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Effect of X-Ray Tube Voltage Variation to Value of Contrast to Noise Ratio (CNR) on Computed Tomography (CT) Scan at RSUD Bali Mandara

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Keywords

contrast to noise ratio;
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exposure factor;
image quality;
X-ray tube voltage;

Abstract

Research has been conducted on the effect of variations in X-ray tube voltage to value of Contrast to Noise Ratio (CNR) on CT Scan at Bali Mandara Hospital using a phantom as a patient replacement. This research aims to determine the effect of X-ray tube voltage to the CNR value. Exposure factors used are X-ray tube voltage with variations of 80, 110, 120 and 135 kV, constant X-ray tube current of 150 mA and constant exposure time of 1 s. The readings of I_o, I_b, and σ_b values in phantom images were performed using RadiAnt DICOM Viewer software (64 bit) and analysis of the effect X-ray tube voltage on CNR values was determined by regression test. The results of the analysis show that the variation of the X-ray tube voltage has a significant effect on the CNR value, where the greater X-ray tube voltage, the greater the CNR value. When the X-ray tube voltage is adjusted to 135 kV, the optimal CNR values are 113.52 for air, 35.06 for derlin, 13.93 for acrylic, 10.44 for nylon and 12.19 for polypropylene.

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1 Introduction

Along with technological developments, radiation is widely used in the medical sector, one of which is radiological examination. Radiology is an examination using ionizing radiation sources to diagnose a disease in the body that is displayed in the form of digital images (Carrol, 2000). One of the imaging modalities in radiology is Computed Tomography (CT) Scan which utilizes tomography and computerized techniques to produce cross-sectional images of the body (Irnawati, 2018).

In a CT scan, the X-ray tube rotates around the patient from an angle of 1^o to 360^o so that the organ being examined will be exposed to radiation from all angles. This causes the distribution of radiation doses on CT scans to be very large (Schauer & Linton, 2009). The dose on the CT scan will affect the quality of the resulting image. One method to simplify image quality analysis can be done by calculating the Contrast to Noise Ratio (CNR) value (Varghese et al., 2000; Netzelmann & Müller, 2020). CNR is the ratio between the intensity of the object and the noise around the background. The greater the CNR value, the clearer difference between the object and the noise around the background (Bontrager, 2014). An image with a high CNR value will be easier to use for diagnosis than an image with a low CNR value (Kofler et al., 2015). Therefore, it is very important to notice the CNR value so that the resulting image is good quality. To produce an optimal CNR value, it is necessary to pay attention to the exposure factor used during the CT Scan examination. Setting the right exposure factor will produce an image that can show a clear difference in the degree of blackness between organs (Sparzinanda et al., 2017).

The exposure factor consists of tube voltage (kV), tube current (mA), and exposure time (s). Changes in X-ray tube current and exposure time will affect the quantity of X-rays produced. Meanwhile, the change in the voltage of the X-ray tube is related to the intensity of the X-ray which shows the amount of X-ray energy. The greater the voltage of the X-ray tube, the greater energy of the X-rays produced (Huda & Abrahams, 2015; Ratini et al., 2020). The increase in energy causes the X-ray penetrating power to be greater, there by reducing noise in the image. This shows that changes in X-ray tube voltage affect image formation (Bourne, 2009; Bushberg et al., 2013).

Based on the above background, it is seen that it is necessary to choose the right X-ray tube voltage in the CT Scan examination in order to obtain an optimal CNR value. Therefore, in this research an analysis of the effect of variations in X-ray tube voltage on the CNR value on CT Scan.

2 Materials and Methods

Research on the effect of variations in X-ray tube voltage on CNR values on CT Scan was conducted at the Bali Mandara Hospital. The tools used are CT Scan brand Canon Aquilion TSX 201A type and Phantom brand Toshiba PX78-01377. In Phantom, there are six materials that have similarities with the density of organs, namely air as a substitute for a vacuum in the body, derlin as a substitute for bone, acrylic as a substitute for cartilage, nylon as a substitute for soft tissue, polypropylene as a substitute for fat and water as the main fluid in the body (Hutami et al., 2021).

Before taking data, the necessary tools were prepared and warm up was performed on a CT scan. The phantom is installed on the head holder of the examination table and arranged so that the phantom position is in the middle of the CT Scan gantry (Satwika et al., 2021; Utami et al., 2022). Registration is carried out and the type of examination is set for the adult head protocol. The exposure factor was adjusted, the X-ray tube voltage with variations of 80, 110, 120 and 135 kV, constant X-ray tube current of 150 mA and constant exposure time of 1 s. Then the exposure is carried out so that a phantom image with DICOM format is obtained which can be seen on the CT Scan control console (Afifi et al., 2020; Yin et al., 2015). The image is inputted into the RadiAnt DICOM Viewer software and a Region of Interest (ROI) is performed which is marked with a circle of 4,575 cm^2 on each phantom material. Next, read the values of I_o, I_b, and σ_b on the five image slices for each variation of the X-ray tube voltage as shown in Figure 1.

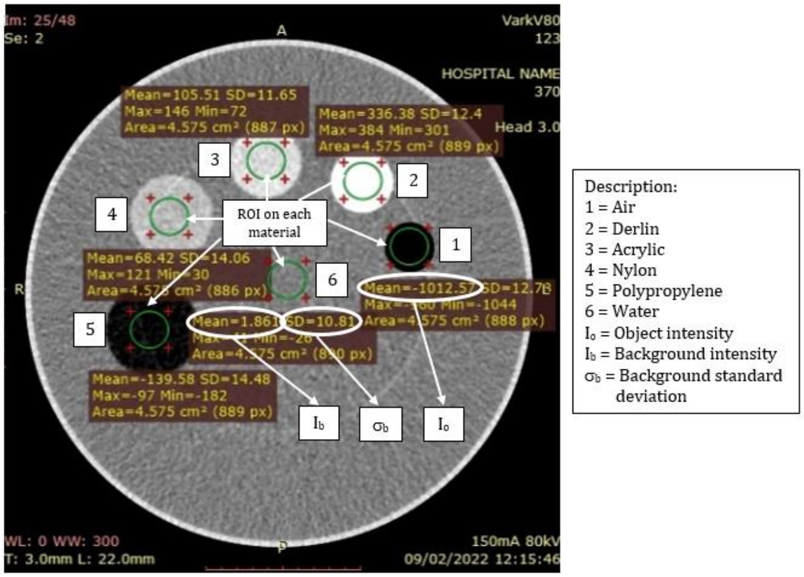

Figure 1. The process of reading the values of I_o, I_b, dan σ_b.

After obtaining the values of I_o, I_b, and σ_b for each phantom material, the CNR value was calculated using Equation 1. Then a regression test was performed using Microsoft Excel to determine the correlation between X-ray tube voltage and CNR value (Kofler et al., 2015).

$$CNR = \frac{I_o - I_b}{\sigma_b} \quad (1)$$

Where I_o is object intensity (HU), I_b is background intensity (HU) and σ_b is background standard deviation (HU).

3 Results and Discussions

The results of calculating the CNR value using equation 1 on air, derlin, acrylic, nylon and polypropylene materials are shown in Tables 1 to 5.

Table 1
CNR value in air material

X-ray tube voltage	I_O (HU)	I_b (HU)	σ_b (HU)	CNR
80	-1012,77	2,667	12,41	81,82
100	-1003,87	2,452	10,80	93,18
120	-1004,73	4,667	9,53	105,92
135	-1004,44	3,557	8,88	113,52

Table 2
CNR value on derlin material

X-ray tube voltage	I_O (HU)	I_b (HU)	σ_b (HU)	CNR
80	337,07	2,667	12,41	26,95
100	324,48	2,452	10,80	29,82
120	323,25	4,667	9,53	33,43
135	314,91	3,557	8,88	35,06

Table 3
CNR value on acrylic material

X-ray tube voltage	I_0 (HU)	I_b (HU)	σ_b (HU)	CNR
80	105,82	2,667	12,41	8,31
100	117,09	2,452	10,80	10,61
120	124,59	4,667	9,53	12,58
135	127,29	3,557	8,88	13,93

Table 4
CNR value on nylon material

X-ray tube voltage	I_0 (HU)	I_b (HU)	σ_b (HU)	CNR
80	69,14	2,667	12,41	5,36
100	83,29	2,452	10,80	7,49
120	92,25	4,667	9,53	9,19
135	96,31	3,557	8,88	10,44

Table 5
CNR value of polypropylene material

X-ray tube voltage	I_0 (HU)	I_b (HU)	σ_b (HU)	CNR
80	-140,13	2,667	12,41	11,51
100	-122,30	2,452	10,80	11,55
120	-110,67	4,667	9,53	12,10
135	-104,67	3,557	8,88	12,19

Furthermore, from Tables 1 to 5, can be made a graph correlation of the X-ray tube voltage against the CNR value shown in Figure 2 and the regression equation and coefficient of determination are presented in Table 6.

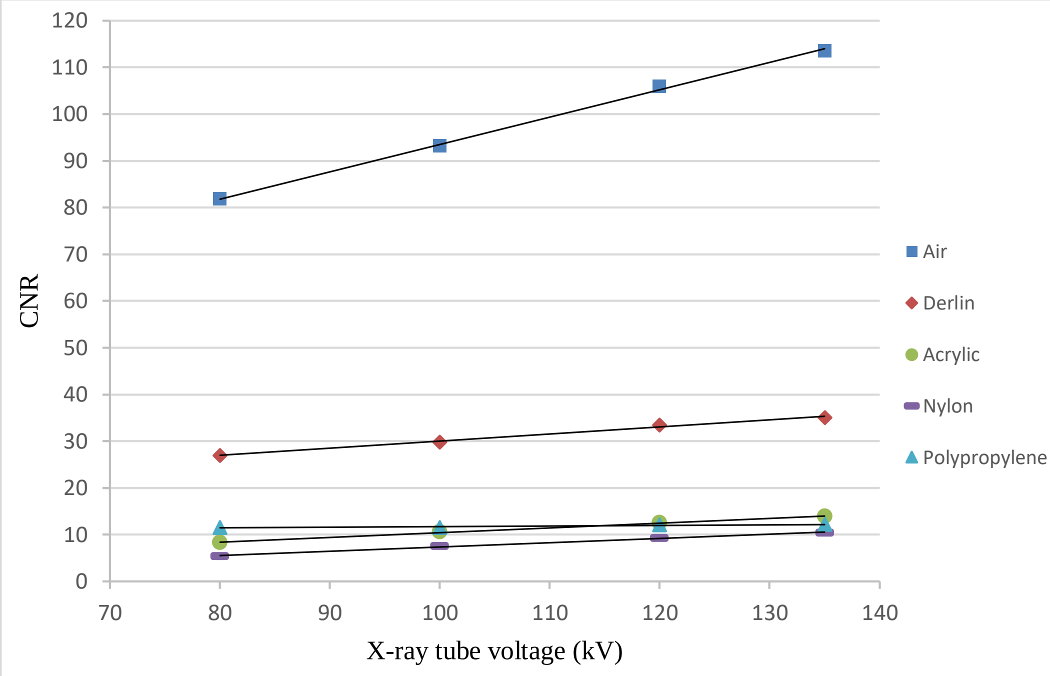

Figure 2. Graph correlation of X-ray tube voltage against CNR value

Table 6
Regression equation (y) and coefficient of determination (R^2)

	Air	Derlin	Acrylic	Nylon	Polypropylene
y	0,584x+35,09	0,152x+14,82	0,102x+0,26	0,092x+1,86	0,015x+10,31
R^2	0,9986	0,9937	0,9972	0,9963	0,8849

In Figure 2, the lowest CNR value in air is 81.82 and the highest is 113.52, in derlin the lowest CNR value is 26.95 and the highest is 35.06, in acrylic the lowest CNR value is 8.31 and the highest is 13.93, in nylon the lowest CNR value was 5.36 and the highest was 10.44, and in polypropylene the lowest CNR value was 11.52 and the highest was 12.19. Based on these results, it can be seen that the increase in the X-ray tube voltage causes an increase in the CNR value for each phantom material.

From the results of the linear regression test shown in Table 6, the R^2 value of 0.8849-0.9986 means that the X-ray tube voltage has an effect of 88.49%-99.86% on the CNR value. This shows that the X-ray tube voltage has a significant effect on the CNR value. The increase in the voltage of the X-ray tube causes the wavelength of the X-rays to be shorter so that the intensity is greater (Liang et al., 2010; Liu et al., 2014). In addition to changes in X-ray intensity, the increase in tube voltage also affects image formation. Where the greater the voltage of the X-ray tube, the formation of electrons will be accelerated so that the X-rays produced have a higher energy. This is what causes the X-ray penetrating power to be greater, thereby reducing noise in the image (Bushberg et al., 2013; Fauber, 2012). This noise reduction causes an increase in the CNR value. This is also compatible with the results of this research, where the greater the X-ray tube voltage, the greater the CNR value.

In addition to intensity, the CNR value is also influenced by the density of the material. Materials with a large density value have a high ability to absorb X-rays, while materials with a small density value will transmit more X-rays (Sarma et al., 2012; Keyak & Falkinstein, 2003). To obtain the CNR value, the density of the tissue is compared with the density of water which is the largest constituent component in the body. The greater difference between the density of the body tissue and water, the greater the value of the resulting CNR (Ginting, 2016). In this research, the highest CNR value was obtained in air material, where air has the smallest density value compared to other materials, which is 0.0013 g/cm^3. Therefore, the air material produces a black image because the air transmits more X-rays than absorbs X-rays.

The CNR value indicates image quality or the ability to visualize organs. A large CNR value indicates the object intensity (I_o) is higher than the amount of noise so that the image quality increases (Dey et al., 2016; Uibu et al., 2004). The greater CNR value, the better the quality of the resulting image, meaning that the image with the largest CNR value is the optimal image (Bequet et al., 2020). Based on this research, the optimal image was obtained when the X-ray tube voltage was adjusted to 135 kV which resulted in CNR values of 113.52 for air, 35.06 for derlin, 13.93 for acrylic, 10.44 for nylon and 12. 19 on polypropylene.

The results of this research can be used as a reference in examining organs using a CT scan, where caution is needed in determining the X-ray tube voltage used. The voltage of the X-ray tube is the dominant factor in producing the X-ray energy level used to penetrate the object (Dabukke, 2017). Therefore, it is very important to determine the X-ray tube voltage used in the examination in order to produce an optimal image. In addition, it is necessary to have Quality Assurance (QA) and Quality Control (QC) on a regular basis to evaluate the X-ray tube voltage, X-ray tube current and other parameters on CT Scans in accordance with BAPETEN Regulation No. 2 of 2018 concerning the Conformity Test of X-Ray Diagnostic and Interventional (Nariswari, 2018).

4 Conclusion

It can be concluded that variations in X-ray tube voltage affect the CNR value, where the greater the X-ray tube voltage, the greater the CNR value. When the X-ray tube voltage is adjusted to 135 kV, the optimal CNR values are 113.52 for air, 35.06 for derlin, 13.93 for acrylic, 10.44 for nylon and 12.19 for polypropylene.

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References

Afifi, M. B., Abdelrazek, A., Deiab, N. A., Abd El-Hafez, A. I., & El-Farrash, A. H. (2020). The effects of CT x-ray tube voltage and current variations on the relative electron density (RED) and CT number conversion curves. *Journal of Radiation Research and Applied Sciences*, *13*(1), 1-11. https://doi.org/10.1080/16878507.2019.1693176

Bequet, A. Y., Rusyadi, L., & Fatimah, F. (2020). Nilai Contrast to Noise Ratio (CNR) Radiograf Thorax PA antara menggunakan Grid dengan tanpa Menggunakan Grid. *Jurnal Imejing Diagnostik (JImeD)*, *6*(2), 60-64.

Bontrager, K. (2014). Textbook of Radiographic Positioning and Related Anatomy (8th Editio). *China: Elsevier Mosby*.

Bourne, R. (2009). Fundamentals of Digital Imaging in Medicine. New York, Springer London Dordrecht Heidelberg.

Bushberg, J.T., Seibert, J.A., Leidholt, E.M., & Boone, J.M. (2013). The Essential Physics of Medical Imaging Third Edition. USA, Williams and Wilkins.

Carrol, Q.B. (2000). Radiographic Exposure Processing and Quality Control. USA, Charles C. Thomas.

Dabukke, H. (2017). Pengaruh Perubahan Tegangan Terhadap Kontras Resolusi Pada CT Scan. *Jurnal Mutiara Elektromedik*, *1*(1), 24-33.

Dey, S., Purdon, M., Kirsch, T., Helbich, H., Kerr, K., Li, L., & Zhou, S. (2016). Exposure Factor considerations for safety evaluation of modern disposable diapers. *Regulatory toxicology and pharmacology*, *81*, 183-193. https://doi.org/10.1016/j.yrtph.2016.08.017

Fauber, T.L. (2012). Radiographic Imaging and Exposure Fourth Edition. USA, Commonwealth University.

Ginting, M.D. (2016). Analisis Kualitas Gambar Radiografi pada Pemeriksaan Mammae terhadap Densitas Gambar dan Faktor Eksposi, Medan, *Thesis*, Sumatera Utara University.

Huda, W., & Abrahams, R. B. (2015). Radiographic techniques, contrast, and noise in x-ray imaging. *American Journal of Roentgenology*, *204*(2), W126-W131.

Hutami, I. A. P. A., Sutapa, G. N., & Paramarta, I. B. A. (2021). Analisis Analisis Pengaruh Slice Thickness Terhadap Kualitas Citra Pesawat CT Scan Di RSUD Bali Mandara. *BULETIN FISIKA*, *22*(2), 77-83.

Irnawati, I. (2018). *Studi Dosis Radiasi pada Pemeriksaan CT-Scan Dengan Nilai Computer Tomography Dose Index (CTDI) Di Rumah Sakit Bhayangkara Makassar* (Doctoral dissertation, Universitas Islam Negeri Alauddin Makassar).

Keyak, J. H., & Falkinstein, Y. (2003). Comparison of in situ and in vitro CT scan-based finite element model predictions of proximal femoral fracture load. *Medical engineering & physics*, *25*(9), 781-787. https://doi.org/10.1016/S1350-4533(03)00081-X

Kofler, J. M., Yu, L., Leng, S., Zhang, Y., Li, Z., Carter, R. E., & McCollough, C. H. (2015). Assessment of Low-Contrast Resolution for the ACR CT Accreditation Program: What is the Impact of Iterative Reconstruction?. *Journal of computer assisted tomography*, *39*(4), 619.

Liang, X., Jacobs, R., Hassan, B., Li, L., Pauwels, R., Corpas, L., ... & Lambrichts, I. (2010). A comparative evaluation of cone beam computed tomography (CBCT) and multi-slice CT (MSCT): Part I. On subjective image quality. *European journal of radiology*, *75*(2), 265-269. https://doi.org/10.1016/j.ejrad.2009.03.042

Liu, L., Liu, B., Huang, H., & Bovik, A. C. (2014). No-reference image quality assessment based on spatial and spectral entropies. *Signal processing: Image communication*, *29*(8), 856-863. https://doi.org/10.1016/j.image.2014.06.006

Nariswari, N. N. (2018). Analisis Variasi Faktor Eksposi Dan Ketebalan Irisan Terhadap Ctdi Dan Kualitas Citra Pada Computed Tomography (Ct) Scan.

Netzelmann, U., & Müller, D. (2020). Modified pulse-phase thermography algorithms for improved contrast-to-noise ratio from pulse-excited thermographic sequences. *NDT & E International*, *116*, 102325. https://doi.org/10.1016/j.ndteint.2020.102325

Ratini, N.N., Yuliara, I.M., Windaryoto. (2020). Anode Heel Effect Application with Step Wedge Against Effect of Signal to Noise Ratio in Computed Radiography. *International Journal of Health Sciences*, 4 (3), 75-82. https://doi.org/10.29332/ijhs.v4n3.467

Sarma, A., Heilbrun, M. E., Conner, K. E., Stevens, S. M., Woller, S. C., & Elliott, C. G. (2012). Radiation and chest CT scan examinations: what do we know?. *Chest*, *142*(3), 750-760. https://doi.org/10.1378/chest.11-2863

Satwika, L. G. P., Ratini, N. N., & Iffah, M. (2021). Pengaruh Variasi Tegangan Tabung Sinar-X terhadap Signal to Noise Ratio (SNR) dengan Penerapan Anode Heel Effect menggunakan Stepwedge. *Buletin Fisika Vol*, *22*(1), 20-28.

Schauer, D. A., & Linton, O. W. (2009). NCRP report No. 160, ionizing radiation exposure of the population of the United States, medical exposure—are we doing less with more, and is there a role for health physicists?. *Health physics*, *97*(1), 1-5.

Sparzinanda, E., Nehru, Nurhidayah. (2017). Pengaruh Faktor Eksposi terhadap Kualitas Citra Radiografi. *Journal Online of Physics*, *3*(1), 14-22.

Uibu, T., Oksa, P., Auvinen, A., Honkanen, E., Metsärinne, K., Saha, H., ... & Roto, P. (2004). Asbestos exposure as a risk factor for retroperitoneal fibrosis. *The Lancet*, *363*(9419), 1422-1426. https://doi.org/10.1016/S0140-6736(04)16100-X

Utami, N. W. M. S., Ratini, N. N., & Juliantara, I. P. E. (2022). Pengaruh Kombinasi Arus Tabung Sinar-X dan Waktu Eksposi Terhadap Contrast to Noise Ratio (CNR) dengan menggunakan Computed Radiography. *Buletin Fisika Vol*, *23*(1), 26-33.

Varghese, T., Ophir, J., & Krouskop, T. A. (2000). Nonlinear stress-strain relationships in tissue and their effect on the contrast-to-noise ratio in elastograms. *Ultrasound in medicine & biology*, *26*(5), 839-851. https://doi.org/10.1016/S0301-5629(00)00199-X

Yin, W. H., Lu, B., Gao, J. B., Li, P. L., Sun, K., Wu, Z. F., ... & Schoepf, U. J. (2015). Effect of reduced x-ray tube voltage, low iodine concentration contrast medium, and sinogram-affirmed iterative reconstruction on image quality and radiation dose at coronary CT angiography: results of the prospective multicenter REALISE trial. *Journal of Cardiovascular Computed Tomography*, *9*(3), 215-224. https://doi.org/10.1016/j.jcct.2015.01.010

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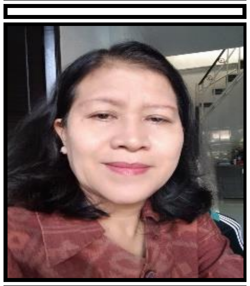	**Ni Luh Putu Trisnawati** Is a lecturer in the physics department of the Faculty of Mathematics and Natural Sciences, Udayana University who has conducted research since 2002 in biophysics and medical physics published in national and international journals. *Email: trisnawati@unud.ac.id*