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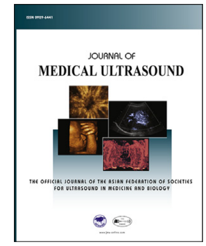

ORIGINAL ARTICLE

Validation of a Low-cost Optic Nerve Sheath Ultrasound Phantom: An Educational Tool

David L. Murphy [1*], Stephanie H. Oberfoell [2], Stacy A. Trent [1,3], Andrew J. French [1,3], Daniel J. Kim [4,5], David B. Richards [1,3]

[1] University of Colorado, Denver School of Medicine, Aurora, [2] Denver Health Residency in Emergency Medicine, [3] Denver Health and Hospital Authority, Department of Emergency Medicine, Denver, CO, USA, [4] University of British Columbia, and [5] Vancouver General Hospital, Department of Emergency Medicine, Vancouver, BC, Canada

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Abstract *Objective:* To validate an ocular phantom as a realistic educational tool utilizing *in vivo* and phantom optic nerve sheath (ONS) images obtained by ultrasound.
Methods: This prospective study enrolled 51 resident physicians from the Denver Health Residency in Emergency Medicine (EM) and 10 ultrasound fellowship-trained EM attending physicians. Participants performed optic nerve sheath diameter (ONSD) measurements on five *in vivo* and five phantom ocular ultrasound images and rated the realism of each image on a 5-point Likert scale. Chi-square analysis was performed to evaluate the subjective "realness" of *in vivo* and phantom images.
Results: Sixty-one participants performed ONSD measurements. Mean Likert scale values were 3.43 (95% confidence interval: 3.31—3.55) for *in vivo* images and 3.41 (95% confidence interval: 3.28—3.54) for phantom images. There was no statistical difference in subjective "realness" between *in vivo* and phantom ONSD ultrasound images among EM residents. Ultrasound fellowship-trained EM attending physicians aptly differentiated between *in vivo* ($p < 0.01$) and phantom ($p < 0.01$) images, as compared with EM residents.
Conclusion: Our ocular phantom simulates *in vivo* posterior ocular anatomy. EM resident physicians found the phantom indistinguishable from *in vivo* images. Our ONS model provides an inexpensive and realistic educational tool to teach bedside ONSD sonography.

Conflicts of interest: The authors do not have any potential financial or nonfinancial conflicts of interest.
* Correspondence to: David L. Murphy, University of Colorado, School of Medicine, 13001 East 17th Place, Mailstop C292, Aurora, CO 80045, USA.
E-mail address: david.murphy@ucdenver.edu (D.L. Murphy).

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Introduction

Ocular ultrasound is a very useful tool in the emergency department to diagnose a wide array of ocular and orbital pathology including vitreous hemorrhage, foreign body, and retinal detachment [1]. Ocular ultrasound of the optic nerve sheath diameter (ONSD) has been proposed as a useful screening tool for elevated intracranial pressure [2]. However, in order for emergency medicine (EM) physicians to safely use sonographic measurements of ONSD as a screening tool for elevated intracranial pressure, providers must first learn the technique in order to accurately and reliably measure the ONSD.

Simulation for ultrasound training is a useful tool in EM physician education [3]. Although performing ocular ultrasound on patient models is relatively safe, phantom models are convenient, easily accessible, and allow for prolonged scan time without endangering injury to the retina of patient models. Prior ocular models have focused on simulating vitreous hemorrhage, retinal detachment, and globe rupture [4]. *In vivo* tissue-based bovine and rabbit cadaveric eyes for ocular ultrasound may be cost-limiting. However, a low-cost realistic training tool that is indistinguishable from human anatomy to teach EM physicians to measure ONSD has not yet been developed or validated.

We developed a low cost, easily made phantom model that may assist with training and improve the quality of sonographic measurements of the ONSD. This study aims to: (1) provide a step-by-step description of producing a sonographic phantom of the posterior chamber of the eye; and (2) validate the model as a realistic educational tool utilizing *in vivo* and phantom ONS images obtained by ultrasound.

Materials and methods

Study design

This was a cross sectional study that recruited resident and ultrasound fellowship-trained EM physicians to evaluate still-frame sonograms of five separate ocular ultrasound phantom, and five separate adult eyes that included the retrobulbar optic nerve. This study received Colorado Multiple Institutional Review Board approval (protocol number 13-2134).

Participants

Ten ultrasound fellowship-trained EM physicians and 51 resident EM physicians in postgraduate years (PGY) 1–4 from a single residency were recruited for the study. The ultrasound fellowship-trained EM physicians included in this study completed residency and fellowship at four different institutions and had ultrasound experience ranging from recent EM graduates to >15 years postfellowship. Resident EM physicians had varying degrees of prior ultrasound training ranging from none to 2–3 weeks of general EM-related ultrasound training as part of their medical school or residency curriculum. Any resident or ultrasound fellowship-trained EM physician who was either directly involved with the project or who had previously seen any of the still-frame sonogram images were excluded. All physicians were enrolled using a convenience sample of available and willing volunteers. Informed consent was obtained from all subjects.

Phantom development

The ONS phantom is constructed utilizing the following: a 40-mm diameter ping-pong ball, assorted sizing of clear vinyl tubing, superglue or waterproof sealant, a drill with assorted bits, unflavored gelatin, sugar-free psyllium powder (e.g., Metamucil Sugar Free Dietary Fiber Supplment, Procter & Gamble, Cincinnati, USA), 18 gauge needle, 30 mL syringe, 473.176 mL plastic cups (e.g., Solo Plastic Party Cup, Dart Container Corporation, Mason, USA), and water (Figure 1A). To make the ONS portion of the model, a hole was drilled in the bottom of the disposable cup that matched the outer diameter of the clear vinyl tubing approximating the desired ONSD (for sizing, note that the outer diameter tends to correspond with sonographic ONSD). A section of tubing 7 cm long was cut. All but 2 mm of the tubing was inserted through the bottom of the cup and stabilized in a vertically plumb orientation in the middle of cup using a stylet (e.g., drill bit fixed with tape to brim of cup; Figure 2A). The tubing protruding from the bottom of the cup should be tight-fitting to ensure a tight seal, and its shallow profile allowed the cup to sit flush on the countertop (Figure 2B). This ONS portion was set aside.

The gelatinous matrix used to suspend our phantom eye and ONS was formed using a procedure described by Kendall and Faragher [5] by combining water, unflavored gelatin, and sugar-free Metamucil. Briefly, 250 mL water was boiled, then three packets of gelatin were gradually whisked over a medium heat until the gelatin was completely dissolved. Next, one tablespoon of Metamucil was added and whisked until it completely dissolved. With a spoon, the remaining bubbles were skimmed off. If clumps were present, a sieve was used to remove them. Lastly, this mixture was poured into the plastic cup with the ONS portion of the model. The cup was filled flush to the level of the upper vinyl tubing and placed in the refrigerator for 1–2 hours or until firm. Once the gelatin congealed, the stylet was removed.

To make the eye portion of the model, two small puncture holes 2 mm apart were made on the ping-pong ball with a straight needle and syringe. One hole was used to fill the ball with water until all the remaining air was displaced through the other hole. A small amount of waterproof sealant (e.g., Gorilla Super Glue, Gorilla Glue Company, Cincinnatti, USA; Loctite Stik'n Seal outdoor adhesive, Henkel, Rocky Hill, USA, etc.) was applied over the holes and allowed to cure.

To connect the ONS and eye portions of the model, a small portion of super glue adhesive was applied to the exposed cross section of tubing in the cup with the ONS and congealed gelatin. The cup was placed in the refrigerator and the ping-pong ball was carefully positioned atop the vinyl tubing (Figure 2C). This can be challenging when smaller diameter vinyl tubing is used, therefore, a clean, perfectly horizontal cut of tubing is key. A second batch of the gelatin–Metamucil mixture was made. The second