VG) in radiology is still rarely used since this technology is still new and literature information is scarce. The objective of this study is to evaluate image quality between virtual grid (VG) and physical grid at a grid ratio of 10:1 using digital radiography (DR). This study employed a descriptive analytical method conducted between June and July 2025 at the Physics and Radiography Laboratory of the Department of Diagnostic Imaging and Radiotherapy, Poltekkes Jakarta II. The equipment used included an X-ray multipurpose, a DR imaging system equipped with a VG at a ratio of 10:1, a physical grid at a ratio of 10:1, Radiant DICOM Viewer software, and a stepwedge. The research preparation involved testing the X-ray machine and DDR modalities, followed by exposure at varying tube voltages (kV) of 60 kVp, 70 kVp, 80 kVp, and 90 kVp, with three variations in tube current-time (mAs): 10 mAs, 16 mAs, and 20 mAs. The obtained images were analyzed using the Radiant DICOM Viewer to assess image quality based on the measured signal-to-noise ratio (SDNR) and figure of merit (FOM). The results demonstrated consistent graphical patterns across with increases in kV and mAs indicate that the VG ratio of 10:1 tends to show improved SDNR and FOM values compared to the physical grid ratio of 10:1 and non-grid configurations. The image quality of the VG with a 10:1 ratio outperforms both the physical grid and non-grid configurations in DDR imaging.

1. Introduction

Radiography imaging is a modality used to diagnose diseases using X-rays. Based on experimental data, X-rays exhibit three behaviors when interacting with objects. First, X-rays that pass through objects without interaction are called primary radiation. Second, when X-rays interact with objects, they are called absorbed dose. Third, when X-rays interact with objects and are then reflected in all directions, they are called scattered radiation [1]. In a radiography examination procedure, scattered radiation that reaches the imaging detector is 5-6 times more than the homogeneous X-ray beam. Therefore, reducing the effects of scattered radiation can basically be done in two ways, namely the air gap method and the use of a grid, but the air gap method is not used because it can enlarge the size of the object in the image. A grid is a tool with an aluminum and lead mesh structure to minimize the effects of scattered radiation [2].

Several studies have shown the advantages of grids, especially in chest radiography examinations in intensive care units (ICUs) using mobile X-ray imaging systems, as they can improve image quality in showing lung infiltrates [3]. However, the increased workload has led radiographers to not use grids during radiographic examinations [4]. It should be noted that the use of grids causes the intensity of X-rays reaching the imaging detector to tend to decrease, so radiographers control image quality by increasing the radiation dose by 4-5 times compared to without using grids [5], [6].

To overcome this problem, radiography (DR) imaging systems can be a solution, as they are considered better than conventional radiography and computed radiography (CR) [7], [8]. The paradigm of reducing scattered radiation effects using physical grids is still accepted today. One report comparing image quality between DDR and CR using physical grids showed that DDR with physical grids was able to improve image quality compared to CR with physical grids. However, in this study, there was an increase in radiation dose when using physical grids [9]. Various radiology equipment vendors have begun to develop software with post-processing algorithms in DDR imaging systems to reduce the effects of scattered radiation while maintaining image quality without using physical grids. One of these is Virtual Grid (VG), which is considered capable of reducing radiation doses while maintaining image quality [1], [10]. The application of VG has been implemented in clinical practice by comparing it with physical grids in chest radiography procedures, showing that VG can improve image quality while minimizing radiation dose [11].

Based on observations, the use of VG in radiology is still rare because this technology is still new and there is little information available in the literature. In general, the use of physical grids in radiology uses a grid ratio of 10:1 [7], so it is necessary to adjust the exposure factor when using DDR imaging to obtain the best image quality. In addition, VG has the same concept as physical grids, so changes in exposure factors can affect image quality [12]. Therefore, this study focuses on evaluating image quality between virtual grids and physical grids at a ratio of 10:1 using DR imaging.

2. Methods

This study used a descriptive analytical method to analyze the comparison of image quality between virtual grid (VG) and physical grid at a ratio of 10:1 using DR. This study was conducted from June to July 2025 at the Physics and Radiography Laboratory of the Department of Imaging Diagnostic and Radiotherapy, Polytechnic of Jakarta II. The equipment included X-ray modality, a DDR imaging system equipped with a VG with a ratio of 10:1, a physical grid of 10:1, Radiant Dicom Viewer software, and a step wedge. The research procedure began with ensuring that the equipment was in optimal or reliable condition. For the X-ray machine modality, the tests conducted included tube voltage (kVp) accuracy testing with a maximum error value of 1%, irradiation time accuracy testing with a maximum error value of 0.6%, a large and small focal spot radiation output linearity test with a maximum linearity coefficient value of 0.01, and a tube voltage (kVp), exposure time (s), and dose (mGy) reproducibility test with a coefficient variation value of 0.001-0.003. For DDR testing, the radiation exposure response test was used against the mean pixel value shown in Figure 1. The radiation exposure response test results against the mean pixel value were R2=0.9695. The test results showed the ideal response of the flat panel detector when the radiation exposure increased, so the mean pixel value also increased.

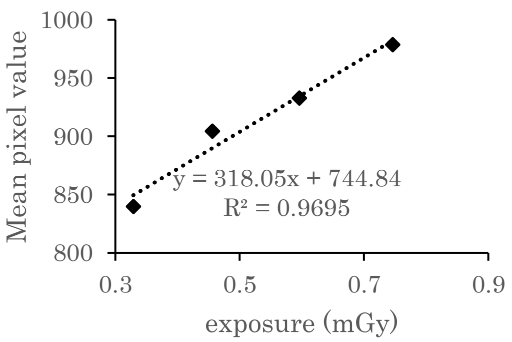


Fig. 1: Radiation exposure response to pixel value

The irradiation exposure procedure begins by setting the distance between the source and the DDR detector at 100 cm, then adjusting the irradiation field area to match the shape of the stepwedge and ensuring that the source does not rotate. Next, set the exposure factor to vary with tube voltage of 60 kVp-90 kVp with an increase of 10 points with a fixed mAs and 10 mAs-20 mAs with an increase of 5 points with a fixed tube voltage. Irradiation was performed twice, namely non-grid and physical grid. The image results were analyzed using Radiant Dicom Viewer software to measure the region of interest (ROI) with a diameter of ±0.5 cm2 to determine the S0 pixel value of the object, SBG pixel value of the background, and SDBG standard deviation of the background, as shown in Figure 2.

In analyzing the DDR imaging system, image quality indicators that are considered relevant are measured using the signal-to-noise ratio (SDNR), as it is more effective in assessing contrast changes due to the influence of X-ray file quality. SDNR measurement uses the following equation (equation 1) [13]:

$$SDNR = \frac{|S_o - S_{BG}|}{SD_{BG}} \quad (1)$$

Then, to determine the best image quality by considering the lowest possible radiation dose with optimal image quality, the figure of merit (FOM) measurement is used, after determining the radiation dose using the radiation output equation from the results of the tube voltage variation test measurements (equation 2). Radiation dose and FOM measurements use the following equation (equation 3) [14]:

$$Radiation\ output\ (mGy) = 0.000004\ x\ kV^{2.1846}\ x\ mAs\ x\ \left(\frac{100}{SID}\right)^2 \quad (2)$$

$$FOM = \frac{SDNR^2}{doses\ (mGy)} \quad (3)$$

3. Results and Discussion

Virtual grid (VG) is software that replicates the principles of physical grids in minimizing the effects of scattered radiation using computational algorithms in digital radiography imaging. This technology can solve the problem of using physical grids in radiography procedures in the intensive care unit (ICU), as well as improve image quality and reduce radiation doses compared to using physical grids [15]. The use of DDR in radiography examinations is often assumed to increase radiation doses. Especially when using physical grids, radiation doses need to be increased by 2-6 to maintain image quality. This is related to the basic concept in conventional radiography imaging to increase radiographic contrast when using physical grids [5].

Optimization is one of the principles of radiation protection, which aims to minimize radiation doses while maintaining image quality in every radiographic examination procedure. The use of grids in radiographic examinations can improve image quality, but at the same time, radiation doses also increase. However, with the application of VG, it is expected to reduce radiation doses while maintaining image quality [10].

The results of comparing image quality between VG and physical grid at a ratio of 10:1 in measuring SDNR and FOM values against tube voltage variations of 60 kVp-90 kVp with a fixed mAs value shown in Figure 3, as well as mAs variations of 10 mAs - 30 mAs with a fixed kVp value shown in Figure 4 have almost the same graph pattern when increasing the tube voltage and mAs, The use of a VG with a ratio of 10:1 tended to produce higher SDNR and FOM values than the physical grid ratio of 10:1 and the non-grid technique. This indicates that VG has more optimal image quality and radiation dose compared to the use of grids and non-grids.

The same results were also found in several studies by Tim Gossye, that an increase in exposure factors and grid ratio variations showed that VG had superior image quality in both objective and subjective measurements. subjective compared to physical and non-grid grids. In addition, according to

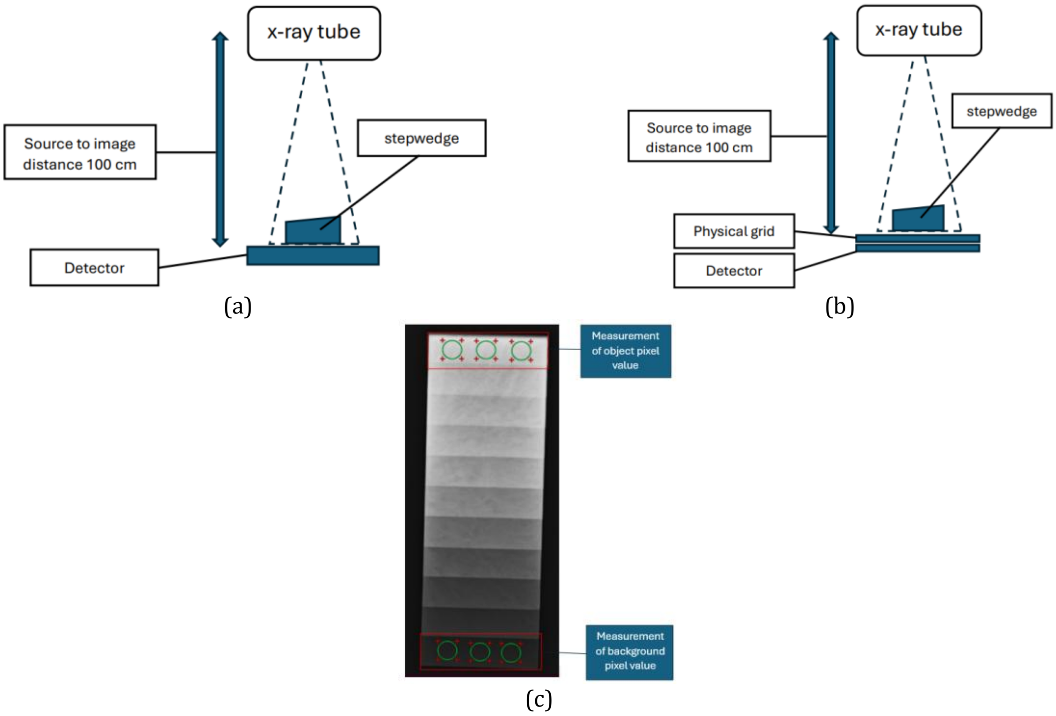


Fig. 2: Image measurement: (a) non-grid and virtual grid (VG), (b) physical grid, (c) object and background ROI

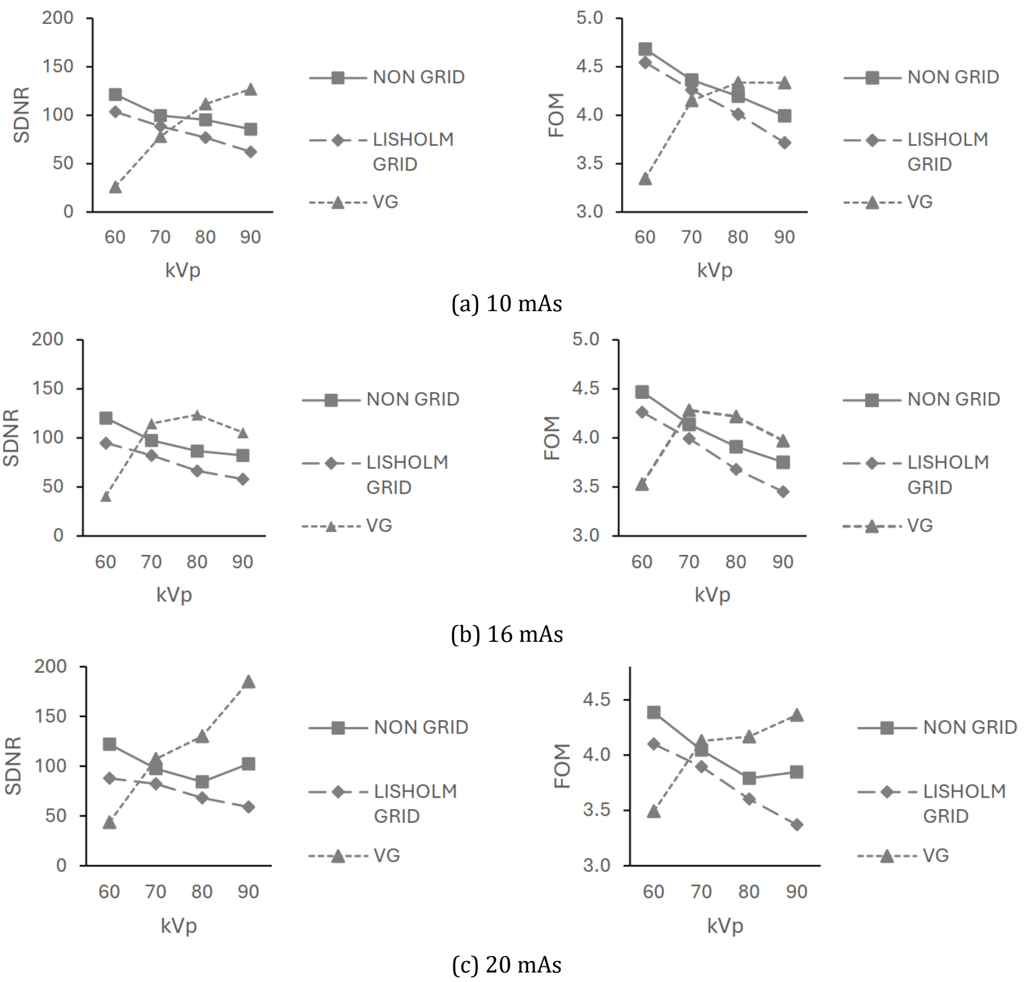
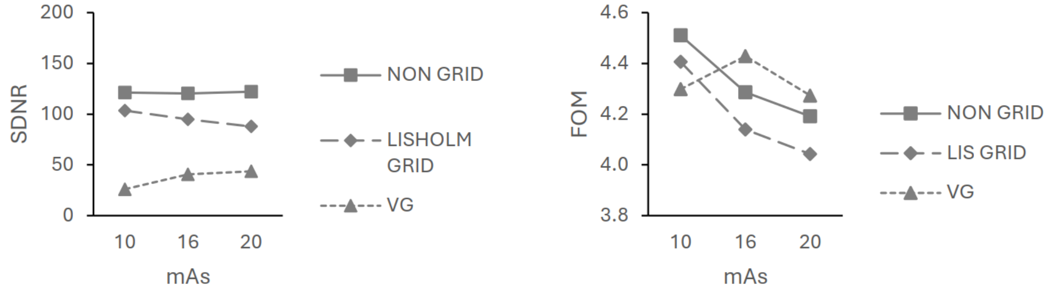


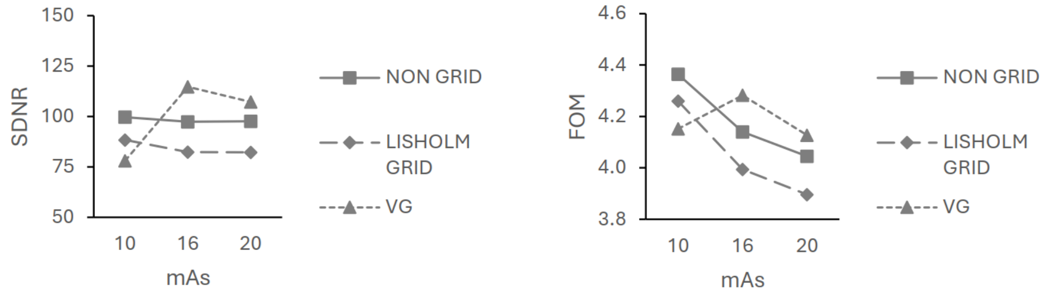
Fig. 3. SDNR and FOM measurements at increased tube voltage

him, there is the potential for a reduction in radiation dose while maintaining image quality when using VG. It is recommended to use a high kV exposure factor, which can address the issue of service effectiveness, because VG is considered to make it easier for radiographers to perform radiographic examinations in the ICU [4], [16], [17].

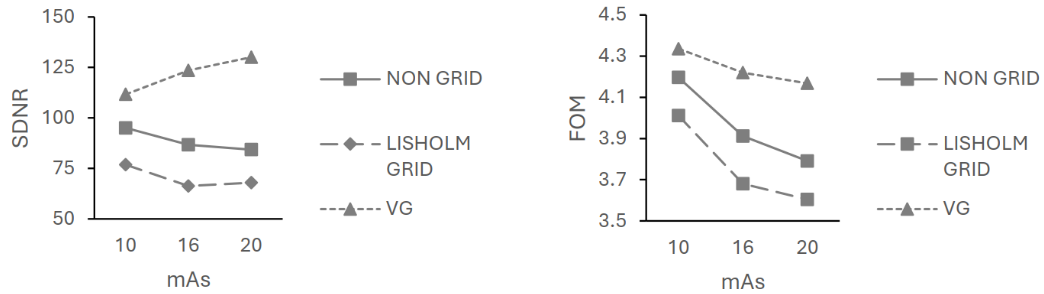
Our research also found that the increase in tube voltage when using VG becomes effective at an exposure factor >70 kVp, producing a better SDNR value compared to grid and non-grid. According to Helle Precht, grid software is not effective in detecting scattered radiation at low kV, because at low kV, photoelectric interactions are considered more dominant than scattered radiation interactions, so VG is considered unable to effectively correct scattered radiation [18].



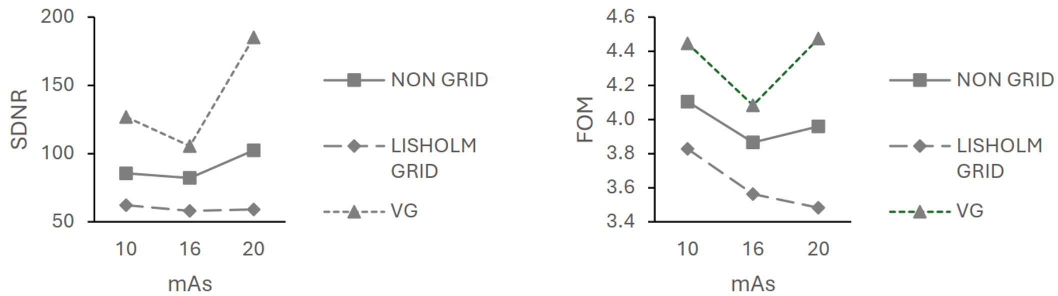
(a) 60 kVp



(b) 70 kVp



(c) 80 kVp



(d) 90 kVp

Fig. 4: SDNR and FOM measurements at increased tube current

Furthermore, our results also found that at increased tube voltage and tube current, non-grid had higher values than physical grid. Several literature sources explain that improvements in DDR technology enable better radiation detection, thereby increasing contrast and spatial resolution, especially in flat panel detector materials that can significantly improve image quality with a 60-65% increase in detection quantum efficiency (DQE) [9], [19]. Meanwhile, physical grids experience a decline. According to Hiroshi Kunitomo, an increase in tube voltage causes a decline in image quality when using physical grids [13].

Our research also found that images using physical grids experienced artifacts as shown in Figure 5. These results were seen in almost all images that used physical grids when the exposure factor was increased. Similar results were also found by Hyun-Jin, who noted that physical grids can cause gridline artifacts that can affect diagnostic assessment [20]. Several studies have found that the gridline effect is caused by the asymmetrical positioning of the X-ray beam focus point relative to the grid and in clinical procedures such as radiographic examinations in the ICU with the patient in a semi-sitting position [16], [21].

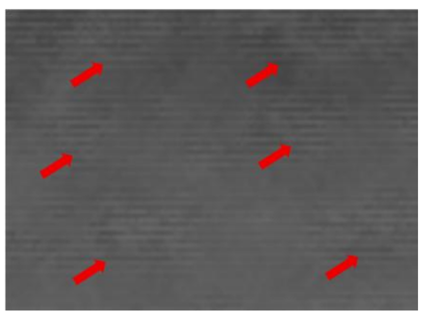


Fig. 5: Artifacts (gridlines)

From our research results, there are several notes on the application of VG and physical grids in radiographic examinations. Our research results show the potential for optimization protocols in radiographic examinations by determining the ideal VG for high kV exposure factors. From Gossey's research results, high kV can minimize radiation doses while maintaining image quality [4], [17]. Although high kV can increase scattered radiation, VG can be minimized by selecting the appropriate VG [22]. Users of physical grids should consider exposure factors, the field of view, the grid ratio, and patient thickness. Selecting variations in tube voltage can control scattered radiation, while variations in mAs can reduce noise. In several studies, the use of physical grids was limited to body thicknesses > 10 cm with tube voltage ranges > 60 kVp or 70 kVp [1], [13], [23].

Research by Lenhart reports that DDR with a grid can improve image quality compared to non-grid in clinical conditions of semi-sitting chest radiography examinations in the ICU. For DDR that does not yet use VG software, a physical grid can be used as an alternative to reduce scattered radiation in order to maintain image quality [9]. Therefore, according to Masayoshi Mizuta, DDR imaging with physical grids should no longer consider the grid factor ratio (GFR) as in conventional radiography modalities, but it is recommended to determine the signal-to-noise ratio improvement factor (SIF) to consider changes in exposure factors when using DDR modalities [24].

Image artifacts or gridlines resulting from the use of physical grids can be seen in digital imaging at grid ratios lower or higher than 10:1. This is because digital imaging uses an image acquisition system with a larger dynamic range so that the amount of exposure can be detected during image acquisition [4], [9], [19]. Therefore, according to Anderson, to minimize gridlines, high kV in the range of 80-100 kVp can be used, as well as optimizing post-processing [1][3].

It should be noted that the use of physical grids will automatically increase the exposure factor, so that the radiation dose using physical grids will tend to be higher than without grids. In the application of physical grids, radiation protection needs to be considered. The latest recommendation is that the use of grids is not recommended for pediatric patients, even if they have a body thickness of > 20. Therefore. There needs to be collaboration between radiographers, medical physicists, and radiologists in designing optimization procedures for grid use in pediatric and adult patients [23], [25].

This study has limitations, including the use of step wedges. Although optimal results were seen with the use of VG, further studies are needed to strengthen the literature by using human-specific pantom or direct application on patients. This study did not vary the VG ratio, using only 10:1. Therefore, further exploration is needed to determine the impact of variations lower or higher than those in this study.

4. Conclusions

The results of the study show that the image quality of VG ratio 10:1 is superior to that of physical grid ratio 10:1 and non-grid. Furthermore, our study shows that the improvement in image quality of VG ratio 10:1 is effective when using tube voltage parameters > 70 kVp and tube current-time parameters > 10 mAs. Image artifacts resulting from the use of physical grids are visible in all variations of kV and mAs, so the use of physical grids in DDR imaging needs to be considered.

References

[1] M. Sayed, K. M. Knapp, J. Fulford, C. Heales, and S. J. Alqahtani, "The principles and effectiveness of X-ray scatter correction software for diagnostic X-ray imaging: A scoping review," *Eur. J. Radiol.*, vol. 158, Jan. 2023, doi: 10.1016/j.ejrad.2022.110600.

[2] T. Porubszky, "Anti-scatter grids, applied in diagnostic radiology," *Proceedings of European Medical Physics and Engineering Conference*, pp. 198–204, 2012, Accessed: Jul. 18, 2025. [Online]. Available: https://inis.iaea.org/records/d2phz-gay30.

[3] D. W. Anderson, "Introduction of grids to mobile ICU radiography in a teaching hospital," *British Journal of Radiology*, vol. 79, no. 940, pp. 315–318, Apr. 2006, doi: 10.1259/BJR/66912494.

[4] T. Gossye, P. V. Smeets, E. Achten, and K. Bacher, "Impact of Software Parameter Settings on Image Quality of Virtual Grid Processed Radiography Images: A Contrast-Detail Phantom Study," *Invest. Radiol.*, vol. 55, no. 6, pp. 374–380, Jun. 2020, doi: 10.1097/RLI.0000000000000646.

[5] H. Kawashima *et al.*, "Radiation dose considerations in digital radiography with an anti-scatter grid: A study using adult and pediatric phantoms," *J. Appl. Clin. Med. Phys.*, vol. 24, no. 9, Sep. 2023, doi: 10.1002/ACM2.14081.

[6] Wayne Forrest, "Antiscatter grids may not be helpful in some DR applications | AuntMinnieEurope," AuntMinnie.com. Accessed: Jul. 18, 2025. [Online]. Available: https://www.auntminnieeurope.com/clinical-news/article/15642212/antiscatter-grids-may-not-be-helpful-in-some-dr-applications.

[7] L. Court and T. Yamazaki, "Technical note: A comparison of antiscatter grids for digital radiography," *British Journal of Radiology*, vol. 77, no. 923, pp. 950–952, Nov. 2004, doi: 10.1259/BJR/21117919.

[8] T. M. Bernhardt, U. Rapp-Bernhardt, T. Hausmann, G. Reichel, U. W. Krause, and W. Doehring, "Digital selenium radiography: Anti-scatter grid for chest radiography in a clinical study," *British Journal of Radiology*, vol. 73, no. 873, pp. 963–968, 2000, doi: 10.1259/BJR.73.873.11064649.

[9] T. Lehnert *et al.*, "Comparative study between mobile computed radiography and mobile flat-panel radiography for bedside chest radiography: Impact of an antiscatter grid on the visibility of selected diagnostically relevant structures," *Invest. Radiol.*, vol. 49, no. 1, pp. 1–6, 2014, doi: 10.1097/RLI.0B013E3182A56654.

[10] A. J. Abdi, H. Precht, C. B. Outzen, and J. Jensen, "Quantitative Evaluation of Image Quality and Radiation Dose Using Novel Intelligent Noise Reduction (INR) Software in Chest Radiography:

A Phantom Study," *Diagnostics 2025, Vol. 15, Page 1391*, vol. 15, no. 11, p. 1391, May 2025, doi: 10.3390/DIAGNOSTICS15111391.
[11] Wayne Forrest, "Virtual antiscatter grid improves chest x-ray images | AuntMinnie," AuntMinnie.com. Accessed: Jul. 18, 2025. [Online]. Available: https://www.auntminnie.com/resources/conference/rsna/article/15621735/virtual-antiscatter-grid-improves-chest-x-ray-images.
[12] C. S. Moore *et al.*, "Investigating the use of an antiscatter grid in chest radiography for average adults with a computed radiography imaging system," *British Journal of Radiology*, vol. 88, no. 1047, Mar. 2015, doi: 10.1259/BJR.20140613.
[13] H. Kunitomo and K. Ichikawa, "Signal-to-noise ratio improvements using anti-scatter grids with different object thicknesses and tube voltages," *Phys. Med.*, vol. 73, pp. 105–110, May 2020, doi: 10.1016/J.EJMP.2020.04.014.
[14] Ika Hariyati, Lukmanda Evan Lubis, Djarwani Soeharso Soejoko, Supriyanto Ardjo Pawiro, and Indah Lestariningsih, "The optimization of image acquisition on direct-digital radiography system using in-house phantom," Universitas Indonesia, Depok, 2019. Accessed: Dec. 12, 2024. [Online]. Available: https://lib.ui.ac.id/detail?id=20481866&lokasi=lokal
[15] Takahiro KAWAMURA, Satoshi NAITO, Kayo OKANO, and Masahiko YAMADA, "Improvement in Image Quality and Workflow of X-Ray Examinations using a New Image Processing Method, 'Virtual Grid Technology,'" FUJIFILM RESEARCH & DEVELOPMENT (No.60-2015). Accessed: Jul. 19, 2025. [Online]. Available: https://asset.fujifilm.com/www/jp/files/2019-12/af33379bc12c07f84a63f59ebdeef431/ff_rd060_004_en.
[16] T. Gossye *et al.*, "Evaluation of Virtual Grid Processed Clinical Chest Radiographs," *Invest. Radiol.*, vol. 57, no. 9, pp. 585–591, Sep. 2022, doi: 10.1097/RLI.0000000000000876.
[17] T. Gossye *et al.*, "Evaluation of Virtual Grid processed clinical pelvic radiographs," *J. Appl. Clin. Med. Phys.*, vol. 25, no. 6, Jun. 2024, doi: 10.1002/ACM2.14353.
[18] H. Precht *et al.*, "CAN SCATTER CORRECTION SOFTWARE REPLACE A GRID in DR PELVIC EXAMINATIONS?," *Radiat. Prot. Dosimetry*, vol. 187, no. 1, pp. 8–16, Dec. 2019, doi: 10.1093/RPD/NCZ129.
[19] B. Ween, M. Olstad, J. Å. Jakobsen, and D. R. Olsen, "Pediatric digital chest radiography, comparison of grid versus non-grid techniques," *European Journal of Radiography*, vol. 1, no. 4, pp. 201–206, Dec. 2009, doi: 10.1016/J.EJRADI.2010.09.002.
[20] Hyun-Jin Yang and ong-Kyoon Han, "A Study on the Usefulness of VGR (Virtual Grid Role) Algorithm for Elevation of Image Quality in DR System," *J. Korean Soc. Radio*, vol. 14, no. 6, pp. 763–772, 2020, Accessed: Jul. 19, 2025. [Online]. Available: https://www.koreascience.kr/article/JAKO202035066033779.
[21] D. W. Anderson, "Introduction of grids to mobile ICU radiography in a teaching hospital," *British Journal of Radiology*, vol. 79, no. 940, pp. 315–318, Apr. 2006, doi: 10.1259/BJR/66912494.
[22] H. Precht *et al.*, "CAN SCATTER CORRECTION SOFTWARE REPLACE A GRID in DR PELVIC EXAMINATIONS?," *Radiat. Prot. Dosimetry*, 2019, doi: 10.1093/rpd/ncz129
[23] S. Fritz and A. K. Jones, "Guidelines for anti-scatter grid use in pediatric digital radiography," *Pediatr. Radiol.*, vol. 44, no. 3, pp. 313–321, Mar. 2014, doi: 10.1007/S00247-013-2824-9.
[24] M. Mizuta *et al.*, "Comparison of anti-scatter grids for digital imaging with use of a direct-conversion flat-panel detector," *Radiol. Phys. Technol.*, vol. 5, no. 1, pp. 46–52, Jan. 2012, doi: 10.1007/S12194-011-0134-1.
[25] I. Šabič, D. Ključevšek, M. Thaler, and D. Žontar, "The effect of anti-scatter grid on radiation dose in chest radiography in children," *Central European Journal of Paediatrics*, vol. 12, no. 1, pp. 75–80, Mar. 2016, doi: 10.5457/p2005-114.138.