TIPS FROM THE TRENCHES

Ultrasound-guided central venous access: a homemade phantom for simulation

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Introduction

Various medical specialty organizations and the Agency for Healthcare Research and Quality (AHRQ)[1] have advocated using ultrasonography to guide central venous cannulation. It is surprising then, that very few instructional models have been described to teach this technique. Consequently, we developed a model to teach ultrasound-guided central venous access. This paper presents a recipe for an ultrasonographic model or "phantom" that is easily made, inexpensive and simulates vessel cannulation extremely well.

Methods

The phantom is formed using water, unflavored gelatin, sugar-free Metamucil, latex tubes and a rectangular Pyrex glass cake pan (17 × 27 × 5 cm). Preparation of the container includes cleaning the inner surface and spraying it with a small amount of a non-stick product.

To make the phantom mixture, first determine the volume of water needed to fill the desired container one-third full. Boil the water and then gradually whisk in 3 packets of gelatin for every 250 mL of water. Continue to whisk or stir the mixture until the gelatin is completely dissolved. Next, add the Metamucil in portions of 1 tablespoon for every 250 mL of water. Whisk until it is completely dissolved. Any remaining clumps of gelatin and Metamucil should be removed at this time. Lastly, pour this mixture into the container and put it in the refrigerator for 1–2 hours or until it is firm. This concoction now forms the base layer of the mould.

While the base layer of the mould is congealing, select the latex tubes (Penrose drains) that will be used to simulate the vessels. One-half inch diameter tubes work well to simulate the neck and femoral vessels and one-quarter inch diameter tubes appear like brachial vessels. Tie the latex tubes at one end and fill them with water, being careful to minimize the amount of trapped air. The volume of water in each tube determines whether it will be used to simulate an artery or a vein. For example, tubes that have less water will compress easily and therefore will appear like veins. After the desired volume of water is placed in the latex tube, tie off the open end.

After the base layer of the mould is firm, place the latex tubes on top of it. A second aliquot of the gelatin–Metamucil mixture (enough to fill one-third of the container's volume, as described above) is poured onto the base layer, with enough volume to surround and cover the latex drains. This will form the middle layer. Chill the mould again until firm.

Lastly, prepare another gelatin–Metamucil mixture and pour it on top of the middle layer until the container is filled to the point that the latex drains are no longer visible. Chill the mould a third time until it is firm and then remove it from the Pyrex container. At this point the phantom is ready for use.

Discussion

Unlike other indications for emergency ultrasound, where the primary goal of the exam is recognition of normal and abnormal structures, ultrasound-guided central access in-

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volves unique spatial orientation and hand–eye coordination. These characteristics make this skill difficult to acquire without real-time practice. Unfortunately, practical education is not currently available and the standard methods for teaching the Focused Assessment with Sonography for Trauma (FAST) exam, such as normal or dialysis models, cadavers, swine or simulators, have significant limitations.

Ultrasound phantoms were first described in the 1970s. They are generally of 2 types: those for simulating tissue and those for practising biopsy procedures. The tissue-like phantoms are meant to produce a B-scan appearance similar to the parenchyma of an organ, such as the liver (a finely textured echo pattern). They are used for routine testing and calibration of grey-scale ultrasound scanning equipment so great effort is taken to control factors like the speed of sound through the phantom and the coefficients related to scattering and attenuation.[2–4] As such, they can be time-consuming and expensive to produce, which typically precludes them from being used to simulate procedural ultrasound.[4]

In contrast to the tissue-like phantoms that mimic the acoustic properties of tissue, biopsy phantoms are developed to represent the sonographic appearance of tissue. They are made with inexpensive materials that are easy to obtain, so many homemade models have been developed. The typical ingredients have 3 components: one to provide bulk, another to simulate ultrasound scatter and a third to represent targets.

The components of the phantom described in this paper were chosen for their unique properties. Unflavored powdered gelatin was chosen as the bulking agent because it is commercially available, inexpensive ($3.00–$5.00 per phantom) and easy to suspend in water. When mixed in a concentration of 20 g (3 packages) in 250 mL of water, it gels quickly and provides both firmness and elasticity to the phantom. When refrigerated, the mould can last several weeks before significant microbial degeneration occurs. One downside of using gelatin is that the phantom can tear relatively easily. This damage can occur when a finger, transducer, or large-bore needle lacerates the mould. To minimize this problem, a thin layer of gauze can be coated onto the scanning surface with a small amount of gelatin, prolonging the life of the phantom.[5] Agar can also be used as a bulking agent. Although it typically has a longer life span, it is more difficult to obtain and much more complicated and time-consuming to create.[5]

Sugar-free Metamucil was used because it contains psyllium hydrophilic mucilloid fibre, which is an excellent scattering agent. When mixed with gelatin, it has an echo texture that simulates testicular, thyroid or subcutaneous tissue, and it is opaque. Thus the needle and targets are only visible sonographically, not with the naked eye. As well, after the mixture is initially prepared, no further mixing is required to maintain an even suspension of the scattering medium. It is also easy to obtain (most supermarkets carry bulk quantities) and relatively inexpensive. The sugar-containing variety can also be used, but 3 times the

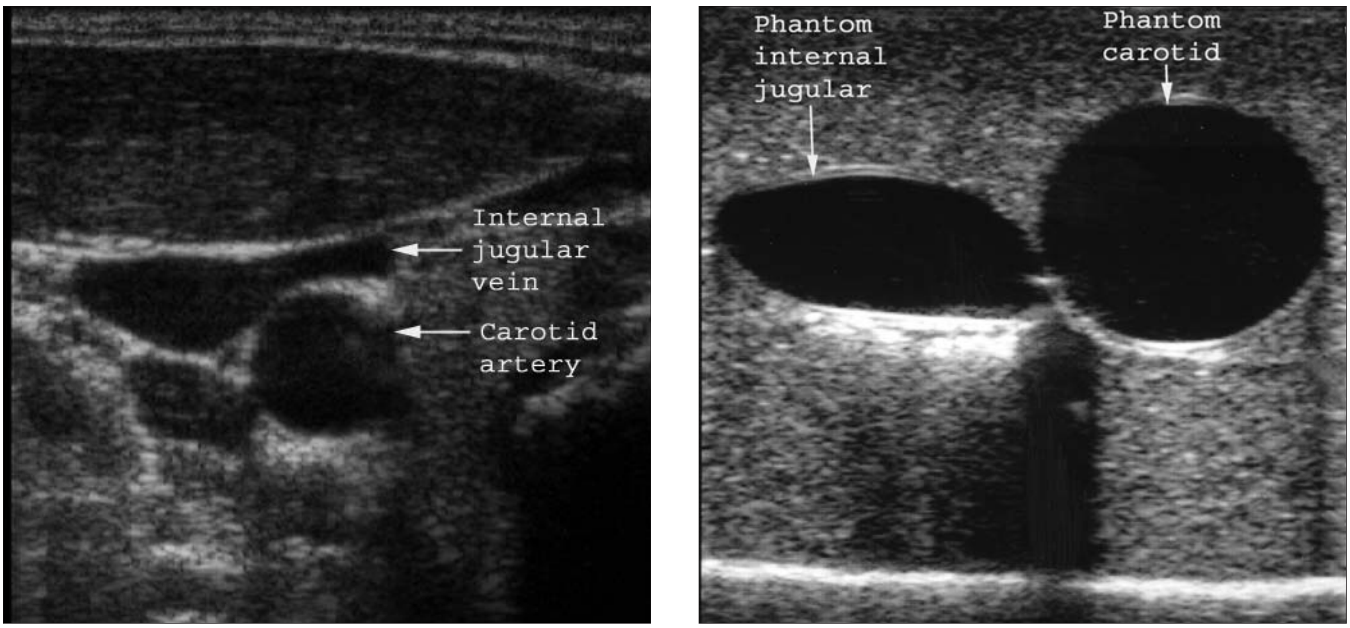

Fig. 1. Comparison of the sonographic appearance of the internal jugular and carotid artery vessels in the neck (left) with those simulated by the phantom (right).

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volume will be required to obtain the same amount of psyllium fibre. Other materials, such as flour, cornstarch or calcium carbide, can be used as scattering agents, but they require intermittent stirring during cooling until the mixture congeals, which can take more than an hour.[4]

Finally, one-half inch latex drains were used in this phantom to simulate vessels in the neck (internal jugular vein and carotid) or groin (Fig. 1). If both arteries and veins are being simulated, 2 tubes can be placed side-by-side in the mould, with one filled more tensely than the other. Other sizes of latex drains can also be used. For example, one-quarter inch most closely simulates the diameter of brachial vessels. While latex drains simulate the sonographic appearance of vessels extremely well, the downside of their use is that they have a limited life span. Most can be punctured multiple times with little deformity of their structure (Fig. 2), but if fluid is removed, they will collapse quickly. From experience, each simulated vessel can be cannulated 5–10 times with little change in its appearance except for the delineation of each needle track as air enters it during the procedure.

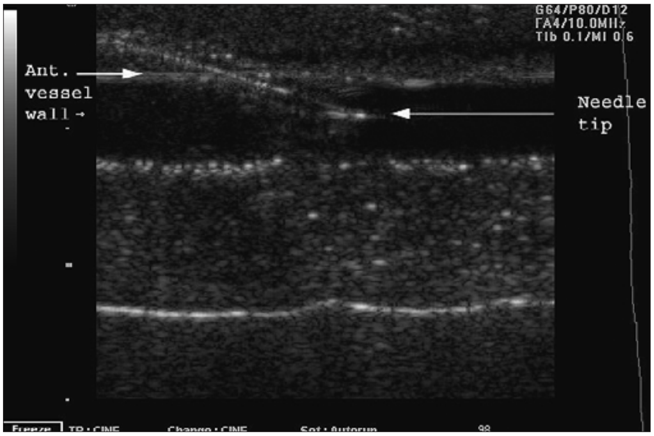

Fig. 2. Sonographic view of the phantom vessel being cannulated in the long axis plane.

Conclusion

Ultrasound-guided central venous access is a skill that emergency physicians will need to add to their armamentarium. Prior educational tools are limited, and this paper describes a phantom that is easily made, inexpensive and simulates ultrasound guidance of vessel cannulation extremely well. Further study will need to address whether it improves skill acquisition and subsequently, procedural success.

Competing interests: None declared.

Key words: Ultrasound, phantom, vascular access, ultrasound-guided

References

1. Rothschild JM. Ultrasound guidance of central vein catheterization. Evidence Report/Technology Assessment, No. 43. Making healthcare safer. A critical analysis of patient safety practices. Agency for Healthcare Research and Quality Publication, No. 01-E058. 2001; 245-53. Available: www.ahrq.gov/clinic/ptsafety/.

2. Lerski RA, Duggan TC, Christie J. A simple tissue-like ultrasound phantom material. Br J Radiol 1982;55:156-7.

3. McNamara MP, McNamara ME. Preparation of a homemade ultrasound biopsy phantom. J Clin Ultrasound 1989;17:456-8.

4. Bude RO, Adler RS. An easily made, low-cost, tissue-like ultrasound phantom material. J Clin Ultrasound 1995;23:271-3.

5. Fredfeldt KE. An easily made ultrasound biopsy phantom. J Ultrasound Med 1986;5:295-7.

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