International Journal of Advanced Research in Engineering Innovation
e-ISSN: 2682-8499 | Vol. 2, No. 4, 26-36, 2020
http://myjms.mohe.gov.my/index.php/ijarei

Creating A Low-Cost Calibration Phantom for Diagnostic Ultrasound

Nurul Fazarina Md Buhari[1*], Lyana Shahirah Mohd Yamin[1]

[1] Faculty of Health Sciences, Universiti Teknologi MARA Selangor

*Corresponding Author: faza_reenas@yahoo.com.my

Accepted: 1 January 2021 | Published: 15 January 2021

Abstract: *The main objective of this experiment is to create a low-cost calibration phantom for diagnostic ultrasound (US) machine using gelatin, agar, nylon filaments and lead filaments. Four custom-made calibration phantoms were produced using cost effective materials to produce a combination of gelatin and nylon, gelatin and lead, agar and nylon and agar and lead. Each of these phantoms contains the filaments designed specifically to produce reading for calibration parameters. The parameters include the measurements of the horizontal distance measurement (HDM), vertical distance measurement (VDM) and axial-lateral resolution (ALR) of the different phantoms were performed by three observers who are qualified to do the tests. For the image criteria section, the visibility, echogenicity and reverberation were investigated. Lastly, the observers also need to choose their preferred low-cost calibration phantom among the four phantoms; gelation-nylon, gelatin-lead, agar-nylon and agar-lead. The results for parameter measurements produces no significant difference between the phantoms and each parameter (p<0.001). Results for image criteria proves to give statistically significant difference between the phantoms and the echogenicity (p=0.005) while for the reverberation appearance, data proves to give statistically no significant difference between the phantoms and the reverberation (p=0.029). All four low cost phantoms were able to give measurements and provide good image criteria for US QA assessment data collection and is comparable to the commercial 84-317 Multipurpose tissue equivalent phantom. After analyzing the data in terms of parameters of HDM, VDM and ALR, we can conclude that phantom D which is agar and lead produces more reliable results while for image criteria, phantom B which is the gelatin and lead combination is the most preferred phantom. Therefore, this experimental study has successfully produced a preliminary evidence in creating a low-cost calibration phantom for diagnostic ultrasound machine as declared in the main objective.*

Keywords: Ultrasound, quality assurance, custom made calibration phantom, gelatin, agar

---

1. Introduction

This study was done to create a quality assurance (QA) phantom using tissue mimicking material (TMM) and determine if it is safe to utilize as an alternative to the original phantom. The purpose of QA is to characterize specific performance parameters of equipments used within medical imaging (Kofler, n.d.). The performance parameters are recorded and compared to the recommended parameter that is already established known as the baseline. The baseline is usually determined by vendor specifications, published guidelines or previous readings of the machine. These comparison helps to determine the image quality of the US system which obvious changes in parameters signal faulty element of the system. However, based on the study of Mannila & Sipila, (2013), they discussed that detection of problem does not only rely on baseline values from a long term follow up QA. There are various factors that can cause damage to a US system which in turn will lead to different complications to the user, subject being scanned, image quality and the electrical supply (Dietrich, n.d.). Eventually, this may lead to misinterpretation and misdiagnosis of the patient. Moreover, a reliable QA test can effectively reduce scanning time, minimize repeats, guarantee proper scanning protocols and elevate confidence level in diagnosis (Kofler, n.d.). The result of this experiment is hoped to induce confidence in targeted practitioner or physicists to perform QA tests using this low-cost phantom.

2. Literature Review

Ultrasound Quality Assurance

Importance of Quality Assurance Program

QA in radiology has been practiced over so many years to control the quality of diagnostic images, maintain optimal services and ensure minimum hazard towards staff and patient. For example, in several countries such as Canada and Croatia, their government enacted legislation to guarantee the protection of the overall population from the diagnostic x-ray facilities which basic QA program is required (Chaloner et al., n.d.;Mihi, Me, Prli, & Suri, 2008). However, many countries only apply this system for diagnostic x-ray. This may be due to lack of education, inadequate quality control tools, absence of obligatory legal acts and poor financial status of a country (Mihi et al., 2008). The World Health Organization (WHO) quoted QA in medical radiological diagnosis as an organized effort by the staff to ensure diagnostic images produced by facilities are sufficiently high quality to provide consistent, adequate diagnostic information at the lowest cost and least possible exposure to radiation (Mihi et al., 2008). The basic groundwork in establishing a QA must include periodic quality control (QC) tests, its preventive maintenance procedures and corrective actions, administrative approaches and personnel training (Chaloner et al., n.d.). Examples of QA program that is often practiced by institutions are film reject analysis, patient dose measurements, equipment inspection program and staff training and educating.

US QA is a program performed with an objective to ensure the system can provide consistent and reliable diagnostic results aside from constantly preventing from any deterioration in US performance system (Dudley et al., n.d.). Evaluation of the US quality system as a whole must show the result of actual performance level of the console, transducers, displays and peripheral equipment are at the expected level. If the measurement results and the reference values show significant discrepancies, corrective measures must be applied (Kofler, n.d.). Moreover, imaging quality is highly dependent on the technical parameters. Thus, a proper guideline must be established to determine and evaluate the relevant qualitative parameters to ensure the scanner system quality is always in check consistently. Zagzebski, Ph, Lu, & Ph, (2017) made a presentation during the 59th American Association of Physicists in Medicine (AAPM) annual meeting in 2017, where they also emphasized on establishing a QA program outline that is responsive to clinical US lab including American College of Radiology (ACR) and American Institute of Ultrasound in Medicine (AIUM), effective in detection of system failure and can be performed by medical physicists efficiently. Phantom tests can detect dangerous problems that basic tests cannot provide, which are the specific performance characteristics of an US imaging system. These assessments include tests such as uniformity tests, depth of penetration measurements and resolution displays (Kofler, n.d.).

Performance Testing

Performance testing is the method done to measure and ensure that the US equipments are operating correctly. To perform this test, special TM phantoms and baseline are required. The suggested defect level is the value that indicates the machine is faulty. Action level is also a prominent tool in QA program. It is termed as value for the image quality indicator to define a range where corrective action should be performed. For VDM, it controls the accuracy of distances along the beam axis to measure the length, area and volume of a structure (Goodsitt, Carson, & Hykes, n.d.). The suggested performance criteria for vertical measurement is 1.5mm (1.5%) of the actual distance (Goodsitt et al., n.d.). If the distance is recorded less than 1cm, then we can conclude that the phantom's velocity of the sound is not 1540m/s or the instrument calibration is faulty (Wayne R Hedrick, David L Hykes & Dale E Starchman, 2005). The horizontal test (HDM) assesses the accuracy of distances perpendicular to the beam axis. Its function is important to gather information regarding the object size. For horizontal measurement, it is considered faulty when the measurement is greater than 2mm (2%) of the actual distance (Goodsitt et al., n.d.). Error in the test is primarily the result of transducer mechanism defect which can be broken crystals, housing integrity or scanning mechanism (Wayne R Hedrick, David L Hykes & Dale E Starchman, 2005).

Axial resolution is defined as the ability of the machine to detect closely spaced objects that lie along the beam axis and display it on the monitor (Goodsitt et al., n.d.). Objects that are too closely placed together than the axial resolution will merge thus depicted as one in the image (Wayne R Hedrick, David L Hykes & Dale E Starchman, 2005). In the phantom, single filament targets with 2mm, 6mm, 10mm and 15mm distances respectively are arranged. The result is recorded as the smallest separation between two targets (Goodsitt et al., n.d.). The suggested performance criteria for this test should be 1mm or less for high frequency transducer; >4Megahertz (MHz). Lateral resolution is described as the scanner's ability to differentiate between two adjacent objects along the imaging plane, perpendicular to the beam's axis (Goodsitt et al., n.d.). In this study, we will integrate both resolution into axial-lateral by the simplest way to conduct the resolution test. The test is performed by calculating the number of filament points visible that can be separated as two adjacent objects axially and laterally.

Phantom Design and Requirements

QA tests require a special tool that act as a medium to test the system performance. In this case, TM materials phantoms are used as the medium. TMM need to have similar tissue properties in terms of scattering, velocity and attenuation which is within 2 to 15MHz diagnostic frequency range (Wayne R Hedrick, David L Hykes & Dale E Starchman, 2005). Goodsitt et al., (n.d.) mentioned that the ideal phantom should have a TM material with specific characteristics including 1540m/s speed of sound at 22C and attenuation coefficient of 0.5-0.7dB/cm/MHz. This standard is also supported by the IEC and AIUM for the usage of conventional B-mode US TMM (Cournane, Fagan, & Browne, 2012).

International Journal of Advanced Research in Engineering Innovation
e-ISSN: 2682-8499 | Vol. 2, No. 4, 26-36, 2020
http://myjms.mohe.gov.my/index.php/ijarei

Figure 1: **84-317 Multipurpose tissue equivalent phantom**

Significance of Substituted Materials

Tissue mimicking materials

TM materials are known as the most commonly used substitutes for soft tissue having almost equivalent values of acoustic attenuation and speed of sound as been mentioned before. Gelatin and agar based are one of the earliest TM materials used for US imaging. Madsen et al has constructed many gelatin-based phantoms using different properties and concentration of materials. According to Culjat, Goldenberg, Tewari, & Singh, (2010), they have achieved the speed of sound desired between 1520 to 1650m/s and ranging from 0.2 to 1.5dB/cm/MHz depending on the concentration of n-propanol contained in the water. However, the disadvantages of gelatin are its inability to withstand long term storage and very prone to microbial infection without the usage of preservatives. Culjat et al, (2010) also mentioned that agar is the most widely used material as soft tissue substitute. This is due to the ease of fabrication, the ease and flexibility of the preparation process and the well-characterized performance in giving desirable results. Besides that, the TM material properties can also be maintained for a couple of years under proper storage conditions (Madsen, 1998). Many studies over the decades has concluded that gelatin and agar are successful in mimicking soft tissue. The acoustic velocity and attenuation values of these TMM ranging between 1492 to 1575 m/s and 0.1 to 0.52dB/cm/MHz have shown great representation of soft tissue (Cournane et al., 2012). Besides, they pose as excellent intermediary medium to visualize the structures between a simple research phantom to an actual patient body or an actual calibration phantom.

Filament targets

The filament targets are the important tool in this experiment to represent the point targets in the commercial QA phantom. Target's size, shape and contrast used within the phantom must be able to justify the purpose of the phantom itself (Kofler, n.d.). The purpose of having them being embedded in the phantoms is to act as indicators for the VDM, HDM and ALR to be measured using calipers. As the commercial phantom has stated that nylon filament is used, this experiment also utilized 0.24mm fishing line to mimic the filament target. For an additional variable, a 0.25mm pencil lead is also being utilized as the filament target because of its small size and low cost. Lead contains graphite and other substances which makes it appear hyperechoic on US displays (Agarwal & Kumar, 2019). This can be supported by study by Kraus, Farooq, & Buschmann, (2009) which found out that pencil graphite or lead usually detected as foreign bodies. In the US images, they can be visualized easily by their bright appearance.

3. Research Methodology

Four homemade phantoms are created using low cost materials to mimic the US QA phantom including gelatin and agar with two different types of filament target substitutes; nylon and lead were embedded in each phantom. This produced four subjects which are gelatin and nylon, gelatin and lead, agar and nylon and agar and lead phantoms. Each of them is scanned by observers for vertical distance measurement (VDM), horizontal distance measurement (HDM) and axial-lateral resolution (ALR) measurements by using different ultrasound machines which are Samsung Sonoace R3, Samsung Sonoacer R7 and eSaote MyLabSix. We used different types of machines in order to verify the performance of those phantoms with different ultrasound systems. The data were then compared to the baseline which is reading from the commercial phantom. Results obtained from the experiment were analyzed using Statistical Package for the Social Sciences (SPSS) software.

Materials

Gelatin and agar

Gelatin powder and agar were used as the main ingredient for the phantom base. Two gelatin phantoms and two agar phantoms were produced with different target materials; nylon and lead. The gelatin and agar have been approved to be a good TMM for US scanning purpose by several studies including Kenwright et al, (2014), Browne, (2003) and Culjat, Goldenberg, Tewari, & Singh, (2010). Besides, these are one of the cheapest and easily attainable material which subjected to this experiment.

Figure 1: Gelatin powder (left) and agar strips (right) used as phantom base in this experiment

Nylon fishing line and mechanical pencil lead

Both items were bought in the same size, +/- 0.25mm embedded in the gelatin phantom as an alternative to represent filament targets in the QA phantom. Filament targets should have size and material combination that exhibits minimal reverberation artifacts. Nylon filaments of 0.25mm is adequate to be used for transducers that operate below 5MHz to avoid reverberation artifacts. (Goodsitt et al., n.d.) The purpose of these targets is to act as indicators for the VDM, HDM, ALR. Nylon fishing line is used as a substitute to the original phantom; 84-317 Multipurpose tissue equivalent phantom which utilized nylon filaments. Lead was used as an additional variable to test the fidelity comparison to the nylon filament. Pencil lead is known to contain graphite and other substances (Agarwal & Kumar, 2019). Graphite appears hyperechoic in ultrasound images. Study by Exhibit, Kraus, Farooq, & Buschmann, (2009) also stated that pencil graphite or lead is visible in ultrasound images and usually detected as foreign bodies.

Figure 3: Nylon (left) and pencil lead (right) used as filaments in this experiment

Ultrasound Quality Assessments forms

Three QA forms specifically for US system were used to record the assessment of the three US machines using four different low-cost phantoms each. Only specific tests that were investigated in this experiment was recorded; vertical distance measurements (VDM), vertical distance measurements (HDM) and axial-lateral resolution (ALR). The QA forms must have the baseline for each section based on the first scanning by using the multipurpose tissue equivalent phantom.

84-317 Multipurpose tissue equivalent phantom

The QA phantom was used as the reference phantom for QA tests. This phantom complies with the AIUM standard for the best performing phantom to evaluate both transducer and system performances. The readings of this phantom were compared to the readings from other gelatin phantoms to decide their fidelity.

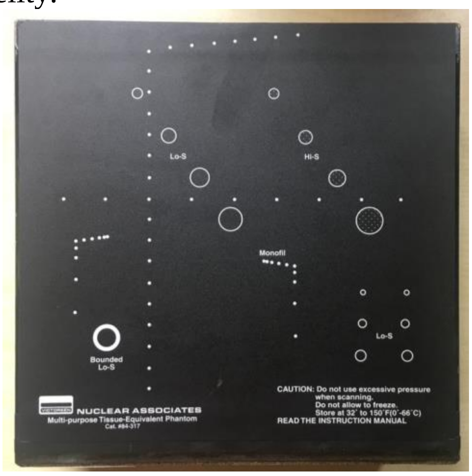

Figure 2: 84-317 Multipurpose tissue equivalent phantom used as baseline

Scanning of US QA phantoms for vertical distance accuracy:

1) The 84-317 Multipurpose tissue equivalent phantom was scanned.
2) A convex transducer was positioned over the vertical group of line targets until a clear image is obtained.
3) The display was frozen to capture the image obtained.

4) Electronic calipers were used to measure the distance that can be visibly imaged between the targets.
5) The measurement obtained was recorded in the QA form.

These processes were repeated using both gelatin and agar phantoms containing nylon and lead filaments respectively.

Scanning of US QA phantoms for horizontal distance measurement:

1) The 84-317 Multipurpose tissue equivalent phantom was scanned.
2) A convex transducer was positioned over the horizontal group of line targets until a clear image is obtained.
3) The display was frozen to capture the image obtained.
4) Electronic calipers were used to measure the distance that can be visibly imaged between the targets.
5) The measurement obtained was recorded in the QA form.

These processes were repeated using both gelatin and agar phantoms containing nylon and lead filaments respectively.

Scanning of US QA phantoms for axial-lateral resolution:

1) The 84-317 Multipurpose tissue equivalent phantom was scanned.
2) A convex transducer was positioned over the axial-lateral resolution group of line targets until a clear image is obtained.
3) The display was frozen to capture the image obtained.
4) The image was examined to determine if all line targets within the group were clearly displayed as separate points.
5) The number of visible points that can be seen as separate points were calculated.
6) The observations obtained was recorded in the QA form.

These processes were repeated using both gelatin and agar phantoms containing nylon and lead filaments respectively. The readings for each respective test was compared to the baseline to detect the performance of the US system.

4. Findings

Parameter Measurements

Data from these observers can be classified into two parts which are parameter measurements consisting of VDM, HDM and ALR and image criteria, which comprises of visibility, echogenicity and presence of reverberation. The independent variables are the phantom combinations; commercial, gelatin and nylon (A), gelatin and lead (B), agar and nylon (C) and agar and lead (D). The dependent variables are the vertical distance measurement, horizontal distance measurement and axial-lateral resolution. As for the image criteria, the independent variables are the phantom combinations A, B, C and D and the three machines. The dependent variables are visibility, echogenicity and reverberation presence.

Table 1: Results for parameter measurements attained from three US machines

PHANTOMS	PARAMETERS								
	VERTICAL DISTANCE MEASUREMENT (cm)			HORIZONTAL DISTANCE MEASUREMENT (cm)			AXIAL-LATERAL RESOLUTION (number of points)		
MACHINES	1	2	3	1	2	3	1	2	3
COMMERCIAL	0.94	1.04	0.99	1.99	2.01	1.91	9	7	9
A	1.00	0.96	1.02	2.34	2.34	1.96	9	5	7
B	1.01	0.97	0.96	2.09	2.36	1.98	9	7	9
C	1.08	0.83	0.99	1.50	1.95	1.99	7	7	8
D	1.03	1.07	1.08	2.03	2.04	2.01	8	5	9

Table above explains the complete result of the parameter measurements including the VDM, HDM and ALR filled by three observers. The phantoms were identified as phantoms A (gelatin and nylon = GN), B (gelatin and lead = GL), C (agar and nylon = AN) and D (agar and lead = AL). Based on the table, data for baseline is firstly defined using the 84-317 Multipurpose tissue equivalent phantom.

Table 2: The table of paired samples test between parameter and baseline readings
Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	VDM - BaselineVDM	.01000	.09592	.02769	-.05094	.07094	.361	11	.725
Pair 2	HDM - BaselineHDM	.07917	.22537	.06506	-.06402	.22236	1.217	11	.249
Pair 3	ALR - BaselineALR	-.83333	.93744	.27061	-1.42895	-.23771	-3.079	11	.010

The table above explains the paired samples test. The VDM data reads the significance as 0.725. Thus, there was no significant difference between the VDM and its baseline t(11) = 0.361, p < 0. 001. As for the HDM, the result for significance is 0.249. Hence, there was no significant difference between the HDM and its baseline t(11) = 1.217, p < 0. 001. Lastly, the ALR has significance of 0.010 which the result proves that there was no significant difference between ALR and the baseline t(11) = -3.079, p < 0. 001.

Image Criteria

Table 3: The results for image criteria sections using five phantoms by three observers.

PHANTOMS	IMAGE CRITERIA					ARTIFACT	
	VISIBILITY		ECHOGENEICITY			REVERBERATION	
	Yes	No	Poor	Good	Excellent	Yes	No
COMMERCIAL	+ ✔ -			✔	+-		+ ✔ -
GN	+ ✔ -		+ ✔ -			+ ✔ -	
GL	+ ✔ -		✔	+-		+	✔ -
AN	+ ✔ -		+-	✔			+ ✔ -

AL	+ ✔ -		+ ✔ -			+ ✔	-
Preferred phantom *Please circle your answer				A	B + ✔ -	C	D

Table above shows the overall result for image criteria filled by three observers during scanning. The phantoms, observers and ultrasound systems are similar to the ones used for parameter measurements section. The symbols (+, ✔ and -) are the indicators for the score given by the observer using different US machines for each criterion in the chosen column; yes or no and poor, good or excellent. Each symbol is coded to each machine, which (+) indicates first machine, (✔) indicates second machine and (-) is for third machine.

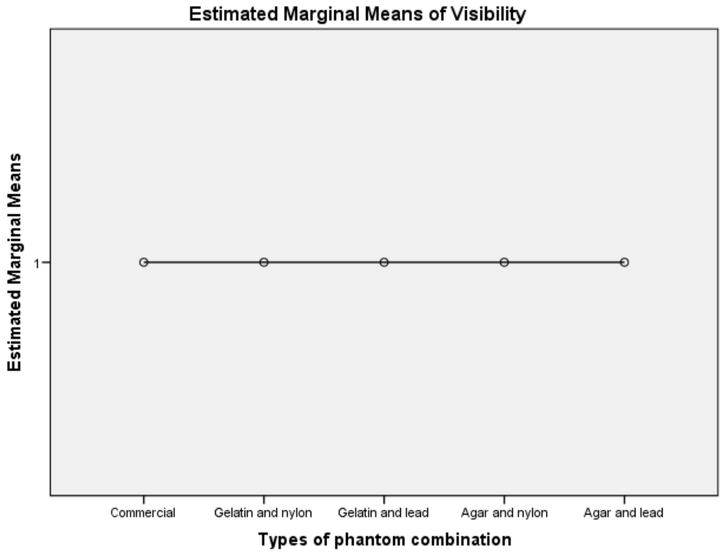

Figure 2: The estimated marginal means between phantom combinations and visibility

From the figure above, it concludes that all phantom combinations show similar results which indicates that they are able to visualize the nylon and lead filaments embedded in the gelatin and agar phantoms.

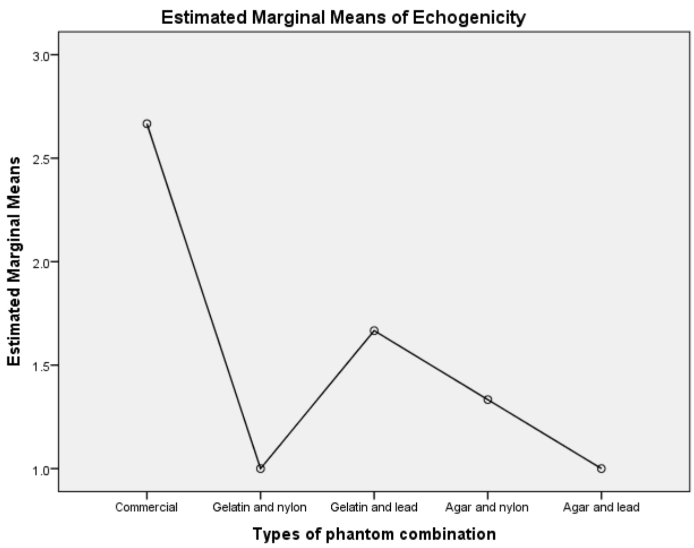

Figure 3: The estimated marginal means between phantom combinations and echogenicity

International Journal of Advanced Research in Engineering Innovation
e-ISSN: 2682-8499 | Vol. 2, No. 4, 26-36, 2020
http://myjms.mohe.gov.my/index.php/ijarei

The post hoc turkey test above shows that the commercial phantom has the best echogenicity in its display which marginal means is 2.67. Among four low-cost phantom combinations, gelatin and nylon combination produce the best echogenicity which is (m=1.67) compared to the others. The second best echogenicity is the agar and nylon combination which is (m=1.33). Lastly, the phantom combinations that produce the worst echogenicity is (m=1.00) for both gelatin and nylon and agar and lead combinations.

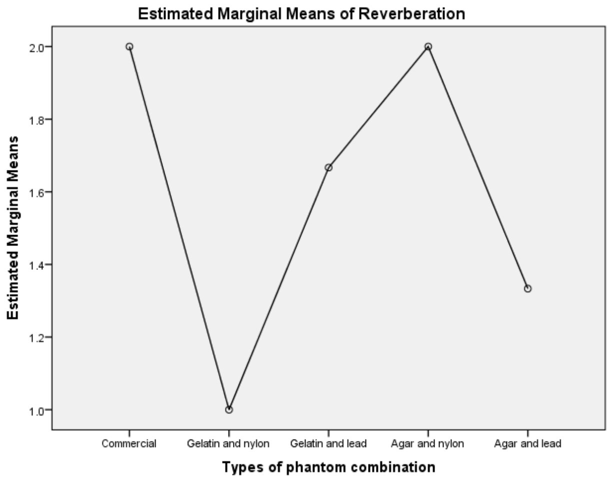

Figure 4: The estimated marginal means between phantom combinations and reverberation

Details above illustrates the formation of reverberation in the phantoms. The commercial phantom gets the perfect mean score of (m=2.0) which indicates the absence of the artifact throughout scanning process. This is comparable to the agar and nylon phantom combination which produce the similar result. Gelatin and nylon combination produced the most reverberation thus its marginal means is (m=1.00). Gelatin and lead combination produced lesser reverberation compared to agar and lead combination which is (m=1.67) and (m=1.33) respectively.

Based on the results for image criteria, data proves to give statistically significant difference between the phantoms and the echogenicity (p=0.005). Thus, we can conclude that we reject the second null hypothesis 'there is no significant difference of image criteria between low cost calibration phantoms with the multipurpose tissue equivalent phantom'. For the reverberation appearance, data proves to give statistically no significant difference between the phantoms and the reverberation (p=0.029). Thus, we can conclude that we fail to reject the second null hypothesis 'there is no significant difference of image criteria between low cost calibration phantoms with the multipurpose tissue equivalent phantom'.

5. Conclusion

To summarize this whole experimental research, all four low cost phantoms of the TMM are able to give measurements and provide good image criteria for US QA assessment data collection and is comparable to the commercial 84-317 Multipurpose tissue equivalent phantom. After analyzing the data in terms of parameters of VDM, HDM and ALR, it can be concluded that phantom D which is agar and lead produces more reliable results while for image criteria, phantom B which is the gelatin and lead combination is the most preferred phantom. Therefore, this experimental study has successfully produced a preliminary evidence in creating a low-cost calibration phantom for diagnostic ultrasound machine as declared in the main objective.

References

Assessment, A., & Material, C. T.-M. (2014). Edinburgh Research Explorer Acoustic Assessment of a Konjac – Carrageenan Tissue- Mimicking Material at 5 – 60 MHz. https://doi.org/10.1016/j.ultrasmedbio.2014.07.006

Browne, J. (2003). Assessment of the Acoustic Properties of Common Tissue-mimicking Test Phantoms, 0–31. https://doi.org/10.1016/S0301-5629(03)00053-X

Browne, J. (2017). Broadband Acoustic Measurement of the Agar- based Tissue Mimicking Material : a Longitudinal Study, *43*(7), 1494–1505. https://doi.org/10.1016/j.ultrasmedbio.2017.02.019

Chaloner, P., Section, X., Radiation, C., Division, H., Bureau, R. P., Directorate, E. H., … Canada, H. (n.d.). Diagnostic X-Ray Imaging Quality Assurance : An Overview, 1–22.

Com, W. W. W. C. (n.d.). Multi-Purpose, Multi-Tissue Ultrasound Phantom.

Cournane, S., Fagan, A., & Browne, J. (2012). Review of Ultrasound Elastography Quality Control and Training Test Phantoms Review of Ultrasound Elastography Quality Control. https://doi.org/10.1258/ult.2012.012e01

Culjat, M. A. O. C., Goldenberg, D. A. G., Tewari, P. R. T., & Singh, R. A. S. S. (2010). A review of tissue substitutes for ultrasound imaging m, *36*(6), 861–873. https://doi.org/10.1016/j.ultrasmedbio.2010.02.012

Dietrich, E. C. F. (n.d.). EFSUMB – European Course Book, 1–23.

Dudley, N., Russell, S., Ward, B., Hoskins, P., Qa, B., & Party, W. (n.d.). Special Feature BMUS guidelines for the regular quality assurance testing of ultrasound scanners by sonographers. https://doi.org/10.1177/1742271X13511805

Exhibit, E., Kraus, A., Farooq, A., & Buschmann, E. (2009). Foreign bodies : Their appearance on X-ray , ultrasound , CT and MRI.

Goodsitt, M. M., Carson, P. L., & Hykes, D. L. (n.d.). Real-time B -mode ultrasound quality control test procedures a … Report of AAPM Ultrasound Task Group No . 1.

Kofler, J. M. (n.d.). Quality Assurance of Ultrasound Imagers : Procedures , Expectations , and Philosophies.

Madsen-AAPM-391-1978.pdf. (n.d.).

Mannila, V., & Sipila, O. (2013). Phantom-based quality assurance measurements in B-mode ultrasound, *2*(8), 1–4. https://doi.org/10.1177/2047981613511967

Mihi, M. S., Me, T., Prli, I., & Suri, D. (2008). Importance of Quality Assurance Program Implementation in Conventional Diagnostic Radiology, *32*, 181–184.

Onwuchekwa R.C. (2016). [Radiological anatomy of the liver]. *Journal of Medicine and Medical Sciences*, *7*(4), 072–078. Retrieved from http://www.interesjournals.org/jmms/july-2016-vol-7-issue-4/radiological-anatomy-of-the-liver

Surgery, O., & Edition, N. U. S. (2019). Pencil injury can lead to ocular graphite foreign body, (Figure 2), 7–10.

UniversalMedicalInc.com. (n.d.). *Universal Medical*. Retrieved from Universal Medical: https://www.universalmedicalinc.com/multi-purpose-multi-tissue-ultrasound-phantom.html

Wayne R Hedrick, David L Hykes & Dale E Starchman. (2005). *Ultrasound Physics and Instrumentations.* United States of America: Elsevier Mosby.

Zagzebski, J. A., Ph, D., Lu, Z. F., & Ph, D. (2017). Assurance Information on US QA Annual Surveys , Routine QA (ACR) Physical and Mechanical Inspection , ACR Image Display (Scanner and PACS) Monitor agreement Routine QA : Transducers, 1–8.