An Inexpensive and Easy Simulation Model of Ocular Ultrasound That Mimics Normal Anatomy as Well as Abnormal Ophthalmologic Conditions

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We have constructed a simple and inexpensive simulation model for the educational instruction of health care providers to detect normal and abnormal ocular conditions in the bedside emergency setting. Such a training model serves to increase the comfort level in performing ocular ultrasound examinations and can increase the accuracy of examination interpretation. Ophthalmologic examinations can be difficult in the emergency setting, and ultrasound has become a useful tool in the diagnosis of emergent ocular conditions.

Key Words—ocular ultrasound; phantom model; retinal detachment; retrobulbar hematoma; vitreous hemorrhage

Two percent of emergency department visits can be attributed to ocular conditions, ranging from primary ophthalmologic concerns to infectious or traumatic causes.[1] Although many of these conditions do not require emergent ophthalmologic consultation or intervention in the emergency department, certain conditions must be diagnosed promptly. Because of a combination of environmental limitations, difficulty accessing the necessary equipment, and lack of physician comfort, a comprehensive ophthalmologic examination can be difficult to perform. Ultrasound has become a tool used by both emergency physicians and ophthalmologists in diagnosing ocular emergencies. A recent study of board-certified residents and attending physicians in an emergency department showed that ultrasound examinations had 100% sensitivity and 97.2% specificity for detecting globe rupture, retinal detachment, and vitreous hemorrhage.[2] Simulation training in ultrasound has been shown to improve patient safety in procedures.[3,4] and early diagnosis in a variety of areas.

There are currently a few ocular simulation models commercially available, eg, harvested rabbit or porcine eyes and or glass models layered with bovine tissue.[5,6] Given the importance of simulation training and the relative paucity of easily obtainable and financially feasible ocular models, we developed an ocular ultrasound phantom using readily available materials. We were able to, easily and with little expense, create reasonable models of the normal eye as well as the eye with retinal detachment, a foreign body, an increased optic nerve sheath diameter, vitreous hemorrhage, and retrobulbar hematoma. The procedures for creating the phantom are listed in the "Appendix."

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Abbreviations
ECG, electrocardiographic

Using previously described methods for creating phantom models, we used water, sugar-free psyllium powder, and unflavored gelatin to create the globe.[7] For the globe mold, we used a round plastic container that acts as packaging for small toys sold in vending machines typically found outside supermarkets. The ocular lens was created by making an elliptical incision on the anterior portion of the globe with the model-air interface creating a thin hyperechoic line that is visualized by a high-frequency probe. We were able to simulate retinal detachment in a similar manner by making a linear incision along the posterior aspect of the globe, the size of the incision representing the size of the retinal detachment. For the insertion of the optic nerve, we used the standard metal tip of an electrocardiographic (ECG) chest adhesive, creating shadowing similar to the hypoechoic sheath. Cutting the same metal lead to a larger diameter created an increased optic nerve sheath diameter mimic. Vitreous hemorrhage was recreated by injecting hyperechoic fluid into the globe during the model cooling process. We found that Elmer's Glue (Elmer's Products, Inc, Columbus, OH) or casting plaster dissolved in a small amount of water simulated hyperechoic fluid well. Recreating a foreign body in the globe consisted of simply placing a small piece of plastic or metal into the globe during the model cooling process. To mimic retrobulbar hematoma, we placed a fluid-filled latex glove underneath the posterior portion of the model.

Ultimately, we were able to make an ultrasound model that provides a realistic representation of both normal ophthalmologic ultrasound anatomy as well as 5 examples of potentially emergent ophthalmologic conditions. The entire process was performed in as little as 2 hours at a total cost of less than US$20 (not including readily available emergency department items such as ECG leads). If kept refrigerated, the models can be reused, although in our experience, the gelatin/psyllium powder base decompensates over the course of a few weeks. The low cost and ease of creation make this model feasible for attending physician, resident, and medical student education.

We recognize that increasing the shelf life of the models would increase their utility as teaching tools over the long term. With that goal in mind, we are investigating the use of evaporated milk, which has been shown in published phantom models to remain stable for up to 2.5 years,[8] as the primary absorbant for the model. Alternatively, creating models based on an *n*-propanol mixture with a thimerosal preservative may provide a template for future improvements in the durability or our design. At this juncture, however, we are pleased with both the quality of our current models and the ease with which all of the component ingredients can be obtained.

This model was recently tested on participants of an ultrasound division meeting involving emergency medicine attending physicians, residents of all years of training, and fourth-year medical students. The models were found to be user-friendly and served as educational tools for detecting normal anatomy and abnormal ocular conditions to all levels of training.

Appendix: Procedures for Making the Ocular Model

Ingredients

250 mL of water
3 packets of unflavored gelatin
1 tablespoon of psyllium powder
Round plastic mold
Size 15 scalpel
Electrocardiographic sticker adhesive with metal snap for lead attachment
18-gauge needle
Elmer's Glue or casting plaster
Balloon or latex glove

Normal Eye

Step 1—Place 350 mL of water in a metal pan and set to boil.

Step 2—Add 3 packets of unflavored gelatin for each 350 mL of water until completely dissolved. Add 1 tablespoon of psyllium powder.

Step 3—Pour mixture into the plastic mold and allow to sit in a refrigerator for 2 hours. Remove from the mold (Figure 1A).

Step 4—Using a size 15 scalpel, make a circumferential incision at a 15° angle with the tip of the blade facing the middle of the globe at the most superior portion to create the lens. Leave the excised portion in situ on top of the mold (Figure 1B).

Step 5—Cut a metal ECG lead to no more than 3 mm in diameter, and place on the bottom of the globe (optic sheath diameter; Figure 1, C and D).

Step 6—Use a high-frequency linear probe to image the model (Figures 1E and 2A).

To recreate models of abnormal eye conditions, follow steps 1 through 6 above, making the following changes as indicated.

Retinal Detachment
Use the size 15 scalpel to make an incision through the posterior portion of the globe. The size of the incision will correspond to the size of the retinal detachment (Figure 2, B and C).

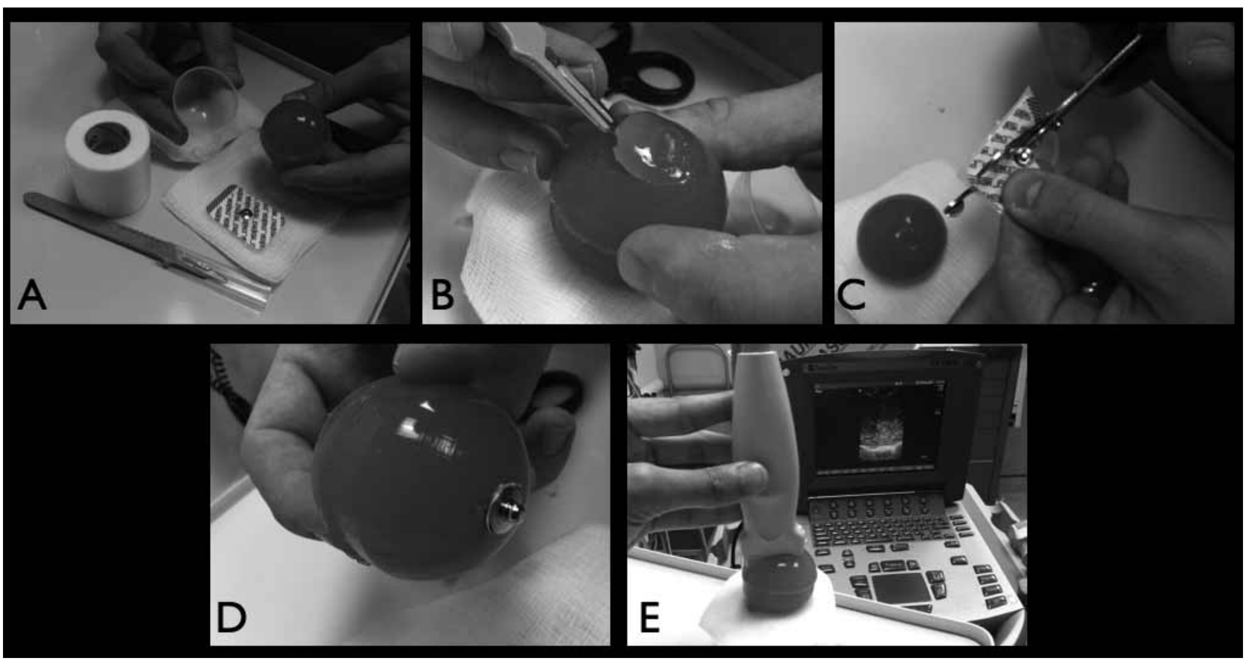
Increased Optic Nerve Sheath Diameter
Instead of cutting the metal ECG lead to 3 mm in diameter, use the entire metal ECG lead, the average size being greater than 5 mm in diameter, and place on the posterior surface of the globe (Figure 2D).

Vitreous Hemorrhage
Insert an 18-gauge needle into the globe, and manipulate the needle to create a pocket of air. Inject a hyperechoic fluid such as Elmer's Glue or casting plaster dissolved in water. Alternatively, inject the fluid into the mold after the mixture has cooled for 20 to 30 minutes (Figure 2E).

Ocular Foreign Body
While creating the mold, insert a hyperechoic foreign body such as a piece of plastic or metal, again waiting 20 to 30 minutes until the gel has cooled but not completely solidified (Figure 2F).

Retrobulbar Hematoma
Place a fluid-filled structure under the posterior portion of globe, adding enough pressure to gently curve the posterior portion anteriorly (Figure 2G).

Figure 1. A, Creation of the ocular mold. **B**, A circumferential incision is made to create the lens. **C**, A metal electrocardiographic lead is cut to create the optic nerve. **D**, The electrocardiographic lead is placed on the mold. **E**, The model is imaged using a high-frequency linear probe.



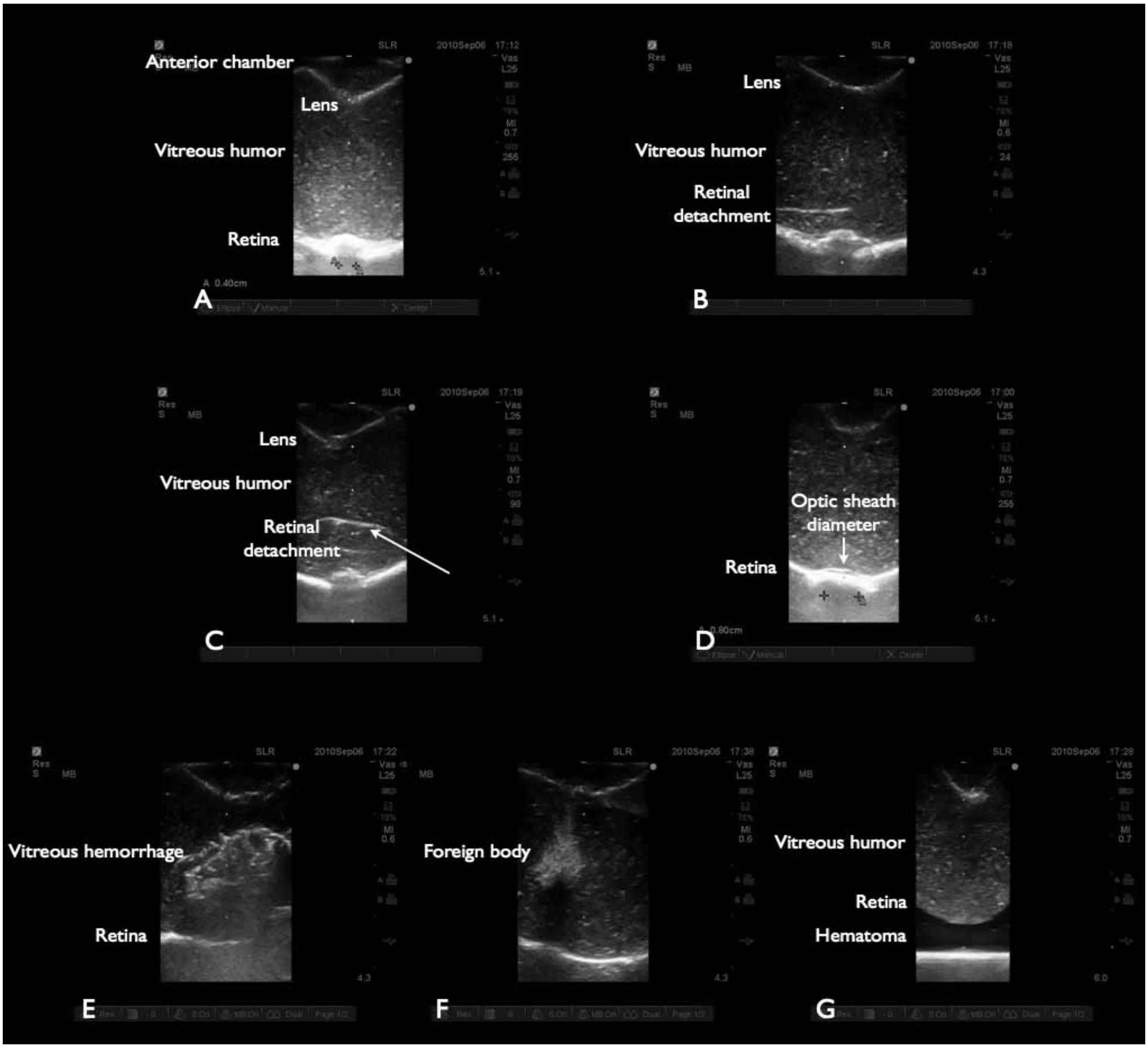


Figure 2. A, Appearance of the normal ocular phantom showing the anterior chamber, lens, vitreous humor, and retina. **B,** An incision made through the posterior portion of the globe creates the appearance of retinal detachment. **C**, A larger incision can be made to create a greater degree of retinal detachment. **D**, A larger electrocardiographic lead is used to create an enlarged optic nerve sheath diameter. **E**, Hyperechoic fluid is injected to give the appearance of vitreous hemorrhage. **F**, A piece of plastic or metal is inserted to simulate an ocular foreign body. **G**, A fluid-filled balloon is placed behind the globe to create retrobulbar hematoma.

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