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# Techniques and Procedures



## COST-EFFECTIVE, REUSABLE, LEAK-RESISTANT ULTRASOUND-GUIDED VASCULAR ACCESS TRAINER

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**Abstract—Background:** Ultrasound guidance for insertion of a peripheral venous catheter is becoming common practice in many emergency departments in the difficult-to-access patient, and simulation has become an important tool for health care practitioners to learn this technique. Commercial trainers are expensive, and low-cost alternatives described to date provide a sub-optimal training experience. We introduce ballistics gel as a new material for the creation of simulating phantoms. **Materials and Methods:** Directions describe construction of a simulating phantom composed of 10% ballistic gelatin and commonly available latex tubing. The model's success as used by one residency training program and medical school is described. **Results:** Cost per phantom was \$22.83, with less than an hour preparation time per phantom. We found these phantoms to offer a comparable user experience to commercially available products and better than other homemade products. **Discussion:** Ballistics gel is a novel material for production of simulation phantoms that provides a low-cost, realistic simulation experience. The clear gel material works well for novice learners, and opacifying agents can be added to increase difficulty for more advanced learners. The material offers flexibility in design to make models for a broad range of skill instruction. **Conclusion:** A relatively quick and easy process using ballistics gel allowed us to create a simulation experience similar to commercially available trainers at a fraction of the cost. © 2015 Elsevier Inc.

**Keywords—**ultrasound; medical education; ultrasound simulation; peripheral vascular access

## INTRODUCTION

Ultrasound guidance for insertion of a peripheral venous catheter is becoming common practice in many emergency departments (EDs) in the difficult-to-access patient. Ultrasound-guided peripheral venous cannulation is now a mandatory skill for Emergency Medicine Residents (1). Simulation has become an important tool for health care practitioners to learn this technique, allowing the learner to perform the procedure in an ideal setting, to recreate mistakes in a safe environment, and to troubleshoot the procedure prior to attempts in living patients.

Procedural simulation for venous cannulation requires a model providing the learner with a realistic tactile, haptic, visual, and cognitive experience. Commercial trainers are available, but cost between \$400 and \$549 (Blue Phantom Corporation, Redmond, WA/Universal Medical, Inc. Norwood, MA). The relatively high cost has led multiple authors to describe low-cost tissue-simulating phantoms using Metamucil, gelatin, chicken breast, or bologna to achieve realistic tactile and sonographic characteristics (2–5). However, all require refrigeration, some can pose risk of transmission of pathogens such as *Salmonella* and *Campylobacter* without proper handling, and all have limited capacity for reuse. Gelatin models have become the most popular of these methods, but melt rapidly when used at room temperature, can leak with successful puncture,

and fall apart with multiple uses. We introduce ballistics gel as a new material for the creation of simulating phantoms. With ballistics gel, there is no risk of transmission of pathogens such as when using raw meats. In contrast to Metamucil or gelatin, ballistics gel retains all its simulation properties without leaking or falling apart, even during extended training sessions, in which it is exposed to warmer temperatures and is used continuously and repeatedly.

## MATERIALS AND METHODS

### Required Materials

- 10% ballistic gelatin (Clear Ballistics, LLC, Fort Smith, AR), a 100% synthetic material, nontoxic, odorless, clear material
  - Size: 9 inches long, 4 inches width, and 4 inches high
  - Weight: 4.5 lbs (2.04 kg) volume: 144 cubic inches (2359 mL)/2.5 US quarts
  - \$36.66
- Heating equipment
  - 3-quart (2800 mL) sauce pan or pot with lid
  - 13 × 9 × 2<sup>1</sup>/<sub>4</sub> -inch cake/cookie pan
  - Heating element (stove range, Waring SB30 1300-Watt Portable Single Burner Range)
    - Alternative heating element via oven safe container set at 93.3°C (200°F)
  - Culinary temperature gauge
  - Personal protective equipment (gloves, apron, eye protection)
- 60-mL catheter tip syringe
- Hemostat
- Packing tape
- Latex tubing. Sizes range from internal diameter of 8 mm–1.5 mm. Multiple sizes available ([Latex-tubing.com](http://Latex-tubing.com)). Prices range from 0.75–0.89\$ per foot of material and are cheaper if bought by the reel of 50 ft (\$25 dollars/50 ft or 0.50\$ per foot.)

### Construction Process

#### Step 1: 13 × 9-inch pan and vessel lane setup

Taking approximately 12 inches (30.4 cm) of your latex rubber tubing, tie off one end completely with a knot ([Figure 1](#)).

Tape each vessel's knotted terminus with packing tape to the bottom of the pan at one end. Apply slight tension and tape the open end of the tubing to the opposite end of the pan with the opening projecting from the pan ([Figure 2](#)).



**Figure 1.** Twelve inches of rubber tubing tied at one end.

The finished product can contain 4–5 lanes of vessels, each of which can be divided for individual stations once the project is completed.

Additional latex tube segments can be placed in each lane to simulate adjacent veins or arteries.

#### Step 2: Gel melting, layer 1

Carefully read your manufacturer's product information prior to proceeding. Clear Ballistics, LLC recommends performing this melting process in a well-ventilated space, as exceeding recommended temperatures will cause boiling and release of vapors. Refer to the material safety data sheet (MSDS) of your product for specific safety recommendations.

Manufacturers' recommendations may vary; 10% ballistic gel has a melting point of around 93.3°C (200°F). Clear Ballistics recommends using a slow cooker and monitoring the temperature. In our process, using a Waring SB30 1300-watt portable single-burner range (Conair Corporation, Stamford, CT) on "low" setting, the gel melted completely within 20 min at a temperature of around 93.3°C (200°F) using a standard culinary temperature gauge. Break the gel into pieces ([Figure 3](#)) to speed the melting process.

Fill a 3-quart pot up to about 2/3 with broken gel pieces and cook on low, covered, until gel is completely melted and in liquid form. Pour the liquid gel into the baking pan with the latex vessel lanes. Be careful, as the material is very hot when it is being poured, and



**Figure 2.** 13 × 9-inch baking pan with the tied tubing taped to the base and the open end taped to the upper rim.



**Figure 3.** Ballistic gel inside 3-quart pot in small divided pieces to increase melting speed.

standard safety precautions for handling of thermally active elements should be used (gloves, apron, and eye protection).

Given the high temperature, some tape may come loose and the tubing may float to the top of the gel. This is normal and does not require intervention (Figure 4).

Note that air bubbles may be present in the model at this point, but as the product cools, it releases those bubbles. Some bubbles will remain in the finished model, but do not pose substantial sonographic artifact.

Allow about 30 to 40 min of cooling time for the first layer to solidify prior to proceeding to Step 3.

**Step 3: Gel melting, layer 2**

Fill approximately half the volume of the 3-quart pot with broken gel pieces and repeat the melting process.

Pour the liquid gelatin on top of the cooled solid gelatin in the baking pan.

This will add 0.5–1 inches (1.3–2.6 cm) in depth on top of the tube material.

**Step 4: Preparing your phantom for use**

Once both gel layers have cooled and are no longer easily deformed under gentle finger pressure, remove the mold from the pan (Figure 5).

Using water (with optional red food coloring), add approximately 30 mL of solution to a 60-mL catheter tip syringe. Attach the syringe to the open end of each latex tube segment, which should be protruding from the phantom. Aspirate with the syringe until you observe some collapse of the latex tubing and air bubbling through the solution. Release the syringe plunger to allow the vacuum you created to pull the solution into the tubing/vessels. You can leave the syringe attached to simulate arterial flow, as described below, or remove the syringe and clamp the free end with a hemostat to keep the fluid stationary in the tubing (behaving more like a vein). A hemostat or other removable device allows you to refill the tubing later, if needed.

**Step 5: Use of the model for vascular access**

To simulate an artery: Refill the syringe with fluid, being careful to remove air from the syringe. Air injected into the tubing will create a sonographic artifact, which can easily be remedied by re-aspirating the model as in Step 4. To simulate a pulsatile artery, attach the syringe to the open end of a latex tube and perform cyclic compressions of the syringe plunger.

You are ready to begin the simulation. Identify your vessels (tubing) with ultrasound and perform your ultrasound-guided procedures as you would normally instruct.



**Figure 4.** (A) A completely melted ballistic gel appearance. (B) First layer applied to pan with tubing in place.



**Figure 5.** Removed finished product after both layers have cooled.

Puncturing the vessels will not cause loss of fluids to the environment unless the vessels are pressurized by the catheter tip syringe.

Repeated needle punctures will leave a small volume of air in the fluid medium within the vessels. To correct any air defects in the tubing, simply angle the phantom with the syringe attached, aspirate the vessel lumen, and allow it to refill with the solution.

Re-use: The entire phantom can be recycled to raw materials by breaking the model into small pieces, removing tubing and debris, and reapplying the heating element. The material can be remolded multiple times.

## RESULTS

With each phantom composed of 2.25 lbs of ballistic gel and six lanes of 1-ft tubing sections, the cost per phantom came to \$22.83, with less than an hour preparation time per phantom. We found these phantoms to offer a

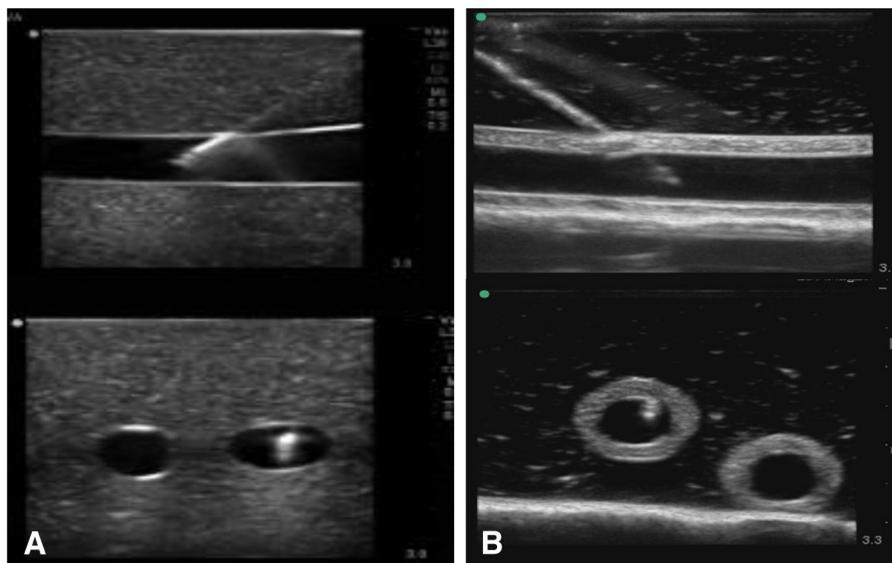
comparable user experience to commercially available products (see [Figure 6](#) and [Videos 1 and 2](#) for side-by-side comparisons). In contrast to other homemade products, our model did not leak with repeated catheter insertions (>100 punctures), retained its shape well through multiple uses, and did not require any special storage or handling conditions.

## DISCUSSION

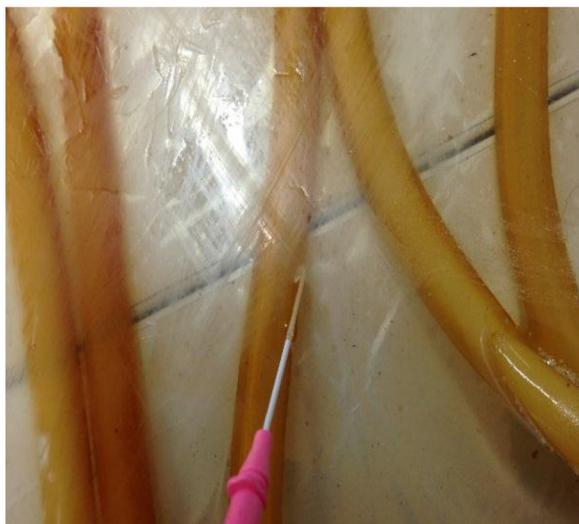
At our institution, ultrasound-guided peripheral venous catheterization is an optional instructional course for our nurse providers and a mandatory skill for our residents. With a multitude of learners in our ED, availability of multiple realistic and inexpensive models is of great value. We found commercial products to be too expensive to provide an adequate number to have available to our number of learners. In pursuing homemade models, currently available recipes using gelatin or other materials had disadvantages (melting, falling apart, requiring refrigeration), preventing us from using them as a viable alternative. Ballistics gel is a novel material for production of simulation phantoms that provides a low-cost, high-yield simulation experience.

### *Clear vs. Opaque Models*

The clear gel material allowed learners to compare the ultrasound image with the physical location of the catheter, a potential educational advantage ([Figure 7](#)). We noted some learners who had not previously performed any ultrasound-guided procedures were able to reorient when they had lost the catheter by looking down through



**Figure 6.** (A) Commercially available ultrasound phantom. (B) Ballistic gel vascular phantom.



**Figure 7. Visualization of side-wall cannulation.**

the model to see the physical location of the catheter. Opacifying agents or phantom coverings could be added to make the cannulation more difficult and realistic for more advanced learners (6).

#### *Flexibility in Design*

The model we describe can be altered to create more complex scenarios, such as thrombosis or branching vessels, foreign bodies or abscess, and vascular dissections. The gel material can be used to construct other ultrasound-compatible anatomic models for both diagnosis and procedures. Future studies of this model could include comparisons of learner perceptions/satisfaction and attainment of competency using this and other models or real patients.

#### *Limitations*

A homemade product requires a time investment greater than that of commercially available products. The time for construction of our models was similar to preparation times for other currently described materials and models.

In contrast to some homemade simulators such as meat, our product requires a heating element that does introduce the risk of burns, mitigated with reasonable caution and equipment. Gelatin molds also require heating for their construction, but do not require a

well-ventilated area as recommended by the ballistics gel MSDS. The ballistics gel does cost more than the gelatin, but cost per use is decreased by reusing the same gel over and over again.

Each needle approach through the gel will leave a small artifact visible on ultrasound. This does not occur with commercially available products, but does occur with other homemade products. With ballistics gel, these small defects can be repaired by applying heat to the surface of the phantom using a hair dryer on “high” for 30–60 s and allowing 5 min for cooling.

## CONCLUSION

A relatively quick and easy process using ballistics gel allowed us to create a simulation experience similar to commercially available trainers at a fraction of the cost. The product does not break down, melt, or otherwise get degraded by the environment and withstands heavy, repetitive use. With this unique material we have been able to effectively teach more learners the process of ultrasound-guided vascular access at a much more reasonable price.

## SUPPLEMENTARY DATA

Supplementary data related to this article can be found at <http://dx.doi.org/10.1016/j.jemermed.2015.04.005>.

## REFERENCES

1. Accreditation Council for Graduate Medical Education (ACGME). 2013 EM-RRC Requirements, Milestone #14, level 3. ACGME Program and Institutional Accreditation Hospital-Based Specialties Emergency Medicine. American Board of Emergency Medicine, 2012. Available at: [http://www.acgme.org/acgmeweb/portals/0/pfassets/2013-pr-faq-pif/110\\_emergency\\_medicine\\_07012013.pdf](http://www.acgme.org/acgmeweb/portals/0/pfassets/2013-pr-faq-pif/110_emergency_medicine_07012013.pdf). Accessed August 30, 2014.
2. Bude RO, Adler RS. An easily made, low-cost, tissue-like ultrasound phantom material. *J Clin Ultrasound* 1995;23:271–3.
3. Kendall JL, Farragher JP. Ultrasound-guided central venous access: a homemade phantom for simulation. *CJEM* 2007;9:371–3.
4. Ultrasound Village. Vascular access training phantom: the ultimate recipe (2009). Dr. James Rippey. Available at: <http://www.ultrasoundvillage.com/educationresources/modules/lectures/?lecture=14>. Accessed August 20, 2014.
5. Wells M, Goldstein L. The polony phantom: a cost-effective aid for teaching emergency ultrasound procedures. *Int J Emerg Med* 2010;3:115–8.
6. Clear Ballistics. Clear ballistics: synthetic ballistic gelatin. Available at: <https://store.clearballistics.com/>. Accessed August 20, 2014.