

# Measurement of CT Number Uniformity Value at Various X-ray Tube Current Settings in CT Scanning

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**Abstract:** Studies on the analysis of variations in CT number uniformity values for CT-Scan images has been conducted. This study aims to evaluate the image quality value by uses various tube currents (mAs) in Siemens merk water phantom irradiation to assess the value of image quality. A Siemens Somatom Scope CT-Scan with current variations of 180 mAs, 200 mAs, 220 mAs, 240 mAs, and 260 mAs was used. The image results were then analyzed for quality through the CT number uniformity value test. Using a marker size of 12.56 cm<sup>2</sup>, the ROI method was applied at five different picture points: the center, 3, 6, 9, and 12 o'clock. For each current variation used in this study, 3 irradiation was carried out and 5 image slices were taken from each irradiation. This resulted of the analysis the CT number uniformity value was shown to be significantly reduced by the tube current strength ( $R^2=0.9896$ ,  $p\text{-value}<0.05$ ), according to the research. The test showed that the uniformity CT number value decreased from 0.217 HU to 0.031 HU as the tube current strength was increased, bringing it closer to the reference value (0 HU). The consistency CT number values acquired in this study remain within the 2 HU tolerance limits established by BAPETEN.

**Keywords:** CT number; Tube Current, Uniformity Value; Water Phantom

## Introduction

Radiodiagnostics is a discipline of nuclear radiology that uses X-ray imaging to diagnose diseases or anomalies in the body. X-rays are commonly utilized in medical imaging due to their strong penetrating power, which allows them to permeate the material or materials through which they pass (Milvita & Prasetyo, 2019). CT-Scan is one of the most often utilized medical imaging modalities and was created as a result of the advancement of conventional X-rays. An organ can be visualized or imaged with CT-scan radiation, without requiring radiation surgery on the organ by using X-ray ionizing radiation. Compared to conventional X-ray irradiation, this sort of irradiation can produce more optimal diagnostic results since it can present images of the inside of the human body in three dimensions as transverse slices (Sari et al., 2023). The CT scan analysis

involves projecting attenuation data from X-rays that penetrate the body at various angles, which is helped by the rotation of the X-ray source and electronic detector around the three-dimensional object. This method produces cross-sectional images of the inside structures.

The detected signals from various angles are transmitted to the Data Acquisition System (DAS), which collects the projection data required to generate CT images (Jung, 2021). CT scans are capable of vividly and clearly show human body parts in small portions and delivers X-ray photons through every single spot in the object at various angles, reaching 360 degrees (Bahurridha et al., 2022; Hermena & Young, 2021). A good CT image that can assist a doctor's or radiographer's analysis is needed for the diagnosis of an issue or disease because inadequate image could affect a potential misdiagnosis (Irsal et al., 2022). The inadequate image can be caused by variety of factors, including a

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decrease performance or quality of the CT-scan itself. A reasonably complex medical imaging device may malfunction at some point in its system (Bahurridha et al., 2022). CT scan, like other radiographic modalities, must operate properly provided the number and quality of photons emitted from the x-ray tube align with the scan acquisition settings built on the control panel. The quality of the generated image and the patient's dose of X-ray radiation can be affected by calibration errors and malfunctions of the X-ray generating equipment in the X-ray tube in a CT scan (Jessning Gamalita Mberato et al., 2023). In addition to diagnostic uses, CT scanners are utilized in radiotherapy areas to acquire images for treatment planning. So, for the optimum treatment CT scanners should be quality-controlled (Bissonnette et al., 2008). Quality control (QC) of the CT scan must be performed to ensure the best possible quality of the image produced by the CT scan while ensuring that the dose given during irradiation remains consistently within the permitted limits (Contillo et al., 2018; Mekonin & Deressu, 2023).

CT scans should be free of system artifacts, and images of uniform phantoms should be uniform in appearance, with no blurring or artifacts (A. N. Christensen, 2014). An image quality test using a water phantom is one of the quality control approaches for CT-Scan applications. Water is recommended as a CT-Number indicator since it contributes to more than 90% of soft tissue loss in humans (Astuti et al., 2018). Meanwhile, phantom is used as a replacement material to allow for repeated measurements while research is being conducted. As a result, the calculation will be more precise (Jessning Gamalita Mberato et al., 2023; Mustafidah et al., 2022).

The quality of an image is extremely important since it determines whether an accurate diagnosis will be reached. Object size, exposure factors (tube voltage, tube current, exposure time), slice thickness, field of view (FOV), pitch, and other parameters may have an impact on the quality of an image (Park et al., 2019). The Nuclear Energy Regulatory Agency (BAPETEN) Regulation Number 2 of 2018 about conformity testing of diagnostic and interventional radiology X-ray equipment regulates image quality parameters in Indonesia. According to this regulation, the appropriateness of CT number values in the form of CT number accuracy value, CT number image noise uniformity value, and CT number uniformity value can be evaluated in order to assess the acceptance of CT-Scan image quality (BAPETEN, 2018).

The value of an image's CT number, which is represented in Hounsfield Unit (HU) units, is the coefficient of attenuation of X-rays on a homogeneous material (Bryant et al., 2012). Water CT numbers are defined as the density assigned to a voxel CT scan on an arbitrary scale set at 0 HU (Das et al., 2016; Sidi et al.,

2020). The Region of Interest (ROI) area can be used to determine CT number value characteristics such as accuracy value, image noise uniformity value, and CT number uniformity value. The CT number values obtained through ROI processing on the water phantom image indicate tissue attenuation in homogenous tissue, which is an important parameter in medical imaging applications.

This characteristic is essential for accurate treatment and diagnosis planning in a variety of medical fields. The maximum value of the computation of the absolute difference between the mean CT value at the image center and the mean CT at each image edge is known as the CT number uniformity value (Anam et al., 2023; BAPETEN, 2018; IAEA, 2012) In each ROI area, the same object might have a different mean CT value. The X-ray attenuation value through the object slice varies due to varying mean CT values in each ROI area (Setyowati, 2015). There is a simple method for assessing the accuracy of the radiation reconstruction procedure, and that is the CT number uniformity value test. If the uniformity CT number value is  $\leq 2$  HU, it indicates that the CT scan is still performing well and the image is accurate.

## Method

At the Radiology Installation of Bali Jimbaran General Hospital, a Siemens Somatom Scope CT-Scan was used for this study. A Siemens water phantom picture was exposed to radiation, which produced the data that was obtained. At a constant voltage of 110 kV, slice thickness of 3 mm, FOV of 240 mm, and scan length of 40 mm, the water phantom was tested with radiation at current tubes of 180 mAs, 200 mAs, 220 mAs, 240 mAs, and 260 mAs.



**Figure 1** Siemens Somatom Scope CT Scan in Bali Jimbaran General Hospital

The first step in getting the water phantom image is to prepare the CT scan, which is then placed on the examination table and positioned in the center of the gantry. The phantom was irradiated to obtain an overall topogram, and the area to be irradiated was determined using the parameters specified by the research. The irradiation will generate a phantom image. The image's results are then measured as CT number values by making a round marker-shaped ROI plot of 12.56 cm<sup>2</sup> at five different points: the image's center, 3 o'clock, 6 o'clock, 9 o'clock, and 12 o'clock. This procedure was carried out on five image slices for each change in current usage. The ROI procedure displays the mean and standard deviation numbers on the computer.

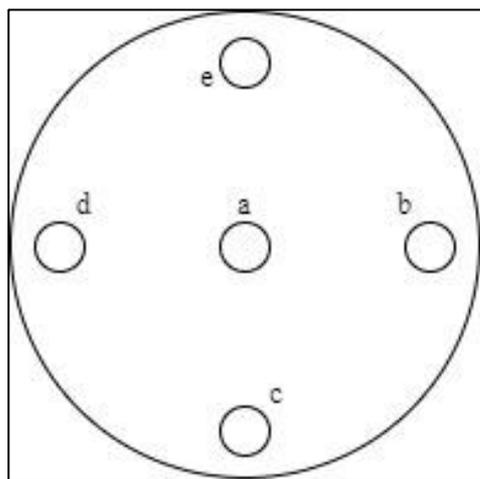


Figure 2 Illustration of marker placement during ROI process

The CT number uniformity value is calculated by collecting the CT mean value listed on the image ROI procedure results. The CT number uniformity value is calculated by taking the largest value of the difference

between the CT mean at the image center and the CT mean at the four edges of the image itself, as shown in Equation (1) (Anam et al., 2023).

$$\text{Uniformity CT number} = \frac{\text{The maximum value of } |CT\ mean_{center} - CT\ mean_{edge}|}{\text{The maximum value of } |CT\ mean_{center} - CT\ mean_{edge}|} \quad (1)$$

The uniformity value is calculated using the five slices of ROI image results acquired for each variation in current usage. After getting the uniformity value on each slice, calculate the average value for the five slices. This study obtained data on three separate occasions per irradiation for each X-ray tube current variation. After obtaining the average of the five image slices, the average calculations are repeated using the three irradiations, and the results are analyzed.

To find out how the X-ray tube current strength affects the image quality value based on the calculated outcomes, a simple linear regression statistical test is performed using the IBM SPSS software application version 25. In this test, the confidence level is 95%, yielding a p-value of 0.05. The hypotheses are H<sub>0</sub> (insignificant regression coefficient or tube current does not significantly affect image quality value) and H<sub>i</sub> (significant regression coefficient or tube current significantly affects image quality value). If the p-value obtained is greater than 0.05, H<sub>0</sub> is accepted, while H<sub>i</sub> is rejected, and vice versa. The calculated image quality values are compared to BAPETEN regulations, which require a tolerance limit of ≤ 2 HU for CT number uniformity.

### Result and Discussion

The results of the calculation of the uniformity CT number value using Equation (1) with a current change for three irradiations are shown in Tables 1-3.

Table 1. CT number uniformity value in the first measurement

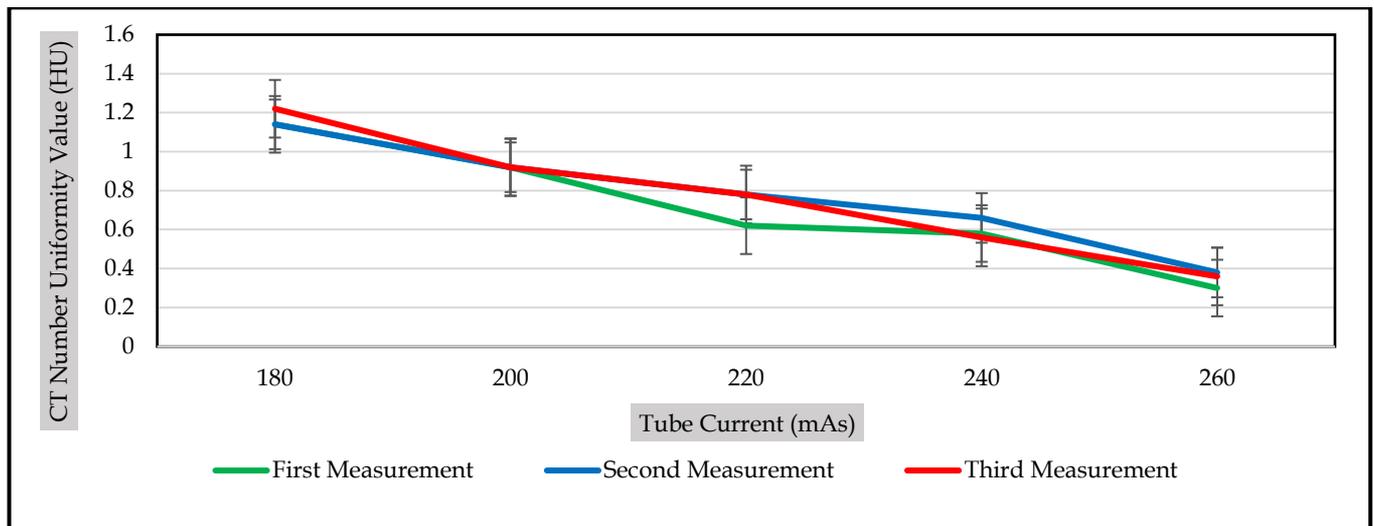
Tube Current (mAs)	CT Number Uniformity Value (HU)					Average
	Slice 1	Slice 2	Slice 3	Slice 4	Slice 5	
180	1.2	1.2	1.1	1.4	0.8	1.14
200	0.9	1.0	0.9	0.9	0.9	0.92
220	0.5	0.5	0.5	0.8	0.8	0.62
240	0.7	0.6	0.6	0.5	0.5	0.58
260	0.4	0.3	0.2	0.3	0.3	0.30

Table 2. CT number uniformity value in the second measurement

Tube Current (mAs)	CT Number Uniformity Value (HU)					Average
	Slice 1	Slice 2	Slice 3	Slice 4	Slice 5	
180	1.1	1.1	1.1	1.2	1.2	1.14
200	0.9	1.0	0.9	1.0	0.8	0.92
220	0.8	0.7	0.7	0.8	0.9	0.78
240	0.7	0.7	0.7	0.6	0.6	0.66
260	0.4	0.3	0.4	0.4	0.3	0.38

**Table 3.** CT number uniformity value in the third measurement

Kuat Arus Tabung (mAs)	CT Number Uniformity Value (HU)					Average
	Slice 1	Slice 2	Slice 3	Slice 4	Slice 5	
180	1.1	1.2	1.3	1.2	1.3	1.22
200	1.0	0.9	0.9	0.8	1.0	0.92
220	0.8	0.8	0.7	0.8	0.8	0.78
240	0.6	0.6	0.6	0.5	0.5	0.56
260	0.4	0.3	0.4	0.4	0.3	0.36



**Figure 3** The effect of increasing current tube on the uniformity value of the CT number. All the three ROI measurements shows a decrease in value as the current strength rises

The graph above shows that the highest uniformity value occur at a current of 180 mAs, while the lowest value occurs at a current of 260 mAs for all measurements. Based on the data acquired above, if the

three measurements are averaged for each current change and then checked for standardization using BAPETEN regulations, the following results can be achieved:

**Table 4.** Average CT number uniformity values for the three measures and conformity test results according to BAPETEN requirements

Tube Current (mAs)	CT Number Uniformity Value at Measurement			Average	Tolerance Limit	Conformity Test Information
	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>th</sup>			
180	1.14	1.14	1.22	0.217	≤ 2 HU	Accepted
200	0.92	0.92	0.92	0.184		Accepted
220	0.62	0.78	0.78	0.145		Accepted
240	0.58	0.66	0.56	0.101		Accepted
260	0.30	0.38	0.36	0.031		Accepted

Table 4 shows the mean uniformity CT number results for all three measurements. Simple linear regression analysis using IBM SPSS Statistics version 25 yielded an R2 value of 0.9896. This R2 indicates that the X-ray tube current has an effect of 98.96% on the variation in CT number uniformity value reached. The test showed a significant effect on X-ray tube current (p-value = 0.0004, p-value < 0.05).

The analytical results in Table 4 indicate that the X-ray tube current strength value is inversely correlated to the CT number uniformity value. An increase in tube current strength could affect the uniformity of an image's CT number value. The lower the CT number

uniformity value, the better the reconstructed image. This is because the smaller the greatest difference value between the CT mean of the circle's center region and its outer limits, the better the reconstructed image, which has a high uniform value. The uniformity refers to how uniform an image of a homogeneous material appears. Uniformity measures are necessary for eliminating cupping and beam hardening artifacts. If the uniformity value obtained is excessively large, the image's contrast resolution will be reduced (Gulliksrud et al., 2014). The more X-ray tube electricity that passes across the cathode and anode during imaging, the more electrons interact with the material or object. This current affects the

number of electrons available for interaction with the anode target material, hence influencing the amount of X-rays produced (Prabhu et al., 2020). A bigger tube current permits more electrons to collide with the target, leading to more X-ray photons. Increased X-ray photon frequency leads to more intense X-ray beams, which can improve image quality (Seeram, 2023). The higher the tube current used during imaging, the greater the resulting image, which will have less noise, making the CT mean of the irradiated object closer to the reference value (Fitriana et al., 2021). Although increasing tube current strength may produce a better image, it should be noted that giving the patient excessive tube current strength can be damaging to them because it is inversely related to the radiation dose given (Irsal & Winarno, 2020).

Based on the results in Table 4, increasing the tube current strength increases the uniformity CT number value to approach the reference value, which is 0.031 HU at 260 mA of current. Table 4 shows that all uniformity CT number values obtained are within the limits given by BAPETEN, which remain  $\leq 2$  HU. These results indicate that the radiation dose received by the detector remains the same for a homogeneous object. In addition, the value that is still in the range of the standard indicates that the detector response is still in good condition; the distribution of the dose received by the object is evenly distributed, which has an impact on image quality and gives good density, sharpness, detail, and contrast when reconstructed. The results that are still in accordance with this requirement indicate that the CT scan at Bali Jimbaran General Hospital is still in good condition for operation and fulfills the BAPETEN standards (BAPETEN, 2018).

## Conclusion

The study showed a significant correlation (p-value  $< 0.05$ ) between tube current and CT number uniformity value. Increasing mAs decreased the uniformity CT number value, bringing it closer to the object reference value. The results indicate that the CT- scan is still in good condition, with no measurements higher than BAPETEN's limit of  $\leq 2$  HU.

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## Author Contributions

Conceptualization, N.N.R. & A.J.G.M, Methodology and conductor of experiment G.N.S; data analyzer and data visualization, N.K.N.A & I.G.A.K.

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## Conflicts of Interest

The authors declare no conflict of interest.

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