Development of an In-house Endoanal Ultrasound Teaching Phantom

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Objectives—The aim of this study was to construct an anatomically correct phantom for visualization of anal sphincter complex structures.

Methods—To make an endoanal ultrasound phantom, we experimented with a variety of commercially available materials to simulate hyperechoic, hypoechoic, and isoechoic tissue consistency. We created external anal sphincter muscle and the levator plate using stand-alone density gel and microbubbles to simulate the echogenicity of the muscles. A mold was created in a container, the muscles were inserted, and the mold was filled with high-density clear gel and allowed to fill. Once finished, the container was sealed tightly and stored for later use. To evaluate the accuracy of the model, 6 ultrasound imaging raters from different disciplines were included. The raters were administered a 6-item Internet-based interactive test using 2-dimensional images obtained from scanning the phantom. Rater agreement was determined. The Fleiss κ statistic was calculated to determine inter-rater reliability.

Results—The raters identified the structures in 32 (89%) of 36 test questions. There was good to excellent agreement among the readers. Agreement rates for visualization of the external anal sphincter, perineal body, and internal anal sphincter were 67%, 83%, and 100%, respectively.

Conclusions—An endoanal phantom can be constructed as a simulator for endoanal sonography.

Key Words—anal sphincter; endoanal ultrasound; phantom

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Abbreviations
3D, 3-dimensional

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Phantoms are devices or objects used in various imaging techniques to visualize or enhance visualization by simulating conditions encountered in the procedures. They are used very often in procedures employing or measuring x-irradiation or radioactive material to evaluate performance. Phantoms often have properties similar to human tissue. Water shows absorption properties similar to normal tissue; hence, water-filled phantoms are used to map radiation levels. We can find many studies using phantoms in this manner to evaluate the harm or usefulness of radiation as an imaging or treatment modality. Phantoms are used also as teaching aids to simulate ultrasound imaging of the liver, prostate, and abdomen.

Endoanal sonography is recognized as the reference standard for imaging the anal sphincter complex.[1] When teaching endoanal sonography, there are no phantoms available, and live volunteers are used for training. Endoanal ultrasound examinations can be painful, unpleasant, and embarrassing for the volunteers, especially when large numbers of trainees are present. In this article, we report a phantom constructed for teaching endoanal sonography.

Materials and Methods

All aspects of this project were approved by the Institutional Review Board at the University of Oklahoma Health Sciences Center.

Phantom

Our ultrasound phantom was created for anal sphincter imaging. The main challenges in creating an endoanal phantom were (1) finding materials that had the echogenicity of the structures they were intended to mimic and (2) placing the materials in anatomically correct positions. We experimented with a variety of commercially available materials to simulate hyperechoic, hypoechoic, and isoechoic tissue consistency.

Finding acceptable methods to cut down the cost while maintaining quality is of great value. Making homemade gel wax, instead of buying it premade, can help reduce the cost of most gel projects. In addition to cutting down the cost, making gel from scratch gave us complete control over the gel density right from the beginning. This approach makes specific projects easier from the start. Gel is made from a combination of polymer resin and mineral oil: approximately 95% mineral oil and 5% polymer resin. Because gel is clear, properly made gel will resemble gelatin in its consistency. The higher the density, the thicker the gel will be. The different thicknesses of gel can work equally well in most projects, although the most appropriate for our phantoms is a high-density gel, which will allow for the embedding of most objects. When making gel, the density can be made higher or lower, making more projects possible. There are 4 density grades to choose from, depending on the project and thickness necessary to complete it.

Materials Needed

1. CP9000 thermoplastic resin powder (Calumet Specialty Products, Indianapolis, IN);
2. White mineral oil with a flash point of 375°.

Possible Density Grades

1. Low-density gel—made with 450 g of mineral oil and 25 g of resin. This density will only allow for small, light objects to be embedded successfully.
2. Medium-density gel—made with 450 g of mineral oil and 31g of resin. This density has a nice ability to embed, except for extremely heavy objects, successfully.
3. High-density gel—made with 450 g of mineral oil and 35 g of resin. This density allows successful embedding of even heavy objects.
4. Stand-alone density gel—made with 450 g of mineral oil and 40 g of resin. This gel does not require a container but needs a stand instead. It allows for the heaviest successful embedding.

We created the external anal sphincter muscle and levator plate using the stand-alone density gel and microbubbles to simulate the echogenicity of the muscles. A mold was created by the senior author using a cylindrical 10 × 10-cm container, the muscles were inserted, and the container was filled with medium-density clear gel and allowed to fill. Once finished, the container was sealed tightly and stored for later use (Figure 1).

Figure 1. Endoanal phantom.

Imaging

An UltraView ultrasound machine and transducers were used for pelvic floor imaging (BK Medical, Peabody, MA). A BK 2052 transducer, which is a 6–16-MHz scanner with a built-in automatic mover, was used for 360° 3-dimensional (3D) endoanal imaging, in which 360° views of the external anal sphincter, internal anal sphincter, and perineal body were obtained. A length of 6 cm was scanned in 60 seconds with scans of every 0.2 mm, for 300 cumulative scans from which a 3D rendered cube was calculated. The midsagittal view of the endoanal phantom is shown in Figure 2. There is an air gap seen fanning toward C, which is not visualized in the midsagittal view of the endoanal 3D volume obtained from a healthy woman in Figure 3.

Accuracy Assessment

A 6-question Internet-based interactive test using phantom ultrasound images simulating normal anatomy was administered to 6 ultrasound imaging experts with extensive 3D imaging experience (2 pelvic floor surgeons, 2 radiologists, 1 sonographer, and 1 colorectal specialist). The images were those used routinely for assessment of internal and external anal sphincter muscles in axial and sagittal views (Figure 3). The individuals were identified as experts based on the fact that they teach this ultrasound modality.

We used QuizCreator (Wondershare, Shenzhen, China) to administer a blinded Internet-based quiz to the raters, which was timed to be finished in 6 minutes without the ability to see the correct answers or the ability to return to previous questions. For each question, the image was displayed on the screen, and the rater was asked to click on the structure in question. If the rater clicked on any area of the image other than the structure of interest, it would count as a wrong answer. The raters had no indication of whether their answers to the questions were right or wrong, and the computer program shuffled the questions that appeared on the screen. The raters did not have any role in conceptualization or creation of the endoanal phantom; thus, the results were not biased.

The accuracy of the model was calculated by taking the percentage of correct answers by all raters. Four of 6 correct answers (67%) for each rater was deemed successful simulation of normal anatomy. In addition, agreement among the 6 raters was deemed good if 4 or 5 of 6 raters (67%–83%) agreed that they could identify the same structure. Agreement among all 6 raters (100%) was deemed excellent. The agreement was calculated by dividing the total number of agreements by the total number of questions.

Figure 2. Sagittal anterior view of the phantom obtained with an endoanal probe. This image is question slide 2 administered to the raters. A indicates perineal body; B, endoanal probe; C, anterior position; D, external anal sphincter; E, internal anal sphincter; and F, caudad position.

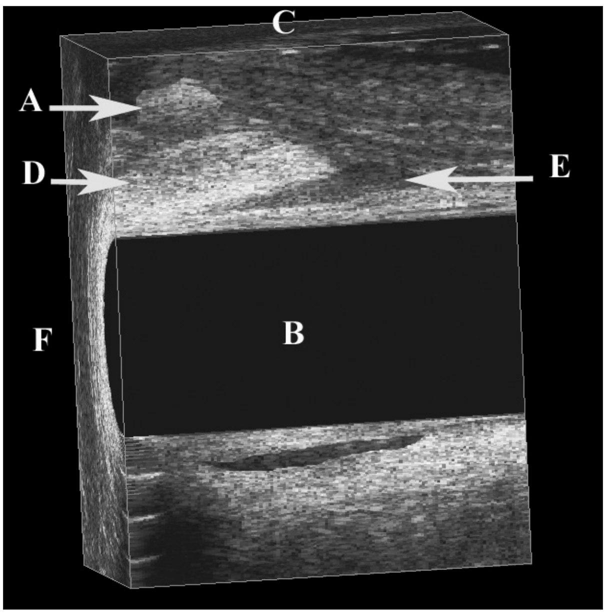

Figure 3. Midsagittal endoanal view in a healthy woman. Structures and positions are as in Figure 2.

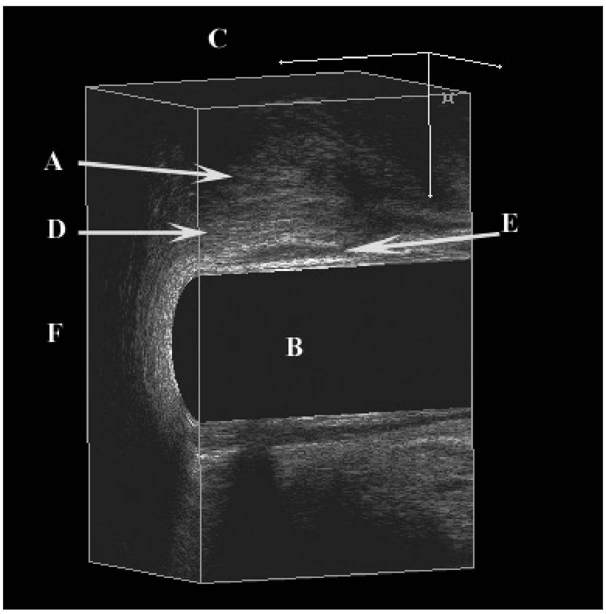

Table 1. Questions Administered to the Raters on the Interactive Test

Question (1, Correct; 0, Incorrect)	Rater 1	Rater 2	Rater 3	Rater 4	Rater 5	Rater 6	Inter-rater Agreement, n (%)
1. This an interactive image. In this image, please click on external anal sphincter.	1	1	1	0	1	0	4/6 (67)
2. This an interactive image. In this image, please click on internal anal sphincter.	1	1	1	1	1	1	6/6 (100)
3. This an interactive image. In this image, please click on where the transducer is.	1	1	1	1	0	1	5/6 (83)
4. This an interactive image. In this image, please click on where the anterior position is.	1	1	1	1	1	1	6/6 (100)
5. This an interactive image. In this image, please click on where the perineal body is.	1	1	0	1	1	1	5/6 (83)
6. This an interactive image. In this image, please click on where the caudad position is.	1	1	1	1	1	1	6/6 (100)
Individual score, %	100	100	83	83	83	83	

Results

Agreement was reached in 32 (89%) of 36 questions. All raters answered more than 4 of 6 questions correctly. Table 1 shows the questions, answers, and agreement rates. There were good to excellent individual scores for visualization of all structures. There was also good to excellent inter-rater agreement for visualization of all structures.

Discussion

In this study, we created an endoanal ultrasound phantom that mimicked findings relevant to key radiographic and structural tissue characteristics. The rater testing showed good to excellent agreement for this phantom.

This study had its strengths and limitations. Phantoms are not real and, as such, simply simulate real circumstances. Possible alternatives to the use of a phantom include the use of live volunteers, minimally embalmed human cadavers, or computer simulation.[2] However, the use of these alternatives to a phantom can be cost-prohibitive for most workshop organizers. In addition to cost, live volunteers are logistically prohibitive because of the need for privacy while performing an endoanal ultrasound examination. Fresh-frozen or minimally embalmed human cadavers do not have the echogenic characteristics of living tissue and last, computer simulation may not allow the examiner to gain skills in ultrasound techniques and experience in how to perform and interpret the examination. The use of any model presents inherent limitations to the practical application of these results. A phantom allows the trainee to perform an examination using endoanal ultrasound transducers without the fear of hurting the patient or apprehension about making mistakes.[2–4] The trainee can instead concentrate on operating the keyboard and orienting the transducer. The ease of teaching such a modality in a reproducible manner is important, as it would move the imaging modality out of the hands of a few experts and into the hands of practicing physicians. The 3D endoanal technology has rapidly evolved and is increasingly used by specialists who evaluate the anal sphincter complex.

Improvement in the quality of the phantom is an ongoing process. Ultimately, participants who master 3D endoanal sonography using phantoms will reinforce their learning by following the same steps when scanning a live person. This phantom familiarizes the learner with the instruments and techniques performed in live scanning. Further investigation is ongoing to incorporate more detail into the models and create models that simulate specific pathologic conditions.

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