



Article

The Effect of Ultrasonic Wave Frequency and Resolution on Image Quality in Ultrasonic Devices

Nada Cinta^{1*}, Nani Lasiyah²

Teknologi Rekayasa Elektro-medis, Fakultas Teknologi Kesehatan, Institut Kesehatan dan Teknologi Al Insyirah, Pekanbaru, Indonesia

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E-mail: nadacintaa19@gmail.com

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ABSTRACT

Ultrasonography (USG) is a non-invasive medical imaging tool that is widely used in clinical diagnosis due to its safety and ability to visualize internal body structures. This study aims to analyze the effect of ultrasonic wave frequency and resolution on image quality in ultrasound devices. The experiment was conducted at RSUD Petala Bumi, Riau Province, using ultrasound images of four organs, namely the abdomen, cubital joint, prostate gland, and femoral artery. The frequency variations displayed on the ultrasound device were 17, 28, 31, 48, and 93. These values represent internal system preset levels rather than the actual transmitted ultrasonic frequencies. In diagnostic ultrasonography, acoustic waves operate in the megahertz (MHz) range (typically 2–10 MHz). Therefore, in this study, frequency is interpreted as a relative parameter influencing imaging performance, particularly resolution and penetration depth. The images were analyzed using ImageJ software to obtain grayscale histograms as indicators of image quality. The results demonstrate that higher frequency settings improve image resolution but reduce tissue penetration, whereas lower frequency settings provide deeper penetration with reduced resolution. Histogram analysis shows that most images exhibit low brightness intensity with dominant gray-level distributions in darker regions, indicating suboptimal image quality for diagnostic purposes. Therefore, appropriate selection of frequency presets and ultrasound parameter settings is essential to support accurate medical diagnosis.

1. Introduction

Ultrasonography (USG) is a diagnostic health tool widely used in medical practice. Its advantages include relatively fast examination times, patient safety, accurate results, and freedom from harmful radiation. The accuracy of manual ultrasound image interpretation is highly dependent on the physician's skill and precision, so the potential for error remains.

In practice, the ultrasound image recognition process has limitations, resulting in poor image quality, high noise, and challenging classification analysis (Arwoko, 2022).

Technological advances have expanded the use of sound waves, This includes the medical field, using ultrasound to visualize the structure of internal organs. Ultrasound operates on the principle of non-ionizing sound waves, making it a safe, accurate, and efficient method for detecting organ abnormalities. The flow of sound waves is influenced by the density of the medium through which they pass, as they are absorbed to varying degrees by each medium. The reflected waves are formed due to the difference in acoustic impedance between the two media (Pangestuti et al., 2019).

The frequency of ultrasound waves plays a crucial role in determining the quality of images produced by an ultrasound device. Higher frequencies can increase image resolution, allowing for the visualization of fine details in body tissues. However, these frequencies also have a disadvantage in terms of penetration, as the waves are unable to penetrate deeper body tissues. Selecting the appropriate frequency for ultrasound depends heavily on the clinical objectives and the examination being performed (Apriansyah et al., 2024).

One factor affecting the quality of images produced by an ultrasound device is the spatial resolution achieved during the scanning process, which refers to the ultrasound system's ability to distinguish between adjacent objects or structures within the body. Ultrasound image quality is influenced not only by spatial resolution but also by other parameters such as the frequency and ultrasonic waves used in the imaging process. Phantom Silicone rubber-based models are used as simulation models of human body tissue that allow for more controlled evaluation of ultrasound systems and understanding how these parameters

interact and affect the accuracy of medical diagnosis quality (Ratar et al., 2020).

Based on the description above, the author would like to publish a scientific paper on the impact of the combination of frequency and resolution of ultrasonic waves on image quality, with the title "The Effect of Ultrasonic Wave Frequency and Resolution on Ultrasonographic Image Quality in USG Devices"

Research objective is analyzing the effect of frequency and resolution of ultrasonic waves on the quality of ultrasound images and their impact on the accuracy of medical diagnosis

2. Literature Review

2.1 Ultrasonography

Ultrasonography (USG) is a medical imaging procedure used to observe the condition of internal organs, including their shape, size, anatomical structure, movement, and relationship to surrounding tissues. This procedure is non-invasive, painless, and allows for quick, safe examinations and provides accurate diagnostic results. In the past two decades, the use of ultrasound for diagnosis has grown rapidly, making it a crucial tool in identifying various diseases (Al-Munawar et al., 2023).

Unlike other modes, the image produced by ultrasound has A special characteristic is the spectrum of white, black, and gray. An ultrasound image is an image formed by sound waves emitted by a transducer. Sound waves are a form of physical energy that travels from one point to another, allowing observation of almost all parts of the body, except for air-filled or hollow organs. Bones and air cannot be visualized because they have difficulty transmitting sound, but fluids have the ability to transmit sound well (Sanjaya et al., 2022)

2.2 Ultrasound components

The following are the main components of an ultrasound machine:

2.2.1 Transducer

The transducer is the primary component of an ultrasound device, responsible for generating ultrasonic waves. This ability comes from the piezoelectric material it contains. When electrical stimulation is applied, the transducer generates high-frequency sound waves that are then transmitted to the body's tissues. The reflected sound waves are detected by the receiver, which then amplifies and stores the sound waves, converting them into an image on a monitor.

2.2.2 Ultrasound Monitor

The monitor is used to view the ultrasound results directly. The monitor on an ultrasound machine has several image display models:

- a. Mode A (Amplitude Modulation) is a sound wave displayed as a vertical line on the monitor screen. The amplitude of the sound wave is determined by the height of the deflection line. The distance between the transducer and the reflecting surface is determined based on the location of the deflection on the baseline. Mode A is useful for measuring the biparietal diameter and identifying the difference between cystic and solid tumors.
- b. Mode B (Intensity Modulation) displays sound waves as bright dots scattered along a baseline. By reconstructing these dots to their original positions, a two-dimensional image of the object being examined can be produced.
- c. Mode M (Motion Modulation) is a wave used to observe moving objects, such as fetal heart movements.

2.2.3 Ultrasound Machine

An ultrasound machine is a component of an ultrasound device that converts the received wave signals into images that can be viewed on a monitor. This machine functions similarly to a computer's central processing unit (CPU). The ultrasound machine significantly impacts ultrasound imaging results. The higher the CPU performance, the faster and clearer the images displayed on the monitor (Herlambang, 2021).

2.3 Parameter Settings

When using an ultrasound device, basic knowledge is required to operate it, which applies to all types and brands of ultrasound devices.

2.3.1 Gain

Gain is the setting for how dark or bright an ultrasound image is.

Gain settings can be adjusted based on user needs. Gain can be adjusted using the TGC knob, which can increase or decrease gain across the entire scan area. The TGC knob adjusts the gain for each layer and helps display a uniform image.

2.3.2 Focus

Focus is used to highlight a specific part of an image. In its settings, the focus point is placed at a specific point to make it more visible. Focus can

be set to 1, 2, 3, and so on, with 1 focus being the most common. The more focuses used, the lower the device's frame rate.

2.3.3 Frequency

Frequency settings vary depending on the patient's condition. Frequency, penetration, and resolution are governed by the following law: The higher the frequency, the greater the resolution, but the wave penetration power decreases/flattens. The lower the frequency, the better. The wave penetration power becomes stronger and deeper, but the resolution decreases. When wanting to use an ultrasound device, you must consider this. If the patient is overweight, use a low frequency (2 MHz), if the patient is medium, use 3.5 MHz, and if the patient is thin, use a high frequency (5 MHz).

2.3.4 Depth

Depth is the scanning depth displayed on the monitor screen, which can be adjusted as needed. Depth reduction can also be used as a zoom function (Wibowo, CP et al., 2018).

2.4 How Ultrasound Works

The working principle of ultrasound imaging is that the transducer emits ultrasonic waves that penetrate the tissue and are reflected back into the transducer, where the transducer acts as both an ultrasonic source and sensor. Echoes are the result of the reflected ultrasonic waves that are detected by the instrument. The duration required from the generation of sound waves to the detection of echoes indicates how deep the structure that reflects the waves is. If there is a large difference in acoustic impedance between the two media being passed, the resulting echo will be greater. The transducer receives the echo signal, processes it into radio waves, and then converts it into a digital image (Winaya & Koesoemoprodjo, 2019).

2.5 Ultrasound Imaging

Imaging refers to the process of producing an image of an object, generally two-dimensional, it is used to display the structure of certain body tissues. Medical applications require imaging systems with high- frequency changes that affect the state of human body systems (Oktaviani et al., 2009).

2.6 Resolution

Wavelength affects the quality of image resolution. The more The higher the frequency used,

the shorter the wavelength, resulting in better image resolution. Bone has a greater ability to absorb ultrasonic waves than soft tissue, so examinations can only be performed on its surface. These waves cannot penetrate the bone's interior. Ultrasound images often reveal dark areas behind the bone, known as acoustic shadows, which would be visible if the frequency were not too low (Epsilawati et al., 2020).

2.7 Sound Waves

Sound waves have a number of characteristics such as frequency, time distance traveled, wavelength, propagation speed, amplitude, intensity, and other acoustic variables. These acoustic variables include pressure, density, temperature, and particle movement.

2.8 Types of Ultrasound Examination

Ultrasound examinations can be distinguished based on the dimensions of the images they produce. The following are the types of ultrasound examinations based on their dimensions.

a. 2D ultrasound

This type of ultrasound produces a two-dimensional image that appears flat and unclear because it only displays a one-sided view, often making it difficult for patients to understand. This ultrasound can detect 80-90% of abnormalities by observing internal organs, fetal movement, and measuring fetal length and weight. The resulting images can be printed and given to the patient.

b. 3D ultrasound

With the ability to produce three-dimensional images, this ultrasound provides more detailed and informative visualizations, making them easier for patients to understand. It's commonly used to review fetal anatomy and identify abnormalities in greater detail. The resulting images can be saved as JPG files on a CD and accessed via a computer.

c. 4D ultrasound

Known as SD-Live or real-time, this ultrasound is the most advanced technology because it produces highly realistic, video-like images. Through this ultrasound, patients can see the fetus's body structure, movements, and facial expressions with great clarity. Furthermore, this ultrasound is effective in

identifying abnormalities such as placental problems and ectopic pregnancies. The resulting images can be saved in JPG or video format and accessed via computer.

d. Doppler ultrasound

Doppler ultrasound is a device used to obtain information about the direction and velocity of blood flow, based on changes in the frequency of ultrasonic waves within the body due to the Doppler effect. As blood moves away from the transducer, the received frequency decreases, and increases as blood moves closer to the transducer (Herlambang, 2021).

2.9 Ultrasound Examination Categories

Ultrasound examinations can be differentiated based on the area of the body being examined. The following are the examination categories for ultrasound.

a. Pregnancy ultrasound is used by obstetricians and gynecologists to calculate gestational age and estimate the time of birth.

b. Cardiac ultrasound is used to examine the structure and function of the heart, as well as detect problems such as valve disorders or abnormalities in the blood

c. vessels.

d. Abdominal ultrasound is divided into two parts: the upper and lower abdomen. The upper abdominal examination is used to evaluate organs in the upper abdomen, such as the thyroid, breasts, liver, spleen, and pancreas. The lower abdominal examination includes the kidneys, bladder, and prostate. This examination can be used to detect abnormalities or problems in these organs (Sianturi, 2015).

2.10 Software ImageJ

ImageJ is a digital image processing software developed by Wayne Rasband in National Institutes of Health (NIH). This software is written in the Java programming language, so it can run on various operating systems such as Linux, Macintosh, and Windows, in both 32-bit and 64-bit versions. One application of ImageJ in the medical field is the use of histograms, which are used to evaluate the quality of radiographic images, especially in terms of contrast and image sharpness.

The quality of the images used will be processed and analyzed by observing the histogram in the ImageJ application. A histogram is a feature in the ImageJ application that presents a graph to display the

frequency distribution of color intensity in an image. Color intensity values are displayed on the horizontal axis (ranging from 0 to 255), while the number of pixels with that intensity is displayed on the vertical axis (Fitriani, 2021).

3 Research Methodology

3.1 Time and Place

The Final Project research entitled "The Effect of Ultrasonic Wave Frequency and Resolution on Ultrasonography Image Quality on USG Equipment" was conducted from May to July 2025 at Petala Bumi Regional Hospital, Riau Province.



Figure 1. Petala Bumi Regional Hospital, Riau Province

3.3 Tools and Materials

The tools and materials used to analyze the quality of ultrasound images using SoftwareImageJ is as follows:

- a. Ultrasound equipment.
- b. Laptops are used to process data and run software.
- c. Software Image J for reading images.

3.3 Types of Experiments

This study is a quantitative data collection experiment that aims to evaluate the effect of frequency and resolution of ultrasonic waves on the quality of ultrasound images produced by the USG device on images of the abdomen, cubital articulation, prostate gland and femoral artery.

3.4 Experimental Procedure and Flow



Figure 2. Experiment Flow

The experimental procedure consisted of five stages. The first step was preparing all the equipment and materials. The second step was collecting ultrasound data. The third step was running the ImageJ software. The fourth step was processing the data. The fifth step was analyzing the data.

1. Preparation of Tools and Materials
The researcher prepared all the tools and materials needed for the research, where these tools and materials were needed to carry out testing and write the research report.
2. Ultrasound Data Collection
Data collection in this study was in the form of direct data collection on the ultrasound device.
3. Data Processing
This data processing is in the form of image data and histograms from the results of images of the abdomen, cubital articulation, prostate gland and femoral artery which are then analyzed to obtain results in the form of good quality images.
4. Data Analysis

Data analysis was carried out based on data processing using ImageJ software, which then analyzed the image quality.

5. Results and Conclusions

The results and conclusions of this study are conclusions regarding the quality of the images of the abdomen, cubital articulation, prostate gland and femoral artery obtained.

3.4.1 Experimental Control and Image Selection Criteria

To ensure reproducibility, all ultrasound images were acquired using the same device model, transducer type, and standardized imaging parameters (gain, depth, focus, and patient positioning). Image acquisition was performed by a certified sonographer to minimize operator-dependent variability.

From a dataset of 20 images, 6 images were selected using a purposive sampling strategy based on distinct frequency preset variations. Images with redundant parameter configurations were excluded to avoid duplication bias. This selection ensures representative variability across experimental conditions while maintaining consistency.

Although the sample size is limited, this study is designed as a controlled experimental analysis focusing on parameter variation rather than population generalization. Therefore, the selected dataset is considered sufficient to observe the effect trends of frequency presets on image quality.

3.5 Data Collection Techniques

The following are data collection techniques in this study:

3.5.1 Preparation of Tools and Materials

The first step is to prepare all the tools and materials needed for the research, such as the ultrasound unit, laptop and SoftwareImageJ.

3.5.2 Ultrasound Data Collection

The second step involves directly capturing data using the ultrasound device, including images of the abdomen, cubital joint, prostate gland, and femoral artery. The images were captured in the Radiology Installation of Petala Bumi Regional Hospital, Riau Province, with frequency settings

of 17 Hz, 28 Hz, 31 Hz, 48 Hz, and 93 Hz. The resulting ultrasound images were saved in JPG format.

It should be noted that the frequency values displayed on the ultrasound system represent internal preset levels rather than physical ultrasonic frequencies. The actual operating frequencies correspond to standard diagnostic ultrasound ranges (approximately 2–5 MHz), depending on the transducer and imaging mode. Thus, the variation used in this study reflects relative system configurations rather than absolute acoustic frequency changes.

3.5.3 Running Software ImageJ

The first step is to open software ImageJ is installed on the laptop then click Open, select the image to be inserted into ImageJ. The second step after the image appears on the ImageJ screen, select the tool rectangle, oval or freehand from toolbar to select the area you want to measure. After selecting the area, click the menu analyze and select measure, the measurement results will be displayed in the window results. Step third, select the menu Analyze, choose Histogram to see the distribution of data in the image. The fourth step is to select the menu File and click Save As to save the image

3.5.4 Data Processing

The fourth step is data processing, this data processing is in the form of image data and histograms from the results of images of the abdomen, cubital articulation, prostate gland and femoral artery which are then analyzed to obtain results in the form of good quality images.

3.6 Data Analysis

The fifth step involves analyzing the data from the ultrasound images of the abdomen, cubital joint, prostate gland, and femoral artery. The resulting data is saved in JPG format. A histogram is used to illustrate the distribution of data at the frequencies and resolutions used.

4 Results and Discussion

Ultrasonography images were taken of the internal organs in the abdomen, cubital joint, prostate gland, and femoral artery. Of the 20 ultrasound images obtained, only six were selected and entered into ImageJ software. This selection was made selectively based on differences in the ultrasound wave frequencies used. The variation in frequency values refers to system preset levels, which are used as relative

indicators of imaging configuration differences. Several images showed similar frequencies, thus not providing significant differences in the context of the analysis.

The following are the image results that have been entered into the software. ImageJ, so that a histogram graph can be obtained. The histogram graph obtained is from each image of the abdomen, cubital articulation, prostate gland and femoral artery at frequencies of 17 Hz, 28 Hz, 31 Hz, 48 Hz and 93 Hz.

4.1 Research result

In this study, the image results from abdominal examination are presented, cubital articulation, prostate gland, and femoral artery in several patients at Petala Bumi Regional Hospital, Riau Province. Figure 4.1 shows images from an ultrasound examination of the abdomen, prostate gland, and femoral artery. These images are displayed in figures (a), (b), and (c) with varying frequency settings. Figure (a) is the result of an image from an examination of the right and left kidneys using a frequency of 31 Hz. Figure (b) is the result of an image from an examination of the prostate and bladder using a frequency of 17 Hz. Meanwhile, figure (c) is the result of an image from an examination of the left femoral artery (large blood vessel) in the left thigh using a frequency of 48 Hz.

Figure 3. shows the results of an ultrasound examination of the elbow joint, consisting of three images: (a), (b), and (c). Image (a) was generated using a frequency of 28 Hz, image (b) with a frequency of 48 Hz, and image (c) with a frequency of 93 Hz. These three images were used to assess image quality in the elbow joint area.

All obtained images were further analyzed using histograms to measure the illumination and intensity distribution at frequencies and resolutions that affect the image quality of internal organ structures in each examination. The following are images from examinations of the abdomen, cubital joint, prostate gland, and femoral artery:

a. Image of the abdomen, prostate gland and femoral artery

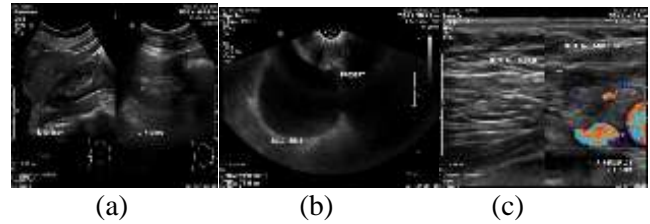


Figure 3. Abdominal, Prostate Gland, and Femoral Artery Imaging Results

b. Image of the Cuboid Articulation

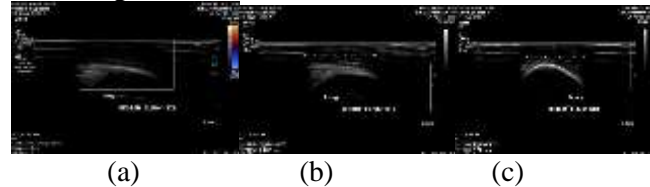


Figure 4. Articulatio Cubiti Image Results

The following images show the histogram results processed by ImageJ software. Figure 4 displays the histogram results of the abdominal examination, prostate gland, and femoral artery, shown in images (a), (b), and (c). Figure 4.4 displays the histogram results of the cubital articulation examination, which also consists of three images, namely (a), (b), and (c).

The following are the histogram results from the examination of the abdomen, prostate gland and femoral artery:

a. Histogram of Abdomen, Prostate Gland and Femoral Artery Images

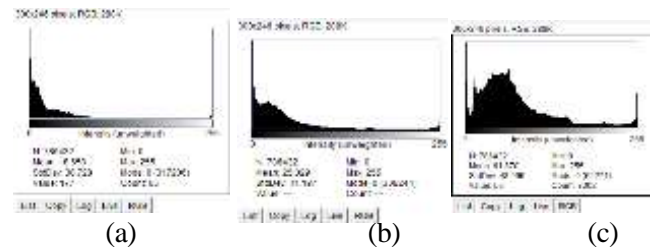
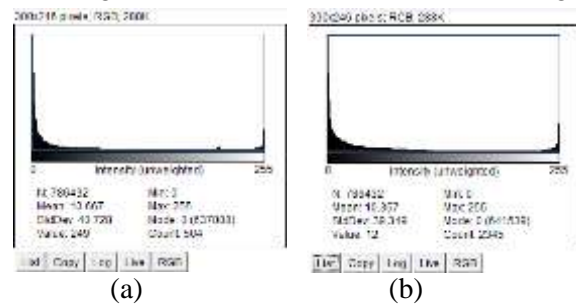


Figure 5. Histogram of the Abdomen, Prostate Gland and Femoral Artery

b. Histogram of the Cuboid Articulation Image



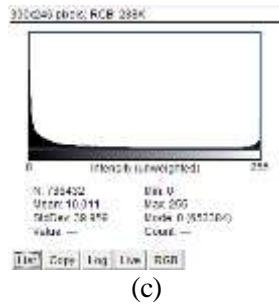


Figure 6. Femoral Joint Histogram

4.2 Discussion

It is important to emphasize that the frequency values (17–93) used in this study do not represent physical frequencies in Hertz, but rather internal preset levels of the ultrasound system. These presets indirectly control imaging parameters associated with MHz-range ultrasonic transmission, such as bandwidth, gain optimization, and spatial resolution. In diagnostic ultrasonography, acoustic waves typically operate in the range of 2–10 MHz. Therefore, the frequency parameter in this study should be interpreted as a relative control variable influencing image resolution and penetration depth. This clarification ensures the physical consistency of the study with established ultrasound theory.

From Figures the histogram results from the abdominal examination are presented. Prostate gland and femoral artery. In the histogram (a), the gray level distribution is visible on the left and there is a dominant peak in the dark area. Based on the histogram, the image has low brightness intensity and the Mean and StdDev values can be seen in table 1 (a), namely with values of 25,029 and 41,197.

Histogram (b), shows the distribution of gray levels on the left and a dominant peak appears in the dark area. Based on the histogram, the image has low brightness intensity and the Mean and StdDev values can be seen in table 1 (b), namely with values of 18,658 and 38,728.

In the histogram (c), we can see an even distribution of gray levels towards the center. The center and peaks are visible in the dark and dominant area on the left. Based on the histogram, the image has low brightness intensity and low values.

Mean and StdDev can be seen in table 1 (c), namely with values of 61,870 and 48,999.

Table 1 Abdominal, prostate gland and femoral artery image values

Picture	Mean Value	StdDev Value
(a)	10,667	40,728
(b)	10,357	39,349
(c)	10,011	39,959

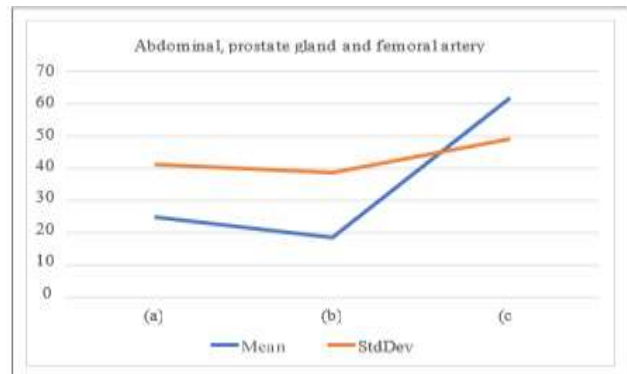


Figure 7. Graphical values of abdominal images, prostate gland and femoral artery

Thus, it can be compared that of the three images, The image with the best overall quality is the image in image (c). The histogram shows a balanced intensity graph even though the distribution is dominant in the dark areas. Figure 7 also presents the histogram results from the cubital articulation examination. In the histogram (a), the gray level distribution is visible on the left and there is a dominant peak in the dark area. Based on the histogram, the image has low brightness intensity and the Mean and StdDev values can be seen in table 2 (a), namely with values of 10,667 and 40,728.

Histogram (b), shows the distribution of gray levels on the left and There is a dominant peak in the dark area. Based on the histogram, the image has low brightness intensity and the Mean and StdDev values can be seen in table 2 (b), namely with values of 10,357 and 39,349.

In the histogram (c), the gray level distribution is visible on the left. and a dominant peak appears in the dark area. Based on the histogram, the image has low brightness intensity and the Mean and StdDev values can be seen in table 2 (c) with values of 10.011 and 39.959.

Table 2 Articulatio cubiti image value

Picture	Mean Value	StdDev Value
(a)	25,029	41,197
(b)	18,658	38,728
(c)	61,870	48,999

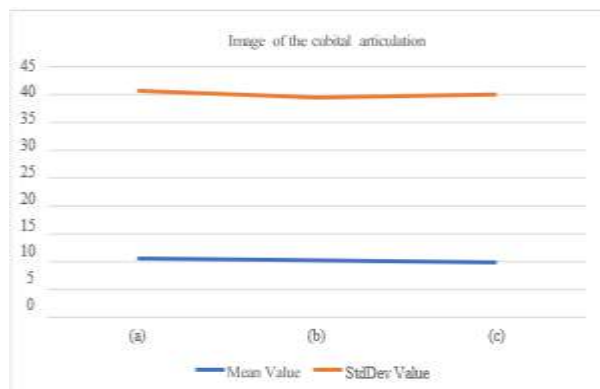


Figure 8. Articulatio cubiti image value graph

Thus, it can be compared that of the three cubital articulation images, none of the images have good overall quality. All histograms in the three cubital articulation images show a more dominant gray level distribution in the dark areas.

Based on the analysis of six histograms of the abdominal examination results, prostate gland, femoral artery, and cubital articulation, and considering the even distribution of gray-levels, contrast, and brightness levels, it can be concluded that there are no decent histogram results from the entire image of the abdomen, prostate gland, femoral artery, and cubital articulation obtained. Because all histograms only have a mean below 128, which indicates a low level of brightness and contrast. The histogram has an even distribution of gray-levels but is more dominant to the left, indicating that the image has a dark area. Therefore, this image is considered less good for medical diagnostic purposes because the frequency used is too low.

Similar research has been conducted by Michael O. Harris-Love et al. (2016) by title Ultrasound estimates of muscle quality in older adults: reliability and comparison of Photoshop and ImageJ for the grayscale analysis of muscle echogenicity who analyzed ultrasound image results using ImageJ software. The image

quality in this study was analyzed using gray level histograms through ImageJ software to obtain good image quality results based on the parameters used.

This study compares two methods of determining the analysis area. (Region of Interest/ROI), namely the Rectangular Marquee Tool (RMT) and the Free Hand Tool (FHT). Longitudinal image of the *musclerectus femoris* were obtained using B-mode ultrasound and analyzed by applying both ROI methods to two different types of software. The results showed that both achieved a very high level of reliability, both for intra-rater and inter-rater measurements, with values *Intraclass Correlation Coefficients* (ICC) ranged from 0.97 to 0.99 ($p < 0.001$). Mark *Standard Error of Measurement* (SEM) ranged from 0.72 to 1.05 grayscale levels, with ImageJ producing a slightly smaller SEM than Photoshop. The average difference in grayscale values between the RMT and FHT methods was recorded at 0.87 (95% CI [.54–1.21], $p < .0001$), although statistically significant, the difference does not have much practical impact.

The main differences between these and our studies lie in the subjects and parameter variations. This study used JPG images of the abdomen, prostate gland, femoral artery, and cubital joint, with varying frequencies based on clinical data from the hospital. However, there are similarities in the data processing: both used ImageJ software to generate histograms as a reference for determining image quality.

In this study, additional *noise* on the ultrasound image with the aim is to simulate the condition of an image that has experienced a decrease in quality. Type *noise* that is used is *Gaussian noise*, which is random noise that follows a normal distribution and often appears in digital images.

Addition *noise* carried out with two levels of intensity, namely with standard deviation values of 50 and 100. The standard deviation value of 50 represents the level *noise* moderate, while the standard deviation value of 100 represents the level of *noise* high. The greater the standard deviation value, the *noise* the more visible the addition, the lower the image quality will be.

The following is the result of the image histogram with additional *noise* of 50 on the image of the abdomen, cubital articulation, prostate gland and femoral artery.

- a. Histogram of Abdomen, Prostate Gland and Femoral Artery Images

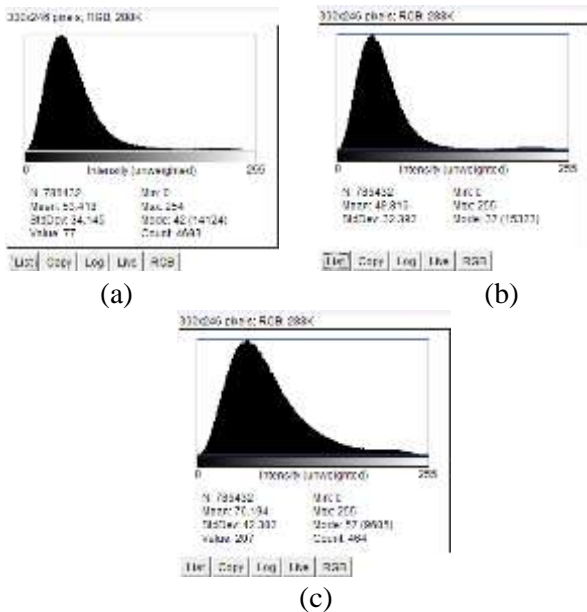


Figure 9. Noise 50 on the image of the abdomen, prostate gland and femoral artery

b. Histogram of the Cuboid Articulation Image

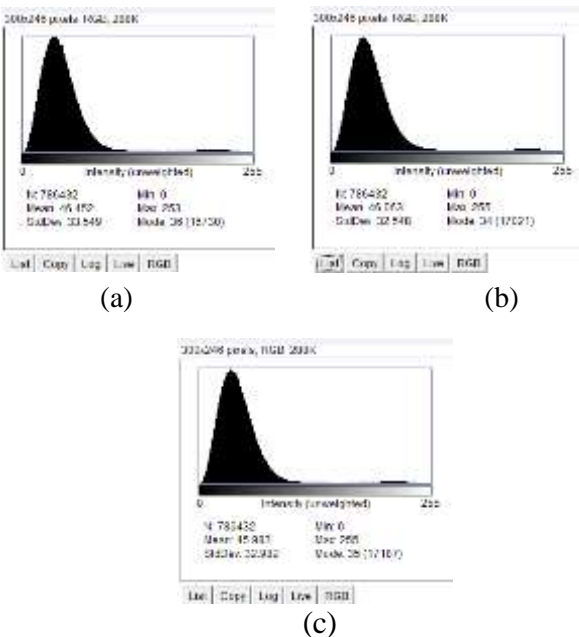


Figure 10. Noise 50 on the image of the cubital articulation

From Figure 10, the histogram results from the abdominal examination are presented. prostate gland and femoral artery have been added *noise*. In the histogram (a), the Mean value is 53.418, indicating that the image generally tends to be dark. Furthermore, the

StdDev value of 34.145 indicates a fairly large spread of pixel intensity values. This may be due to the addition of Gaussian noise, which results in random intensity variations across the image. The Mean and StdDev values can be seen in Table 3 (a).

Histogram (b), shows the Mean value is at 49,816 which indicates that the image tends to be at a low brightness level or darker in general. The StdDev value of 32,392 indicates that there is a fairly large spread of pixel intensity values, although slightly lower than the previous histogram. The range of pixel values read is also very wide, from 0 to 255, which indicates that the entire gray scale is used in this image due to the spread *noise* high. The Mean and StdDev values can be seen in table 3 (b).

In the histogram (c), the Mean value is 76.194, indicating that the image generally appears brighter than the previous histogram. This indicates that structures in the image may be more easily recognized due to the clearer contrast between dark and light areas. The StdDev value of 42.382 indicates that the distribution of pixel intensity values is quite large. The Mean and StdDev values can be seen in table 3 (c).

Table 3 Noise value 50 on images of the abdomen, prostate gland and femoral artery

Picture	Mean Value	StdDev Value
(a)	53,418	34,145
(b)	49,816	32,392
(c)	76,194	42,382

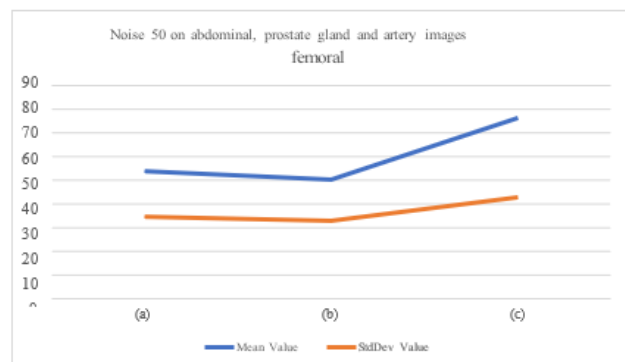


Figure 11. Graph of noise value 50 on abdominal, prostate gland and artery images femoral

Figure 11 also presents the histogram results from the examination of the cubital articulation which has been added *noise*. In the histogram (a), the Mean value is 46.452, indicating that the image generally tends to be dark. Furthermore, the

StdDev value of 33.549 indicates a fairly large spread in pixel intensity values. This may be due to the addition of Gaussian noise, which results in random intensity variations across the image. The Mean and StdDev values can be seen in Table 4 (a).

Histogram (b), shows the Mean value is at 46.063, which indicates that the image tends to be at a low brightness level or darker in general. The StdDev value of 32.548 indicates that there is a fairly large spread of pixel intensity values, although slightly lower than the previous histogram. The range of pixel values read is also very wide, from 0 to 255, which indicates that the entire gray scale is used in this image due to the spread noise high. The Mean and StdDev values can be seen in table 4 (b).

In the histogram (c), the Mean value is 45.983, indicating that the image tends to be dark due to its low intensity value. This indicates that although the majority of pixels are dark, there are still a small number of pixels with high intensity. The StdDev value of 32.982 indicates that the distribution of pixel intensity values is quite large. The Mean and StdDev values can be seen in table 4 (c).

Table 4 Noise value 50 on the cubital articulation image

Picture	Mean Value	StdDev Value
(a)	46,452	33,549
(b)	46,063	32,548
(c)	45,983	32,982

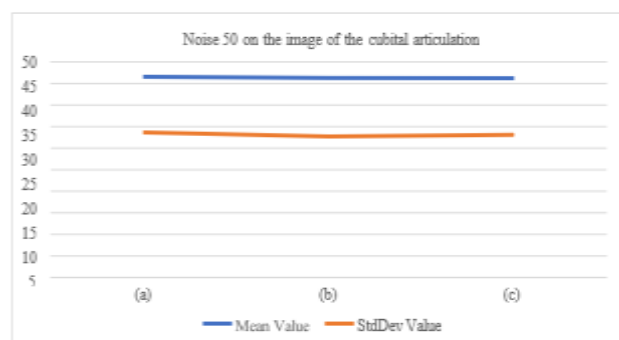


Figure 12. Graph of noise value 50 on abdominal, prostate gland and artery images femoral

In an image with Gaussian noise $\sigma = 50$, the histogram shows a wider pixel distribution

compared to the original image. This indicates that pixel intensity values have become more variable due to random noise interference, indicating that the image has experienced quite severe degradation, although the main image structure is still recognizable. This noise causes the pixel intensity values to be distributed unevenly, thereby reducing the contrast and sharpness of the original image.

Meanwhile, in the noise-free ultrasound image, the histogram shows a more regular intensity distribution with clear peaks at certain intensity values, reflecting image quality with easily recognizable tissue details. The difference between the noise-free and noise-free ultrasound images can be clearly observed in Figure 13 and 14

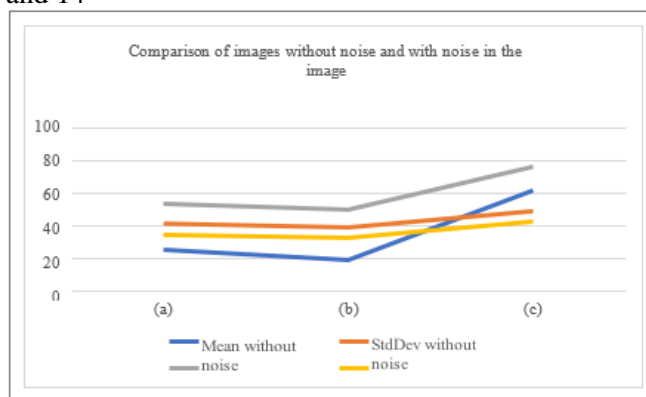


Figure 13. Comparison graph of images without noise and with noise in the image abdomen, prostate gland and femoral artery

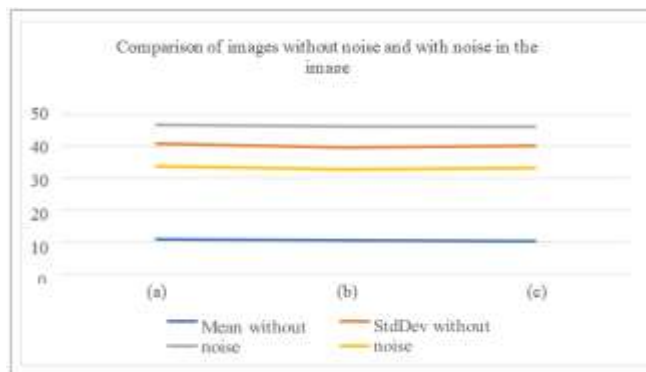


Figure 14. Comparison graph of images without noise and with noise in the image cubital articulation

Based on the graph, it can be concluded that the greater the value The higher the standard deviation of Gaussian noise added, the higher the level of pixel intensity dispersion, which directly affects the visual quality and clarity of structures in ultrasound images.

5 Conclusion

This study demonstrates that frequency preset variations significantly influence ultrasound image quality, with higher presets yielding increased mean grayscale values (up to 61.87) and higher entropy, indicating improved spatial resolution. However, this improvement is accompanied by reduced penetration capability.

Quantitative analysis confirms that most images exhibit mean intensity values below 128, indicating low brightness and contrast under the tested conditions.

The main contribution of this study lies in the integration of histogram-based and quantitative metrics (SNR, CNR, entropy) to evaluate ultrasound image quality, providing a more objective framework for optimizing imaging parameters in clinical practice.

For future research, several improvements are recommended:

1. Using software other imaging such as MATLAB and MicroDicom.
2. Adding object variations, namely images of problematic organs.
3. Add test parameters such as gain, depth, or focus settings to strengthen the validity of the findings.
4. Compare the quality of 3D, 4D and 5D ultrasound images.

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