A Cost-effective, Gelatin-Based Phantom Model for Learning Ultrasound-Guided Fine-Needle Aspiration Procedures of the Head and Neck

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The rise in popularity of ultrasound imaging has seen a corresponding increase in demand for effective training tools such as phantom models. They are especially useful for teaching and practice of invasive procedures, such as fine-needle aspiration of lesions of the head and neck. We have created 2 gelatin models out of inexpensive, commonly available materials that can be used in sequence to learn head and neck fine-needle aspiration. Fundamental skills can be learned first on the flat, rectangular model, whereas the second, cylindrical model more closely represents human anatomy and can be used to develop more advanced technique.

Key Words—fine-needle aspiration; gelatin model; head and neck ultrasound; phantom mode

With the rise in popularity of ultrasound imaging, the demand for effective training tools has exponentially increased. Ultrasound models, or phantoms, are widely popular for facilitating the learning of hand-eye coordination needed for ultrasound imaging and ultrasound-guided procedures. Unfortunately, many available ultrasound models are expensive and have limited life spans.[1] Gelatin is frequently used to create phantoms because of its ease of use and low cost, and gelatin models have been used in fields such as anesthesiology, pain management, general surgery, and medicine.[2–17]

For the otolaryngologist, as well as other providers treating head and neck disorders, ultrasound in an invaluable tool for visualizing head and neck structures. It provides an inexpensive, radiation-free way to visualize the airway, identify tumors, assess thyroid nodules, and guide fine-needle aspiration of the salivary glands, lymph nodes, and thyroid.[14,18–20] However, similar to other fields of medicine in which ultrasound is used, training tools for head and neck procedures can be expensive and difficult to acquire. With this factor in mind, we developed 2 simple gelatin-based phantom models that can be used for instruction on fine-needle aspiration technique for the head and neck.

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Materials and Methods

The first model was prepared by using items available for purchase at any general grocery store. Materials included a 2-L microwave-safe plastic container, Knox gelatin (Kraft Foods, Northfield, IL), psyllium husk fiber powder, green olives, blueberries, and food coloring. Two separate gelatin layers were created to simulate different degrees of tissue echogenicity. The first, lower layer was made by using a ratio of 2 cups of boiling water to 4 tablespoons of psyllium to 42 g (6 packets) of gelatin to 20 drops of food coloring. The solution was stirred thoroughly until all particles were dissolved and was then poured into the plastic container. Any lumps or bubbles were removed to create a smooth surface. Olives and blueberries were placed at evenly spaced intervals through this layer, and it was placed in a refrigerator at 35°F to set for 2 hours (Figure 1A). A second solution was prepared by using a ratio of 4 cups of boiling water to 4 of tablespoons psyllium to 84 g (12 packets) of gelatin to 40 drops of food coloring. The solution was mixed well, allowed to cool for 15 minutes, and poured into the plastic container on top of the first layer (Figure 1B). The entire model was refrigerated at 35°F overnight to set, and any raised plastic edges were trimmed away to create the final model (Figure 1C).

The second model was prepared by using the same commonly available items as the first model, with the addition of a pig laryngotracheal complex obtained from an online supplier (Nebraska Scientific, Omaha, NE). Additionally, a cylindrical 2-liter container was used for this model to simulate the anatomic shape of a human neck. The pig laryngotracheal complex was prepared by inserting an inflated oblong balloon into the lumen to maintain airway patency (Figure 2A). Olives and blueberries were then sutured to it to simulate nodules (Figure 2B), and the entire complex was secured in the center of the 2-L container. A solution of 6 cups of boiling water to 6 tablespoons of psyllium to 126 g (18 packets) of gelatin to 60 drops of food coloring was mixed and added to the vessel (Figure 2C). The model was set in the refrigerator overnight at 35°F, removed from the plastic container, and wrapped in clear plastic wrap to crate the final model (Figure 2D). Before use, the balloon was removed from the center of the laryngotracheal complex.

Materials used to practice fine-needle aspiration technique on the models included a Sparq diagnostic ultrasound system (Philips Healthcare, Bothell, WA), a 12.4-MHz linear probe, and 22-gauge, 1.5-in needles attached to 10-mL syringes.

Results

Both gelatin phantom models were successfully used to obtain images and practice fine-needle aspiration technique. Images of the flat, rectangular model depicting an olive "nodule" as well as needle visualization during a nodule biopsy are depicted in Figure 1, D and E. Transverse views of the cylindrical model complete with tracheal rings, thyroid tissue, and a blueberry nodule are depicted in Figure 2, E and F. The cost of all necessary materials for creation of both models was less than $40.

Discussion

These gelatin phantoms provide low-cost, easily constructed models for instruction and practice of ultrasound-guided head and neck interventions. In recent years, ultrasound has experienced exponential growth in clinical indications and applications. What was once a modality used mainly by radiologists has evolved into a widely used, accurate, and portable point-of-care imaging tool. Introducing ultrasound into medical training at the resident or even the medical student level improves understanding of anatomy, augments physical diagnostic skills, and facilitates learning of interventional techniques.[21–23]

Within the field of otolaryngology in particular, ultrasound skills are rapidly becoming invaluable. Not only is ultrasound useful for visualizing the complicated anatomy of the head and neck, but it has also become incredibly useful for diagnosis of conditions including lymphadenopathy, cysts, lipomas, carotid body tumors, thyroid malignancy, salivary gland stones and tumors, and tumors of the oral cavity and airway.[24–26] In the diagnosis of these conditions, ultrasound-guided fine-needle aspiration is superior in accuracy, cost-effectiveness, and diagnostic value compared to palpation alone and is now considered the reference standard for evaluating conditions such as thyroid nodules.[27–31] Despite its unquestionable utility, it can be difficult for physicians to gain competence because of a lack of universal training, and many complete their otolaryngology residencies without learning basic ultrasound skills.[32]

As it is generally no longer considered ethical to use live patients for initial instruction,[1] ultrasound training devices are becoming more widely used. Unfortunately, many available instructional models are expensive and impractical for routine use.[1,14] Low-cost gelatin phantoms provide a convenient way to practice invasive procedures before performing them on live patients, and we have developed 2 examples of these easily made models that can be used to teach head and neck fine-needle aspiration.

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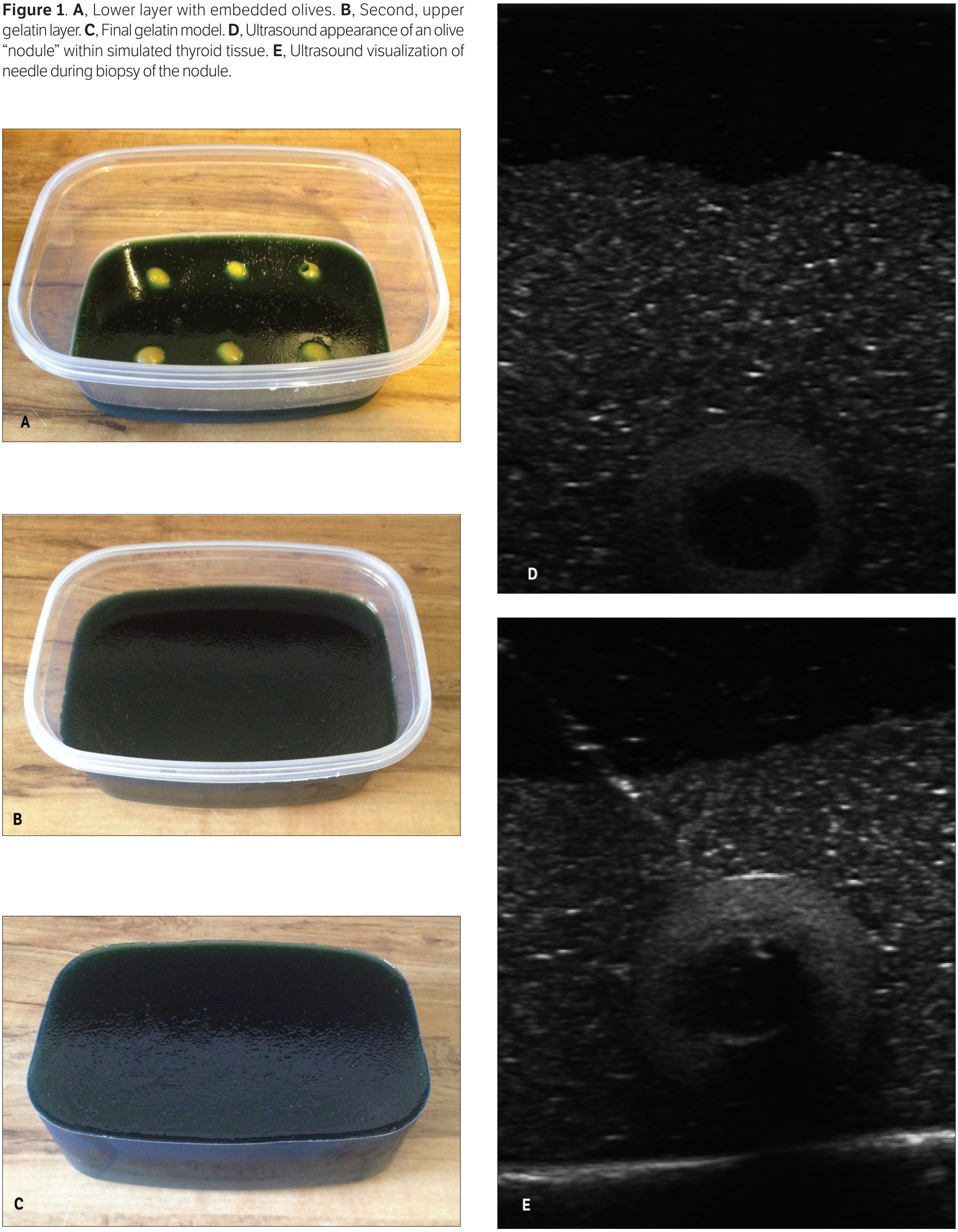
Figure 1. **A**, Lower layer with embedded olives. **B**, Second, upper gelatin layer. **C**, Final gelatin model. **D**, Ultrasound appearance of an olive "nodule" within simulated thyroid tissue. **E**, Ultrasound visualization of needle during biopsy of the nodule.

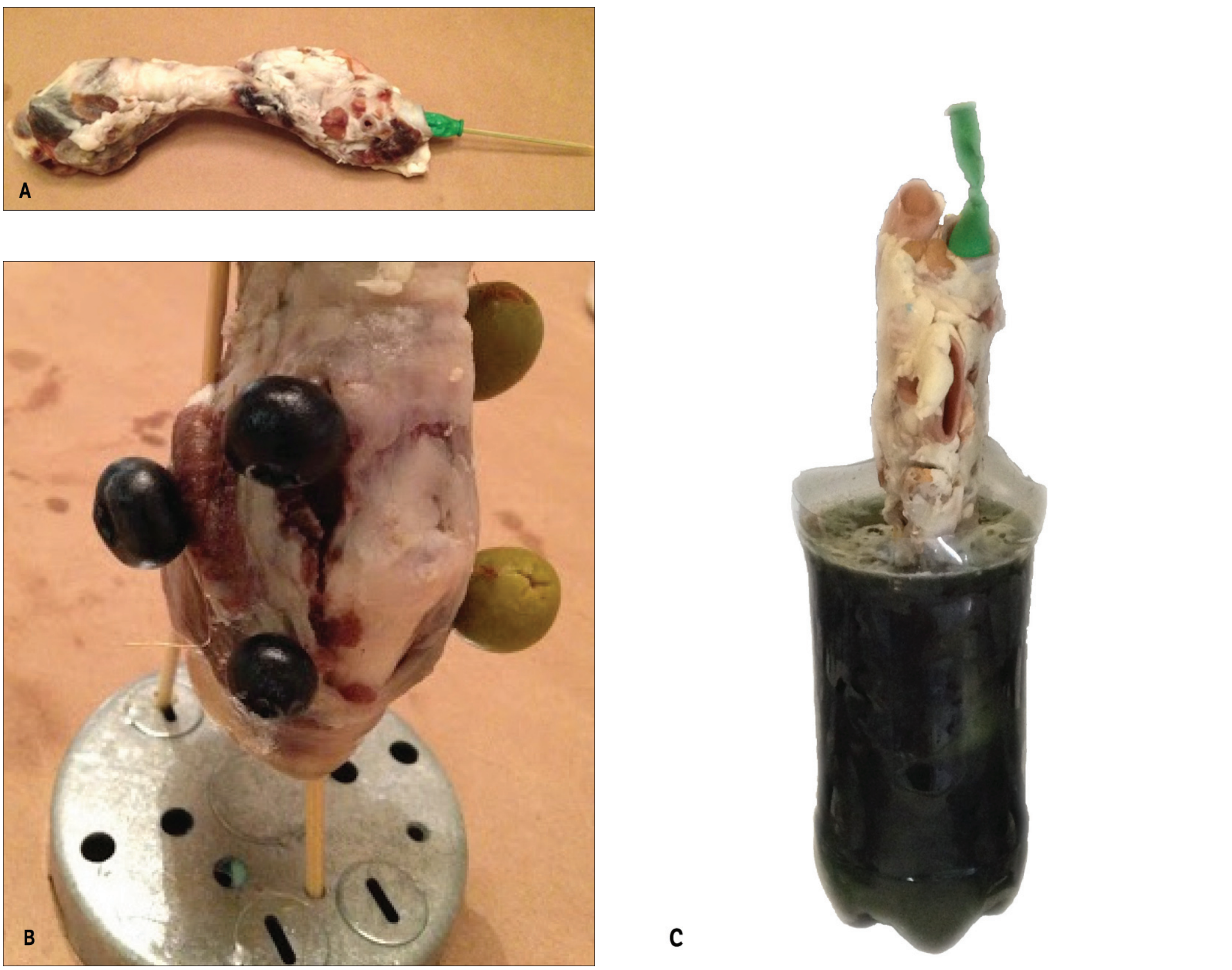


Our phantoms have several advantages over other simple gelatin models. In the basic, flat phantom (Figure 1, A–C), different concentrations of psyllium husk powder are used to create different degrees of echogenicity within a single model. The denser, lower layer containing the embedded olives resembles the appearance of thyroid tissue, whereas the upper layer represents soft tissue. These varying layers of echogenicity are similar to the appearance of the corresponding tissues in live patients. If psyllium husk powder is unavailable, Metamucil (Procter & Gamble, Cincinnati, OH) or generic fiber supplement powder containing psyllium husk may be used interchangeably with equivalent results. The use of other materials such as cornstarch and graphite powder to change gelatin echogenicity has also been described in the literature.[1,33] Psyllium husk powder was selected for our model because of its commercial availability and solubility within the gelatin mixture.

Another benefit is the addition of blueberries to our models. In the past, items such as olives, hot dog pieces, synthetic beads, balloons, and foam have been used to simulate soft tissue masses.[1] Fresh blueberries provide an advantage over these items in that juice from them can be aspirated during fine-needle aspiration to confirm needle placement (Figure 3).

Additionally, our models provide a stepwise approach to learning ultrasound technique that may not be achieved from one model alone. Fundamental skills such as probe positioning, image adjustment, and needle placement can be learned first on the flat, rectangular model. After sufficient mastery of basic technique and hand-eye coordination on the

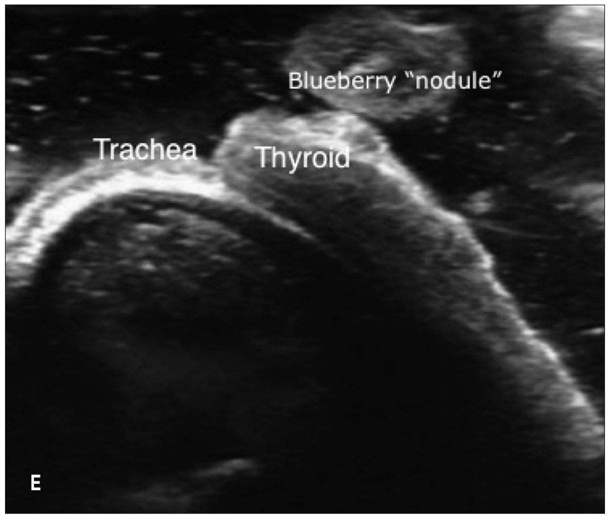
Figure 2. **A**, Pig laryngotracheal complex with balloon in the lumen. **B**, Blueberry and olive nodules sutured to the laryngotracheal complex. **C**, Pig laryngotracheal complex ready for refrigeration in the cylindrical gelatin mold. (continued)

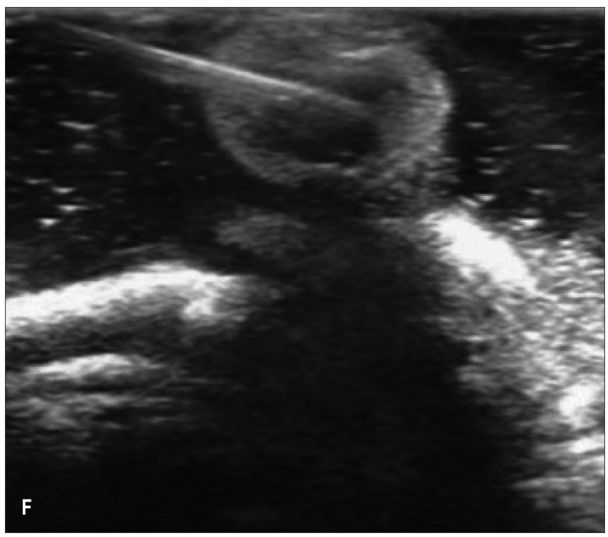


first model, the second, cylindrical model can be used to develop more advanced skills. Its shape and incorporation of the pig laryngotracheal complex provide a phantom that realistically simulates human neck anatomy and bridges the gap between initial learning and clinical application on live patients.

Although our gelatin models provide many advantages in instruction on head and neck ultrasound imaging, they are not without limitations. While gelatin may be mixed to simulate the appearance of anatomic structures, it lacks realistic tissue consistency. Passing a needle through real skin and soft tissue may require more pressure than is needed for the gel. There is also no way to practice tactile localization, which is routinely used as an adjunct to ultrasound in clinical situations, as simulated masses cannot be palpated through the gelatin. It is important that users appreciate these differences before attempting fine-needle aspiration in a clinical scenario. Additionally, as the models are used multiple times, needle track marks become visible and disrupt the ultrasound image. The literature has described gelatin models that can be microwaved to remove these tracks,[2,11,13] and such a technique was attempted in our models with success. We recommend microwaving the models at 10-second intervals until track marks disappear and then resolidifying in a refrigerator before use. Excessive microwaving will cause destabilization of olives and other embedded objects. Finally, our phantoms have a limited shelf life, as the gelatin, fruit, and pig laryngotracheal complex naturally decompose and provide growth media for bacteria. If stored in a refrigerator, models can be preserved and used for up to 2 weeks.

Figure 2. (continued) **D**, Final cylindrical gelatin model. **E**, Ultrasound appearance of the pig laryngotracheal complex with a blueberry nodule. **F**, Ultrasound appearance of the needle completing a biopsy of the blueberry nodule.





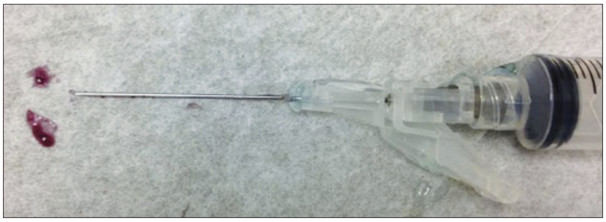


Figure 3. Juice aspirated from the simulated blueberry nodule.

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