

Performance Evaluation of Ultrasonic Imaging System (Part I)

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Abstract

Background: Diagnostic ultrasound or sonography is an image which can provide valuable information for diagnosing and treating a variety of diseases and conditions. This experiment was done to check the performance and evaluate the ultrasonic imaging system. There were three tests performed in this experiment: dead zone (transducer ring-down), vertical measurement calibration, and horizontal measurement calibration. **Methods:** The evaluation was made by performed all the tests with different depth on two different multipurpose phantom model #539. The tests were also performed by two different probes which were curved and flat (linear probe). The images were taken, and the measurements were made by electronic calipers on the ultrasound machine system. Observations and evaluations were done via all images and measurements taken. **Results:** The images formed by two various probes were different. The penetration settings were different since the depths were different. The depth influenced the penetrations to the formed image. From the comparison of all results and measurements recorded were all under the accepted value of the standard that was given by the manufacture of the phantom. **Conclusion:** Therefore, it can be concluded that the measurements were all not exceeding 2% of the standard value given based on the result that we get.

Keywords: Calibration, dead zone, diagnostic ultrasound, penetration settings, probes

INTRODUCTION

Ultrasound is a type of imaging that uses high-frequency sound waves.^[1,2] The function is still the same as other imaging which is to produce images of internal organs and structures within the body.^[3-5] Commonly, physicians use it to view the heart, blood vessels, kidneys, liver, and other organs.^[6-9] They also use ultrasound to view the fetus during the pregnancy.^[10-12] The images can provide valuable information for diagnosing and treating a variety of diseases and conditions.^[13] Most ultrasound examinations are done using a sonar device outside your body. However, some ultrasound examinations involve placing a device inside your body.^[14]

During the ultrasound test, the transducer will be used over the parts of your body. Then, will sends out sound waves which be bounce off the tissues inside the patient body.^[8,15] Then, it captures the waves that bounce back. The ultrasound machine creates images from the sound waves. Ultrasounds are longitudinal waves that cause particles to oscillate back and forth and produce a series of compressions and rarefactions.

The velocity is the speed of the wave with a unit of m/s. Since ultrasound images are captured in real time, they can show the structure and movement of the body's internal organs as well as blood flowing through blood vessels. Two different probes were used in this study. They are curved and linear probe. Commonly, the curved probe has frequencies of 2–5 MHz to allow for a range of patients from obese to slender. It is a compromise of the linear and sector scanners. The density of the scan lines decreases with increase distance from the transducer.^[16-23]

On another side, a linear probe is often used with high frequencies of 7 MHz and produces sound waves parallel to each other and produces a rectangular image. The width of the image and the number of scan lines are the same at all tissue levels. This has the advantage of good near-field resolution. Thus, the main objective of this study is to evaluate the performance and check the ultrasonic imaging system using

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three tests which are dead zone or transducer ring-down, vertical measurement calibration, and horizontal measurement calibration.

METHODS

Note IRB: All manuscripts reporting data from experimental laboratory studies involving and not from human participants or animals

In this study, quality assurance of tissue-mimicking phantoms was used to evaluate the accuracy and performance of the ultrasound imaging system. US model HI vision was used in this research study. It is a US diagnostic scanner that provides

a lot of functions like Doppler wave, color flow, and other tasks with high quality and fully digitalizes. This device is worked with linear, phased array, and convex transducer. Linear transducer called EUP-L74M with central frequencies ranging from 5 to 13 MHz was used to collect data from the phantoms. Moreover, the curved probe has frequencies of 2–5 MHz to allow for a range of patients from obese to slender. The phantoms mimic the acoustic properties of human tissue and provide test structures within the stimulating environment. They can detect the change of the performances that occur through normal again and the deterioration of system components. Routine performance monitoring can reduce the

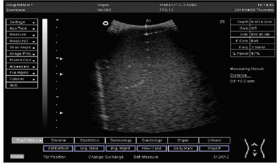
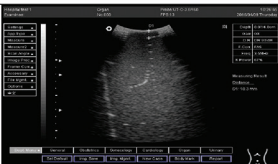
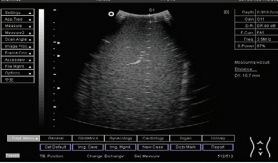
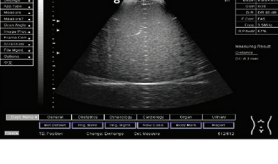
| Depth (cm) | Diagram | Distance (mm) |
|------------|---|---------------|
| 14.0 |  | 10.2 |
| 16.0 |  | 10.3 |
| 18.0 |  | 10.7 |
| 24.0 |  | 8.2 |

Figure 1: Scanned phantom 1 for Dead zone measurement by curve probe with different depths and distances

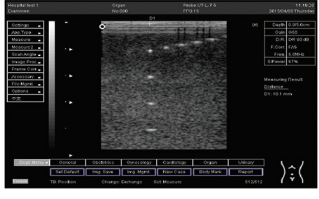

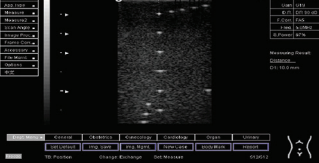

| Depth (cm) | Diagram | Distance (mm) |
|------------|--|---------------|
| 5.0 |  | 10.1 |
| 6.0 |  | 10.0 |
| 7.0 |  | 10.0 |
| 9.0 |  | 9.6 |

Figure 2: Scanned phantom 1 for Dead zone measurement by the linear probe with different depths and distances

| Table 1: Several basic control functions for a common ultrasound imaging system | |
|---|--|
| Basic control | Function |
| Trackball | Moving objects on the monitor. It is used in conjunction with measuring, annotating, moving Res/Dopler boxes to the desired location |
| Freeze | Allows the image to be held or froze on the screen. Measurements can be taken in this setting and permit it to be saved |
| Zoom | Allow magnification of areas of the ultrasound image to observe area of interest in more detailed |
| Caliper | Used to measure a distance. It is used by selecting a starting spot by pressing a set button key and using the trackball to measure to a second mark. The distance between the two marks will then be displayed on screen measured in cm |
| Gain | Similar to function of a brightness control. The echo signal returning to the body is converted into an electronic signal by the transducer. This electronic signal has to be amplified to produce images on the monitor |
| Time gain | Adjustment for the sensitivity at each depth to allow compensation for signal loss from deeper in the tissue |

number of repeat examinations, duration of examinations, and maintenance time.

Most diagnostic imaging systems and tissue-mimicking phantom are calibrated at room temperature, commonly on a standard of 23°C. Therefore, tests are required to be done at the average of the standard temperature. Model #539 was used to run the experiment. This multipurpose phantom is designed to provide the user with a comprehensive means of evaluating the performance of the sector, linear array, phased array, and annular array diagnostic imaging system.

Ultrasound machines have a large array of options and features. There are several important machines functioned that need to know and familiar while doing his study. These functions are basically universal to all ultrasound equipment. Table 1 shows the basic control function in the ultrasound imaging system.

The first experiment is to measure the dead zone (the distance from the front face of the transducer to the first identifiable echo at the phantom interface). The materials used in this part are ultrasound machine with curve and flat (linear) probe, viscosity gel, and phantom 1 and 2. The procedure was done by placing the phantom on a clean, flat surface with scanning surface #1, moreover, an adequate amount of low viscosity gel was applied to the scan surface, after that, the instrument setting such as

time-gain-compensation (TGC), output, and etc., was applied to establish baseline values for “normal” liver scanning.

However, the bottom of the phantom was visualized, and the gain settings unit was adjusted, and the phantom was scanned until the dead zone target group was clearly displayed. Thus, the distance between the first target image and the echo produced by the scan surface was measured by using the electronic calipers, finally the depth measurement was documented on the quality assurance record.

The second experiment is to measure the vertical distance obtained along the axis of the sound beam. Ultrasound machines with curve and linear probe, viscosity gel, and phantom 1 and 2 were used in this study. The procedure started with the place the phantom clean, flat surface with scanning surface #1, an adequate amount of low viscosity gel was applied to the scan surface, the instrument setting such as TGC, output, and etc., was applied to establish baseline values for “normal” liver scanning. The bottom of the phantom was visualized, and the gain setting unit was adjusted; the transducer was positioned over the vertical group of line targets until a clear image was obtained; and the greatest distance that can be clearly imaged between line targets was measured using the electronic calipers. Ultimately, the measurement obtained was documented on the quality assurance record. The last experiment was to obtain

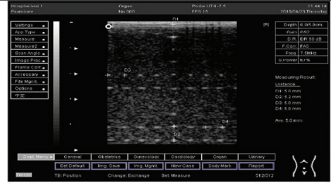
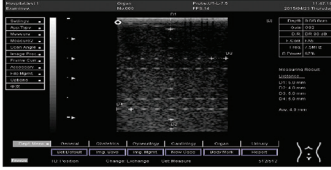
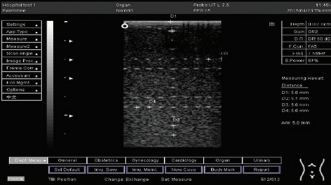
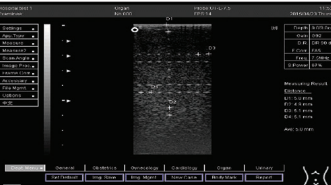
| Depth (cm) | Diagram | Distance (mm) |
|------------|---|---------------|
| 5.0 |  | 5.0 |
| 6.0 |  | 5.0 |
| 7.0 |  | 5.0 |
| 9.0 |  | 5.0 |

Figure 3: Scanned phantom 2 for Dead zone measurement by the linear probe with different depths and distances

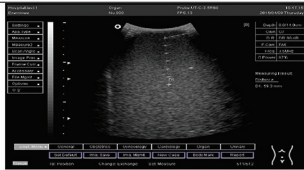
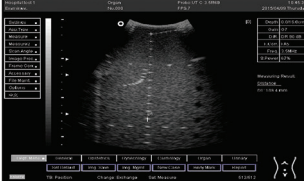
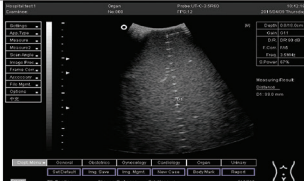
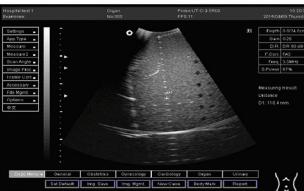
| Depth (cm) | Diagram | Distance (mm) |
|------------|--|---------------|
| 14.0 |  | 59.3 |
| 16.0 |  | 109.4 |
| 18.0 |  | 99.0 |
| 24.0 |  | 110.4 |

Figure 4: Scanned phantom 1 for vertical measurement by curve probe with different depths and distances

horizontal distance measurements perpendicular to the axis of the sound beam. Moreover, the procedures are the same as too, but the transducer was positioned over the horizontal group of line targets until a clear image was obtained.

RESULTS AND DISCUSSION

The result of the first part (dead zone of phantom 1 measurement) had been recorded and scanned by both linear and curve probes. The linear probe was applied for the dead zone measurements of phantom 2 [Figures 1-3]. The Dead zone in contact ultrasonic testing is the area just below the surface of a test object that cannot be inspected because the transducer is still ringing down and not yet ready to receive signals.^[24,25] From the results, all measurements were under the accepted values of that had been given by the manufacturer. Based on the manufacturer, the dead zone value or distance given is 5 mm. Therefore, it can be concluded that the measurements were all not exceeding 2% of the standard value given based on the result. From the observation that can be made from the result, the highest depth setting for both curve and linear probes shows the highest difference between the measurement that had been recorded with the actual distance given on the

phantom. Moreover, the acoustical measurements were not changed with temperature, because the phantom is made of urethane, and the urethan is become strong and fix after pouring it in the phantom box.

The result of the second part (vertical of phantom 1 measurement) had been recorded and scanned by both linear and curve probes. The linear probe was applied for the vertical measurements of phantom 2 [Figures 4-6]. From the result, there were different distances of vertical measurement recorded for each depth. This is due to the different depth of penetration since it is influenced by the setting of the depth for each probe. As the depth increases, more dots can be seen. Therefore, the measurement of dots that make up a vertical line increases. This is because penetration increases as the depth increases. As the penetration increases, more dots can be seen, and the measurements also increase. The result is then compared to the actual distance for the phantom. Since the distance of each dot given by the manufacturer is 20 mm for both phantoms, it can be said that the difference between the result to the actual distance is very small. The differences were very small with the average percentage difference <2%. The inaccuracy of the measurement might be due to operator error such as parallax error while doing the measurements.

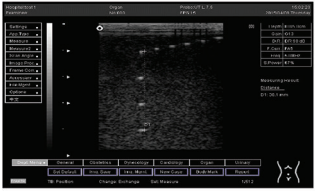
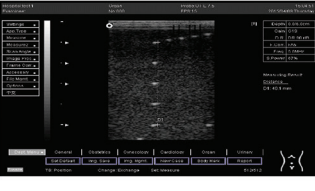
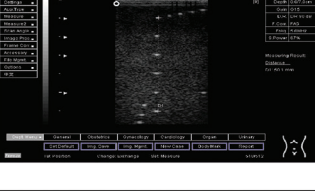
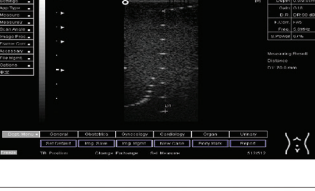
| Depth (cm) | Diagram | Distance (mm) |
|------------|---|---------------|
| 5.0 |  | 30.1 |
| 6.0 |  | 40.1 |
| 7.0 |  | 50.1 |
| 9.0 |  | 70.0 |

Fig 5

Figure 5: Scanned phantom 1 for vertical measurement by the linear probe with different depths and distances

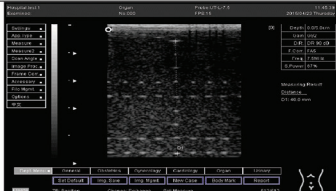
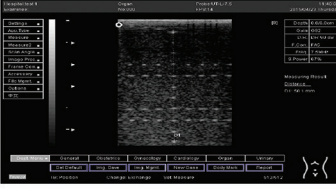
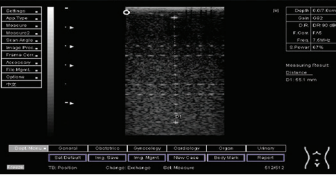
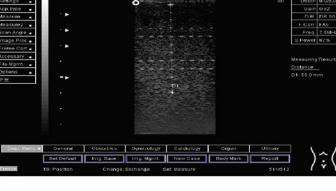
| Depth (cm) | Diagram | Distance (mm) |
|------------|--|---------------|
| 5.0 |  | 40.8 |
| 6.0 |  | 50.1 |
| 7.0 |  | 55.1 |
| 9.0 |  | 55.0 |

Figure 6: Scanned phantom 2 for vertical measurement by the linear probe with different depths and distances

The last experiment of horizontal measurement of phantom 1 measurement had been recorded and scanned by both linear and curve probes [Figures 7 and 8]. Based on the result, there were different distances of measurements recorded for each depth. This is due to the limitation of linear array field-of-view in the lateral direction. As the depth increases, the penetration increases, and the measurements will also increase. The distance of each dot given by the manufacturer is 20 mm from each dot for both phantoms like the vertical line. Therefore, the difference between the result to the actual distance is very small. The error such as parallax error while taking the measurement might be one of the reasons for the inaccuracy of the results. The result is then compared to the actual distance for the phantom. The differences were very small with the average percentage difference of <2%. Then, it was considered under the acceptable value. As shown in the results, the horizontal distance cannot be measured at 5.0 cm depth using a flat probe on phantom 1. This is due to low penetration using a flat or linear probe. In 5.0 cm depth, the penetration was not penetrated enough to measure the horizontal line on phantom 1.

CONCLUSION

The results from this experiment show high accuracy as it compared with the value given by the manufacturer. Even

though there were slightly different from the result and the actual distance value, but the difference is still under an acceptable value. From this study, the setting of depth in the ultrasound system affects the penetration and image. As the depth increased, the penetration will increase. As known, the axial and lateral resolution is important to ensure the accuracy of distance measurements. There is little uncertainty in the measurement and the expected value is known. This difference in result might occur due to some errors such as the human error that occurs when taking the measurement.

In conclusion, based on the analysis and observation that had been made from the result for all tests in this experiment, it can be concluded that this ultrasound machine is still in a good condition and can be used for a medical purpose without leading to the case of misdiagnosing. Frequent quality control and calibration test should be done to ensure the ultrasound machine in a good condition.

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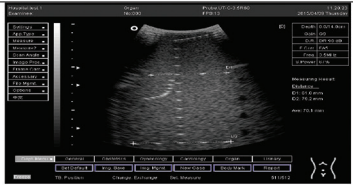
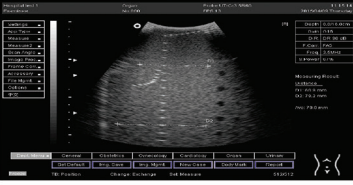
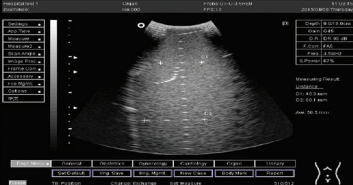
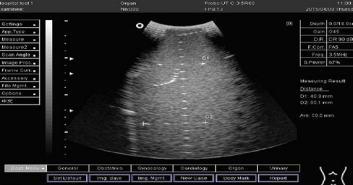
| Depth (cm) | Diagram | Distance (mm) |
|------------|---|---------------|
| 14.0 |  | 70.1 |
| 16.0 |  | 70.0 |
| 18.0 |  | 50.5 |
| 24.0 |  | 50.5 |

Figure 7: Scanned phantom 1 for horizontal measurement by curve probe with different depths and distances

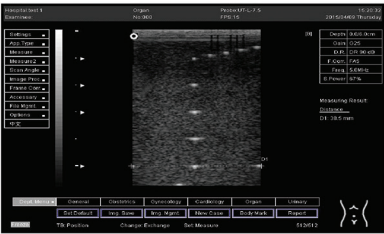
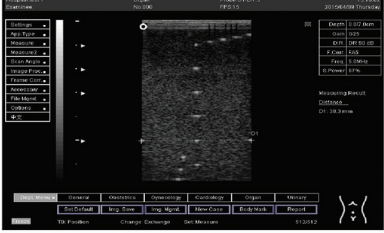
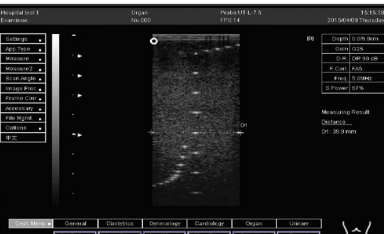
| Depth (cm) | Diagram | Distance (mm) |
|------------|--|---------------|
| 5.0 | The horizontal distance cannot be measured for the image of this depth | |
| 6.0 |  | 38.5 |
| 7.0 |  | 38.3 |
| 9.0 |  | 39.0 |

Figure 8: Scanned phantom 1 for horizontal measurement by the linear probe with different depths and distances

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Nil.

Conflicts of interest

There are no conflicts of interest.

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