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TECHNIQUES IN VASCULAR ACCESS

An affordable and easily constructed model for training in ultrasound-guided vascular access

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ABSTRACT

Purpose: This paper describes a simple and inexpensive method to make high-fidelity simulators for use in ultrasound-guided vascular access teaching. The phantoms can be created to reflect the ultrasound appearance and feel of central or peripheral arteries and veins. Different clinical states such as hypovolaemia may be readily displayed using the phantoms.
Methods: The article and associated videos describe the production, appearance and use of phantoms for central vascular access, for peripheral venous access and for peripheral arterial access. Key ingredients are readily accessible and include chicken breasts, modelling balloons and thin walled latex or silicone tubing.
Results: The phantoms are easily and rapidly constructed and may be used repeatedly in a training session. As the needle passes through the phantom and vessel wall, the ultrasound appearance and tactile sensation is very similar to that of human tissue and vessels.
Conclusions: Using this method, simple and inexpensive phantoms can be created. These are ideal for use in training for ultrasound-guided vascular access. Links to videos describing the phantom construction process, their appearance and the teaching techniques utilised by the authors are found in the text.

Keywords: Cannulation, Education, Phantom, Training, Ultrasound, Vascular access

Introduction

Vascular cannulation is a fundamental clinical skill. Common vascular access procedures in adults and children include peripheral venous, central venous and arterial cannulation. Although these procedures can have major and minor complications, their success depends on patient anatomy, comorbid conditions and operator skill (1).

The use of ultrasound imaging before or during vascular cannulation greatly improves first-pass success and reduces complications (2). Appropriate training is required for ultrasound-guided vascular cannulation. Formal training will reduce the failure rate of ultrasound-guided cannulation and ultimately improve patient safety (3, 4). All forms of training must emphasize the importance of developing proficiency in both cognitive and psychomotor skill sets (2).

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A portion of this training can also be accomplished in a simulated environment that allows a trainee to develop the dexterity needed for simultaneous probe manipulation and needle insertion (2). In this instance, the use of ultrasound simulators (or phantoms) is an attractive component in such training (5). Phantoms allow repeated practice of ultrasound-guided needle placement without risk to patients (6).

A variety of models have been described in the literature for training in ultrasound-guided interventional procedures (6, 7); from commercially available (e.g. Blue Phantom™) to homemade models (meat and nonmeat based), created with materials such as agar (5), gelatin and sugar-free Metamucil (8-10), tofu, chicken breast, porcine meat (7) and highly processed mixed-meat roll ('polony') (11). Nonmeat-based phantoms often have low background echogenicity, which enhances needle visibility. Meat-based phantoms provide more realistic tissue feedback and have a background echogenicity that is closer to that of human tissue. However, they suffer from a short shelf life even with the various methods described to preserve and prepare them (6).

Commercial phantoms are expensive whilst the previously described homemade phantoms require time, skill and the availability of the necessary materials to assemble (11).

Methods

We have developed a simple meat-based vascular access phantom made from chicken breast and other readily available materials that can be constructed within 10 min with

TABLE I - Equipment required to make the vascular access phantom

Veins	Modelling balloons of varying diameter (2-16 mm ID) • Thin walls simulate the ultrasound appearance and tactile sensation of vessel wall puncture
Small and medium sized arteries	Thin walled silicone tubing (2-3.5 mm ID) • These have a slightly thicker wall than the balloons, and a smaller internal diameter. They more accurately represent the look and feel of small arteries.
Large arteries	A latex or silicone tube (8 mm ID) e.g. a Pezzer tube • This gives the feel of a hardened femoral artery, and casts some posterior acoustic shadow as a slightly calcified femoral artery often does. • Alternatively a modelling balloon can be used
Blood	Food colouring Water Container 50 ml catheter tipped syringe to fill vessels
Soft tissue	Chicken breast Cling film to wrap the model
Other	Wooden skewers Small tube clamps 3 ml syringe A cup of water A plastic tray Zip tie 3 way tap

minimal effort and low cost. These phantoms can be made to simulate both arteries and veins, ranging from small peripheral vessels to large central vessels. Tables I and II describe the required equipment and construction process.

A video describing the construction process is available as supplementary material at www.vascular-access.info (Affordable and easily constructed phantoms for training in ultrasound guided vascular access - The Construction Process).

The practical ultrasound-guided vascular access training session

Training in ultrasound-guided vascular access must incorporate a combination of theoretical knowledge regarding the procedure and technique, ultrasound exploration of normal human vascular anatomy and a practical component where ultrasound-guided cannulation is practiced on vascular access phantoms.

Useful tips when using the phantom

1 Candidates are encouraged to cannulate as many different models as possible.
2 Practice using both the in-plane and out-of plane techniques.
3 Ensure that the users do not inject air either into the soft tissues or into the balloon, as air will obscure vision; to minimize the chance of this occurring, prefill the syringe with 5 ml water, and ensure that the needle is also primed with water.
4 As the trainee hits target vessels and aspirates from them, their volume is reduced. Reinject the aspirated fluid (without air) to ensure that the vessels remain appropriately filled.
5 A partially emptied vessel will simulate a hypovolaemic patient and may challenge the trainee further.
6 Pulsatility of arteries may be reproduced by squeezing an attached sphygmomanometer bulb, or by rhythmically squeezing and releasing the simulating vessel at one end.
7 The latex balloons, the silicone tubing and the latex pezzer tubes can endure numerous punctures without popping or deflating.
8 The chicken and the phantoms are discarded at the end of the simulation session.

A video describing how the authors teach using the phantom, including tips and pitfalls, is available as supplementary material at www.vascular-access.info (Affordable and easily constructed phantoms for training in ultrasound guided vascular access - Teaching with the Phantoms).

Results

Results are best documented by demonstration of the vascular phantom images compared with images of the normal patient shown in Table III. A video describing the appearance

TABLE II - Guide to creating the vascular access phantoms. A video describing the construction process is available as supplementary material at www.vascular-access.info

Step 1 Choose the appropriate vessels for your model	Central vein • large modelling balloon for the vein (12-16 mm ID) Central artery • balloon (8 mm ID) or Pezzer tube (latex or silicone tubing with thicker wall) Mid-sized proximal upper limb vein (basilic vein) • small to medium modelling balloon (6 mm ID) Small superficial vein (cephalic vein in forearm) • small modelling balloon (2-4 mm ID) Small artery (radial artery) • small thin walled soft latex tubing (2-3 mm ID)	
Step 2 Prepare your vessels	Make the "blood" using food colouring and water Vein simulation • Attach a balloon to the filled catheter tipped syringe and withdraw all air; gently inject the fluid to fill the lumen without actually distending the walls. • Ensure all air is removed – this may require repeat aspiration and injection. • Tie the balloon. The tension created will determine the compressibility of the vessel with the ultrasound probe. A loosely filled vessel will simulate a hypovolaemic vein.	
	Large artery simulation • Use either a balloon or the Pezzer tube. • Again ensure all air is removed and the vessel filled. • Tie off or clamp both ends. A 3-way tap is useful, especially if you wish to make the artery appear pulsatile – you can attach a sphygmomanometer or more simply just get someone to repetitively squeeze and release the vessel at one end.	
Step 3 Encase the vessels with soft tissue	Central vessel and peripheral venous phantoms • Put the chicken breast down on a single layer of cling film • Lay the selected vessels on the exposed under surface of the chicken breast • The vessels may now be sandwiched between another chicken breast, or the rolled up in the cling film package • Try to expel air from around the balloons • Try to keep only one layer of cling film, with no trapped air on the smooth breast surface (the working surface)	 

To be continued

TABLE II - Continued

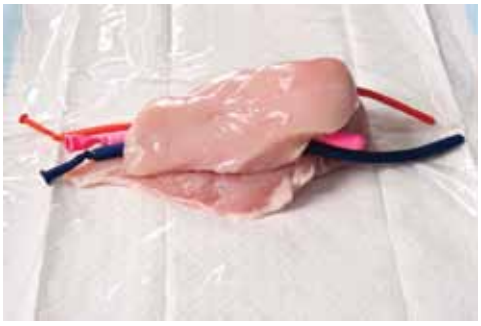
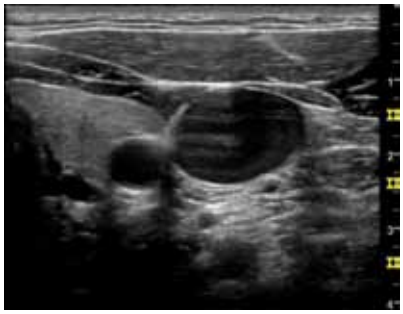
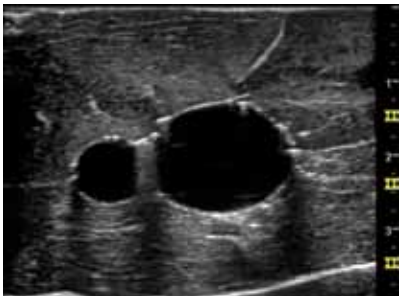
Step 3	Continued	 
Step 4 Superficial small artery simulation	Small superficial artery simulation • The thin walled silicone tubing needs to be passed through the substance of the chicken breast close to the surface. • Feed the soft silicone tubing a short distance onto the blunt end of a wooden skewer. • Now pass the skewer through the chicken breast at whatever depth you wish the vessel to run. The tubing will follow, being threaded through the chicken breast. • Remove the skewer and now carefully fill the small silicone tube with simulated blood. • Clamp either end of the tubing ensuring no air is left in the tube. • Wrap the model with cling film	 
The completed phantoms	Place the phantoms onto a tray or plastic plate. A simple IV cannula may be used for training. Try not to inject any air into the phantom as air causes artefact that disrupts the image.	

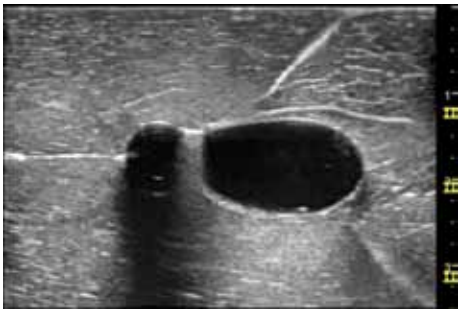
TABLE III - Appearance of human vessels compared to the various phantoms. A video describing the appearance of the phantoms is available as supplementary material at www.vascular-access.info



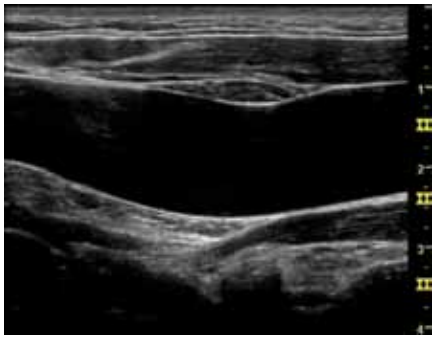
Human neck: carotid artery and internal jugular vein in cross section



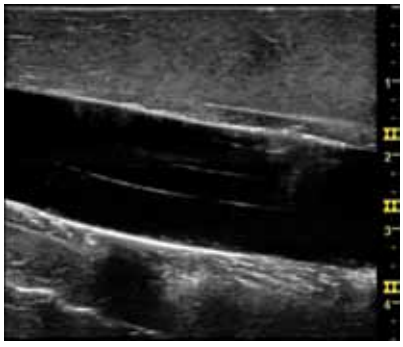
Phantom using two balloons to simulate the great vessels



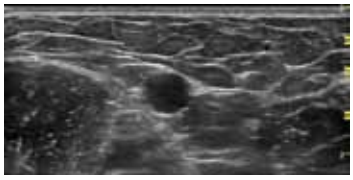
Phantom using the Pezzer tube to simulate the carotid artery and a balloon the IJ



Human internal jugular in longitudinal section

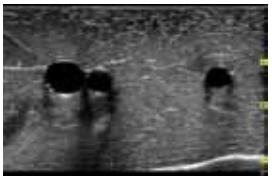


Phantom balloon in longitudinal section

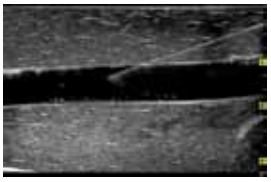


Human basilic vein transverse

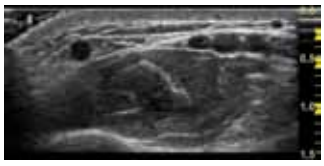
Human basilic vein longitudinal



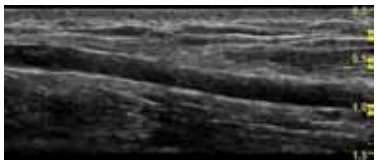
Modelling balloon phantom



Balloon phantom longitudinal

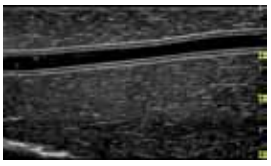


Human radial artery (and veins)



Radial artery longitudinal

Silicone tubing phantom



Silicone tubing phantom longitudinal

of the phantoms is available as supplementary material at www.vascular-access.info (Affordable and easily constructed phantoms for training in ultrasound guided vascular access - Appearance of the Phantoms).

The phantom's appearance and dynamic change as the needle passes through it is similar to that of human tissue and vessels.

The feel of the phantom is also very similar to human tissue. The additional resistance offered by the vessel wall as it is being punctured is also well demonstrated by the various phantoms. The resistance of the thin latex balloon wall is similar to that offered by veins. The slightly greater resistance demonstrated by the radial artery is similar to that of the silicone tubing, and the latex Pezzer tube simulating the femoral artery offers greater

resistance still, as is often the case with a hardened femoral artery.

The hypovolaemic vein is also well simulated by the balloon phantoms if they are partially emptied of fluid.

Discussion

The dexterity required to successfully manipulate the ultrasound probe and negotiate a needle into a target vessel needs to be taught and practised prior to its application on a real patient (3, 4, 11).

For this training, a model or phantom is required. An ideal phantom should reproduce the ultrasound appearance of human tissue and vessels. It also needs to replicate the texture and resistance of human soft tissue, as well as the increased resistance and then give, experienced as a needle meets and then crosses a vessel wall. In addition, it should withstand multiple needle punctures, have a long shelf life, be easily transportable and have different levels of difficulty/complexity that can easily be changed. It should also be easily reproducible, be inexpensive, simple to construct, not be time-consuming to produce (7) and finally be reusable (11).

Our chicken breast and latex or silicone tubing phantom meets almost all of these mandates and is an ideal choice for to training in ultrasound-guided vascular access.

Conclusion

Ultrasound-guided vascular access is an essential skill in the emergency and critical care clinician's repertoire. This paper describes a phantom that is easily made, reproducible, inexpensive and simulates ultrasound guidance of vessel cannulation in high fidelity.

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Disclosures

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