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# The Effect of Tube Current Variations on Cranium Radiograph Images Using the MATLAB Program

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**Abstract:** Matrix Laboratory (MATLAB) is a software based on matrices, which is easy to use for solving various mathematical and computing problems. This study aimed to determine how variations in tube current (mA) affect the radiographic image of the cranium using the MATLAB program and to assess the program's quantification of this effect. The sample in this study consisted of 3 volunteers who performed AP projection cranial radiography examinations with varying tube current at Pelamonia TK. II Hospital, Makassar. Each sample had the same treatment in patient preparation, examination position, examination projection, and the same exposure factor value, which differed only in the use of tube current values, where the volunteer 1 with 200 mA, the volunteer 2 with 250 mA and volunteer 3 with 320 mA. Measurement of the quality of the AP projection cranium image with tube current of 200 mA, the percentage was 96.11%. At 250 mA, the percentage was 95.00%; at 320 mA, it dropped to 92.78%. It was determined that the optimal tube current variation was 200 mA with the highest percentage in measuring the image quality (density, contrast, sharpness, and detail) of the AP projection Cranium against variations in tube current is almost perfect.

**Keywords:** Cranium Radiography; Image; MATLAB Program; Tube current

## Introduction

Since it was discovered that X-rays can penetrate almost any object and cause chemical changes in photographic film, radiographic images can be used (Fauber, 2020). X-ray images (radiography) are the result of photographs obtained from X-rays passing through a body or object and then recorded on analog radiograph film or digital radiograph film (Robertson et al., 2024). The next advancement uses storage media made of phosphorus (phosphor storage), which is then read using a laser beam in a process known as computed radiography (CR) (Seeram, 2019). A digital image is an optical representation of an object exposed to radiation, such as X-rays. The conversion from analog to digital images enables image processing aimed at achieving the best image quality (Archana & Jeevaraj, 2024; Fauber, 2020). When the resulting radiograph contains all the information necessary to confirm the diagnosis, it is considered to have high image quality. A radiograph must meet high image-quality criteria, including density, contrast, sharpness, and detail (Bastos & Nogueira, 2025; Kjelle & Chilanga, 2022).

Otherwise, the radiograph cannot be considered to have good image quality. One factor affecting image quality is exposure (Fauber, 2024; Kleefeld et al., 2024). Matrix Laboratory (MATLAB) is a software based on matrices. MATLAB matrices are elementary to use. Getting good at MATLAB quickly in a book that MATLAB has at least five general uses: mathematics and computing, modeling and algorithm development, simulation and prototyping, data analysis, exploration and visualization, and application development, including Graphical User Interface (GUI) development

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(Atina, 2019). The fields of computing and mathematics are certainly heavily involved in MATLAB, which is synonymous with matrices. MATLAB is easy to use for solving various mathematical and computing problems. MATLAB is a high-level programming language dedicated to technical computing, visualization, and programming needs, including mathematical computation, data analysis, algorithm development, simulation and modeling, and graphical calculations (Abdulrazzaq et al., 2024; Idoko et al., 2024; Routh, 2016).

In the same book, he states that mathematics involves many complex and intricate analyses that can be easily implemented using the facilities available in MATLAB. It can be used in the field of computing for digital image acquisition and also for algorithm development. Computing is related to modeling, simulation, and prototyping (Atina, 2019; Perez-Sanz et al., 2017). Application of Digital Radiography (DR) tools in the development of X-ray services. This study developed software for image analysis in MATLAB and a prototype model of a digital radiography imaging system for bone fracture examination. This research directly refutes several arguments that claim DR is expensive, complex, and requires a large number of highly skilled personnel (Cappelli, 2015; Mc Fadden et al., 2018; Susilo et al., 2013).

The results of this study can also be easily copied by hospitals using MATLAB analysis software. MATLAB is a program that functions to convert qualitative analysis data into quantitative data in this study. This is done by converting the radiographic image's gray levels to 0-255, with 0 representing dark and 255 representing light. Thus, problems in analyzing examinations will be reduced with the MATLAB program, as the image's gray levels can be clearly displayed. In processing the MATLAB application, it is expected that the image will have the same sensitivity as the same exposure factor (Atina, 2019; Martinez et al., 2017).

Exposure factors include kilovoltage (kV), milliampere tube current (mA), and exposure time (ms) (Hassan, 2020). Kilovolts (kV) controls the energy quality and penetrating power of the X-ray beam, and milliampere tube current (mA) controls the number of electrons released, which in turn controls the quantity of X-rays produced (Breitkreutz et al., 2020; Prakash & Kotian, 2025). In radiology, DR is a type of digital imaging. The system or process of converting an analog system to a conventional radiography system is known as DR (Oborska-Kumaszyńska & Wiśniewska-Kubka, 2010).

DR is an X-ray imaging system, with digital X-ray sensors used to replace conventional radiophotography films and chemical processes, such as filmless, so that operational costs are relatively cheap because the results of the image can be seen directly, and replaced by a computer system connected to a monitor or laser printer that is easy to store and use, and is also environmentally friendly (Ou et al., 2021; Thayalan, 2020). In the DR system using X-rays that have high penetrating power to obtain images in accordance with the existing radiography classification, in line with that to support the performance of DR, image acquisition devices are developed, increasing the signal ratio and applying various filtering techniques, digital images are obtained using a flat panel detector, which then the image is processed digitally using processing and visualization programs in the field of data acquisition, in the quality of radiography that is quite influential, namely the tube voltage and tube current (Lee et al., 2023; Mustapha et al., 2021; Utami & Istiqomah, 2023).

The tube current, measured in milliamperes (mA), controls the number of electrons released, which in turn controls the quantity (amount) of X-rays produced. This is the main factor affecting the blackness or brightness of a radiographic image. The tube current determines how many X-rays the X-ray tube produces (Huda & Abrahams, 2015; Prabhu et al., 2020). The mA value is also related to the focal spot size: higher mA values correspond to a larger focal spot, and vice versa. In practice, mA is selected based on the exposure time or duration of the X-ray beam. Exposure time (s) is the number of seconds used to describe the length of time the X-ray beam is exposed to the organ being examined (Astolfo et al., 2022; Oglat, 2022; Yamashita et al., 2021). This exposure time varies depending on the object being examined. To prevent blurring caused by movement, the exposure time is shortened. Research results show that each time the object thickness increases, the mAs value will increase along with the number of X-rays emitted (Sari & Fransiska, 2018).

Based on the researcher's observations, the exposure factor system, specifically the tube current, is automatically determined and not adjusted to the patient's condition or the object's thickness. Meanwhile, according to Bontrager & Lampignano (2013), cranial radiography uses a tube current of 200 mA. The tube current remains the same at 200 mA for AP and Lateral projections, while the tube voltage is 73 kV. Based on the obtained mA range, the author aims to use mA values between 200 and 320 and determine the exact tube current (mA) value in order to obtain clear anatomical information with the same kV and time (s) (Nuraini, 2021).

Many diseases affect the cranium, but manual diagnosis requires great precision. Furthermore, manual methods require skill in accurately selecting abnormal areas, which can be time-consuming. Furthermore, the highly complex structure of the human cranium also presents challenges in disease identification, with varying gray levels, texture, color, motion, and uneven signal distribution making detection difficult. Therefore, the low image quality produced in cranial radiographs, such as excessive noise and low density, can lead to misdiagnosis or require repeated exposures. Therefore, using MATLAB enables very detailed image-quality analysis, especially by measuring and increasing soft-tissue density in the cranium to ensure that the selected tube current (mA) setting produces the best image to detect even the slightest abnormalities. This underlies the difficulty radiologists have in establishing a diagnosis. Therefore, it is necessary to adjust the tube current (mA) appropriately and to develop a MATLAB-based support method to improve image quality and reduce the subjectivity of radiologists' expertise.

Based on the above background details, the author intends to conduct additional research on the effect of tube current (mA) variations on cranial radiograph images using the MATLAB program and present it in a scientific paper entitled "The Effect of Tube Current (mA) Variations on Cranium Radiograph Images Using the MATLAB Program." This study aimed to determine how variations in tube current (mA) affect the radiographic image of the cranium using the MATLAB program and to assess the program's quantification of this effect.

## Method

This research is quantitative and uses an experimental design. The goal is to determine how controlled conditions of specific treatments affect other treatments. Using the MATLAB program, this study explores the impact of changes in tube current on cranium radiograph images (Sugiyono, 2019). This study was conducted from March to May 2025 at the Radiology Unit of Pelamonia TK. II Hospital, Makassar. The sample in this study consisted of 3 volunteers who performed AP projection cranial radiography examinations with varying tube current, using the minimum exposure factor, at Pelamonia TK. II Hospital, Makassar. The data collection method was with literature and documentation studies (Hasbi, 2024). The purposive sampling technique is a sampling method based on specific criteria; in this study, patients must have the same characteristics and behaviors to obtain accurate results (Sugiyono, 2019).

Tools and materials in cranium examination are X-ray machines, cassettes, and DR film processing. This study used three volunteers with the same body weight of 57 kg. Each sample had the same treatment in patient preparation, examination position, examination projection, and the same exposure factor value, which differed only in the use of tube current values, where the volunteer 1 used a tube current value of 200 mA, the volunteer 2 used a tube current value of 250 mA and volunteer 3 used a tube current value of 320 mA. Then, the film was exposed and processed with DR, and a radiology specialist read the images. Input DICOM radiograph results into MATLAB, Then the cross validation steps are Data Preparation and input of 3 radiograph results and selection of quality measurements (density, contrast, sharpness, detail), then Selection of cross validation, Selection of model validation on test data to collect performance such as accuracy, precision, and recall, evaluation of results and decision of the final accuracy value, then detection of optimal tube current and analyzing the accuracy of MATLAB detection. The research flowchart in Figure 1 shows the data analysis section of this research begins with data collection, data reduction, data presentation, and conclusion drawing.

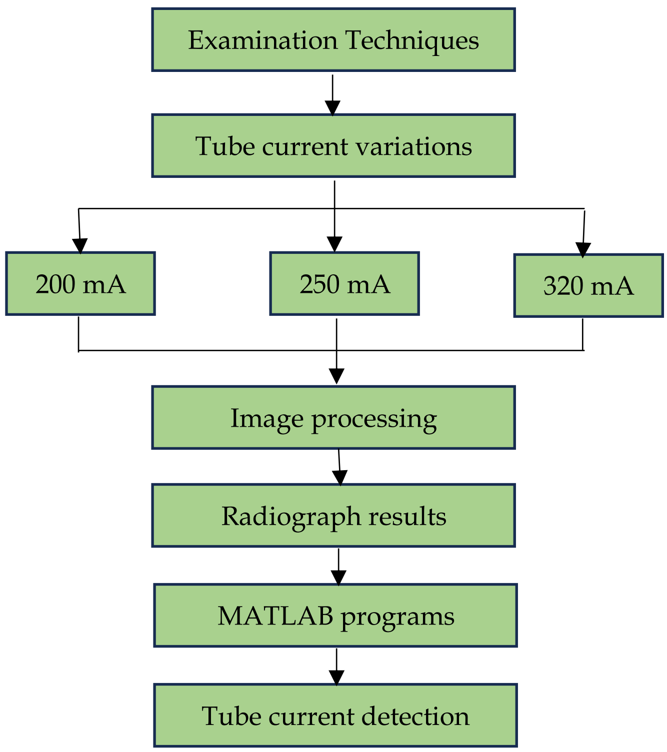


**Figure 1.** Research Flowchart

Preparation of equipment and materials used in the cranium examination in Figure 2 include: a conventional machine, a DR detector, an image printer, and an image console.

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

**Figure 2**. Equipment: (a) X-ray machine, (b) DR detector size 35X43 cm, (c) Image Printers, and (d) Image console

Next, the examination procedure is radiographer the radiographer explains the cranial examination procedure to the patient from start to finish. Meanwhile, the examination projection is used in the cranial examination is the Anterior-Posterior (AP) projection. In this projection, the patient is positioned erect, facing away from a bucky stand. The object is placed in the mid-sagittal plane with the OML upright, with a FFD of 100 cm, with the central point at the glabella, and the central ray perpendicular to the horizontal plane. The upper vertex and lower vertex are at the Symphysis Menti. The exposure factor is 70 kV, with mA settings of 200, 250, and 320. The film is processed using DR.

The image criteria are: no rotation of the cranium, the frontal plane is clearly visible, the petrous ridge is symmetrical, the frontal, ethmoidal, maxillary, and crista galli sinuses are visible, and no parts of the cranium are cut off.

## Result and Discussion

Based on research conducted from March to May on the Effect of Tube Current Variation (mA) on Cranium Radiograph Images Using MATLAB at Pelamonia TK. II Hospital, Makassar. Identity of the patient volunteer in Table 1. Patient Volunteer identity include: Name, gender, age, weight, and the type of examination projection used.

**Table 1.** Identity of the Patient Volunteer

| Identity | Volunteer 1 | Volunteer 2 | Volunteer 3 |
|---|---|---|---|
| Name | Mr. A | Mr. L | Mr. R |
| Gender | Male | Male | Male |
| Age | 21 years | 22 years | Male |
| Weight | 57.30 kg | 57.05 kg | 57.89 kg |
| Examination | All volunteers are cranium AP | | |

(a) (b) (c)

**Figure 3**. Cranium radiograph for volunteers: (a) 1 with 200 mA, (b) 2 with 250 mA, and (c) 3 with 320 mA

Patient Volunteer identity is carried out to determine the patient's identity and examination projection used. Next, determine the radiograph results of Cranium radiograph with tube current variation in Figure 3. Validation results using the MATLAB program Cross Validation test on the results of measuring the quality of the AP projection cranium image against variations in tube current in Table 2 and Table 3.

**Table 2.** Kfold, Density, and Sharpness

| Patients | Tube current (mA) | Value | Kfold | Density (%) | Sharpness (%) |
|---|---|---|---|---|---|
| volunteer 1 | 200 | Initial | 1.00 | 71.00 | 77.00 |
| | | Final | 1.00 | 91.67 | 98.33 |
| volunteer 2 | 250 | Initial | 2.00 | 71.00 | 78.00 |
| | | Final | 2.00 | 91.67 | 98.33 |
| volunteer 3 | 320 | Initial | 3.00 | 60.00 | 80.00 |
| | | Final | 3.00 | 80.00 | 99.17 |

**Table 3.** Sharpness, Contrast, and Quality

| Patients | Tube current (mA) | Value | Detail (%) | Contrast (%) | Quality (%) |
|---|---|---|---|---|---|
| volunteer 1 | 200 | Initial | 70.00 | 71.00 | 78.00 |
| | | Final | 96.49 | 91.67 | 96.11 |
| volunteer 2 | 250 | Initial | 76.00 | 66.00 | 76.00 |
| | | Final | 96.49 | 86.67 | 95.00 |
| volunteer 3 | 320 | Initial | 85.00 | 60.00 | 72.00 |
| | | Final | 97.96 | 80.00 | 92.78 |

Based on Table 2 and Table 3 are the results of the Cross Validation of the MATLAB program. There are standard percentages of image quality such as density, sharpness, detail and contrast values where the data is the benchmark used to assess how close the data is to the facts or values, namely Tube current (mA) is a technical parameter that affects the quantity of X-rays and image quality. This standard ensures that the data used can be relied upon in decision-making and analysis. Assessing the percentage in the context of the MATLAB program, namely the Cross Validation test, refers to how closely the measurement or image analysis results match the actual or expected values. In other words, the percentage indicates the accuracy of the image analysis results produced by MATLAB. So, the following display of validation results with the Cross Validation test of measuring the quality of the AP projection cranium image in tube current shows in Figure 4 and Table 4.

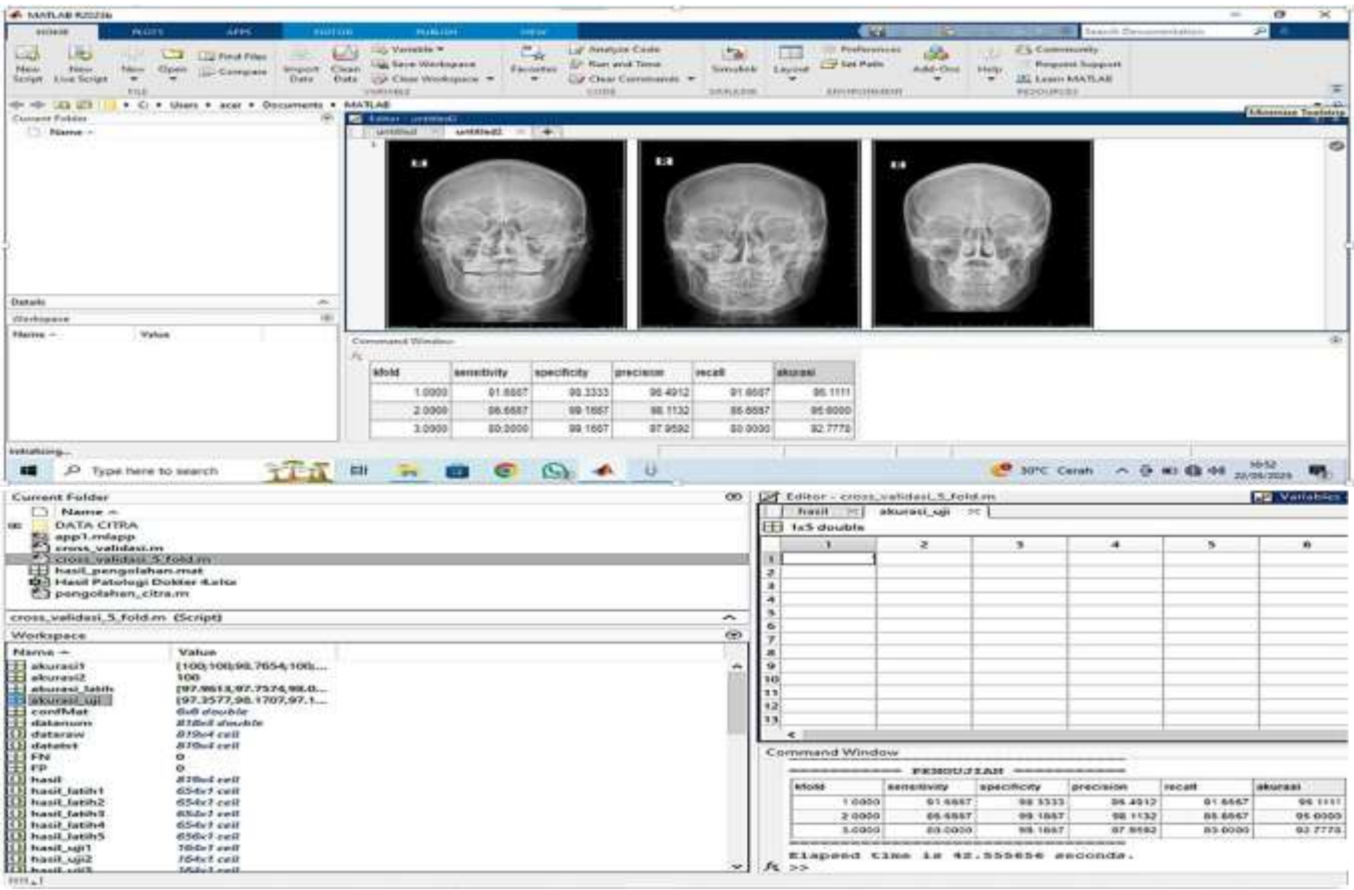

**Figure 4.** Display of validation results with the cross-validation test in the MATLAB program

**Table 4.** Quality results with the MATLAB program Cross Validation test

| Kfold | Density (%) | Sharpness (%) | Detail (%) | Contrast (%) | Quality (%) |
|---|---|---|---|---|---|
| 1.00 | 91.67 | 98.33 | 96.49 | 91.67 | 96.11 |
| 2.00 | 86.67 | 99.17 | 98.11 | 86.67 | 95.00 |
| 3.00 | 80.00 | 99.17 | 97.96 | 80.00 | 92.78 |

Based on the Table 4, the value Based on the evaluation of validation results with the Cross Validation program MATLAB on the results of image quality measurements (based on density, sharpness, detail, contrast) on the AP projection cranium against variations in tube current obtained a percentage of data 1, namely with a tube current value of 200 mA of 96.11%, while in the percentage of data 2, namely with a tube current value of 250 mA of 95.00%, while the percentage of data 3, namely with a tube current value of 320 mA of 92.78%. So, from the results of image quality measurements from the three variations of mA, the most optimal is data 1, namely with a tube current value of 200 mA, with the highest percentage value of 96.11% so that it represents the composite image quality score measured by MATLAB (based on density, contrast, sharpness, and detail).

Digital image processing with MATLAB was successfully applied to radiographic images. This program performs several image processing operations, such as density, contrast, sharpness, and detail. Image processing results show an increase in image quality, enabling visual identification of the object's internal state and its classification (Kurniasari & Akhlis, 2012). Based on this study, the use of a tube current value of 200 mA has a higher percentage in showing density and contrast, reaching a value of 91.67%, so this increase (tube current) means an increase in the number of photons produced and reaching the detector. More photons produce a stronger signal, thereby increasing the average pixel value (density) in the digital image.

In contrast, the tube current of 250 mA with a lower percentage shows density and contrast, reaching 86.67%, and at 320 mA, a lower percentage shows density and contrast, reaching 80.00%. This can be caused by the difference in pixels between two adjacent tissues (contrast) being small because both areas are already outside the optimal dynamic range of the detector. Too low contrast at tube currents of 250 mA and 320 mA makes it challenging to differentiate cranial structures.

Digital detectors (either Flat Panel Detectors in DR or Photostimulable Phosphors in CR) have a physical limit (pixel well capacity) in storing the electrical charge generated by X-ray photons. This explains why Density (brightness) begins to drop at high tube currents (mA), even though more X-rays are physically produced (Purwanto & Nastasia, 2022). Display of validation results with the cross-validation test in the MATLAB program. Based on the results showing a density value of 200 mA higher. The Main Cause is Digital Detector Saturation. In DR/CR systems, each detector element has a maximum signal-capture capacity. When the mA value is too high (e.g., 250 and 320 mA), the detector saturates (overexposes). Then, many digital systems are programmed to correct overexposed images automatically. This correction often results in a final image that actually appears darker (low density/brightness) than an optimally exposed image or slightly underexposed (such as at mA 200) to keep the image within the acceptable visual range.

Dynamic Range Compression and Contrast in digital radiographic images are the differences in pixel values between two adjacent anatomical structures. Lower contrast at high tube currents (mA) is caused by the detector's reduced ability to distinguish structures, as the signal has reached its maximum (Malisngorar et al., 2022). Based on the results showing a contrast value of 200 mA or higher are the leading causes of loss of signal differentiation. Contrast is the ability to distinguish signal differences between two adjacent structures. At optimal exposure (200 mA), slight variations in X-ray absorption by tissue (for example, between compact bone and spongy bone of the cranium) translate into apparent differences in pixel values. Therefore, at high exposures (250 and 320 mA), because all pixels are overexposed and reach saturation, the signal differences between the two structures are compressed or lost (all become saturated). Therefore, when all pixel values become homogeneous (equally saturated), the contrast differences between anatomical structures will decrease.

The optimal tube current (mA) is the point at which the detector operates at its best dynamic range for cranial examination, maximizing the detector's ability to differentiate tissue structures. Higher tube currents (mA) cause signal saturation and compression, permanently impairing diagnostic contrast (Biantari et al., 2025). Research shows that the Optimal Exposure Point at 200 mA lies at the peak of the digital system sensitometry curve, where the best balance between photon quantity and detector capability occurs. Also, given the limitations of the Digital System, this Research shows that the Tube Currents of 250 mA and 320 mA exceed the recommended exposure range for the imaging system, resulting in a loss of image quality (low contrast).

## Conclusion

The results of the study conducted on AP cranium radiograph examination with tube current variations of 200 mA, 250 mA, and 320 mA at Pelamonia TK. II Hospital, Makassar. The quality value was measured using a cross-validation test with the MATLAB program: Measurement of the quality of the AP projection cranium image with tube current variations showed different results. At a tube current of 200 mA, the percentage was 96.11%. At 250 mA, the rate was 95.00%; at 320 mA, it dropped to 92.78%. It was determined that the optimal tube current variation was 200 mA with the highest percentage in measuring the image quality (density, contrast, sharpness, and detail) of the AP projection cranium against the tube current variation almost reaching perfection (excellent detection) and also found validation results based on the level of deficiency of 3.89% which in principle the accuracy level of the MATLAB program does not consistently achieve 100% accuracy using any data, because not all data have the same quality, the same size, the same matrix and this measurement still requires reading a lot of data.

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**Author Contributions**
Nurul Auliyaa Hasbi: Conceptualization, methodology, writing—original draft preparation; Asmiati Amir: Methodology; Muhammad Yunus: Curation; Nurul Jannah Jamal: Writing—review and editing; Nurbeti Salam: Formal analysis; Muh. Rusli: Validation.

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**Conflicts of Interest**
The authors declare no conflict of interest.

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