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Analysis of the Effect of Irradiation Projection on the Signal-to-Noise Ratio in Mammography Images

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ABSTRACT

Mammography is a special type of radiography for the breast, to increase the contrast in breast images, mammography uses much lower X-ray energy compared to general radiography. Mammography is the best technology available for early detection of breast cancer. Image quality is one of the main things to consider in viewing the quality of mammography. This study aims to analyze the effect of radiation projection on image quality in mammography images using the Signal to Noise Ratio (SNR) parameter so as to produce the highest Signal to Noise Ratio (SNR) value for Mediolateral oblique (MLO) and Craniocaudal (CC) radiation projections. The study was conducted based on secondary data from mammography examinations of Right-Craniocaudal (RCC), Left-Craniocaudal (LCC), Right-Mediolateral oblique (RMLO), and Left-Mediolateral oblique (LMLO) radiation projections at Persahabatan Hospital, the exposure factor chosen was the exposure factor that had the most data, namely at a tube voltage of 28 kV. The results of the study showed that the overall average SNR results were obtained for each projection, namely the highest SNR value of 10,68 in the Left-Craniocaudal projection, while the lowest SNR was 8,84 in the Right-Mediolateral oblique projection. The CC projection provided images with higher SNR values, resulting in better image quality, while the MLO projection was still needed to obtain wider breast tissue coverage.

Keywords: Mammography, Radiation Projection, Signal to Noise Ratio (SNR), Region of Interest (ROI), Image Quality

I. INTRODUCTION

Breast cancer occurs due to the abnormal growth of cells in the breast tissue. According to the Global Cancer Observatory (Globocan) 2020 data from the World Health Organization (WHO), breast cancer ranks first in Indonesia with 65,858 cases, accounting for 16.6% of all cancer cases (Global Cancer Statistics, 2020). Early detection of breast cancer remains the key to reducing morbidity and mortality, as the five-year survival rate is influenced by the extent to which the cancer has spread within the breast tissue [1].

Mammography is the most effective technology currently available for the early detection of breast cancer. High-spatial-resolution X-ray mammographic images are valuable tools for achieving early diagnostic goals. Image quality is one of the primary factors to consider in assessing the performance of mammography. This is because optimal image quality leads to higher detection rates and fewer missed interval cancers by enhancing the radiologist's ability to accurately interpret and read mammograms [2].

One of the key parameters used to assess image quality is the Signal-to-Noise Ratio (SNR). This parameter quantifies the ratio between the desired signal (clinical information) and unwanted noise (random disturbances) in the image. A higher SNR indicates better differentiation between signal and noise, facilitating improved image interpretation. The use of SNR is particularly important as it directly impacts the diagnostic accuracy derived from the resulting image. A high SNR is desirable in medical imaging, as it implies that the signal is significantly greater than the noise, thereby allowing the visualization of low-contrast tissue structures. Conversely, a low SNR is undesirable, as it indicates that the signal is weak and the noise is dominant, leading to obscured visualization of soft tissues and producing grainy or mottled images [3].

The thickness of the object being examined—in this case, the breast—has a significant impact on the resulting image quality. As breast thickness increases, the X-rays used during imaging undergo greater scattering and absorption, which contributes to increased noise and a decreased SNR. This degradation in image quality can make it more difficult to detect small lesions or subtle abnormalities [4].

One solution to address this issue is through proper adjustment of the irradiation technique. The direction and angle of the X-ray beam significantly influence the distribution of signal and noise in the image. By selecting an optimal irradiation angle, excessive scattering and absorption effects can be minimized, thereby improving the Signal-to-Noise Ratio (SNR) value [5].

Image evaluation can be performed qualitatively and quantitatively. Qualitative evaluation is influenced by personal standards, expertise level, and individual perception. Quantitative evaluation is determined by standardized image quality metrics, such as spatial resolution and contrast, Contrast-to-Noise Ratio (CNR), Signal-to-Noise Ratio (SNR), and Modulation Transfer Function (MTF) [6].

This study will be conducted objectively by determining image quality through the Signal-to-Noise Ratio (SNR) value, aiming to demonstrate that adjustments in irradiation technique can lead to improved image quality.

II. METHODS AND MATERIAL

A. Data Collection and Grouping

Patient image data were acquired from the mammography modality and stored in the Picture Archiving and Communication System (PACS) in the form of Digital Imaging and Communications in Medicine (DICOM) files. A total of 15 patients who underwent mammography examinations were selected, each with two irradiation projections: Craniocaudal (CC) and Mediolateral Oblique (MLO) for both the right and left breasts. Data selection was based on identical tube voltage exposure factors with the Automatic Exposure Control (AEC) system activated. The tube voltage chosen for analysis was 28 kV, as it represented the most frequently used setting across the available data.

B. Data Processing

After data grouping, the data were processed to calculate the Signal-to-Noise Ratio (SNR) for each projection variation. The DICOM image data obtained from each irradiation projection were quantitatively analyzed using MicroDICOM software. This software was used to select the Region of Interest (ROI), which served as the basis for determining the Mean Pixel Value (MPV) and Standard Deviation (SD) of each image. Based on these ROI measurements, the SNR value was calculated using the standard SNR formula.

$$Signal\ to\ Noise\ Ratio : \frac{Mean\ Pixel\ Value}{Standard\ Deviation}$$

C. Data Analysis

This study employs quantitative analysis to evaluate image quality. The measured Signal-to-Noise Ratio (SNR) values will be compared to analyze the effect of irradiation projection, with the aim of identifying the projection that produces the highest Signal-to-Noise Ratio (SNR).

III.RESULTS AND DISCUSSION

A. Results of Mammographic Image Acquisition

The measurement results were obtained after selecting the Region of Interest (ROI) as shown in Figure 1, and are presented in Table 1, detailing the Mean Pixel Value (signal) and Standard Deviation (noise).

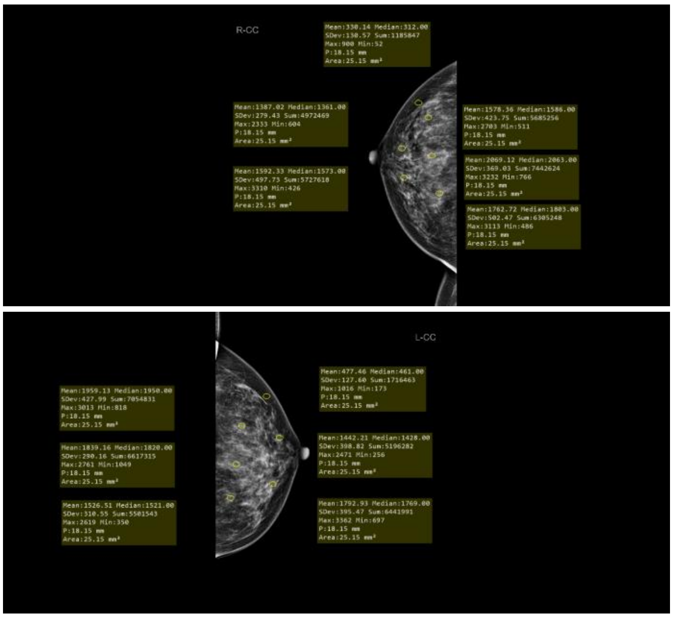

Figure 1. ROI Results of a Sample Mammographic Image for Irradiation Projections: Right Craniocaudal (RCC), Left Craniocaudal (LCC), Right Mediolateral Oblique (RMLO), and Left Mediolateral Oblique (LMLO)

Table 1. Measurement of Mean Pixel Value (Signal) and Standard Deviation (Noise) from ROI Results of a Patient Image Sample in Four Irradiation Projections

Irradiation Projection	Side	Mean Pixel Value (Sinyal) ROI #1	ROI #2	ROI #3	ROI #4	St. dev. (Noise) ROI #5	ROI #1
Craniocaudal (CC)	*Right*	1387,02	1592,33	1578,36	2069,12	1762,72	130,57
	Left	1442,21	1792,93	1959,13	1839,16	1526,51	127,60
Mediolateral Oblique (MLO)	*Right*	589,79	1664,00	1594,41	1698,29	1839,21	153,03
	Left	1423,38	1076,47	1927,44	1748,81	1631,13	146,12

The mammographic image was analyzed to obtain the SNR value by measuring the Mean Pixel Value and Standard Deviation, in order to compare the signal level at a specific location with the noise magnitude at the same location. Based on these measurements, the Signal-to-Noise Ratio (SNR) was then calculated. The results of the SNR calculation are presented in Figure 2.

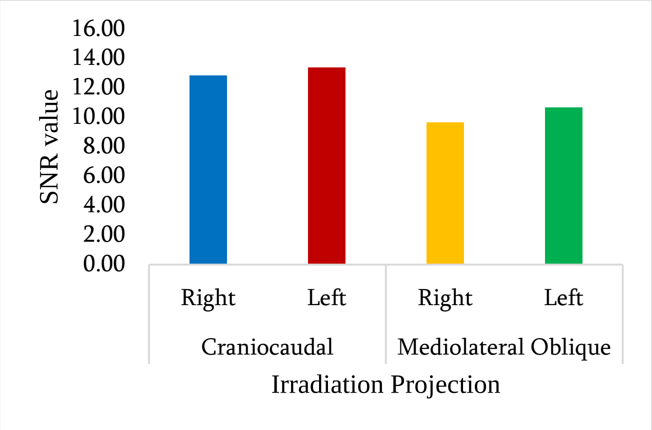

Figure 2. Graph of SNR Calculation Results from a Sample Mammographic Image

Based on Figure 2, which presents the graph of Signal-to-Noise Ratio (SNR) calculation results from a sample mammographic image, it can be observed that the SNR values vary across different irradiation projections and breast sides. The Craniocaudal (CC) projection demonstrates higher SNR values compared to the Mediolateral Oblique (MLO) projection. The higher SNR observed in the CC projection is attributed to a higher signal and lower noise level, indicating that the Craniocaudal projection is capable of producing better image quality.

In contrast, the Mediolateral Oblique (MLO) projection shows lower SNR values compared to the Craniocaudal (CC) projection. The reduced SNR in the MLO projection is primarily due to the higher level of noise generated compared to the CC projection. This increase in noise may be attributed to the steeper angle of irradiation in the MLO projection, which results in greater variation in the thickness of breast tissue penetrated by the X-rays. Such variations in tissue thickness can increase X-ray scatter and lead to a higher distribution of noise, thereby reducing the signal-to-noise ratio in the resulting image [7].

The results of SNR calculations from all research samples obtained from mammographic images across the four irradiation projections are presented in Figure 3.

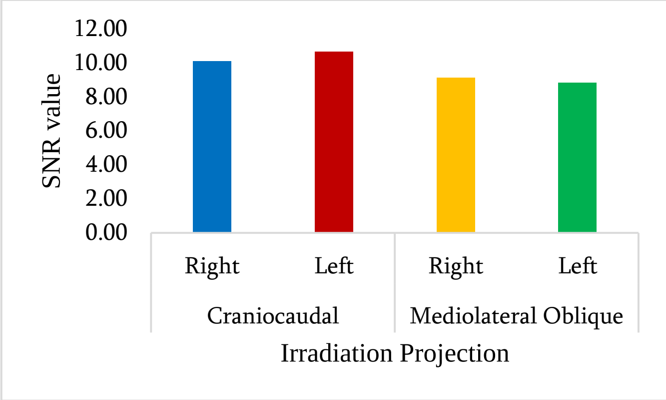

Figure 3. Graph of Average SNR Values for Each Irradiation Projection

Based on Figure 3, which presents the average Signal-to-Noise Ratio (SNR) values for each irradiation projection, the Craniocaudal (CC) projection demonstrates higher average SNR values compared to the Mediolateral Oblique (MLO) projection. The highest average SNR value was 10.68, observed in the Left Craniocaudal (LCC) projection, while the lowest SNR value was 8.84, found in the Right Mediolateral Oblique (RMLO) projection.

B. The Effect of Irradiation Projection on Signal-to-Noise Ratio (SNR) in Mammography Examination

The Mediolateral Oblique (MLO) projection aims to depict the entire breast tissue along with the pectoral muscle. The MLO projection is obtained by directing the X-ray beam from the inner side to the outer side, usually at an angle of 30° to 60°, with compression positioned obliquely against the chest wall. This angle allows a wider visualization, especially of areas near the chest wall and the axilla (armpit). Meanwhile, the Craniocaudal (CC) projection directs the X-ray beam from above downward, pulling the breast away from the chest wall with compression applied from the top. This projection shows most of the breast, excluding the superior part, axillary tail, and the extreme medial region (which contains less glandular tissue than the lateral part). The technique positions the breast away from the chest wall to obtain a more uniform view of the tissue [8].

In the MLO projection, the oblique irradiation angle causes the X-rays to travel a longer path through the breast tissue, especially in thicker breasts. In thicker breasts, many X-ray photons are absorbed by the tissue before reaching the detector, resulting in reduced signal intensity. The X-ray attenuation law explains that photons passing through more tissue interact more with atoms in the tissue. Increased scatter due to greater tissue thickness adds noise to the image. Consequently, the MLO projection tends to produce lower SNR values compared to the CC projection. However, MLO provides a more comprehensive view of the breast tissue, allowing better visualization of the lower breast and tissue near the pectoral muscle, which is crucial for detecting lesions that may be located in these areas.

In contrast, the CC projection, where X-rays are directed vertically, results in a shorter path through the tissue compared to the MLO projection, allowing more photons to reach the detector. Scatter is lower in this projection due to the more uniform thickness of compressed tissue, which reduces noise. The compression applied from above helps flatten the tissue, improving signal distribution and decreasing noise. Therefore, the CC projection generally yields higher SNR values than the MLO projection.

The Craniocaudal projection produces higher SNR values than the Mediolateral Oblique projection, characterized by a higher signal relative to noise. The CC projection provides clearer images with higher contrast, facilitating the identification of lesions or microcalcifications. Nevertheless, the MLO projection remains essential because it covers a wider area and better displays breast tissue, thus providing important information for detecting abnormalities in regions obscured in the CC view. The MLO projection is particularly useful for detecting lesions located in the lower or lateral parts of the breast.

Both projections complement each other in producing optimal diagnostic images during mammography examinations. The combination of CC and MLO projections offers a more comprehensive view of the breast tissue, which is vital for early detection of abnormalities and improving diagnostic accuracy. Using both projections ensures that areas not visible in one view can be better covered in the other, increasing the reliability of mammographic examination results.

C. Signal-to-Noise Ratio Values from Mammographic Images

The SNR calculations using the Region of Interest (ROI) for each irradiation projection—Craniocaudal (CC) and Mediolateral Oblique (MLO)—at the same tube voltage parameter of 28 kV showed different SNR values for each projection, as presented in Table 4.4. The average SNR value for the CC projection was 10.12 on the right side and 10.68 on the left side. Meanwhile, the average SNR for the MLO projection was 9.15 on the right side and 8.84 on the left side. The highest average SNR value was observed in the left CC projection at 10.68, while the lowest average SNR was in the left MLO projection at 8.84.

A study conducted by Salama (2024) titled "Phantom Image Analysis in Mammography Examination Based on Mediolateral Oblique and Craniocaudal Projections" showed that image density in the CC projection was higher than that in the MLO projection. Image density refers to the amount or intensity of X-rays reaching the detector after passing through the object. SNR describes the ratio between the signal (clinically relevant information in the image) and noise (undesired interference or data). A shorter X-ray path length increases image density because more photons reach the detector. When image density increases, it means more X-rays successfully pass through the tissue and reach the detector. This increases the signal, resulting in a higher signal-to-noise ratio (SNR) in the Craniocaudal projection.

IV. CONCLUSION

Based on the conducted study, it can be concluded that the irradiation projection affects the Signal-to-Noise Ratio (SNR) in mammographic images. The highest SNR value was obtained from the Craniocaudal (CC) projection. The CC projection exhibited higher SNR values, thus providing better image quality. The average Signal-to-Noise Ratio (SNR) values for the Right-Craniocaudal (RCC), Left-Craniocaudal (LCC), Right-Mediolateral Oblique (RMLO), and Left-Mediolateral Oblique (LMLO) projections showed that the highest overall average SNR was 10.68 in the Left-Craniocaudal (LCC) projection.

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