Development of Silicone-Based Vascular Ultrasound Phantom: An Instructional Material

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ABSTRACT

This study determined the accuracy of a silicone-based phantom as an instructional material for vascular ultrasound. Three silicone rubber samples (200g) with varying silicone thinner concentrations (5%:10g. 10%:20g, and 15%:30g) were developed as part of prototype testing, each was embedded with ultrasoft epoxy resin vessels (8x12mm and 10x12mm) with water. Experimental research design was employed to assess each sample in terms of physical properties, including appearance, surface texture, durability, elasticity, and curing time. Aside from that, tissue-like softness, echogenicity, as well as ultrasound imaging performance in terms of probe positions (longitudinal and transverse) and movements (sliding and tilting). Findings revealed that increasing the concentration of silicone thinner improved tissue-like softness and elasticity, however, it reduced the durability and imaging capability. Moreover, it revealed that the thicker the ultrasoft resin vessel the lower its reflectivity and harder for ultrasound waves to pass through. Based on the results, the 5% concentration of silicone thinner produced the most stable and well-defined weasel visualization across the probe positions and movements, the 10% concentration demonstrated moderate performance in all aspects, while 15% concentration revealed the poorest image property. Overall, the silicone-based phantom demonstrated potential as an effective instructional material in vascular ultrasound, with the 5% silicone thinner concentration and 10x12mm ultrasoft epoxy resin vessel size as the optimal configuration.

Keywords: Silicone-based phantom, silicone rubber, silicone thinner, ultrasoft epoxy resin, vascular ultrasound phantom

INTRODUCTION

Radiology is a discipline that thrives on the dynamic interplay between technological and clinical advances (J. Yu et al., 2018). With that, studying within the field of radiology relies not only on advanced imaging technologies but also on effective teaching tools that prepare future radiologic professionals for clinical practice.

Ultrasonography is one of the major subjects and specialized areas within the field of radiology. It focuses on using high-frequency sound (ultrasound) waves to produce images of internal organs and other tissues. One of its subspecialties is vascular ultrasonography that centers on creating images of blood vessels in the human body to assess blood flow and detect abnormalities. According to Kankaria et al. (2023), a vascular laboratory workshop can enhance medical students' confidence in utilizing diagnostic tools for assessing vascular pathology and it provides earlier exposure that may inspire students to pursue careers in vascular-related fields.

Studying this profession should not be limited to theoretical and lecture-based knowledge. It requires a learning tool that will help students learn and develop necessary skills, such as identifying anatomic structures and evaluating the presence of abnormalities, as if they are practicing on actual patients. Instructional materials called phantoms are physical models that mimic biological tissue and its properties in medical imaging. Phantoms aid in characterizing the ability of a medical imaging system to safely produce accurate images because of their properties similar to human tissue, known geometries and composition, and ability to remain in an exact location in the imaging system for indefinite periods (Wake et al., 2021). Therefore, they can provide students with opportunities to practice essential imaging techniques without involving patients or actual people.

In line with this, the researchers aimed to provide an in-depth analysis of using silicone rubber, ultrasoft epoxy resin, and water in developing an instructional material for vascular ultrasound. This study sought to evaluate the accuracy of specific materials in terms of tissue-like softness, echogenicity, and vessel appearance, as well as its efficiency and effectiveness as an instructional material for enhancing the training and practice of radiologic technology students in vascular ultrasound.

Background of the Study

Phantoms are known for their capacity to serve as teaching tools in medical schools and radiology courses by mimicking biological tissue and its properties in medical imaging. They have different prices in the market, in which several radiology schools are not equipped with expensive phantom silicone materials that can help students practice and train in every procedure in sonography. Moreover, silicone rubber appears to be a promising material that is capable of producing stable rubbers over time and has mechanical properties that can be adjusted by means of additives to match those of biological soft tissues; thus, it is widely used to manufacture phantoms that simulate human tissue (Mencarelli et al., 2024). Also, the use of ultrasoft epoxy resin and water can mimic the sonographic appearance of vascular walls due to their echogenicity, which allows students to identify and visualize the boundaries of the vessel. Therefore, the researchers developed a silicone-based vascular ultrasound phantom using silicone rubber and ultrasoft epoxy resin.

Meanwhile, according to Costigan and Rosenblum (2022), echogenicity is a term used to describe the brightness of ultrasound in order to visualize a specific organ in the body. Each material utilized in alternative phantoms has a corresponding echogenicity. On the other hand, ultrasound gel is considered a medium that enhances the transmission of sound waves. One of its components is water, which can also help increase contact on the specific organ and show its echogenicity in the ultrasound (Sharma, 2024).

The specification of the silicone-based vascular ultrasound phantom was to provide an accurate and efficient training phantom to be used by schools that offer radiology programs. Furthermore, the development of the vascular ultrasound phantom was also uncomplicated since the materials used, such as silicone rubber, ultrasoft epoxy resin, and water, are accessible both in online and physical stores.

Furthermore, under the broad field of ultrasonography is vascular ultrasound, which creates images of blood vessels to assess blood flow and detect abnormalities. In line with this, Mindray (2023) stated that there is a limited pipeline of professionals entering vascular diagnostic imaging careers. However, there is no specific statistical number of specialized vascular ultrasound technicians in the Philippines. With this, the shortage of radiologic technologists with specialized areas increases the underemployment in specialized areas of ultrasound, specifically vascular ultrasound. According to Kappel et al. (2022), aside from radiologic technologists, respiratory therapists, healthcare professionals who focus on breathing, are also incorporating and practicing point-of-care ultrasound, a clinical practice commonly used for emergency, cardiac, and vascular assessment for immediate clinical decisions. Most qualifications and requirements for vascular ultrasound only require certification from three months of training and allow graduates from any allied medical program to practice. According to HB Calleja Center Academy for Medical Skills Advancement (2025), they offer a basic vascular program with three months of training costing roughly ₱50,990 and allow graduates of any allied medical courses, such as BS Medical Technology, BS Nursing, BS Physical Therapy, and BS Radiologic Technology, to enroll without restrictions.

Given the lack of specialized vascular technologists in the Philippines and the expensive specialized training that is inaccessible to many, this research provided effective educational tools that allow students to develop diagnostic skills. This strengthened the quality of education in radiologic technology; hence, it can create interest in such subspecialty and make students aware of the opportunities and growing demand for professionals in vascular diagnostic imaging.

Objectives of the Study

The general objective of this study was to develop and evaluate a silicone-based vascular ultrasound phantom made from silicone rubber, silicone thinner, and ultrasoft epoxy resin, and determine its accuracy in terms of tissue-like softness, echogenicity, and vessel appearance for use as an instructional material for vascular ultrasonography.

METHODS AND MATERIALS

Research Locale

The study was conducted at the Ultrasound Laboratory in the College of Allied Medicine of Southern Luzon State University in Lucban, Quezon. The experiments were executed in a controlled environment in order to provide precise and factual data collection. The location provided appropriate facilities to conduct thorough and precise testing and was selected to fulfill the objective of analyzing the accuracy and capabilities of silicone rubber, ultrasoft epoxy resin, and water when exposed to the high-frequency sound waves of ultrasound.

Research Design

In this study, the experimental research design was used. According to Appinio (2025), this design involves the evaluation of the cause-and-effect relationship through the manipulation of material concentrations and variations and observing their effects and performance under ultrasound. This design enabled systematic testing and assessment that allowed the researchers to observe and explore how each variation and change influenced each factor. This was specifically applied to the development of prototypes, in which samples of silicone rubber were mixed with varying silicone thinner concentrations. For the ratio of individual materials, the silicone thinner concentration was 5%, 10%, and 15% of the weight of the total system (A+B) of the silicone rubber mixture, while ultrasoft epoxy resin at a 3:1 mixture ratio was molded into two different diameters (8 × 12 mm and 10 × 12 mm). Water installation was dependent on the capacity of the molded vessel, all of which were systematically varied in order to evaluate the structural, acoustic, and imaging properties under ultrasound examination. In other words, the capability of the experimental research design to control the variables and test the phantom under ultrasound imaging allowed the researchers to directly observe and compare the results of the phantom's potential in terms of suitable material properties, echogenicity, and imaging quality in relation to the vessel's appearance in different linear probe positions and movements.

In conclusion, the goal of the study to evaluate the cause-and-effect relationship of material compositions and the performance of the phantom under certain conditions was appropriate for the nature of the experimental research design. Through this approach, valuable insights regarding the potential and feasibility of developing a silicone-based vascular ultrasound phantom as an efficient and effective instructional material in radiologic education were provided.

Research Instrument

The researchers utilized a structured checklist as one of the primary research instruments in this study. The checklist was used to systematically document observations during prototype evaluation in terms of vessel appearance during probe positions and probe movements, ensuring consistency and objectivity in assessing the softness (tissue-like property) and echogenic condition of the silicone rubber as superficial and deep tissue structure. This instrument guided the researchers in recording observations necessary for evaluating the accuracy and suitability of the materials used for the development of the phantom for instructional use in vascular ultrasound. Finally, the experiment was validated by experts, particularly vascular ultrasound technologists, through the provided checklist and observation of the results of the experiment.

Data Gathering Procedure

The data gathering for this experiment was carried out in four distinct phases. The first phase of the experiment involved the preparation and material testing of each individual material. For the silicone rubber, three silicone

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rubber samples were prepared by mixing 100 g of Part A and 100 g of Part B (A1:B1), with a total of 200 g for each sample. Sample 1 was mixed with 5% (10 g) silicone thinner. Sample 2 was mixed with 10% (20 g) silicone thinner, while Sample 3 was mixed with 15% (30 g) silicone thinner. Three samples were made to simulate different degrees of softness and echogenicity. This was done to assess which ratio of the two materials would best mimic and simulate the tissue composition of the human body. On the other hand, the ultrasoft epoxy resin was mixed at a 3:1 ratio of base to hardener and molded into a tube-like structure to replicate a vascular structure. These tubes had different thicknesses and diameters, specifically 8 mm × 12 mm and 10 mm × 12 mm. The varying diameters were chosen for comparison purposes to determine whether the thickness and diameter had the ability to mimic the structural characteristics of a vascular structure. Overall, the prototype samples measured 10 cm × 6.6 cm × 4.5 cm (length × width × thickness), which was considered an ideal size as it provided adequate depth and surface area for realistic simulation of vascular structure in the neck. This size also allowed convenient handling during scanning and evaluation procedures.

The second phase of the data gathering procedure involved prototype development and the scanning session. In this phase, the samples of the tissue-mimicking medium and vessel structure were scanned under ultrasound imaging by a professional vascular technologist. The prototype consisted of three 200 g silicone rubber mixtures in equal ratios (A1:B1), each mixed with silicone thinner at varying concentrations of 5% (10 g), 10% (20 g), and 15% (30 g). These silicone rubber compositions acted as the surrounding soft tissue. Embedded inside each silicone rubber prototype were two different molded samples of ultrasoft epoxy resin, 8 × 12 mm and 10 × 12 mm, simulating the vessel within the tissue. This setup replicated the anatomical relationship between the vessels and soft tissue. Using the ultrasound machine, a vascular technologist scanned each prototype sample. Images and videos using different scanning types and probe movements were acquired for each sample. The echogenicity of the samples was recorded, assessing how the different tissue mixtures and resin arteries appeared in imaging.

In the third phase of data collection, the images and videos of the prototypes during the scanning session were shown to the evaluators for them to evaluate each variable using the checklist provided by the researchers. The evaluation process involved three sonographers with specialization in vascular ultrasound. The limited number was due to the limited availability of qualified evaluators who specialize in vascular ultrasound in the area, as the study required hands-on evaluation and direct assessment of the prototype samples. This phase included the evaluation of the echogenicity of silicone rubber as superficial and deep tissue in each prototype, whether it appeared anechoic, hyperechoic, or hypoechoic. Moreover, the appearance and visualization of each vessel embedded in the silicone rubber were also evaluated based on the media showing the scanning using different probe positions (longitudinal and transverse) and movements (sliding and tilting). The evaluations focused on how clearly the vessel appeared and how it mimicked the actual vascular structures in order to identify whether the proposed phantom could mimic actual ultrasound images. This phase was crucial because it allowed the researchers to identify which silicone thinner concentration within silicone rubber provided the best echogenic property and which diameter of the molded ultrasoft epoxy resin was best visualized under ultrasound imaging. The results of the data collected in this phase served as the basis for the selection of the final materials for the final output.

The fourth phase of data collection focused on the creation of the final output. In this phase, the phantom was fully constructed according to the combination and ratio of materials identified as the most suitable for the phantom. The echogenic property, vascular structure appearance, tissue-like softness, and overall structural integrity were reflected based on the results obtained from the previous phase. This phase focused on the completion of the phantom as a whole, incorporating the finalized shape, selected materials, and successful achievement of the study’s objectives.

The data gathering procedure centered on the development of an efficient and effective vascular ultrasound phantom as an instructional material. The researchers systematically evaluated the raw materials, created prototypes for testing and ultrasound scanning, presented the scanning results to evaluators, and developed the final output through analysis of the results from the checklist answered based on the experts’ observations. Interpreting these results provided a comprehensive understanding of the phantom’s performance, guiding its potential as a cost-effective, accessible, and efficient instructional material for vascular ultrasound in radiologic education.

Experimental Testing

The experimental setup has been an important instrument to guide the process of developing the silicone-based vascular ultrasound phantom. Listed below are the experimental setup conducted in the study.

Phase 1: Preparation and Material Testing.

In this phase, the properties and specifications of the materials to be used were reviewed prior to the development of the ultrasound phantom. This process ensured that the raw materials, such as silicone rubber, silicone thinner, and ultrasoft epoxy resin, had sufficient quality and were suitable to be molded and used in ultrasound imaging. This phase focused solely on assessing the material properties of each material in order to determine their potential and feasibility as part of the phantom's structure.

Phase 2: Prototype Development and Scanning

In this phase, three prototypes of the phantom with different individual material concentrations were developed. After that, the prototypes were subjected to ultrasound scanning in the ultrasound laboratory performed by a vascular technologist in coordination with the researchers. This phase focused on the generation of ultrasound images and video recordings of the developed prototype samples, capturing their imaging characteristics under actual ultrasound scanning and assessing the tissue-mimicking properties, echogenicity, and vessel appearance. The media acquired during the scanning session were stored, as they would serve as the materials to be presented to the evaluators in the next phase, together with the observed physical properties or tissue-like softness.

Phase 3: Prototype Evaluation

In this phase, the prototype underwent a scanning session with a vascular technologist in the ultrasound laboratory. Ultrasound images and videos obtained during the session were presented to three vascular technologist evaluators for assessment using the checklist prepared by the researchers. The results of this phase provided insight into the suitability of material combinations, identified potential design limitations, and guided necessary adjustments and improvements for the development of the final output.

Phase 4: Development of Final Output

After the material testing, a series of prototype trials, and expert evaluation involving different material compositions during prototype development and the ultrasound media acquired through the scanning session, the final version of the ultrasound phantom was created. The material with the acceptable mean rating identified from data collection and interpretation was applied in the production of the final output. The developed vascular ultrasound phantom in this phase served as the final output of the research intended as a learning tool for ultrasound imaging applications.

Data Analysis

This study evaluated the accuracy of the material components of the phantom in vascular ultrasound by assessing the effects of varying silicone thinner concentrations (5%, 10%, and 15%) mixed with silicone rubber on the physical and imaging properties. Aside from that, the effects of varying vessel sizes (8 × 12 mm and 10 × 12 mm) on the physical and imaging properties were also evaluated. The study focused on the assessment of tissue-like properties, echogenicity, and vessel visibility under ultrasound imaging.

The data were collected using tabular checklists and were used in the categorization of the performance of the materials, enabling reliable documentation of the physical properties and imaging characteristics. The tables also documented how the materials responded to different probe movements and positions, including their echogenicity and tissue-mimicking behavior under ultrasound imaging. Mean ratings were computed to determine the level of tissue likeness, echogenicity, and vessel visualization for each sample.

For imaging assessment, qualitative ratings of vessel appearance and pathology detectability were analyzed based on defined criteria (e.g., highly visualized, slightly visualized, not visualized). The consistency of visualization across probe positions and movements was also examined to determine the stability and reliability of each sample.

To ensure the accuracy, validity, and reliability of the findings, the data were reviewed, computed, and interpreted by a professional statistician. This approach ensured objectivity and provided a clear basis for the development of the final output and conclusions regarding the accuracy and suitability of the silicone-based phantom as an instructional material in vascular ultrasound

Statistical Treatment

The data gathered in this study were analyzed using descriptive statistics to evaluate the physical properties, echogenicity, and appearance of vessels within the silicone-based phantom. A comparative evaluation was used to assess the sample performance based on the mean ratings. The computed values were used to identify and determine which silicone thinner concentration and vessel size provided the most optimal balance between the physical and imaging performance of the samples.

Descriptive statistics were used to summarize, organize, and interpret the data gathered from the evaluations. The mean was the primary statistical tool used to assess the level of tissue likeness, echogenicity (anechoic, hypoechoic, and hyperechoic), and vessel appearance (highly visualized, slightly visualized, and not visualized). This approach allowed for a clear comparison of the three silicone-based samples and helped identify patterns in how increasing silicone thinner concentration and changing vessel size affected ultrasound imaging performance and the physical characteristics of the phantom.

Softness	
1.00-1.66	Less Tissue-Like
1.67-2.33	Moderately Tissue-like
2.34-3.00	Highly Tissue-like
Echogenicity	
1.00-1.89	Slightly Anechoic
1.90-2.78	Mostly Anechoic
2.79-3.67	Completely Anechoic
3.68-4.56	Slightly Hypoechoic
4.57-5.45	Mostly Hypoechoic
5.46-6.34	Completely Hypoechoic
6.35-7.23	Slightly Hyperechoic
7.24-8.12	Mostly Hyperechoic
8.13-9.00	Completely Hyperechoic
Appearance during Probe Positions	
1.00-1.66	Not Visualized

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1.67-2.33	Slightly Visualized
2.34-3.00	Highly Visualized
Appearance during Probe Movements	
1.00-1.66	Not Defined
1.67-2.33	Inconsistently Defined
2.34-3.00	Consistently Well-Defined

RESULTS AND DISCUSSION

Table 1. Level of Softness (Tissue-Like) of the Silicone Rubber Depending on the Varying Amounts of Silicone Thinner

Sample No.	Silicone Thinner %	Mean Rating	Interpretation
1	5%	1.67	Less-Tissue Like
2	10%	2.00	Moderately Tissue-Like
3	15%	2.33	Highly Tissue-Like

Legend for Level of Softness (Tissue-Like):

1.00-1.66	*Less Tissue-Like*
1.67-2.33	*Moderately Tissue-like*
2.34-3.00	*Highly Tissue-like*

Table 1 shows the level of softness or tissue-likeness of the silicone rubber depending on the varying amounts of silicone thinner. At 5% silicone thinner, the material was rated as less tissue-like and yielded a mean of 1.67, suggesting that it was soft but had higher stiffness or density. At 10% silicone thinner, the material was rated as moderately tissue-like and yielded a mean of 2.00, indicating that there was a noticeable shift toward softness and lower density. The 15% silicone thinner concentration gained the highest rating with a mean of 2.33 and was classified as highly tissue-like, indicating that the increase in silicone thinner concentration enhanced or altered the density of the material.

The result is supported by Smooth-On (2025), stating that silicone thinner (oil), as a softening agent, can alter the density and viscosity of silicone rubber, resulting in a more flexible and less dense material. Therefore, the gradual increase in the mean rating indicates that even small adjustments in the thinner percentage can influence the physical properties of the material.

Table 2. Echogenicity of the Silicone Rubber (Superficial Tissue and Deep Tissue) with Varying Amounts of Silicone Thinner

Sample No.	Silicone thinner %	Mean Rating (Superficial Tissue)	Interpretation	Mean Rating (Deep Tissue)	Interpretation
1	5%	2.00	Mostly Anechoic	3.33	Completely Anechoic

2	10%	8.33	Completely Hyperechoic	5.00	Mostly Hypoechoic
3	15%	8.67	Completely Hyperechoic	4.67	Mostly Hypoechoic

Legend for Echogenicity:

Anechoic		**Hypoechoic**		**Hyperechoic**	
1.00-1.89	*Slightly Anechoic*	*3.68-4.56*	*Slightly Hypoechoic*	*6.35-7.23*	*Slightly Hyperechoic*
1.90-2.78	*Mostly Anechoic*	*4.57-5.45*	*Mostly Hypoechoic*	*7.24-8.12*	*Mostly Hyperechoic*
2.79-3.67	*Completely Anechoic*	*5.46-6.34*	*Completely Hypoechoic*	*8.13-9.00*	*Completely Hyperechoic*

Table 2 shows a clear progression in the echogenicity of the silicone rubber (superficial tissue and deep tissue) as the silicone thinner concentration increased. In superficial tissue, the 5% sample was rated as mostly anechoic, yielding a mean rating of 2.00, indicating minimal reflectivity and a darker ultrasound appearance. In contrast, both the 10% and 15% samples were rated as completely hyperechoic, yielding mean ratings of 8.33 and 8.67, reflecting strong brightness under ultrasound. Meanwhile, in deep tissue, the 5% sample was rated as completely anechoic, yielding a mean rating of 3.33, while the 10% and 15% samples were rated as mostly hypoechoic, yielding mean ratings of 5.00 and 4.67, respectively.

The observed differences indicate that silicone thinner affects the material's internal structure and capabilities during ultrasound evaluation. The result can be compared with commercially available phantoms, such as those from Humimic Medical, which are designed to provide consistent, repeatable ultrasound images with predictable texture and recognizable speckle patterns across scanning sessions. Meanwhile, the results, particularly in deep tissues, appeared nonlinear and inconsistent. To support the results, Mencarelli et al. (2024) cited the literature indicating that lower, thinner concentrations were more effective at simulating anechoic deep tissue or low-echo structures, while higher concentrations were more effective at simulating deep tissues with greater internal echoes.

Table 3. Level of Appearance of Different Ultrasoft Epoxy Resin Vessel Sizes in Varying Samples During Longitudinal and Transverse Probe Positions

Sample No.	**Silicone Thinner %**	**Ultrasoft Epoxy Resin Vessel Size**	**Mean Rating**	**Interpretation**
A. Longitudinal Probe Position				
1	**5%**	8x12mm	2.67	Highly Visualized
		10x12mm	3.00	Highly Visualized
2	**10%**	8x12mm	2.33	Slightly Visualized
		10x12mm	2.00	Slightly Visualized
3	**15%**	8x12mm	1.00	Not Visualized
		10x12mm	1.00	Not Visualized
B. Transverse Probe Position				
1	**5%**	8x12mm	2.33	Slightly Visualized
		10x12mm	3.00	Highly Visualized

2	**10%**	8x12mm	2.33	Slightly Visualized
		10x12mm	2.33	Slightly Visualized
3	**15%**	8x12mm	1.67	Not Visualized
		10x12mm	1.67	Not Visualized

Legend for Level of Appearance:

1.00-1.66	*Not Visualized*
1.67-2.33	*Slightly Visualized*
2.34-3.00	*Highly Visualized*

Table 3 shows the level of appearance of the ultrasoft epoxy resin vessel during longitudinal and transverse probe positions. In Sample #1 with a 5% silicone thinner concentration, the longitudinal probe position showed high visualization, with mean ratings of 2.67 (8 × 12 mm) and 3.00 (10 × 12 mm). Meanwhile, in the transverse position, the 10 × 12 mm vessel remained highly visualized (3.00), while the 8 × 12 mm vessel was slightly visualized (2.33). In Sample #2 with a 10% concentration, the mean ratings decreased in the longitudinal position to 2.00 and 2.33, while in the transverse position, both vessel sizes obtained a mean rating of 2.33, indicating slight visualization. In Sample #3 with a 15% concentration, the longitudinal position dropped to 1.00 for both vessel sizes, which was interpreted as not visualized, whereas the transverse position retained a mean rating of 1.67 for both, indicating slight visualization.

The results suggest that there is an inverse relationship between silicone thinner concentration and vessel visibility. Increasing the silicone thinner concentration progressively reduced the echogenicity and appearance of the embedded vessels. Higher silicone thinner concentration results in acoustically heterogeneous samples, leading to greater attenuation, reduced echo return, and diminished contrast between the vessel and surrounding medium. This effect was more severe in the longitudinal probe position, where visualization depended on continuous structural clarity along the vessel's length, making it more sensitive to even slight reductions in contrast.

The composition or internal properties of the silicone rubber as the silicone thinner changes as silicone thinner (oil) increases. According to the study of CoLtd (2021), more than 5% silicone oil to a silicone rubber mixture makes the sample less cohesive since silicone oil does not condense. The more acoustically heterogeneous medium, the more it negatively affects the transmission of ultrasound waves. Moreover, Majumdar et al. (2020) reported that when ultrasound passes through an oil layer, the intensity is significantly reduced. This supports the reduction in intensity of ultrasound waves and results in fewer echoes returned to the transducer as concentration increases.

On the other hand, the 10 × 12 mm vessel showed better visualization at a 5% silicone thinner concentration because it is less dense, with a larger lumen and thinner wall compared to the 8 × 12 mm vessel. With that, the increase in density in the 8 × 12 mm vessel reduced ultrasound wave penetration and increased attenuation. According to Nysora (2026), denser structures decrease ultrasound wave propagation, resulting in poorer visualization. The characteristics of 10 × 12 mm vessels were compared to commercially available vascular ultrasound phantoms of VATA. Their phantom has a vessel with 7 mm bifurcating to 5 mm diameter and larger deeply placed veins with 9 mm in diameter. The 10 × 12 mm vessel closely resembles the dimension of larger commercially available vessels, suggesting that increased vessel diameter contributes to enhanced visualization

Overall, the 10 × 12 mm vessel at 5% concentration performed better than the 8 × 12 mm vessel at lower silicone thinner concentrations. However, such differences disappeared at higher concentrations. Therefore, silicone thinner concentration had a stronger effect on vessel visibility and appearance than vessel dimensions.

Table 4. Level of Appearance of Different Ultrasoft Epoxy Resin Vessel Sizes in Varying Samples During Different Probe Movements

Sample No.	**Silicone Thinner %**	**Ultrasoft Epoxy Resin Vessel Size**	**Mean Rating**	**Interpretation**
A. Sliding Probe Movement				
1	**5%**	8x12mm	3.00	Consistently Well-Defined
		10x12mm	3.00	Consistently Well-Defined
2	**10%**	8x12mm	2.00	Inconsistently Well-Defined
		10x12mm	2.00	Inconsistently Well-Defined
3	**15%**	8x12mm	1.33	Not Defined
		10x12mm	1.33	Not Defined
B. Tilting Probe Movement				
1	**5%**	8x12mm	3.00	Consistently Well-Defined
		10x12mm	3.00	Consistently Well-Defined
2	**10%**	8x12mm	2.00	Inconsistently Well-Defined
		10x12mm	2.00	Inconsistently Well-Defined
3	**15%**	8x12mm	1.00	Not Defined
		10x12mm	1.00	Not Defined

Legend for Level of Appearance:

1.00-1.66	*Not Defined*
1.67-2.33	*Inconsistently Defined*
2.34-3.00	*Consistently Well-Defined*

Table 4 shows the level of appearance of the ultrasoft epoxy resin vessel during sliding and tilting probe movements. In Sample #1, at a 5% silicone thinner concentration, both probe movements showed consistently well-defined vessels, with mean ratings of 3.00 for both vessel sizes (8 × 12 mm and 10 × 12 mm), indicating stable and clear visualization throughout probe movement. In Sample #2, at 10%, both movements decreased to 2.00, which was interpreted as inconsistently defined, meaning that visibility was present but varied in clarity and appeared unclear and inconsistent during sliding probe movement. In Sample #3, at 15%, the sliding movement further decreased to 1.33, identified as not defined, while the tilting movement dropped to 1.00, which means completely not defined, indicating a loss of reliable vessel visualization.

The results suggest that there is an inverse relationship between silicone thinner concentration and vessel visibility in both given probe movements. It was observed from the results that both movements followed the same trend; however, the tilting movement showed a more severe decline in mean rating, which may be attributed to its need for consistent echo return at varying angles. On the other hand, the sliding movement allowed continuous tracking even with reduced clarity. Additionally, from the data above, no significant differences were observed between vessel sizes. This indicates that silicone thinner concentration had a stronger effect than vessel size.

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The decrease in vessel visualization as the silicone thinner concentration increased can be explained by the weakening of ultrasound signal transmission within the medium. To support this, CoLtd (2021) stated that adding more than 5% silicone thinner (oil) can make the silicone rubber mixture a more heterogeneous medium, which negatively affects the transmission of ultrasound waves. Also, the effect becomes more evident during probe movements. According to Dutta (2023), sliding movement involves smoothly moving the transducer to maintain the best imaging window. On the other hand, Uibata (2025) explained that tilting requires changes in angle to sweep through tissue layers, and it requires precise tilting and minimal rotation to stay aligned with narrow structures such as vessels, especially when using a linear probe that has a small and flat surface. Therefore, the effect of increasing silicone thinner concentration is more pronounced in tilting movement since it is highly dependent on an optimal angle. Overall, the combination of increasing silicone thinner concentration and changing probe angles resulted in a further decrease in echo detection.

Research Output

The developed silicone-based phantom, derived from materials including silicone rubber, silicone thinner, and ultrasoft epoxy resin, was intended to provide an efficient and effective vascular ultrasound phantom as an instructional material. The researchers evaluated the raw materials, constructed prototypes for testing and ultrasound scanning, presented the scanning results to evaluators, and developed the final output through the analysis of checklist-based evaluations derived from expert observations.

The findings indicate that among the three varying silicone rubber and silicone thinner ratio combinations and ultrasoft epoxy resin size prototype samples, the combination of silicone rubber with a 5% silicone thinner concentration and a 10 × 12 mm vessel size provided the most stable imaging performance and optimal vessel visualization.

The results provide a comprehensive understanding of the phantom's performance and serve as a sustainable and efficient instructional material designed to enhance the competency of students in vascular ultrasound imaging.

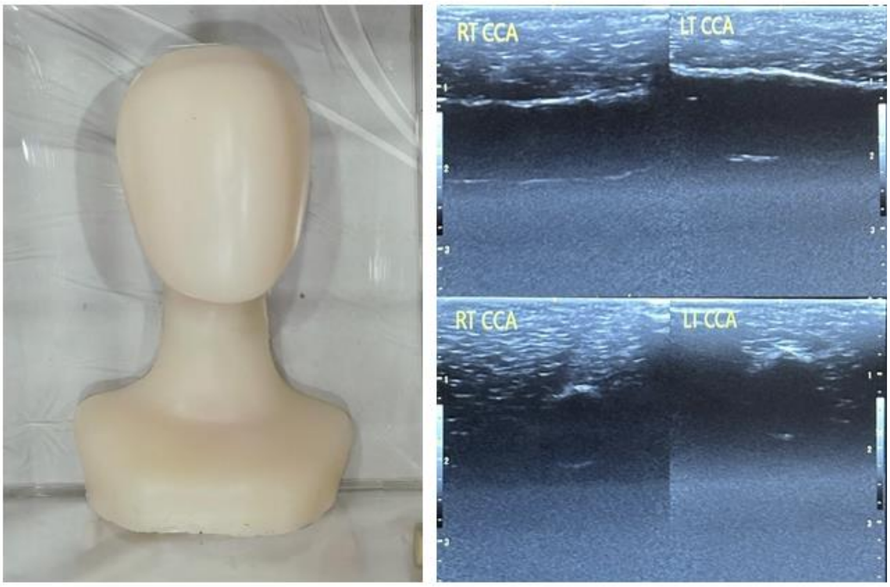

Figure 1. Silicone-Based Phantom

The figure above presents the developed silicone-based vascular ultrasound phantom and its appearance under ultrasound imaging. It was developed using the material composition identified as the most suitable in terms of physical and imaging performance during the data gathering procedure. It simulates tissue-mimicking parts with embedded vascular structures on both sides of the neck intended for training and instructional use in vascular ultrasound. Moreover, the final output serves as a cost-effective and functional instructional material that enhances the learning experience of students in vascular ultrasound while eliminating the need for live patient involvement.

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Figure 2. QR Code of Developed Silicone-Based Phantom

The figure illustrates the QR code of the developed silicone-based phantom, which provided access to the recorded videos and captured images of the developed prototype. Through this, evaluators were able to examine the visual output of the simulated vascular structures and assess the quality of the images presented. The feedback gathered during this stage played a significant role in determining the most suitable materials for the final output. Moreover, Anand et al. (2024) stated that this process contributed to establishing the clarity of the phantom as a cost-effective, accessible, and practical instructional resource for vascular ultrasound in radiologic education.

CONCLUSION

This study indicated that the most acceptable concentration level within the given parameters was the combination of the lowest percentage of silicone thinner and the larger diameter of the ultrasoft epoxy resin vessel, which resulted in more consistent images during probe positions and movements and demonstrated potential as an effective instructional material for vascular ultrasound training in Southern Luzon State University.

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