A Review of the Benefits and Pitfalls of Phantoms in Ultrasound-Guided Regional Anesthesia

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Abstract: With the growth of ultrasound-guided regional anesthesia, so has the requirement for training tools to practice needle guidance skills and evaluate echogenic needles. Ethically, skills in ultrasound-guided needle placement should be gained in a phantom before performance of nerve blocks on patients in clinical practice. However, phantom technology is varied, and critical evaluation of the images is needed to understand their application to clinical use. Needle visibility depends on the echogenicity of the needle relative to the echogenicity of the tissue adjacent the needle. We demonstrate this point using images of echogenic and nonechogenic needles in 5 different phantoms at both shallow angles (20 degrees) and steep angles (45 degrees). The echogenicity of phantoms varies enormously, and this impacts on how needles are visualized. Water is anechoic, making all needles highly visible, but does not fix the needle to allow practice placement. Gelatin phantoms and Blue Phantoms provide tactile feedback but have very low background echogenicity, which greatly exaggerates needle visibility. This makes skill acquisition easier but can lead to false confidence in regard to clinical ability. Fresh-frozen cadavers retain much of the textural feel of live human tissue and are nearly as echogenic. Similar to clinical practice, this makes needles inserted at steep angles practically invisible, unless they are highly echogenic. This review describes the uses and pitfalls of phantoms that have been described or commercially produced.

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Phantom

noun. 1. Something apparently seen, heard, or sensed, but having no physical reality; a ghost or apparition; something elusive or delusive. 2. An image that appears only in the mind; an illusion.

adj. merely apparent, illusory, imaginary, false, fake; devised to imitate or deceive.

(Definitions from the Oxford English Dictionary and Wiktionary)

With the rapidly increasing use of ultrasound in regional anesthesia, we have to consider how best to teach safe ultrasound-guided needle placement. There is an emerging consensus that it is no longer acceptable to use patients to gain this early experience.[1–9] The use of phantoms in ultrasound-guided regional anesthesia (UGRA) can facilitate this process. For the purposes of this review, a phantom is any media other than live human tissue that can be used for research or training. Phantoms provide a simple and often inexpensive method to learn the skills of ultrasound-guided needle placement, before clinical use on patients, with the aim of reducing complications.

However, not all phantoms are equal. Do we really understand what we are dealing with when using phantoms, or are they behaving true to their definition, and the images are an illusion of reality trying to deceive us? During the development and testing of a new echogenic needle, the Pajunk Sonoplex (Pajunk Medizintechnologie, Geisingen, Germany), we gained significant experience with multiple phantoms. Using this experience, we review the types and uses of phantoms in UGRA and highlight the benefits and pitfalls.

METHODS

The literature in this review was obtained from a computer search of the PubMed database through to May 2010 using the search terms "ultrasound" and "phantom" without language restriction. Additional reports were identified from reference list screening and review articles. Abstracts were screened for relevance, and full articles obtained. Authors were not contacted for additional information. Google Scholar was used to ensure that articles published in online journals were also included.

Types of Phantom

Early "tissue mimicking phantoms" were designed for the calibration and testing of diagnostic ultrasound machines where accurate representation of the sonographic characteristics of human tissue was paramount. This involved controlling the acoustic impedance and attenuation properties of the desired material.[3,10–12] In contrast, the phantoms used in interventional work, such as UGRA, need not stringently reproduce these specific physical properties. Ultrasound-guided regional anesthesia phantoms need to be cost-effective and replicate some properties of human tissue such as background echogenicity, the texture, and needle resistance or being visually opaque such that the needle and target cannot be seen from the outside of the phantom.

Numerous interventional phantoms have been described. To illustrate that not all behave the in the same way, we have prepared a series of images of 4 different nerve block needles in 5 different phantom media and at 2 different needle insertion angles (Figs. 1 and 2). All images were obtained with the same ultrasound machine (SonoSite M-Turbo; SonoSite, Inc, Bothell, Wash), using the same settings and depth for each angle. Each represents the best obtainable image as acquired and assessed by 2 senior anesthesiologists experienced in UGRA (S.H. and G.H.).

The Pajunk Uniplex Nanoline (Pajunk Medizintechnologie) is a regional block needle with no echogenic modifications

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C.H.M. was responsible for the design and development of the Pajunk Sonoplex needle (Pajunk Medizintechnologie, Geisingen, Germany). He was excluded from the imaging process to create Figures 1 and 2.

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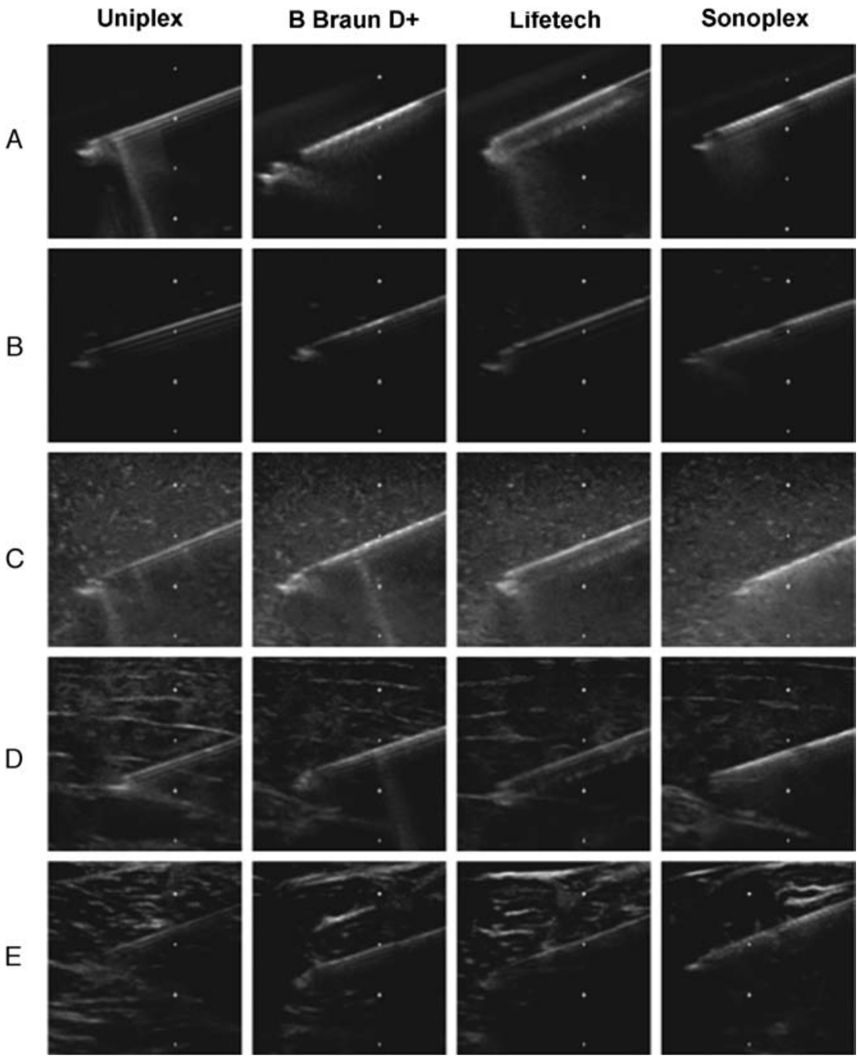

FIGURE 1. Ultrasound images of nonechogenic (Pajunk Uniplex) and echogenic (LifeTech, B-Braun D+, and Pajunk Sonoplex) needles inserted at 20 degrees to the surface and 2 cm deep into a series of phantom media. Water (A), Blue Phantom (B), gelatin/Metamucil (C), pork (D), unembalmed cadaver (E).

and has been the standard peripheral nerve block needle in our institution. The B-Braun Stimuplex D+ (B. Braun, Melsungen, Germany) is an echogenic needle using a texturing method involving indentations arranged over a 20-mm length of the distal needle shaft. These are designed to reflect part of the ultrasound beam back to the probe, even at steeper angles. LifeTech (LifeTech Inc, Stafford, Tex) developed a needle with circumferential laser etching of the distal 12.7 mm of the shaft, starting 3 mm from the needle tip. The Pajunk Sonoplex Nanoline is an echogenic needle using needle surface texturing with "cornerstone reflectors." Two circumferential pattern-embossed sections, each 9 mm in length and 2 mm apart, are arranged at the distal end of the needle. The texturing is specifically oriented to maximize the echogenicity of the needle at steep insertion angles.

The apparent brightness of the needles in these 40 images displays the effect of differing phantoms on needles with varying echogenicity. Needle brightness is not simply a function of the needle, but depends on the difference between the needle and phantom echogenicity and the effect of image processing, in particular, the gain setting.

The needle images at 20 degrees demonstrate that all are easily visible at shallow insertion angles irrespective of the phantom media. The echogenicity of even a plain needle inserted at 20 degrees is always greater than even the most echogenic phantom background, so the needle is visible. This finding is also true in live human tissue[13] and is a reason why UGRA blocks using a shallow needle approach angle have previously been considered easiest to perform. In addition, this is why it is misleading to demonstrate newer echogenic needles at shallow insertion angles and in media with low background echogenicity without providing a direct comparison.

The needle images at 45 degrees demonstrate the importance of knowing the echogenic properties of the phantom when considering visibility. The pure anechoic background of the water phantom allows even the weakest reflection from the needles to be seen. Hence, it even makes the unmodified Uniplex needle visible, and all the echogenic needles highly visible. The gelatin phantom and pork phantom have greater background echogenicity such that the Uniplex needle is now visible only because of needle shadowing and by the echogenicity of the tip. Within the gelatin phantom, all the other echogenic

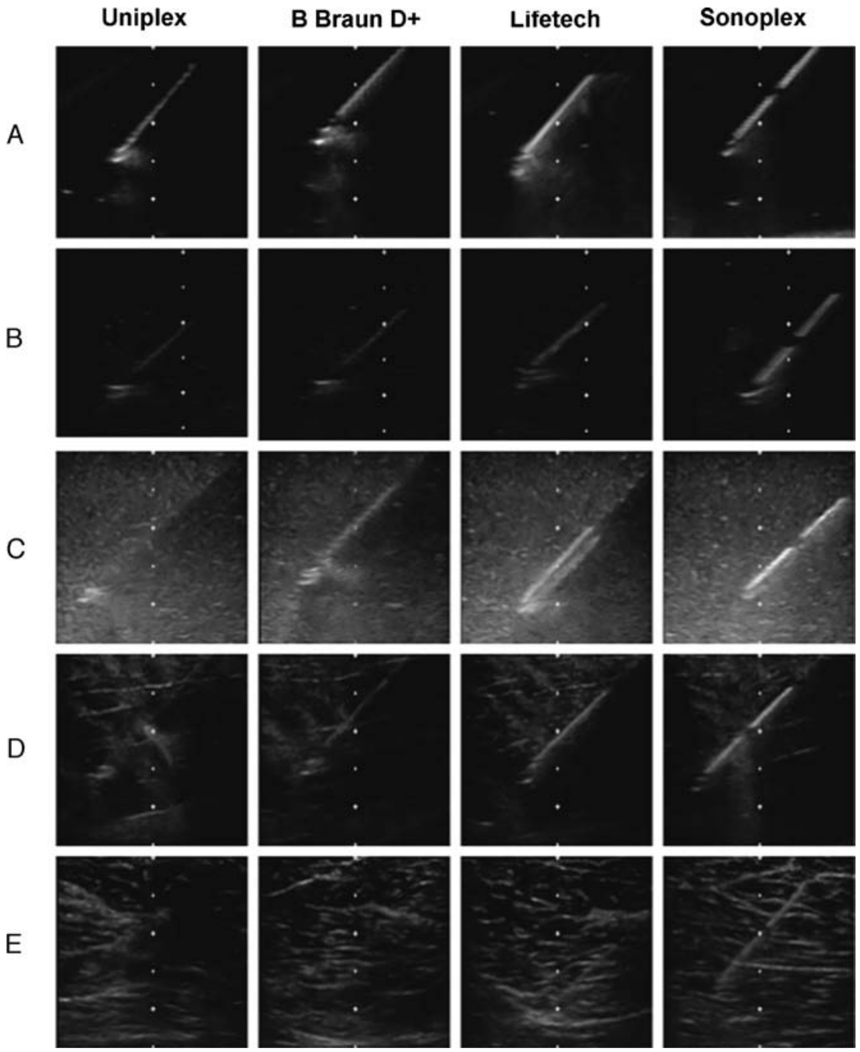

FIGURE 2. Ultrasound images of nonechogenic (Pajunk Uniplex) and echogenic (LifeTech, B-Braun D+, and Pajunk Sonoplex) needles inserted at 45 degrees to the surface and 3 cm deep into a series of phantom media. Water (A), Blue Phantom (B), gelatin/Metamucil (C), pork (D), unembalmed cadaver (E).

needles are visible especially the LifeTech and the Sonoplex. The cadaveric tissue with its higher background echogenicity has made all of the needles almost invisible except for the Sonoplex. This observation is consistent with our ongoing clinical and cadaveric needle visibility studies.[13–15] As explained below, it is our belief that live human tissue is even more echogenic than cadavers, which makes needle visibility even harder. We were able to obtain only 18-gauge Life-Tech needles. The larger gauge may have slightly increased the visibility of the needle, but as nonechogenic areas of the shaft are invisible, most of the needle echogenicity is due to their technology; hence, we felt it appropriate to include this new needle.

Water

Construction

Water baths can be made using any watertight container, with or without the addition of a submerged target structure. Using warm water that cools, and allowing the water to stand, reduces background echogenicity to virtually zero (air bubbles solubilize and disperse). This makes the needle and any target placed in the bath easy to image.

Pros and Cons

Water baths provide a readily available, inexpensive, and simple phantom. They can be used repeatedly over time with no deterioration in image or decomposition of any synthetic target used. A water phantom is of little use in the teaching and practice of needle guidance, as there is no tactile feedback, and it does not "fix" the needle in place (ie, prevent translational movement), making it difficult to keep a needle in-plane.

Recommendations

Water baths are useful during initial studies to define ideal images and confirm relevant sonoanatomy, such as with spinal phantoms.[16,17] Unfortunately, these convenient perfect water-bath images do not translate well into clinical practice.

Agar/Gelatin

Construction

Burlew et al[10] described a simple recipe for use in the calibration of diagnostic ultrasound machines. She added graphite powder and *n*-propanol to control the phantom's attenuation properties and the speed of sound through it, respectively. Madsen et al[12] described a similar phantom using gelatin as the base, along with the addition of preservatives (*p*-methyl and *p*-propyl benzoic acids) to reduce microbiological contamination. These designs have been adapted for use as an ultrasound biopsy phantom and in ultrasound-guided vascular access training.[5,18,19] Some use gelatin alone,[2,20,21] whereas others create a visually opaque and echogenic background by the addition of materials such as flour, corn starch, graphite powder, or Metamucil.[19,21–26] Metamucil is a commercially available dietary fiber supplement (Proctor & Gamble, Cincinnati, Ohio), and we have used this type of phantom with great success in our own institution. Increasing the concentration of gelatin increases the firmness of the phantom. Increasing the Metamucil increases the echogenicity.

Pros and Cons

Such phantoms are relatively simple and cheap to produce; most can be made for less than around US $35.[5,18] A 1-L gelatin phantom can be made in 30 mins and be stored in the fridge for many weeks. Addition of chlorhexidine solution to the surface of the phantom further prolongs its life. Using antireflux valves and priming the needle with fluid to remove the air can reduce needle-tracking artifact. Air in needle tracks is mostly absorbed with time, but persistent tracks can usually be removed by microwaving and allowing to cool overnight, thus producing virgin ultrasound appearances with each set up.[19,27] The addition of echogenic material provides a more realistic background against which to image the needle and prevents the operator from directly visualizing the needle passage in the phantom.

Recommendations

Gelatin phantoms can be constructed in layers to allow the addition of simple or complex targets. The relatively anechoic and transparent background of agar or gelatin enhances needle visibility, which may assist with early learner confidence. Some tactile needle feedback allows for practice of needle guidance.

Blue Phantom

Construction

The patented "Blue Phantom" (Blue Phantom, Seattle, Wash) is constructed from an elastomeric rubber. The physical properties, including speed of sound and attenuation, are tailored to be the same as those of human tissue (personal communication, Brian Keegan, www.bluephantom.com). The material is designed to "self-heal" in an attempt to minimize needle-tracking artifact that can limit the life span of the product. When a needle enters the material, it pushes the neighboring material off to either side of the needle, which then rebounds to its original location when the needle is removed. Healing occurs because the elastomeric rubber has an affinity for itself and thus reconstitutes when the needle is withdrawn. It is important that only unbent and sharp 18- to 21-gauge needles are used. The company recommend replacement of needles every 10 uses or if they get used in material other than the Blue Phantom. Dull or bent needles will drag the tip of the needle through the material, causing "scuffing" resulting in residual visible needle tracks because the material is unable to properly reconstitute.

Pros and Cons

A firm texture for needle insertion is provided, more so than in agar and gelatin models, and targets can again be incorporated in to the structure. It is expensive compared with homemade models (US $499), and being homogenous with low background echogenicity, it can make needle visibility deceptively good. Nevertheless, this model has been the training ground for many UGRA practitioners and has been used as the testing medium in several needle visibility studies.[28,29] The elastomeric rubber molds well to the "smooth" shafts of traditional needles, but many of the recent echogenic technologies depend on texturing of the needle surface. In human tissue, it is assumed that fluid fills these indentations to achieve a tissue-metal interface for the reflection of the ultrasound waves. In the Blue Phantom, many of these needle texturings will not be filled by gel, but instead remain as air pockets adjacent to the shaft. This removes the phantom-needle interface and may alter the echogenicity of the needle. The performance of echogenic needles in a phantom may therefore be different to that seen in human tissue.

Recommendations

Gelatin and Blue Phantoms behave similarly to water baths, but they also provide a degree of texture that both fixes the needle in its path and gives some element of "feel" as the needle is inserted. Needle visibility is high, which makes skill acquisition easier but can lead to false confidence in regard to clinical ability. They are useful in the early stages of learning needle guidance, before progressing to harder targets or meat phantoms.

Other Materials

Other low-fidelity phantoms have been described as listed in Table 1. The features of these are similar to those already mentioned.

Meat Phantoms

Construction

Xu et al[8] described a pork phantom for real-time UGRA practice using an 8- to 10-hr soak in 70% alcohol to deodorize and partially preserve the meat. We have modified this technique using 66% alcoholic hand wash (Aqium Gel; Ego Pharmaceuticals Pty Ltd, Braeside, Australia) to make a pork phantom for ultrasound-guided neuraxial block (Fig. 3).[30] This is a widely available

TABLE 1. Other Low Fidelity Phantom Media in the Literature

Phantom Material	Construction
Extra firm tofu[4]	Block of foodstuff ± wood or wire targets
"Premisorb"[56]	Nonperishable medical solidifying agent poured into an empty crystalloid bag
Foam/saline (US patent 4286455) sponge/degassed water[35]	Sponge immersed in a fluid-filled container
Commercial beef gravy[57]	Mixed with 8 cups of water and kept in suspension using a magnetic stirrer
Evaporated milk (US patents 5902748 and 5625137)	Mixed with water and preservative ± gelatin to solidify

FIGURE 3. Trainee practicing real-time ultrasound-guided neuraxial block on a porcine phantom using a Sonoplex needle (Pajunk Medizintechnologie).

source of alcohol within all areas of the hospital and is perfumed, which helps in the deodorizing process. Bovine extensor digitorum longus muscle has been used successfully as an interventional phantom in a study looking at UGRA learning curves. Turkey breasts or other media have frequently been used in interventional radiology studies[21,23,24,31–35] and more recently as an UGRA training model.[36]

Pros and Cons

The pork phantom is a moderately cheap (about US $20), simple, and surprisingly long-lasting model for practicing needle visualization. Anatomic structures are clearly visualized with background echogenicity, tissue layers, and needle images comparable to those in human tissue. Tactile feedback when crossing tissue planes mimic that felt in clinical practice, and needle-tracking artifact is less pronounced when compared with gel-based models, presumably because they fill with tissue fluid after needle removal. In contrast to synthetic phantoms, hydrodissection and simulated local anesthetic injection can also be performed.[37] Of the other meat phantoms, we have found beef to be less effective because of thick adipose layers excessively degrading the ultrasound images. Experience with turkey has also been disappointing, as it is slippery, hard to hold in position, and difficult to stop the tissue deforming from transducer pressure. Tissue layers are also unlike those in humans, and the smaller size of the animal means that deeper needle insertion techniques are less easily practiced.

Recommendations

Meat phantoms are cheap and provide a more realistic simulation of needle guidance in actual clinical practice. The background, needle visibility, and tactile feedback are closer to those of human tissue than the low-fidelity phantoms.

Cadavers

Construction

Cadavers can be fresh, fresh frozen (unembalmed), or embalmed in a variety of solutions. Cadavers prepared using Thiel's embalming method produce more realistic images and fascial "pop" sensations when compared with fresh (recently deceased) cadavers.[6] Some have also suggested they maintain reasonable flexibility.[38] Cadaveric phantoms also permit the injection of local anesthetic and the assessment of perineural spread, another key component of successful UGRA.[6,38] Our own experience developing a national UGRA workshop has been that fresh-frozen cadavers provide excellent images and tactile feedback.[39,40] One problem with cadavers is the absence of normal vascular anatomy—vessels are usually collapsed. We recently described a gelatin infusion technique in an effort to overcome this problem and improve the realism of this model for UGRA.[39] One fresh male cadaver was identified for perfusion before being frozen. The vascular system of the cadaver was perfused with a dyed gelatin suspension via both superficial femoral arteries. The gelatin concentration was such that 238 g of gelatin was added to 3 L of saline and dissolved by stirring at 70°C for 30 mins. Alizarin red dye was added (5 mL/L) to color the solution red for the benefit of vascular surgeons using the cadaver subsequently. The gelatin solution was infused via gravity feed from a height of 1 m and required 2.75 L for complete perfusion. Others have used a pneumatically driven system to generate palpable pulses in cadavers and demonstrated significantly improved learning experience.[41]

Pros and Cons

Human cadavers can be an expensive and difficult resource to access, whether "fresh" or embalmed, and there are ethical issues to consider. However, when available, they provide an invaluable training resource. Tsui et al[42–44] comment on the opportunities offered by embalmed cadavers. They describe the imaging of "true" human anatomy in a time-rich environment, of needle insertion without the risk of clinical consequence, and of the dissection of target tissues after needle insertion and injection. Sessions in the anatomy class are included in the recently published Mayo Clinic UGRA training curriculum.[7] Many have published on the benefits of regional anesthesia cadaveric workshops,[39,40,45,46] and cadaveric experience is a prerequisite for the ESRA diploma (http://www.esraeurope.org/education_diploma.asp).

Recommendations

Unembalmed cadavers are probably the closest phantom media to live human tissue. Our gelatin infusion technique restored the appearance of vascular anatomy and allowed more

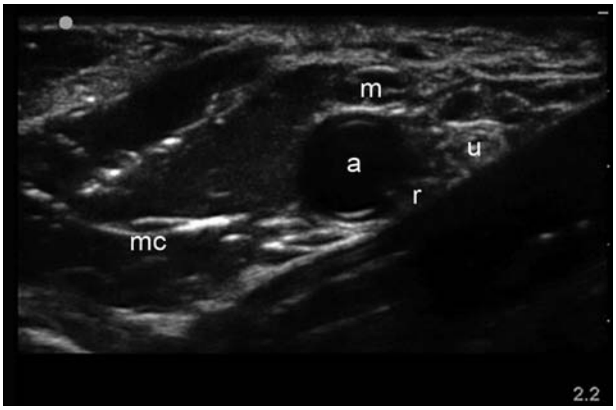

FIGURE 4. Ultrasound image of the axillary brachial plexus in a fresh cadaver illustrating restoration of normal vascular anatomy following gelatin perfusion (m), ulnar nerve (u), radial nerve (r), musculocutaneous nerve (mc), and axillary artery (a). Reproduced with permission from Hocking and McIntyre.[39]

realistic reproduction of the expected anatomy for realistic nerve block practice (Fig. 4).[39] Cadavers also provide a good medium for the testing of new UGRA technology and the development of new UGRA techniques as they more closely mimic the clinical situation.[14] We have noticed that needles still appear more echogenic in cadaveric tissue compared with live human tissue. We hypothesize several explanations for the difference. Dead cells release their intracellular fluid, increasing the extracellular fluid adjacent to the needle. The more watery background decreases echodensity adjacent to the needle, hence enhancing the needle visibility. In addition, tissue density changes when cold; the lack of blood flow and tissue movement may all artificially improve the ultrasound image.

Creating and Troubleshooting Homemade Phantoms

Almost all noncadaveric phantoms have been adapted to include targets mimicking specific tissues or pathology. The optimal target depends on what body structure needs to be simulated. Table 2 lists materials previously described to assist anyone considering making his/her own phantoms. Commercially produced phantoms can be costly and will still suffer image degradation with repeated needle practice. Homemade phantoms offer a simple, inexpensive, and flexible UGRA resource that should not be overlooked. Table 3 lists common problems that need to be prevented along with solutions that have been described.

TABLE 2. Methods Used to Simulate Target Structures in Phantoms

Structure to Be Simulated	Method Used
Cysts	Water-filled balloons[19,25]
	Tied-off surgical glove tips[19,23,32]
Soft-tissue masses	Olives[23,24,31–35]
	Fruit/vegetable pieces[2,23,26,32,58]
	Glycerin suppositories[58]
	Foam pieces[56]
	Hotdog pieces[22]
	Pasta pieces[2,32]
	Synthetic beads[20]
	Pet food[26]
Bone	Animal bone*
	Pork shoulder phantom[8]
	Synthetic spine model[16,17,27]
Vessels	Rubber tubing[5,18]*
	Cooked penne pasta superglued together*
	Perfuse vascular system of cadaver with gelatin[39]
	Pneumatic pump system[41]
Nerves	Wooden dowel[4]
	Electric wire[4]
	Metal rods[59]
	Spaghetti*
	Bovine/porcine tendon[8,37]
Ribs	Rubber strips[20]
	Coffee stirrers[24]

*From http://www.ra-uk.org/ultrasound-sig/83-simulator-for-ultrasound-guided-blocks.

TABLE 3. Potential Problems and Proposed Solutions in the Preparation and Use of Homemade Phantoms

Common Problem	Solutions Proposed
Medium drying out	Surface layer of mineral oil (eg, baby oil[19])
Microbiological invasion	10% Formalin[18,20]
	10 ml Phenol/1000 mL media[32]
	Chlorhexidine[19]
	p-Methyl and *p*-propyl benzoic acids[12]
	70% Alcohol/alcoholic hand wash[8,30]
	Refridgeration[22,26]
	Nonperishable medium (eg, Premisorb[56])
Needle tracking	Attach an antireflux valve to the hub of each needle and prime with crystalloid
	Use needles with central stylets[20]
	Surface layer of mineral oil (eg, baby oil[19])
	Microwave gelatin/agar models to reform and reuse[19,27]
	Use meat/cadaveric phantom (less tracking)
Lack of echogenicity of medium	Metamucil[22,23]
	Graphite powder[19]
	Cornflour[24]
	Flour[25]
	Premisorb[56]
Lack of visual opacity	Food dye[22,56]
	Metamucil[22,27]
Inhomogeneity of medium	Pour the mixture down the side of the bowl to exclude air bubbles[20]
	Add ice cubes/ice-cold water while setting[25]
	Refrigerate to set[34]
	Stir mixture intermittently until firm
	Use Metamucil (maintains even consistency)[34]
Incorporating targets in gel phantoms	Form phantom in stages if using an upright container[2,19,22]
	Pour 1st layer and allow to partially set
	Rest target on layer
	If target floats, pour a thin layer around it and allow to partially set
	Pour further layer to cover
	Use a bag ("Zip-lock,"[23] IV fluid,[56] or barium enema bag[32]) to form the phantom in and rotate it while cooling
	Barium enema bag[32]
	Empty crystalloid bag[56]
Reflection artifact from phantom base	3-mm Ribbed rubber matting[20] or household sponge cloth placed on/in the base during formation[2]

Use of Phantoms for Education

There is emerging consensus that it is no longer acceptable to use patients for first-time practice at needle placement.[1–9] Time spent using phantoms is integral to virtually all published UGRA training programs.[7,47–49] Interventional radiologists have previously demonstrated significant improvements in practitioner confidence, in-plane needle visualization, success rate, and safety of needle approach.[31] Published work on how to teach

UGRA is expanding, with many studies using meat phantoms as their chosen practice medium.[36,37,50] Sites demonstrated rapid improvements in both operator accuracy and efficiency, regardless of prior operator experience.[36] Our own experience using a porcine phantom for practicing ultrasound-guided central neuraxial blockade has resulted in increased confidence among our trainees.[30]

The design of homemade phantoms is flexible and can be altered as a trainee progresses. Simple needle-visualization models can subsequently be replaced or modified to incorporate target structures. These targets can then be progressively decreased in diameter, and as a final step in complexity, their orientation can be changed relative to the phantom's scanning surface.[4] We suggest that background echogenicity and target depth be modified because both play a key role in the ease of identifying both needle and target structure. All current phantoms, to the best of our knowledge, lack the facility to detect needle-to-nerve contact. This remains a key safety issue with regard to subsequent progression to clinical practice. Principles that may prove useful in solving this issue include the completion of an electrical circuit between needle and target or the detection of pressure changes in the target via a transducer set. This additional level of sophistication may be hard to achieve on a homemade phantom. Cadaveric workshops are also becoming an integral component of regional anesthesia training.[6,7,40,42–46] However, given the problems with availability, it seems likely these will be replaced with other simulators or virtual reality devices.[48,51] Rational and ethical use of high-fidelity human cadavers dictates that participants should already have an understanding of the language associated with UGRA and have obtained the basic hand-eye coordination for manipulation of a transducer and needle. These skills can be cheaply and efficiently gained on low-fidelity phantoms.

Phantoms have also been proposed as a platform for the assessment of trainee competence. Minimum standards could be set, and these would need to be achieved before a trainee is allowed to progress to performing ultrasound-guided nerve blocks on patients.[4,7] In the evolving field of UGRA training, some form of in vitro competency testing seems inevitable on grounds of both patient safety and quality of care.

Technical Aspects of Needle Visualization in Phantoms

The choice of medium in which to view a needle is fundamental to obtaining an accurate assessment of its likely performance in clinical practice. Needle insertion angle is also critical. Both these facts are easily explained.

Needle visibility is determined by the difference between the background echogenicity of the phantom and the needle echogenicity (or can be similarly explained in terms of acoustic impedance).[52] Needle echogenicity is determined by the angle of insertion relative to the ultrasound beam, the quality of any echogenic needle technology used, and, to a lesser extent, needle gauge. We illustrated this point with the series of images seen earlier (Figs. 1 and 2). It is also worth noting that, in the less echogenic phantom material, needles often look artificially bright by the use of the autogain feature now available on many ultrasound machines. This is particularly true at steeper needle insertion angles, when needle imaging in a live patient would actually be far more challenging.[13] This effect is less pronounced in tissue phantoms where background echogenicity is closer to that seen in clinical practice because increased gain amplifies not only needle signal but also background. Live human tissue still presents the greatest challenge to needle visibility because of its high background echogenicity. Evaluation of new technology ideally should be in live humans to remove the subtle but important bias introduced by the use of phantoms and to ensure that the results are applicable to clinical practice.[13] However, it is often difficult to design an ethically appropriate way to evaluate needles on patients, and we suggest the most comparable research medium is the unembalmed cadaver.[14,15]

Most needles are easily visualized at angles less than 30 degrees to the skin (Fig. 1)[13–15,29,53–55]; hence, the visibility of new echogenic needles should be tested at insertion angles greater than 30 degrees.

CONCLUSIONS

Phantoms allow repeated practice of ultrasound-guided needle placement without risk to patients. The best option depends on what is required. Water-bath phantoms can be good during the development and investigation of new UGRA techniques, but cannot reproduce tissue properties. Nonmeat phantoms often have low background echogenicity, which enhances needle visibility. This is good when used for practicing needle placement but becomes a problem if these phantoms are used to evaluate needle technology. Meat-based phantoms provide more realistic tissue feedback, permit local anesthetic injection, 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. Cadavers provide a more realistic environment for UGRA practice, but availability is limited and can be expensive. Clinicians need a clear idea of what they require from a phantom before choosing which type to use and to understand that no current phantoms currently replicate clinical practice.

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