African Journal of Emergency Medicine (2016) 6, 18–23

African Federation for Emergency Medicine

African Journal of Emergency Medicine

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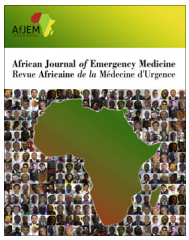

ORIGINAL RESEARCH ARTICLES

Agar ultrasound phantoms for low-cost training without refrigeration

Fantômes d'échographie utilisant l'agar-agar pour une formation à faible coût, sans réfrigération

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Received 25 July 2015; revised 5 September 2015; accepted 18 September 2015; available online 27 November 2015

Introduction: Ultrasound is a technique that can be utilised to augment procedures to increase their safety and efficacy, but requires that health professionals be trained to use this imaging modality before it can be implemented. With the extremely high cost of manufactured phantoms, homemade alternatives are popular substitutes. Gelatine is commonly used as a matrix to suspend analogues and mimic tissue, but other substrates like ground meat can also be used. Both of these substrates require refrigeration and are subject to spoiling. Our research was designed to evaluate whether agar models would be superior to traditional Gelatine models in their sustainability and whether they would produce ultrasound images adequate for training.
Methods: Agar models of varying formulas (percent agar by weight with certain additives varied) were tested for acceptable fidelity to real tissue, ultrasound image quality, and durability compared to gelatine models and human tissue.
Results: A five percent by-mass agar model augmented with small amounts of suspended wheat flour presented as a model that could generate an ultrasound image that remarkably resembled that of real tissue. This agar model does not require refrigeration, is resistant to spoiling and desiccation, mimics tissue texture well, is durable enough to withstand high-volume training, and can be recycled to make new models.
Conclusion: Agar phantoms are easy to make, do not require refrigeration, and have multiple distinct advantages over gelatine models for ultrasound training in austere conditions.

Introduction: L'échographie est une technique qui peut être utilisée pour renforcer les procédures et viser à accroître leur sécurité et leur efficacité, mais elle exige que les professionnels de la santé soient formés à l'utilisation de cette modalité d'imagerie avant sa mise en œuvre. Le coût des fantômes industriels étant extrêmement élevé, les alternatives artisanales représentent des substituts répandus. La gélatine est couramment utilisée comme matrice pour mettre en suspension des produits analogues et imiter des tissus, mais d'autres substrats tels que de la viande hachée peut également être utilisés. Ces deux substrats doivent être réfrigérés et sont sujets à une détérioration. Notre étude visait à évaluer si les modèles utilisant l'agar-agar pourraient être supérieurs aux modèles traditionnels en gélatine en termes de durabilité et s'ils pouvaient produire des images échographiques adéquates pour la formation.
Méthodes: Des modèles utilisant l'agar-agar de formules différentes (variation du pourcentage d'agar-agar par rapport au poids avec certains additifs) ont été testés pour déterminer le degré de fidélité acceptable par rapport au tissu réel, la qualité d'image échographique, et la durabilité par rapport aux modèles de gélatine et aux tissus humains.
Résultats: Un modèle utilisant l'agar-agar à cinq pour cent par masse, renforcé de petites quantités de farine de blé en suspension, s'est avéré capable de générer une image échographique ressemblant de façon remarquable à un tissu réel. Ce modèle utilisant l'agar-agar ne nécessite pas de réfrigération, est résistant à la détérioration et à la dessiccation, imite bien la texture des tissus, est assez durable pour résister à un grand nombre de formations, et peut être recyclé pour fabriquer de nouveaux modèles.
Conclusion: Les fantômes utilisant l'agar-agar sont faciles à faire, ne nécessitent pas de réfrigération et présentent plusieurs avantages distincts par rapport aux modèles en gélatine pour la formation à l'échographie dans des conditions austères.

African relevance

- Agar is a promising material for constructing ultrasound training models, as it does not require refrigeration, resists melting and spoilage, and may be reused.
- Agar models provide images similar to real tissue and commonly used gelatine models while also withstanding more punctures than gelatine models of similar density for venepuncture.

Introduction

Ultrasound is a technique that can be employed to great effect in the assessment of and treatment of patients, especially in emergent situations. As an example, protocols like the Focused Assessment with Sonography in Trauma (FAST) exam are widely used to screen patients for injuries that would otherwise not be evident, and possibly missed. With increased portability and decreasing costs, ultrasound machines provide quality images in many places where they are the only immediate imaging modality available.[1,2] Ultrasound can also augment

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Peer review under responsibility of African Federation for Emergency Medicine.

http://dx.doi.org/10.1016/j.afjem.2015.09.003

procedures like intravenous (IV) catheter placement, paracentesis or thoracentesis and central line placement to increase the procedure's efficacy and safety.[3] This considered, training providers to appropriately utilise ultrasound before introducing it as a part of the standard of care is necessary.

Yet, one of the main barriers noted amongst practitioners in low- and middle-income countries has been access to training.[4] Utilisation of realistic models has been shown to increase the competency of providers using ultrasound to augment standard of care treatment,[5] however, realistic models, also called phantoms, can be cost prohibitive.[6] Many programs create homemade phantoms to save on the cost of procuring commercially made models. However, most homemade phantoms lack durability and many are made of perishable materials that can only be kept for a short time before spoiling.[7–12]

Many homemade phantoms are constructed from a gelatine formula with particulate suspension (e.g. flour or soluble fibre medications) to increase echogenicity. However, gelatine requires refrigeration, both to set the model when poured and to minimise spoilage. The use of Agar-Agar (henceforth called agar) in place of gelatine (henceforth called gel) may provide advantages in durability, ability to hot-set without refrigeration, reusability, and mimicry of human tissue. This research sought to demonstrate feasibility of hot-set, spoilage resistant agar models in constructing low-cost ultrasonographic training models as an alternative to commonly used gelatine models.

Methods

Model formulas were created to produce models with a percent-agar by weight formula (e.g. 10% agar by-weight). The appropriate amount of dry agar powder (i.e. 900 g/cm^2 strength, 38 g for a 5% model) was mixed into 750 mL of cold distilled water until the powder homogenised in suspension (Table 1).

This mixture was brought to a light boil for about five minutes or until the agar solubilised under periodic stirring. Additives (e.g. wheat flour, dyes, ethanol) were mixed in at this stage if required. Model pouring was done in two stages: the first pour set a base for the vessel analogues to be placed upon, and the second pour created a cap to overlie the vessels and act as the tissue analogue. About 300 mL of hot mix was poured into a standard container (8.5″Lx 6″Wx 2″D) to set the base, which set at room temperature (82 °F/28 °C) in about 15–18 min. During this time, the remaining hot mix was kept hot to prevent solidification.

Vessel analogues were created using a variety of water-filled Penrose drains and long latex balloons. These analogues were placed onto the set agar base before the cap was poured. The remaining hot mix, approximately 450 mL, was poured as the cap over the analogues and allowed to set for another 15–20 min. The cap is intended to place about 1–2 cm of agar between the surface of the vessel analogue and the surface of the cap. A nitrile glove with fingers cut off and split down the thumb-side to create a single nitrile sheet was used to cover the surface of the model to simulate skin and to provide a completely opaque layer to obscure the placement of objects in the model. Models were stored in a refrigerator to increase their longevity.

Agar models could be made using a microwave in addition to a stovetop. The same agar slurry was made to the desired percent by-mass and portioned into two equal components. The fractions were microwaved separately and used to pour the base and cap. Complete solubilisation of the agar took about four minutes in a 1.58 kW microwave, with stirring every 45–60 s to prevent settling out of the agar suspension. Volume loss from heating was minimal and estimated to be 5–10 mLs. No physical property discrepancies were noted between the microwave and stovetop agar models.

Agar matrix can be melted down and reused to create new models using either microwave or stovetop methods. Careful heating re-liquefies the matrix and allows the model to be re-poured, with its vessel analogues recycled or replaced as needed. Volume loss during recycling can be compensated for adding the volume of water that was lost during heating.

One-quarter teaspoon of red dye and one teaspoon of wheat flour were tested as possible additives to increase the opacity in separate 5% agar models. Ethanol was tested as a de-gassing agent to remove the bubbles observed in the

Table 1 The optimal recipe and steps needed to make one 5% agar phantom.

Materials	Water* (750 mL) Agar 900 g/cm^2 (38 g) Latex tube/Analogues Flour (1 teaspoon) Stove/Microwave
Steps	Mix 750 mL of cold water with 38 g of 900 g/cm^2 agar gel Stir until agar is suspended in water without clumps Briefly bring mixture to boil, stirring periodically Sprinkle 1 teaspoon of flour into mix, trying to avoid clumping Stir flour into mix until homogenised Using about half of the prepared mix, pour the base layer into mold Let set at room temperature for 20 min Prepare vessel analogues (tie ends and fill with water) Place analogues on base and pour remaining mix over them as the cap layer Let set at room temperature for 20 min (add glove layer if desired)

* Water cannot be boiled before addition of agar or the powder will irreversibly clump.