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Lumbar Puncture: Creation and Resident Acceptance of a Low-Cost, Durable, Reusable Fluoroscopic Phantom with a Fluid-Filled Spinal Canal for Training at an Academic Program

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ABSTRACT

SUMMARY: Simulation-based medical training provides learners a method to develop technical skills without exposing patients to harm. Although fluoroscopic phantoms are already adopted in some areas of radiology, this has historically not been for lumbar puncture. Commercially available phantoms are expensive. We report a cost-effective, accessible solution by creation of an inexpensive phantom for resident training to perform fluoroscopically guided lumbar puncture, as well as instructions on how to make a phantom for residency education. An anthropomorphic ballistics-gel phantom that contains a plastic lumbar vertebral column and simulated CSF space was created. Radiology residents with minimum or no experience with fluoroscopically guided lumbar punctures were given a brief education and practiced fluoroscopically guided lumbar punctures on the phantom. A survey from the residents was then done. The phantom was qualitatively quite durable and deemed adequate for educational purposes. All the residents surveyed expressed the desire to have this phantom available and it increased comfort, knowledge, and perceived likelihood of success. Few articles have been published that focused on low-cost phantom creation for fluoroscopic-procedure training. This study supports the benefits of using phantoms for fluoroscopic training as well as step-by-step instructions for creation of this phantom. The residents responded positively and felt more confident in their fluoroscopically guided techniques. The ability to make a long-term training device for resident education would be inexpensive and relatively easy to implement in academic programs.

ABBREVIATION: LP = lumbar puncture

Simulation-based training provides learners in the medical field a method to develop technical skills without exposing patients to harm.[1] From temporal bone labs to practice drilling on cadaveric temporal bones for otolaryngology to mannequins for intubation, training devices are used across nearly all medical fields. In radiology, anthropomorphic phantoms are used for optimization of imaging hardware and procedural training purposes.[2] For training, they are often used in sonography-guided procedures. Although fluoroscopic phantoms are adopted in some areas of radiology, such a breast imaging to practice interventions, this has historically not been for other fluoroscopically guided procedures, including lumbar puncture (LP), which is commonly performed in practice.

Although anthropomorphic training devices for this purpose are commercially available, they are prohibitively expensive ($3,999.00, Blue-Phantom; CAE-Healthcare, Sarasota, Florida), which limits accessibility to most residents. Few examples in the literature, even across specialties, discuss solutions to solve this challenge for fluoroscopic procedures.[1,2] Here, we report a cost-effective, accessible solution: creation of an inexpensive phantom for resident training to perform fluoroscopically guided LP. The phantoms are built with only a few readily available components and use fluid-filled spaces that allow trainees to experience simulated CSF return, which gives a realistic opportunity for accurate simulation. We demonstrate how residents with minimum exposure were able to improve their comfort level after receiving hands-on phantom-based training.

MATERIALS AND METHODS

Phantom Development

An anthropomorphic ballistics-gel phantom that contains a plastic lumbar vertebral column and simulated CSF space was created. It was built by using a lumbar vertebral column (4-Part Human

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Indicates article with supplemental on-line appendix and table.

Indicates article with supplemental on-line photos.

Indicates article with supplemental on-line video.

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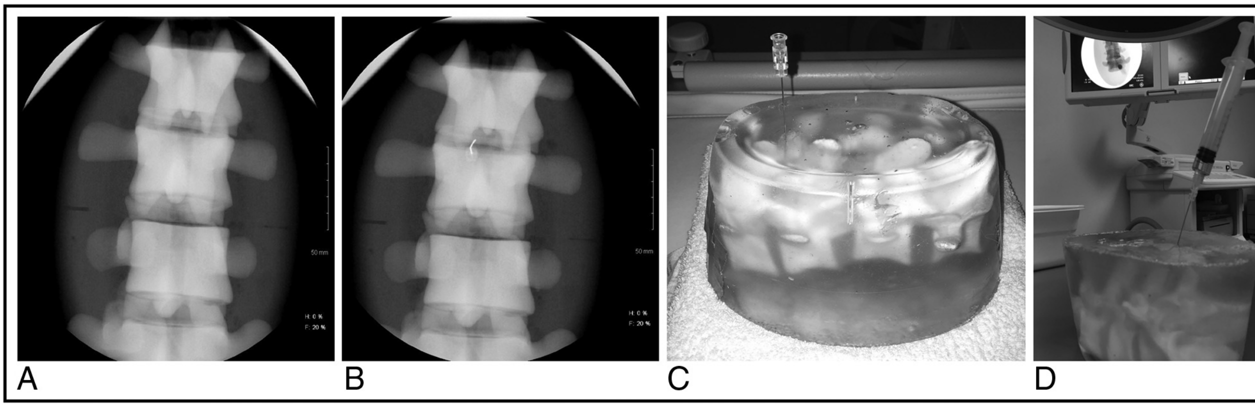

FIG 1. *A* and *B*, Fluoroscopic appearance of phantom without and with access needle. *C*, Phantom, with access needle in place. *D*, Separate phantom, with access needle in place with syringe aspiration displaying simulated spinal fluid.

Lumbar Vertebrae Spine Set; Anatomical, Inc, Lexington, South Carolina) purchased on-line. One 10% Ballistic-Gelatin Air Block (9 × 4 × 4 in) was also purchased on-line (ClearBallistics; Lexington, South Carolina). A plastic storage tub was used as a container for creation of the phantom. Latex membranes simulated the thecal sac (latex probe covers; extra-large condoms when probe covers were not available). Certain spinal columns include a rubber-insert re-creation of the spinal cord and nerve roots, which, if present, was removed. The vertebral model was held together by an internal malleable rod.

Malleable properties of the rod were used to create different challenge levels within the lumbar spaces. For example, one level was positioned kyphotically to open up the interspinous space, another was held in neutral position, whereas a different level was placed in the lordotic position, which simulated more difficult patient positioning. The ballistics gel was heated in a soup pot on medium high until fully melted. While the ballistics gel was heating, the latex membrane was placed through the canal of the spine and filled with water until completely filling the canal. The latex membrane was tied off, and the lumbar spine that contained the fluid-filled latex membrane was positioned within the container. Once the ballistics gel was completely melted, it was carefully poured into the container. This was cooled until solid, (approximately 6 hours). (On-line Video and On-line Fig 1.)

After cooling, the phantom was removed from the plastic mold. A small cut was made adjacent to the metal rod insertion in the lumbar spine and removed because this would cause opacification on fluoroscopy and limit device effectiveness. The result is an anthropomorphic ballistics-gel phantom that can be used under fluoroscopy with fluid-containing space-simulating CSF. The total cost of creating the phantom was approximately $54. The total time spent was approximately 30 minutes to 1 hour (not including the time for the gel to cool). The phantom was qualitatively viewed under fluoroscopy by board-certified radiologists to ensure acceptable accuracy for the purposes of resident training.

RADIOLOGY RESIDENT TRAINING WITH THE PHANTOM

Radiology residents with minimum or no experience with fluoroscopically guided LPs were given a brief lecture, of approximately 15 minutes, on techniques, including needle localization, starting location, advancement technique, and fluoroscopic pedal control. Residents then had an opportunity to practice the techniques while supervised by a faculty member experienced in fluoroscopically guided LPs. This was performed with single-plane fluoroscopy and a median-paramedian interspinous approach, with the phantom in a simulated prone position. Technical success was demonstrated by return of simulated CSF through the needle and visualization of the needle within the spinal canal on fluoroscopy (Fig 1). Surveys from the residents were performed at the end of the workshop to determine the levels of comfort and confidence for performing LP before and after hands-on instruction with the phantom, and whether residents would like to permanently have such a training phantom available for practicing throughout the year (On-line Table and On-line Appendix).

RESULTS

Attenuation of the 10% gel block was 0.91 g/mL, whereas human adipose attenuation is approximately 0.91 g/mL and muscle 1.06 g/mL. The phantom was qualitatively quite durable. At least 100 attempts were performed during evaluation by faculty and training by residents without functional wear or loss of function. Qualitatively, the phantom displayed adequate differentiation between soft tissue and simulated spine and/or osseous structures, which allows for use as a practice mechanism for resident training. Needle visualization throughout the procedure with all calibers (20–22 gauge) used was qualitatively found to be easily identifiable by a staff radiologist who performs LPs. Some residents stated during practice that they were able to feel a "pop" through the needle as they entered the simulated CSF space.

All the residents surveyed expressed a desire to have this phantom available to the residency program for future practice. All the residents gave the highest rank (5/5) for the helpfulness of the phantom. The average comfort level for performing a LP improved from 1.8 to 3.9. The knowledge base for performing a LP increased from 2.7 to 4.4. Expectation for successfully performing a LP increased from 2.8 to 4.3 (On-line Fig 2).

DISCUSSION

Across medical specialties, simulation-based training devices are used for clinicians to gain technical skill sets and improve quality and efficiency for real patient interactions.[3,4] Some of the most well known are mannequins used for Basic Life Support and Advanced Cardiovascular Life Support training. The use of training devices expands into other fields, in which the potential for poor outcomes is possible. For example, the aerospace industry commonly uses flight simulators for pilots to practice certain situations to achieve confidence as well as decrease costs of training.[5,6]

Fluoroscopically guided LP is a commonly performed procedure in most radiologic practices. Historically, trainees have been required to learn these techniques on real patients, which creates risk associated with the inexperience of trainees. Although realistic training devices are available, in many situations, their frequent use is cost prohibitive to many training programs. Having an inexpensive way to allow residents to repeatedly train on a device to build technical competence for fluoroscopically guided LPs before direct patient interaction might be beneficial for improved outcomes.[7] The anthropomorphic phantom herein developed fits such a description.

The ClearBallistics gel was chosen for certain beneficial properties. This gel was developed to simulate the average soft-tissue attenuation of a human, which allows an overall accurate but not necessarily exact duplication of a patient's soft tissue. As a result of their properties, some homemade ballistic gels must be refrigerated to avoid mold formation and/or rotting and may only have a 3-week shelf life, despite refrigeration. However, the ClearBallistics gel does not require refrigeration and will not rot. The long-term shelf life of this product is significant. For example, one model that we developed was still in use for >3 years and showed no significant loss of function or decomposition. In addition, if, after frequent use, the phantom is no longer accurate, the gel can be remelted and cooled for reuse. For repair of superficial components of the phantom, (ie, too many amassed puncture sites), a butane torch can be applied to those areas until just melted and then the phantom is set aside to re-cool. A more complete reconstruction is performed by manually removing the ballistics gel from the other components at room temperature and rebuilding the phantom as described above and in the On-line Video.

Very few articles have been published that focus on low-cost phantom creation for fluoroscopic procedure training.[1,2] This article adds to the literature to further support the benefits of using phantoms for fluoroscopic training by increasing resident confidence and comfort as well as improving patient safety. In addition, compared with previous reported literature of creating an inexpensive phantom, our unit is approximately $90 less expensive[2] to create than previously described low-cost phantoms, and up to $3,945 less than commercially available phantoms while supplying acceptable re-creation for resident training purposes. Our phantom is also unique in that it has a fluid-filled pocket to better simulate the spinal canal for the purposes of fluoroscopically guided LP. This potentially improves the experience because it can replicate the "pop" sensation that can be felt when entering the thecal sac and allows return of fluid through the spinal access needle. A review of the literature for low-cost fluoroscopic LP phantoms did not reveal this type of fluid-filled canal technique.

The residents responded positively to this training mechanism and felt more confident in their fluoroscopically guided procedural techniques. Having the novel opportunity to practice with different anatomic "difficulty" levels in the lumbar spine phantom allowed the residents to progress in an organized manner and to fine tune their technique over the course of multiple attempts, which is also unique to previously described LP phantoms. If more realistic simulation is desired, 3D printed spines with varying degrees of spondylosis and/or scoliosis could be used. A previous article has shown that such training can decrease patient radiation exposure.[1] The ability to make a long-term training device for resident education would be inexpensive and relatively easy to implement in academic programs.

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