Brief Communication

Special Ultrasound Phantom for Interventional Training: Construction, Advantages, and Application

Musaad Taha Qurash*, Nur Yazmin Yaacob, Nik Azuan, Yasir Sabah Khaleel, Rozman Zakaria

Department of Radiology, UKM Medical Center, Hospital Canselor Tuanku Mukhriz, Kuala Lumpur, Malaysia

Abstract

Interventional radiology procedures are becoming more challenging over time; thus, there is a need for excellent and reliable training methods. Training on live patients is neither safe nor an ethical solution. Alternatives are many and varied, but the most popular is ultrasound guided simulators. This report shows how a simple, homemade, low-cost phantom material, and construction modules can provide several advantages over ordinary gelatin phantoms. A new layering technique and target synthesis are described for the biopsy phantom, including tips on decreasing the needle pass artifact as well as controlling the mixture echogenicity.

Keywords: Gelatin, interventional, phantom, training, ultrasound

Introduction

Training for interventional procedures is rather sensitive and constantly evolving. Currently, it still relies on supervised procedures on patients. This type of training leads to longer procedural timing, requiring expert mentoring to provide feedback and also demanding long hours of vigilance.[1]

Ethically, a trainee should not be performing an invasive procedure on a patient until after considerable practice on a phantom.[2]

Simulated training provides the opportunity to acquire and practice technical skills in a safe, controlled, and reproducible environment without the risk of harm to patient.[3]

Interventional radiology simulators for puncturing techniques are variable, from the simple homemade phantoms up to the most sophisticated expensive virtual reality simulators.[1]

A phantom may be described as any medium other than live human tissue that can be used for research or training. It provides a simple tool to learn skills of ultrasound-guided needle placement before clinical use.[4,5]

Ultrasound phantoms are generally of two types. One mimics the acoustic properties of tissue. The other one approximates the sonographic appearance of tissue, which is often used for biopsy training.[6]

The ideal phantom should be isoechoic to human tissue, be readily available, be inexpensive, be capable of repeated use, provide tactile feedback, be able to hold a needle in place, not generate needle tracks, and not be a health hazard.[5]

We will show steps for making two gelatin phantom designs guided with the above criteria, suitable for basic training in vessel cannulation and the performance of a targeted biopsy.

Materials and Methods

How to make the phantom

Material used

For a gelatin mixture with a volume of 500 ml, we use hot water (boiling to tepid) 500 ml, unflavored gelatin powder 70 g, one teaspoon of cornstarch, 5 ml of unsweetened evaporated milk, 2 ml of Dettol antiseptic liquid, and 1 ml of food coloring (blue and red). All flavored or sweetened materials will help gelatin fermentation and shorten the phantom life.

Address for correspondence: Dr. Musaad Taha Qurash, Department of Radiology, UKM Medical Center, Hospital Canselor Tuanku Mukhriz, Kuala Lumpur, Malaysia.
E-mail: mosad_taha@yahoo.com

Received: 10-07-2017 **Accepted:** 09-03-2018 **Available Online:** 18-06-2018

Access this article online

Quick Response Code:

Website: www.jmuonline.org

DOI: 10.4103/JMU.JMU_40_18

How to cite this article: Qurash MT, Yaacob NY, Azuan N, Khaleel YS, Zakaria R. Special ultrasound phantom for interventional training: Construction, advantages, and application. J Med Ultrasound 2018;26:210-4.

- General tools: A calibrated jug with a 1 L capacity for measuring, suitable-sized and-shaped containers, a 22-or 23-G spinal needle, a 5-ml syringe, a spoon, and gauze
- For vascular phantom: Two electric cables about 30 cm in length and of 5–10 mm in caliber, wax, and oil-soaked gauze
- For biopsy phantom: Gelatin, cornstarch, and small containers
- Gelatin mixture: Mix all six components for 2 min in a blender. Pour the mixture and keep it in the container for 10 min. Then, remove the froth. The gelatin is now ready for use.

Vascular phantom

- Prepare container: Measure the volume of selected container using the calibrated jug and water. Make two holes on opposite sides of the container that are of equal caliber to each cable used. Pass the cables through holes and seal the holes with wax. Sweep the cables with oil-soaked cotton piece [Figure 1]
- Gelatin mixture: The same as described before
- Make the phantom (phantom): Pour the mixture into the ready container and keep it at 6°C for 6 h. Remove the wax, fixing the cables and pull it smoothly. Put the phantom in a similar new container and submerse it in water to fill the cable spaces with a thin covering of water film.

Biopsy phantom

Choose a container with suitable size and shape and measure its volume.

Make a similar gelatin mixture of appropriate volume accordingly.

Target preparation: Mix different concentrations of cornstarch 0%, 25%, and 50% with gelatin and hot water, then keep in 6°C for 2 h.

Layering technique: Pour 1/4 of the mixture into the container and keep it in fridge for 30 min (base layer). Place the target on top, cover it by one-fourth of the mixture, allow to congeal (target layer). Then, one-fourth of mixture is then poured over the trapped inclusion and cooled until firm (body layer). Spread the gauze submersed previously in the gelatin mixture followed by covering with the residual mixture (skin layer) [Figure 2].

Tips and tricks

(1)The described material combination seems optimistic. It allows the phantom echogenicity to be homogenously increased near to the human tissue [Figure 3a and b]. (2) By increasing the cornstarch concentration, the target echogenicity and posterior shadowing can be controlled [Figure 4a-c], in comparison to grape [Figure 4d] and carrot piece [Figure 4e] targets, which gave fixed unwanted echoes and posterior shadowing. (3) Air is eliminated between the target and the base layer by adding some liquid gelatin. Air in the gauze layer can be abolished by stretching and squeezing the gauze using a spoon, followed by coverage with gelatin. In addition, air in the vascular phantom cables vacuum can be eliminated by covering and filling the spaces properly with water (4) Reduce needle pass artifact: using the same composition and thin 22G spinal needle for practice and covering the surface by thin water film, [Figure 5]. (5) The gauze layer increases phantom support and durability [Figure 2 - skin layer].

How to use ultrasound phantom for training – The key is understanding the orientation of the ultrasound wave (azimuthal plane), which is the mid-sagittal plane of the transducer face. The beam is a slice approximately 1 mm in thickness. Its utilization allows the operator to visualize the needle pathway and either track the entire needle (parallel approach) [Figure 6] or locate only the bevel of the needle until the target (perpendicular approach) [Figure 7].[7]

Results

This gelatin phantom is practical, especially for beginners due to its homemade constituents and low cost, with echogenicity

Figure 1: The container for vascular phantom

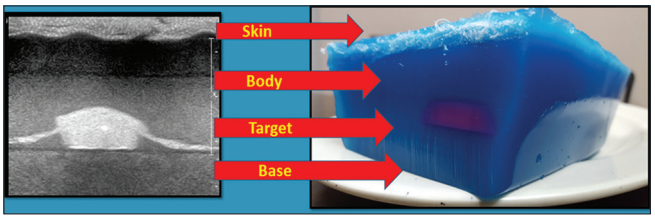

Figure 2: Cross section of the biopsy phantom showing its layers and corresponding ultrasound appearance

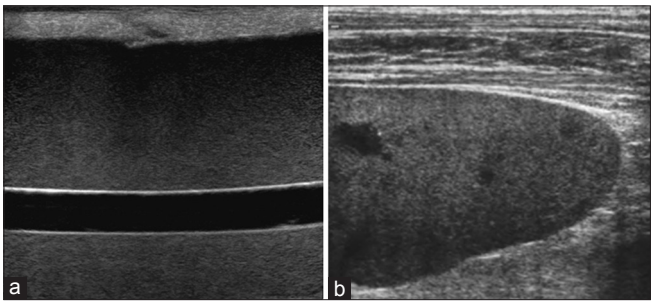

Figure 3: (a) Ultrasound images showing the phantom echogenicity (b) Near to the human tissue echogenicity

Table 1: A comparison between the various ultrasound phantoms[2]

Type	Echogenicity of background	Echogenicity of target model	Availability	Cost	Repetitive usage	Tactile feedback	Needle pass artifact	Shelf life
Gelatin phantom	↓↓ (or ↑↑ with psyllium)	↑↑	+++	+	++	++	+++	++
Blue phantom	↓↓	↑↑	++	+++	+++	++	++	+++
Meat phantom	↑↑	↑↑	+	++	+	+++	+	+
Our gelatin phantom	↑↑	↓↓/-/↑↑	+++	+	++	+++	+	++

↑: Hyperechogenic, --: Isoechoic, ↓: Hypoechogenic, +: Lowest grade, ++: Moderate, +++: Highest grade

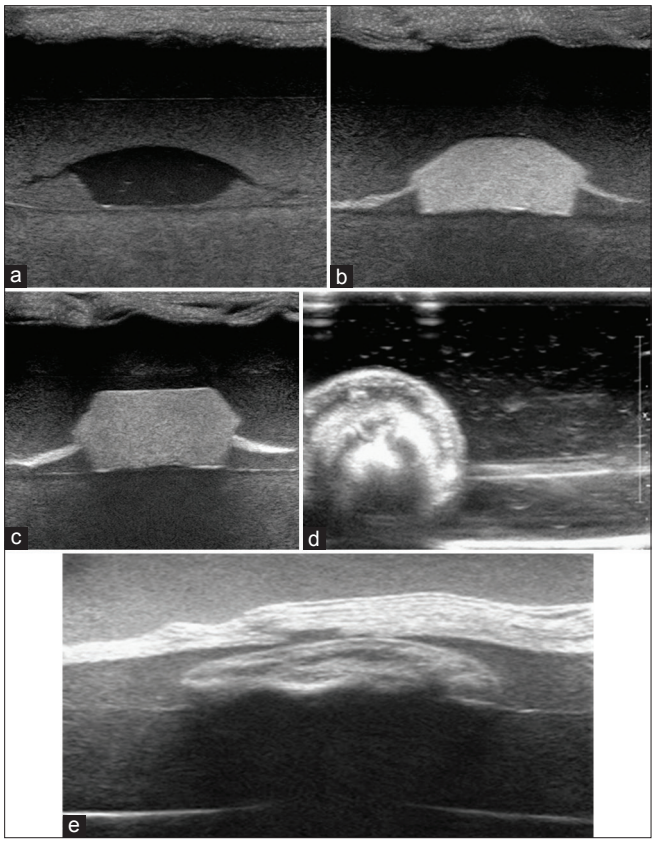

Figure 4: Ultrasound images for different materials used as a target for biopsy phantom. (a-c) Gelatin target with cornstarch of different concentrations 0%, 25%, and 50%. (d) Grape. (e) Carrot piece

simulating the human tissue, and minimal needle pass artifact. meanwhile, it provides excellent tactile feedback.

Discussion

Data collected from earlier studies[4,6,8-10] with some trials and new techniques in phantom construction allow perfect phantom with two designs suitable for vascular and biopsy training. We tried to build on the strengths and overcome the weaknesses of the previously described simulators as shown in Table 1.

This described formula and construction technique offer a phantom with many advantages; (1) Isoechoic to human tissue. (2) Very economical, costing <10 USD. (3) Eliminating needle pass artifact. (4) Able to give different

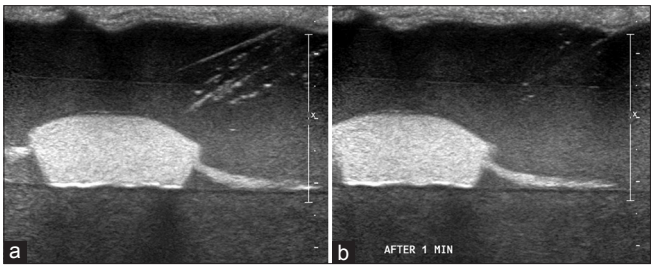

Figure 5: (a) Ultrasound images showing needle pass artifact immediately after 50 needle passes (b) How significantly eliminated after 1 min

difficulty training levels as we could easily vary the opacity, vessel caliber, target size, and echogenicity. (5) Has tactile feedback. (6) Stable at room temperature 6 h. (7) Valid for use for 2 months if preserved in the fridge.

Some authors used gelatin with additional ingredients as psyllium husk powder or generic fiber supplements to change the background`s echogenicity. While others used the ballistic gelatin which is relatively expensive costing 69.99 USD in Amazon with shipping restriction to some countries, so actually not readily available. This problem we did not face during our phantom preparation. We succeed to achieve the desired medium echogenicity using many gelatin brands of the animal source after mixing with cornstarch.[9-11]

The usage of cornstarch helps in adjusting the echogenicity of the gelatin mixture, as well as controlling the different echogenicities of the target with different echo levels as needed and with a significant reduction in the posterior shadowing from other usually used targets. The layering technique used in making the biopsy phantom allows the good positioning of the target in the intended layer.

Richardson *et al*. recommended microwaving gelatin models at 10 se intervals until track marks disappear and then resolidify it in a refrigerator before use. However, excessive microwaving will cause destabilization of the embedded objects.[4,11] A notable reduction in needle pass artifact is a good addition that is achieved using the suggested formula and the covering water film. These also produce the much needed sealing effect in prevention of air entry following each pass made, as well as the excessive white echogenic needle pass artifacts.

A cost-effective, gelatin-based phantom model for learning was described by Richardson *et al*. They used gelatin and animal fleshy parts to improve the tactile feedback.[11] Actually, this

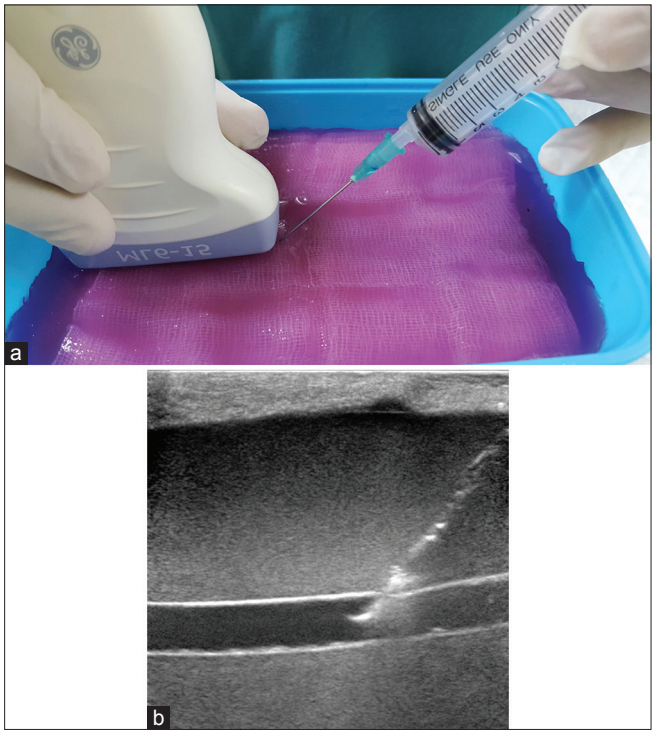

Figure 6: Parallel approach. (a) Needle position and probe alignment. (b) Ultrasound appearance of the needle pathway on the phantom using this approach

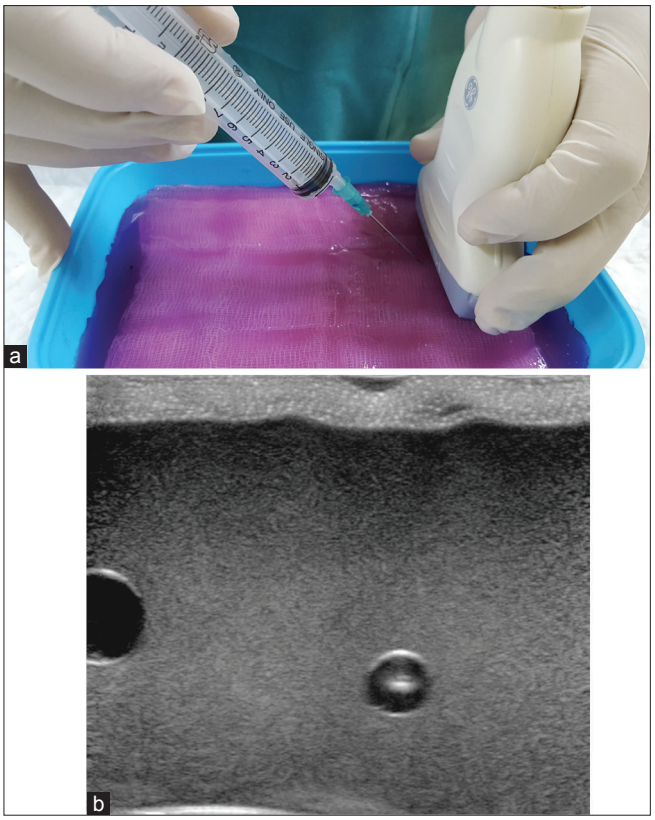

Figure 7: Perpendicular approach. (a) Needle position to probe. (b) Tip of the needle on ultrasound image

model composition gives the human tissue sensation, but it will develop bad odor and affect the phantom's shelf life. In our practice, the layering technique and the use of gauze as the skin layer make our phantom more resistant to frailty under pressure, in addition providing the tactile feedback similar to the human muscle.

Hocking *et al*. concluded that gelatin and blue phantoms have (a) very low background echogenicity, greatly exaggerates needle visibility and makes skill acquisition easier. This can lead to false confidence in regard to clinical ability. The fresh-frozen cadavers retain much of the textural feel of live human tissue and are nearly as echogenic.[5] In our described phantom, we tried successfully to avoid the false confidence feeling by opaque mixture, adjusting its echogenicity, and increasing phantom tactile feedback by gauze layer on the surface.

Pereira da Silva *et al*. mentioned that the simulator selection is very much dependent on the objectives of the training; thus, the model`s cost must be weighed against its proven effectiveness.[1] The blue phantom has a long life and does not need fridge for preservation, but it is expensive, costing more than 1000 USD, while our suggested phantom costs <10 USD. Following multiple uses, air tends to become trapped within the vessels of the blue phantom causing artifacts in addition to the prominent needle pass artifacts. Our phantom is suitable for both vascular cannulation and biopsy models, thanks to its improved echotexture, less needle pass artifact, and the absence of vessel air artifact, but its main problem is its shorter shell shelf life, which means it requires fridge preservation. Nevertheless, if one consider the advantages and remarkable difference in cost, our gelatin phantom seems more practical and cost-effective as most training course or self-training modules usually last only a few days or about 1 week at the most.

Conclusion

The formulation and usage of this homemade gelatin phantom prevent unnecessary training on real-life patients, thereby reducing the morbidity associated with it. The trainees are also able to practice and increase their skill level and confidence safely. In our phantom, we provide easy example for the beginners to start making model for themselves and to avoid drawbacks of ordinary material-based simulators. The phantom life is of medium shell life but provides satisfactory quality comparable to the ready-made relatively long life blue phantom.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Pereira da Silva FM, Donato H, Mota SJ, Donato P, Alves F C, Coimbra PT, *et al*. Phantoms for training ultrasound guided

procedures – Importance of simulation and low cost alternatives. EPOS. 2015:C-2226. [doi: 10.1594/ecr2015/C-2226].
2. Kim YH. Ultrasound phantoms to protect patients from novices. Korean J Pain 2016;29:73-7.
3. Joshi A, Wragg A. Simulator training in interventional cardiology. Interv Cardiol Rev 2016;11:70-3.
4. Sultan S, Iohom G, Shorten G. A novel phantom for teaching and learning ultrasound guided needle manipulation. J Med Ultrasound 2013;21:152-5.
5. Hocking G, Hebard S, Mitchell CH. A review of the benefits and pitfalls of phantoms in ultrasound-guided regional anesthesia. Reg Anesth Pain Med 2011;36:162-70.
6. Bude RO, Adler RS. An easily made, low-cost, tissue-like ultrasound phantom material. J Clin Ultrasound 1995;23:271-3.
7. Duick DS, Mandel SJ. Ultrasound-guided fine-needle aspiration of thyroid nodules. In: Jack Baskin H, Duick DS, Levine RA, editors. Thyroid Ultrasound and Ultrasound Guided FNA. 2nd ed. New York: Springer; 2008. p. 104-6.
8. Gould D. Using simulation for interventional radiology training. Br J Radiol 2010;83:546-53.
9. Amini R, Kartchner JZ, Stolz LA, Biffar D, Hamilton AJ, Adhikari S, *et al.* A novel and inexpensive ballistic gel phantom for ultrasound training. World J Emerg Med 2015;6:225-8.
10. Morrow DS, Cupp JA, Broder JS. Versatile, reusable, and inexpensive ultrasound phantom procedural trainers. J Ultrasound Med 2016;35:831-41.
11. Richardson C, Bernard S, Dinh VA. A cost-effective, gelatin-based phantom model for learning ultrasound-guided fine-needle aspiration procedures of the head and neck. J Ultrasound Med 2015;34:1479-84.