A Low-Cost Ultrasound Phantom of the Lumbosacral Spine

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Background and Objectives: This report describes the production of a low-cost ultrasound phantom of the lumbosacral spine. The phantom should be a very useful tool to teach the basic skills for ultrasound-guided procedures of the lumbosacral spine.

Methods: A lumbosacral spine model is secured to the bottom of a microwave-safe container and is immersed in a concentrated gelatin solution. After the gelatin hardens, the model can be used for scanning practice as well as needle placement. The phantom can be recovered after use by melting the gelatin in a microwave to "erase" any needle track marks.

Results: A transparent and durable gelatin block is produced. This allows trainees to have direct visual access to the lumbosacral spine model to correlate with the ultrasound images as well as to confirm proper needle placement. Disadvantages of the model include lack of simulated soft tissue structures and an absence of simulated haptic feedback during needle placement. Metamucil can be added to the gelatin to simulate the appearance of soft tissue, although this increases the opacity and thus decreases the visual access of the gelatin.

Conclusions: This teaching tool can provide trainees with an opportunity to familiarize themselves with sonoanatomy of the lumbosacral spine in addition to practicing probe handling techniques and needle placement.

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The use of simulator-based training has drawn considerable interest in developing skills required to perform medical procedures. Ultrasound-guided interventions with needles lend themselves well to simulator-based training with the use of gel phantoms, which have been validated as an effective teaching tool.[1–5] These tools assist in teaching ultrasound-guided techniques and fulfill 3 basic training requirements: (1) pattern recognition, (2) probe handling and scanning skills, and (3) manual dexterity to align the needle to the ultrasound beam.[6]

The use of ultrasonography helps to guide needles to nerves and other soft tissue structures for regional anesthesia as well as vascular access. As a corollary, ultrasound for pain management has become a rapidly expanding area of interest, and needle placement around spinal structures using ultrasound imaging has become a relatively new application.[7–12] The appreciation of the ultrasound images of various spine structures can be challenging, and the use of cadavers has been suggested as a viable training option.[13] However, access to cadavers can be limited for practitioners who want to advance their skills in spine injection under ultrasound guidance.

In this report, we describe the preparation of a low-cost gelatin-based phantom used to teach ultrasound-guided interventional pain management techniques around the lumbosacral spine. Although commercial simulators are available, the advantages of our model are its low cost, the transparency of the phantom, the ease of creation, and its ability to reuse.

MATERIALS AND METHODS

The gelatin phantom is produced by simply placing a spine model into a concentrated gelatin solution (Fig. 1). At our institution, we have used an adult-size spine model consisting of the lower 3 lumbar vertebra (L3-L5) and sacrum (Figs. 2 and 3). A spine model with only the bony elements is used (soft tissue structures including nerves and ligaments are not included).

An adult-size lumbosacral spine model was placed into a microwave-safe rectangular container of approximately 4 L in volume. The dimensions of the container used for our model were length of 27 cm, width of 13 cm, and height of 17 cm, which provide a reasonable fit for the model and a satisfactory surface area to allow for scanning and placement of needles. With these dimensions, the depth from the surface of the gelatin to the lamina is approximately 10 cm. The transparency of the mold is preserved as the thickness of the gelatin is increased.

The spine model is placed into the container and is secured to the bottom with modeling clay or a fastener (eg, epoxy adhesive). Approximately 4 L of hot tap water (120°F) is then mixed with ~350 g of gelatin. We prefer to obtain gelatin from a bulk-food store given the large amount required. The mixture is thoroughly stirred using an electric mixer until all gelatin is completely dissolved. This results in a very concentrated gelatin solution, which will later harden into a firm, durable, and transparent block.

Metamucil (Proctor & Gamble, Cincinnati, Ohio) has been added to gelatin ultrasound phantoms to simulate the sonographic appearance of soft tissue.[14] This can be added to the spine phantom for advanced learners, but it will make the gelatin mixture opaque and increase the level of difficulty for beginners.

The dissolved gelatin is then poured over the spine model in the plastic container so that the model is completely immersed. Bubbles often lie on top of the gelatin mixture once poured. These must be removed so there is no distortion of the ultrasound beam, and they should be skimmed off the surface. Alternatively, a plastic wrap can be placed over the gelatin solution and then lifted off to remove the bubbles since they will tightly adhere to the plastic. Depending on the density of the spine model used, it may tend to float in the gelatin if it is not secured to the bottom of the container properly. If this continues to be a technical problem, the gelatin should be poured and set in layers. Once the first layer sets, the spine model will be secured to the container's floor and will be ready for complete immersion.

The model is refrigerated overnight to allow the gelatin to harden. Once accomplished, the model can be used to practice

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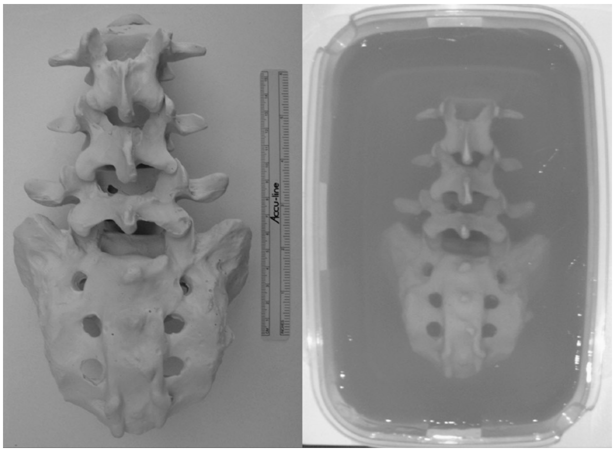

FIGURE 1. A, Spine phantom before placement in gelatin mold. B, Spine phantom after gelatin mold has set.

ultrasound imaging of the bony elements of the spine and placement of needles under ultrasound visualization. Once all material is acquired to produce the phantom, the estimated preparation time is approximately 30 mins. The time to solidify the gelatin mixture in a refrigerator is approximately 6 to 8 hrs. The total cost of the gelatin and container is less than Can $10, whereas the spine model can be purchased for approximately Can $70 from an anatomical model supplier.

The phantom can be maintained by washing its surface with water to remove any ultrasound gel applied to it during scanning practice. Furthermore, like many ultrasound phantoms, needle track marks will be left in the gelatin, which can be seen in subsequent ultrasound scans, limiting its usefulness. To overcome this limitation, the gelatin can be melted in a microwave to effectively "erase" the track marks. Given the large volume of gelatin to be melted, it may take more than 15 mins on a high setting to completely melt in a microwave. The model can then be placed back in a refrigerator overnight to harden again.

DISCUSSION

The lumbosacral spine phantom described can be a very useful tool for teaching basic ultrasound-guided interventional skills. It assists in teaching sonoanatomy of the spine and allows one to practice probe handling skills as well as needle placement.

A distinct advantage of this gelatin phantom compared to other commercially available phantoms is the transparency of the mold. This allows trainees to have direct visual access to the section of the spine the ultrasound probe is scanning. Consequently, they can develop an appreciation of the corresponding sonoanatomy on the ultrasound monitor. Furthermore, needles that are guided via ultrasound can be seen passing through the gel. Again, correlation with the ultrasound images and actual needle placement about the model can be achieved, which permits trainees to improve hand-eye coordination.

An educational program using direct visual access of the spine during ultrasonography has also been developed by Galiano et al.[15] By using an image navigation and reconstruction system, real-time hybrid images of the spine in cadavers are produced by combining ultrasound and computed tomography. The resulting images provide students with immediate computed tomographic verification of sonographically identified structures. Although this system produces superb images and likely results in effective teaching, the system is not accessible for the majority of trainees.

There are several disadvantages of the gelatin spine phantom. The most obvious is that soft tissue structures are not simulated. As such, the model is only suitable for entry-level

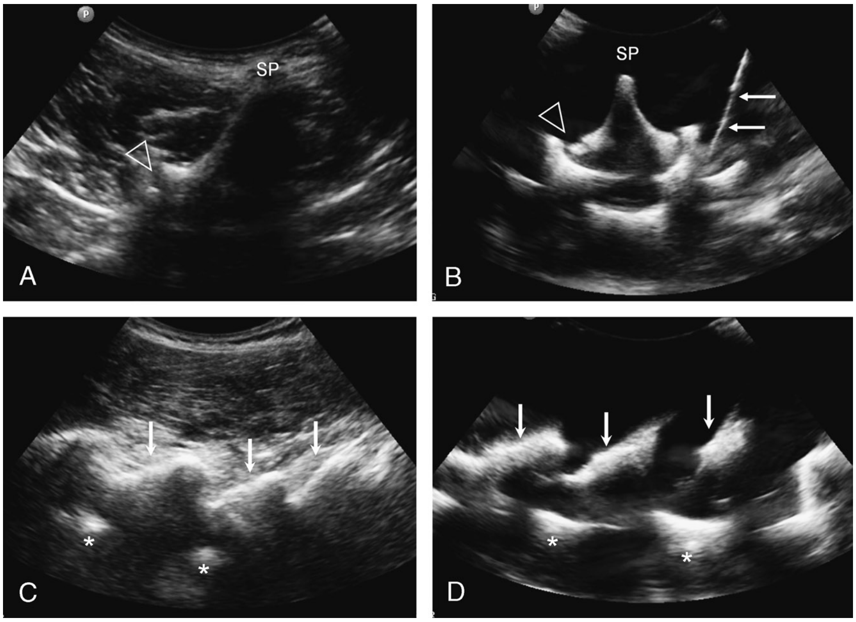

FIGURE 2. A, Transverse scan of lumbar vertebra in a healthy volunteer. B, Transverse lumbar vertebra scan of spine phantom with needle positioned for a medial branch block of the facet joint. Arrowhead indicates facet joint; arrows, needle; SP, spinous process. C, Parasagittal scan of lumbar spine in a healthy volunteer. D, Corresponding parasagittal scan of spine phantom. Arrows indicate vertebral laminae. *Posterior vertebral body.

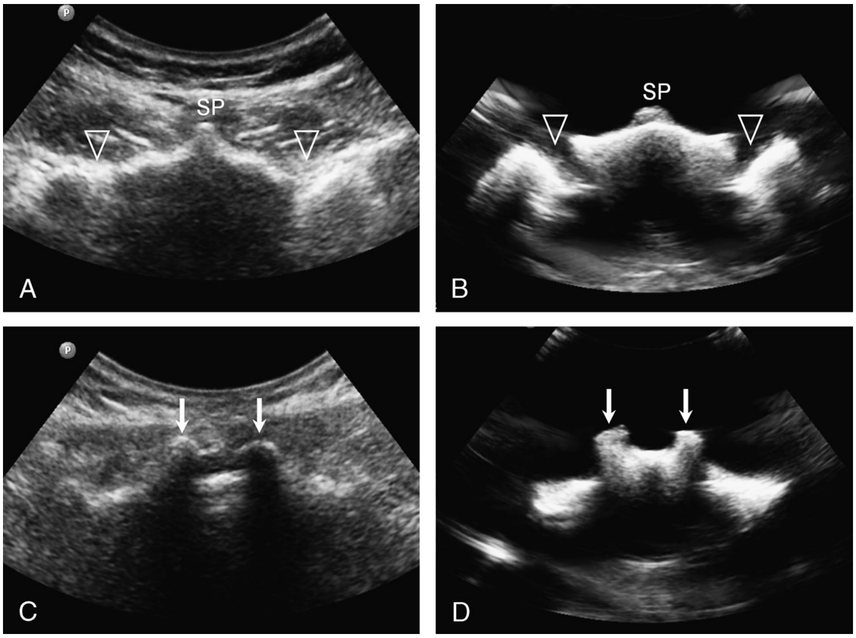

FIGURE 3. A, Transverse scan of sacrum at S1 level in a healthy volunteer. B, Corresponding transverse scan of sacrum at S1 level of spine phantom. Arrowhead indicates S1 foramina; SP, spinous process. C, Transverse scan of sacral cornu in a healthy volunteer. D, Corresponding transverse scan of sacral cornu of spin model. Arrows indicate sacral cornu.

skill development. In addition, there is a lack of haptic feedback for the trainee when inserting the needle to a target on the spine. This is due to minimal resistance against the needle as it passes through the gelatin, which does not simulate the consistency of the tissue. Each needle pass also leaves a needle track visible on ultrasound imaging. In our experience, the quality of the ultrasonographic image will deteriorate after 4 to 5 needle passes for a particular spine level. However, in ultrasound imaging for pain blocks, each vertebral level can be used, and the whole spine phantom can allow trainees up to 20 needle passes per phantom. Microwaving the model and letting it cool overnight allows for its reuse the next day. Finally, the gelatin itself is a growth medium for bacteria and fungus. Although the model can be reused after being heated and cooled, the use will be ultimately limited by the decomposition of the gelatin. At our center, we have been able to use the same gelatin model for more than 3 weeks before there is degradation of the model, making it unsuitable for teaching, after which the old gelatin is melted away and washed under hot tap water.

A variety of commercially available spine training phantoms are available (eg, Simulab [Seattle, Wash], CIRS [Norfolk, Va]). These products are highly detailed and have multiple components to simulate realistic tissue layers. Although these products may be more attractive to students, they are expensive and may not be optimal for teaching basic skills. These models have an advantage with respect to enhancing haptic feedback and viewing tissue layers. However, there is little evidence to suggest that high-fidelity simulators increase the transfer efficiency ratio of clinical skills to patient care.[16] As such, simpler models may be equally effective training devices for entry-level teaching objectives.

The gelatin spine phantom can be a useful tool to teach sonoanatomy of spinal structures and to train students how to place needles around those structures to facilitate injections for pain control. The advantages of this model include the transparency of the mold, its low cost, and its ability to be recovered after use. This is an important addition to ultrasound teaching because it is simple and accessible yet provides an introduction to advanced interventional pain management skills. Further studies evaluating the actual use of our phantom by students are necessary to prove its educational validity.

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