Techniques in Vascular and Interventional Radiology

Tools for Simulation; Low Budget and No Budget

Benjamin J. May, MD,* Joe K. Khoury, BS,† and Ronald S. Winokur, MD*

Interventional Radiology (IR) incorporates a unique set of technical skills such as ultrasound-guided needle placement, inferior vena cava filter placement, and wire/catheter exchange, which are not easily attained in other aspects of medical training. Simple, low cost models can allow medical students and residents to attain these skills in a low risk setting. These simulated tasks will ultimately combine to improve preparedness of trainees during patient procedures allowing them to advance more quickly through the training paradigm without patient risk. Many commercially available devices may be cost prohibitive, so low cost solutions are presented.
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Introduction

Procedural simulation allows trainees to gain familiarity with instrumentation, learn procedural steps, and build technical skills in a risk-free environment.[1] Simulation exercises are also an excellent means of engaging medical students interested in the field of Interventional Radiology (IR) and exposing them to the various techniques and procedures performed by interventional radiologists. While surgical and anesthesia simulators have been available for decades, IR-specific simulation is only recently being utilized at university hospitals and residency/training centers.[2] Various commercially available simulation devices are available but can be prohibitively expensive.[3] Animal models such as calves liver or chicken breast have been used as cheaper substitutes but introduce hygiene concerns, especially if in-situ simulation using typical tools of daily practice is used. This article describes easy to make, low-cost trainers for teaching ultrasound-guided vascular access, ultrasound-guided biopsy, inferior vena cava (IVC) filter deployment and retrieval, catheter exchange, and percutaneous nephrostomy access. Additionally, the basic building blocks described in making the phantoms can be combined in innovative ways to teach additional skills.

*Department of Radiology, Division of Interventional Radiology, Weill Cornell Medicine, New York, NY.
†NYIT College of Osteopathic Medicine, Serota Academic Center, Old Westbury, NY.
Address reprint requests to Benjamin J. May, Department of Radiology, Division of Interventional Radiology, Weill Cornell Medicine, 525 East 68th Street, New York, NY 10065. E-mail: Bjm9002@med.cornell.edu

Ballistics gel

Gelatin -based ballistics gel is an excellent simulator of soft tissue for US- guided procedures and can be easily made using basic ingredients (Fig. 1).[4] Powdered gelatin (Knox) is mixed with warm water in a 1:9 ratio of gelatin powder to water. The volume of solution will depend on the size and number of phantoms made. The gelatin should be added slowly with continuous stirring to avoid clumping.

Electric hand mixers are useful when making large volumes of solution. However, care must be taken not to introduce air bubbles which easily become suspended in the viscous solution and interfere with ultrasound imaging. To provide echotexture, Metamucil is added using one-fourth the volume of gelatin powder. Once the Metamucil and gelatin have been maximally mixed into solution, small bubbles, and residual clumps should be skimmed from the top. Several drops of cinnamon leaf oil can also be added to dissolve surface air bubbles. Dark food coloring can be added to the solution as well to make it more visually opaque masking the target suspended within. The solution can then be poured into the appropriate mold or container depending on the phantom being created.

Ultrasound- guided vascular access

Using the previously created ballistics gel as described above, a penrose drain can be used to simulate the internal jugular or femoral vein (Fig. 2). The penrose drain allows for compressibility and has similar tactile feel as puncturing an

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Figure 1 This photo displays the core ingredients used to make ballistics gel for several of the displayed simulation phantoms (powdered "Knox" gelatin, cinnamon leaf oil and "Metamucil" fiber).

Figure 2 Materials for US-guided vascular access simulation. The penrose drain, filled with colored water, and tied at both ends. The basin is then filled with ballistics gel.

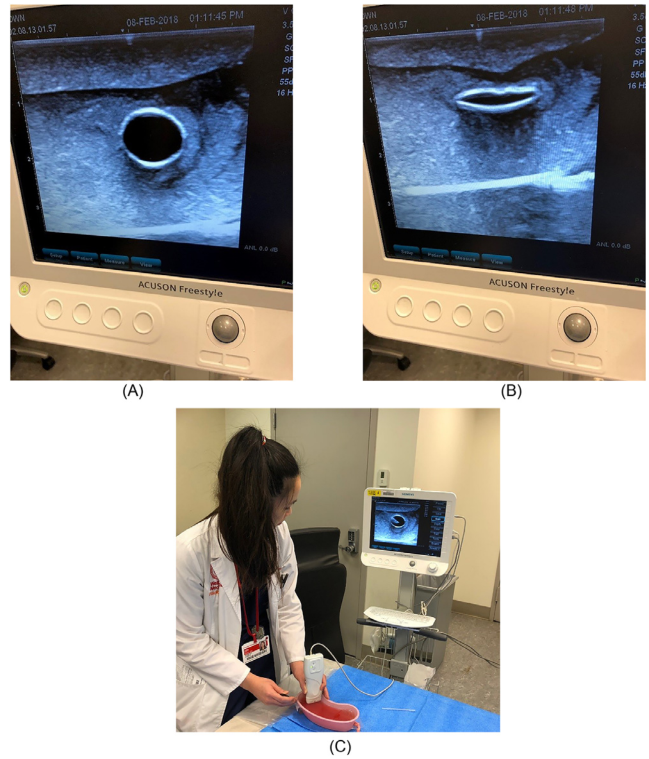


Figure 3 Vascular phantom without (A) and with compression (B), mimicking a compressible vein such as the femoral or jugular vein. Note the echotexture from the Metamucil. (C) Shows the phantom in use with successful needle access.

in-vivo vascular structure (Fig. 3). An emesis basin is a convenient container to use for this project though deeper plastic containers can be used to simulate femoral vein puncture in larger patients. One end of the penrose drain is tied in a knot and the drain is then filled with water. Red food coloring can be added to make the simulated blood more realistic. The opposite end of the tubing is then knotted at a length to match the base of the container. Care should be taken to exclude air bubbles from the solution. The excess tubing is cut and the water filled component is taped to the base of the basin with strong cloth tape or duct tape. The basin is then filled with the ballistics gel solution and placed overnight in a refrigerator to form a gel. The finished product can be punctured repeatedly with a micropuncture needle and allows for passage of a wire. Dilation and completion of central access with a vascular sheath is discouraged as it will damage the model.

Ultrasound-guided nephrostomy

Detailed instructions for building this phantom have been previously described.[5] In short, a surgical glove is used to simulate the hydronephrotic collecting system. The fingers of the glove are knotted a few centimeters from the base to represent blunted calyces. The glove is then filled with water which can be mixed with yellow food coloring to represent urine. The base of the glove is then knotted with care to exclude air bubbles. Alternatively, IV extension tubing can be inserted into the glove from the base, which is cinched with a rubber band. This will allow for the degree of hydronephrosis to be altered or for the glove to be aspirated with a needle and refilled. The base of the glove is then taped to the bottom of a suction canister or similarly sized plastic container. Two tongue depressors are snapped to length and taped in parallel a centimeter below the surface of the container to simulate overlying ribs (Fig. 4). The container is then filled with gelatin solution and allowed to set overnight. Users must orient the probe appropriately to find an intercostal window (Fig. 4c). The phantom allows for simulation of calyceal puncture and wire placement. Dilation and insertion of a nephrostomy tube should be avoided as it will damage the phantom.

Ultrasound-guided biopsy

This commonly used phantom can be created by embedding pimento stuffed olives within ballistics gel to simulate a lesion for biopsy. A large patient basin provides good depth of tissue. The olives must be suspended in place otherwise they will migrate toward the sides of the basin while the gelatin is still aqueous. To suspend the olives, long 21 gauge needles are passed through a piece of cardboard and then through olives (Fig. 5). The basin is filled with gelatin solution and then the olives are lowered into the solution with

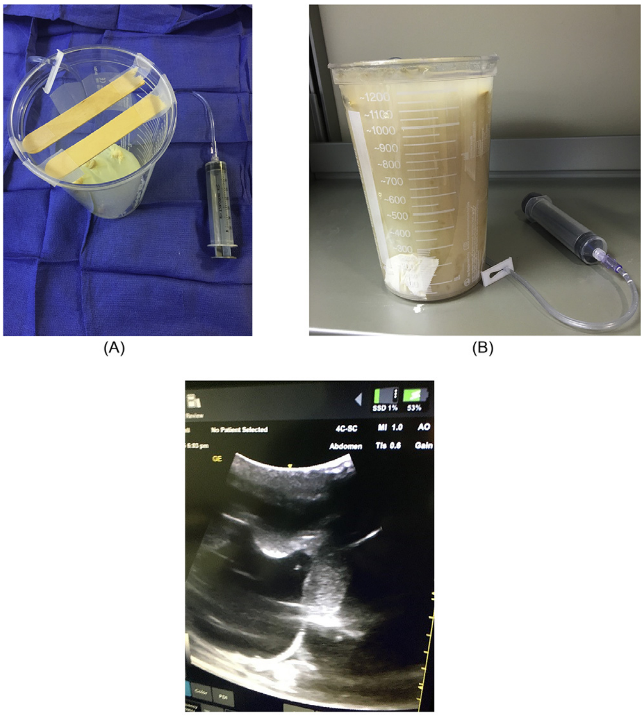


Figure 4 Materials used to make the nephrostomy phantom. (A) Parallel tongue depressors used to simulate overlying ribs. (B) Completed phantom with opaque gelatin based ballistics gel. (C) Ultrasound image showing intercostal window with access needle successfully within a target calyx.

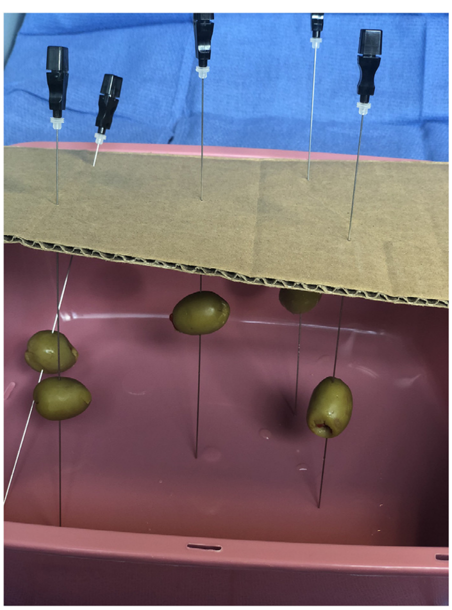


Figure 5 Set-up for the ultrasound-guided biopsy phantom, consisting of pimento stuffed olives suspended by 21G needles before allowing the ballistic gel to solidify.

the cardboard resting on top of the basin. The basin is then placed in a refrigerator to cool overnight. If the basin is treated beforehand with nonstick cooking spray, the mold can be freed from the basin after setting allowing biopsy to be attempted from different angles.

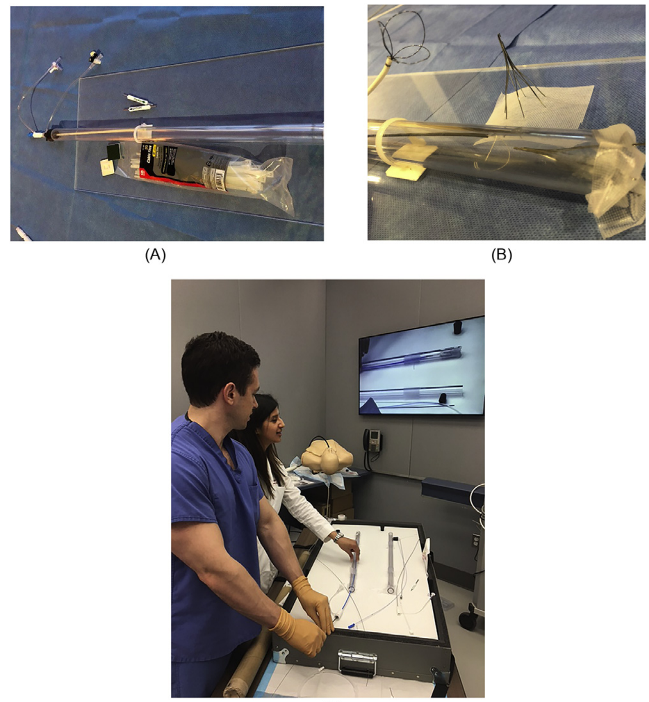


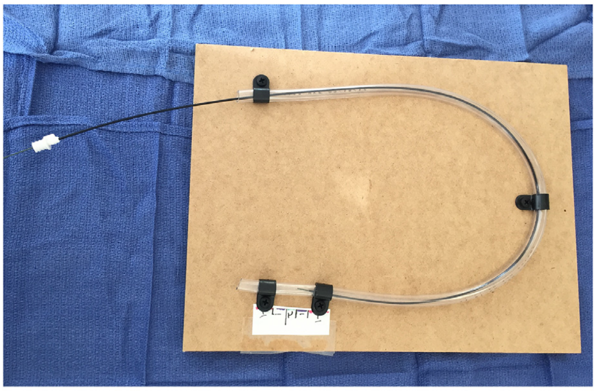
Figure 6 (A) Demonstrates materials required to assemble the phantom. (B) Shows the set up for filter retrieval. Note that the legs of the filter have pierced the plastic tape requiring appropriate force to free them for retrieval. (C) Demonstrate the use of a web cam to simulate fluoroscopy.

Trainees can use linear (9 MHz or 15 MHz) transducers for more superficial olives simulating an inguinal or cervical lymph node. Deeper olives can be targeted with a curved transducer (5-6 MHz) simulating a deeper structure such as a liver lesion. The pimento olives can be targeted with both fine needle aspiration and core biopsy systems, providing visual green and red core material when the core biopsy is successfully passed through the center of the target.

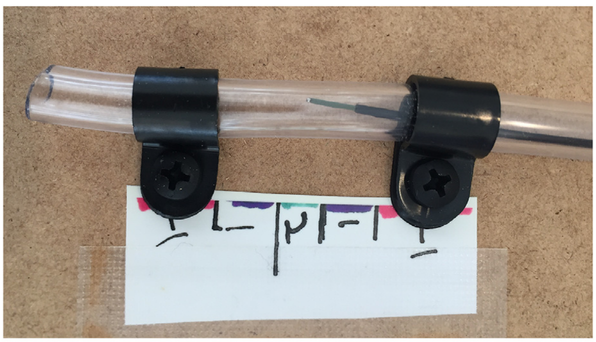
IVC filter deployment and retrieval

Polycarbonate tubing (1 inch diameter, 3 foot length) is a good model for the IVC and can be affixed to a wood or plexiglass board using cable ties and adhesive cable tie mounts (Fig. 6). Plastic tape or a rubber cork with a center hole can be used to support the delivery sheath. Trainees can begin by advancing the delivery sheath over a wire while providing appropriate wire tension to avoid advancing or retracting the wire. Familiarity and practice assembling the various types of filter delivery systems can then be performed. Ultimately, trainees can practice the pin/unsheath technique used to deploy most filters. Care should be taken for the IVC filter to be deployed in the desired location without translation. An overhead webcam can be used to simulate fluoroscopy and the important skill of looking at a monitor rather than down at the tubing or hands (Fig. 6c).

Filter retrieval is also common practice and can be simulated using the same device. The legs of the filter can be embedded into plastic tape at the end of the polycarbonate tubing to



(A)



(B)

Figure 7 (A) Materials used to create the catheter exchange phantom. Three-fourth inch clear vinyl tubing adhered to a medium-density fiberboard (MDF). (B) Scoring system created for the phantom, ranging from −1 (red) to +2 (green). (Color version of figure is available online.)

provide resistance to filter removal (Fig. 6b). A standard IVC filter retrieval set and snare can be inserted to capture the hook and sheath the IVC filter in typical fashion. Use of overhead webcams is again useful in this scenario to simulate the challenge of a 2-dimensional view and difficulty capturing the filter hook, especially if tilted against the vessel wall.

Catheter exchange

Polycarbonate tubing (3/4 inch) is fixed to a medium-density fiberboard using cable clamp fasteners (Fig. 7a). A 5 French catheter and 0.035 inch guidewire can be inserted at one end of the tubing and advanced centrally between the cable clamp fasteners at the distal end of the simulator. Catheter exchange can be performed by pinning the guidewire and removing the catheter. The participant can test their skill by attempting to keep the guidewire still and not allowing it to move beyond the cable clamp fasteners. Trainees can quantify their competency at this technique by using the scoring system mounted on the board, where the tip of the guidewire lies (Fig. 7b). The goal is to remove the catheter while keeping the guidewire within the area designated as "2, resulting in a 2-point score. If the tip of the guidewire slides away from the 2″" in either direction, the score will be lower, according to how much the guidewire tip strayed from the center (ranging from −1 to +1). This technique can be practiced 2-handed or 1-handed and using both dominant and nondominant hands.

Discussion

These low cost and easy to make simulation phantoms are ideal for departments whose budget may not support more expensive commercial phantoms or for smaller entities such as medical student IR interest groups. The incorporation of donated or discarded hospital supplies results in extremely low costs in many cases. The nephrostomy phantom, for instance, can be made for approximately five dollars per unit. We have also found that medical students are eager to build the phantoms and the process adds to their engagement in simulation. Given the availability and affordability of the materials used for these phantoms, there is no doubt countless additional phantoms that can be created to help train the IRs of the future.

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