Prolonging the Shelf Life of Homemade Gelatin Ultrasound Phantoms

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Abstract

A significant limitation of homemade phantoms is shelf life. Our goal was to compare the impact on shelf life of easily obtained additives. Fifteen additives were mixed into a gelatin-psyllium hydrophilic mucilloid fiber phantom; three of these additives were used as a layer on top of the phantom. The mixtures were stored in the refrigerator and at room temperature. The samples were evaluated daily for microbial growth and phantom degradation. A 4% of chlorhexidine gluconate layer on top of the phantom quickly made the phantom unusable. The addition of benzoic acid and bleach to the mixture negatively affected phantom appearance with ultrasound imaging. The addition of household bleach or 4% chlorhexidine gluconate to the mixture or a 10% povidone-iodine layer on top of the phantom was the best way to preserve samples stored at room temperature. The refrigerated sample outlasted the paired room temperature sample in every case, with most room temperature samples becoming unusable by day 10 and most refrigerated samples lasting past 50 days.

Keywords: Education, phantom preservation, simulation, ultrasound phantom

Introduction

Correctly using ultrasound as a diagnostic tool requires significant training. The use of ultrasound-simulation models (i.e., phantoms) allows users to gain experience in seeing normal and abnormal findings before performing ultrasound scans on patients. In addition, ultrasound-guided procedures require expertise and coordination which can be gained through practice on phantoms.[1] There are many commercially available phantoms, but these are often cost-prohibitive and are not customizable. As a result, a large number of homemade phantoms have been created to mimic a variety of anatomical structures and pathologic conditions. Phantoms are constructed using a variety of materials, but a gelatin-psyllium hydrophilic mucilloid fiber mixture is the most common.

One of the main limitations of homemade phantoms is longevity. If left uncovered at room temperature, phantoms can last from a few days to a few weeks.[2,3] Gelatin-psyllium hydrophilic mucilloid fiber phantoms will desiccate over time, but the main limitation to long-term use is microbial growth on or within the phantom.[4] Several studies have tried using refrigeration, which can increase the use of phantoms from around 2 days to 1–2 months.[2,3,5-10] Other studies have used additives in their preparations. Many of these additives, such as phenol,[11,12] formalin,[5] thimerosal,[13,14] benzalkonium chloride,[15] and merthiolate,[16] are expensive, toxic, difficult to obtain, and require special equipment (such as fume hoods) for safe use. Some safer and more easily obtainable additives such as betadine,[3] chlorhexidine,[17-19] and ethanol[20] have been used. In particular, Zerth *et al*. showed longevity of over 2 months with the combination of betadine and refrigeration.

Because many of the gelatin-psyllium hydrophilic mucilloid fiber phantoms are made in home kitchens, we examine the effect on phantom longevity of several inexpensive and easily accessible additives within a gelatin-psyllium hydrophilic mucilloid fiber-based medium stored at room temperature and in refrigeration.

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Materials and Methods

This study was exempt from ethical approval and informed consent. To make the phantom samples, 100 mL water was combined with one tablespoon of unflavored gelatin (Equate, Bentonville, AR), stirred until gelatin was suspended, and heated over low heat until the gelatin dissolved. Then, one tablespoon of sugar-free psyllium hydrophilic mucilloid fiber (Equate, Bentonville, AR) was added and stirred until evenly suspended. This mixture was used as a control. To create experimental samples, additives were combined with 100 mL of the gelatin-psyllium hydrophilic mucilloid fiber mixture as listed in Table 1. The 100 mL mixture containing the additive was divided into two 2 Oz plastic containers with tightly sealing lids. One was kept at room temperature ~22°C (Sample #) and one was kept in a kitchen refrigerator at ~4°C (Sample #R). Both samples were stored and covered with lids. All samples were checked daily to evaluate for microbial growth or degradation. The planned observation period was 30 days but was extended to 50 days because the refrigerated samples had not begun to degrade or show any microbial growth at 30 days.

Ultrasound evaluation of the samples was performed using a Zonare Z.One Pro machine with a linear probe with a frequency range of 3–8 megahertz (model L8-3).

Results

Some of the additives changed the color of the phantom [Figure 1]; color change did not correspond to a change in the quality of ultrasound image [Figure 2]. Three additives affected the composition of the phantom: benzoic acid (#3/#3R), bleach (#9/#9R), and 4% chlorhexidine gluconate layer (#18/#18R). The benzoic acid (#3/#3R) did not dissolve well in the gelatin-psyllium mixture and created large clumps of material suspended in the colloid which were visible on ultrasound imaging [Figure 2]. The addition of bleach (#9/#9R) to the colloid created air bubbles that significantly limited ultrasound imaging [Figure 2]. The 4% of chlorhexidine gluconate layer (#18/#18R) dissolved and liquified the phantom making it unusable before the first observation point. While magnesium sulfate (#16/#16R) did not dissolve easily and left visible clumps in the colloid, these clumps did not affect ultrasound imaging [Figure 2].

Most of the room temperature samples were unusable by day 10 of observation. The first room temperature samples to show

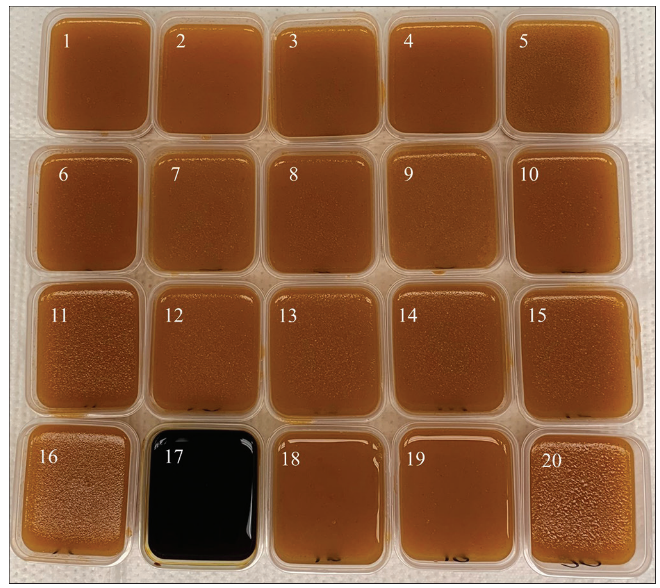

Figure 1: Gross appearance of samples mixed with additives

Table 1: List of additives including amount of additive used and manufacturer

Sample	Additive	Amount	Manufacturer
#1	None (control)		
#2	Ascorbic acid	1/4 (tsp)	The Barry Farm, Wapakoneta, OH
#3	Benzoic acid	1/4 (tsp)	Glycerin Suppliers, Houston, TX
#4	Citric acid	1/4 (tsp)	Milliard Brands, Lakewood, NJ
#5	Potassium sorbate	1/4 (tsp)	North Mountain Supply,
#6	10% povidone-iodine	5 (ml)	CareFusion, Vernon Hills, IL
#7	4% chlorhexidine gluconate	5 (ml)	SC Johnson Professional, Charlotte, NC
#8	0.13% benzalkonium chloride	5 (ml)	Johnson & Johnson, Skillman, NJ
#9	Household bleach	5 (ml)	
#10	Distilled white vinegar 5% acidity	5 (ml)	Walmart, Bentonville, AR
#11	Table salt	1/4 (tsp)	ALDI Inc., Batavia, IL
#12	Ball fruit-fresh	1/4 (tsp)	Rubbermaid Inc., Atlanta, GA
#13	70% isopropyl alcohol	5 (ml)	Vi-Jon, Smyrna, TN
#14	50% isopropyl alcohol	5 (ml)	H.E.B, San Antonio, TX
#15	10% acetone	5 (ml)	Walmart, Bentonville, AR
#16	Magnesium sulfate (Epsom salt)	1/4 (tsp)	Target Corporation, Minneapolis, MN
#17	10% povidone-iodine	Layer on top	CareFusion, Vernon Hills, IL
#18	4% chlorhexidine gluconate	Layer on top	SC Johnson Professional, Charlotte, NC
#19	0.13% benzalkonium chloride	Layer on top	Johnson and Johnson, Skillman, NJ
#20	None (control)		

microbial growths were Ball fruit-fresh (#12) and magnesium sulfate (#16), both on day 4 [Figure 3]. Room temperature 50% isopropyl alcohol (#14) had growth the following day. Both room temperature control samples (#1, #20) followed shortly afterward, with growth on days 6 and 7, respectively. These were rapidly followed by microbial growth on samples containing ascorbic acid (#2), benzoic acid (#3), citric acid (#4), potassium sorbate (#5), 10% povidone-iodine (#6), 0.13% benzalkonium chloride mixed (#8), distilled white vinegar 5% acidity (#10), 70% isopropyl alcohol (#13), 10% acetone (#15), and 0.13% benzalkonium chloride topped (#19), all perishing into foul smelly gelatin over the next 3 days. Room temperature table salt mixture (#11) had white growth on the 11th day of observation. The three remaining room temperature phantoms (household bleach [#9], 10% povidone-iodine topped [#17], and 4% chlorhexidine gluconate mixed [#7]) lasted the longest, eventually decaying on days 20, 24, and 33, respectively.

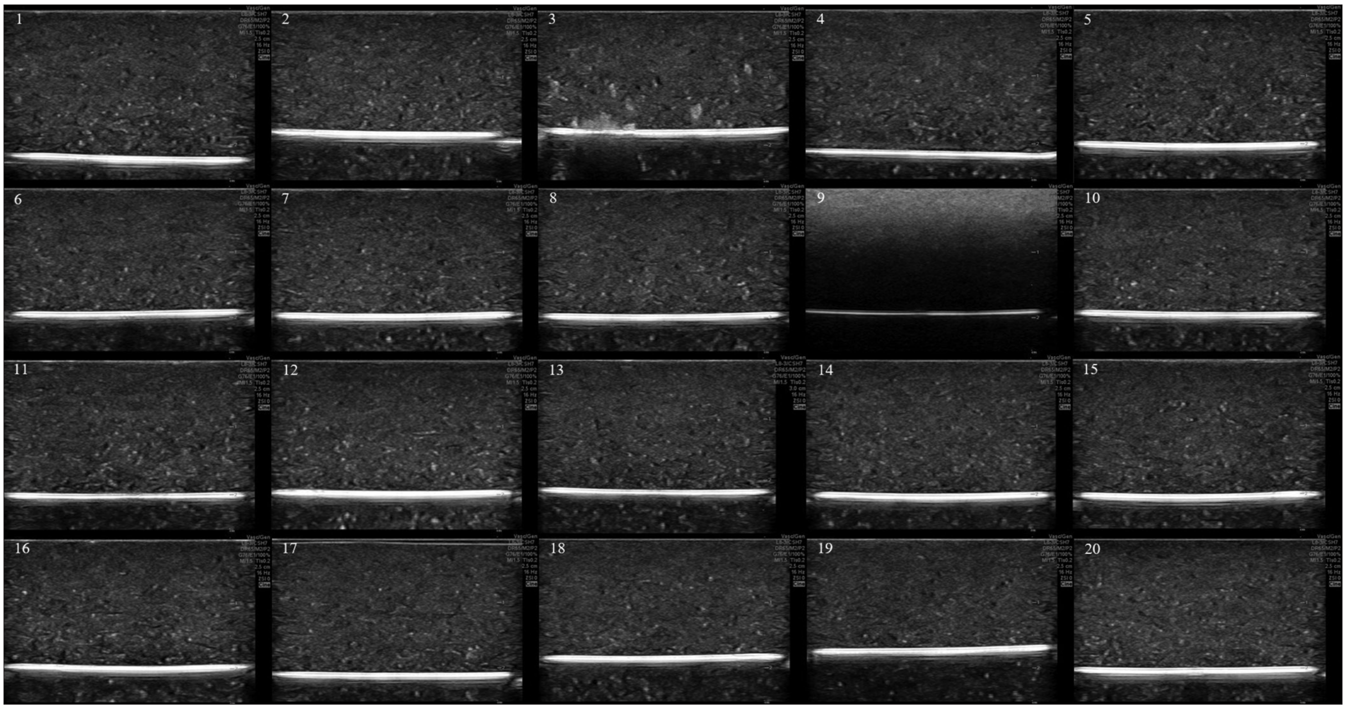

Figure 2: Sonographic appearance of samples mixed with additives

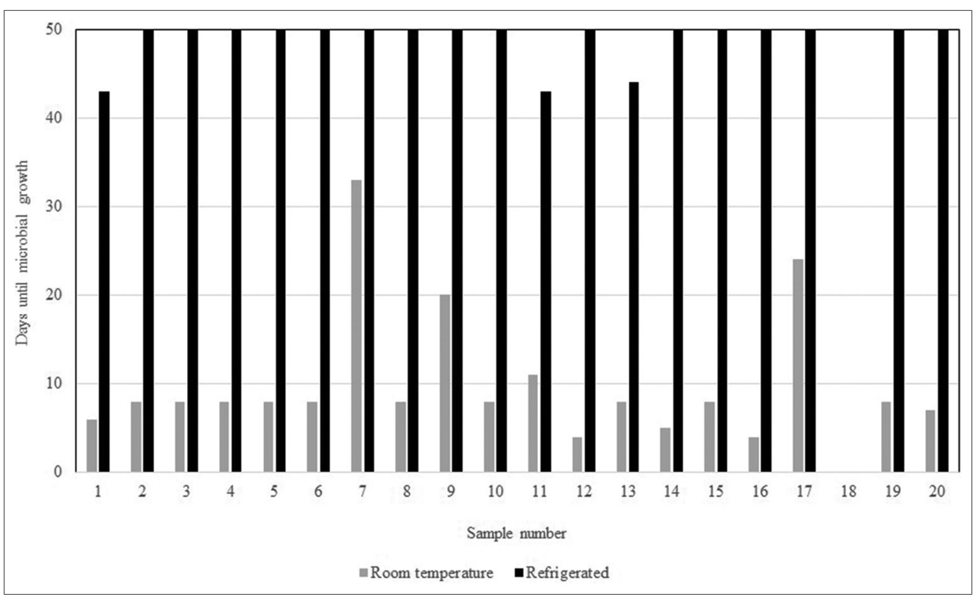

Figure 3: Days until samples showed microbial growth (room temperature [gray] compared to refrigerated [black]). Sample #18 and #18R were unusable due to degradation by the chlorhexidine gluconate layer. Refrigerated samples lasted significantly longer than paired room-temperature samples (46.5 days, standard deviation 11.2 vs. 9.7 days, standard deviation 7.6) ($P < 0.001$)

In all 19 usable sample pairs, the mean usable days of the refrigerated phantoms (9.7, standard deviation 7.6) was significantly longer than the corresponding phantom stored at room temperature (46.5, standard deviation 11.2) ($P < 0.001$). A refrigerated control (#1R), as well as refrigerated table salt (#11R), were the first samples to decay on day 43. The phantom containing 70% of isopropyl alcohol (#13R) was the only other refrigerated specimen to develop microbial growth, doing so on day 44. By the end of 50 days of observation, the refrigerated phantoms had dehydrated to the point that they were no longer usable, and thus measurement was discontinued.

Discussion

Phantoms are used for teaching a variety of ultrasound skills and pathologies. Commercial phantoms exist but are expensive. Many inexpensive homemade phantoms have been created, but they take time to create and do not have a long shelf life. Extending the lifespan of these phantoms would give educators more flexibility in the timing of making the phantoms before a session as well as potentially allowing the reuse of phantoms for multiple sessions that are spread over time. Several solutions for prolonging the lifespans of these phantoms have been mentioned in publications detailing the construction of phantoms,[2,3,5-20] but there has been no direct comparison of preservation methods. We examined the effect on phantom longevity of several inexpensive and easily accessible additives within a gelatin-psyllium hydrophilic mucilloid fiber-based medium at room temperature and under refrigeration. These additives were chosen because they are easily accessible, inexpensive, and safe to use in a home kitchen.

Refrigeration was the main factor in prolonging the lifespan of the phantoms. Refrigerated samples lasted for well over a month, vastly outlasting their nonrefrigerated counterparts. Even the least perishable of the room temperature phantom samples could not outlast the most perishable of the refrigerated samples. Thus, refrigeration is largely necessary if the use of phantom is planned for 3 weeks or more after its creation. If refrigeration is impossible, room temperature storage of phantoms created with 4% chlorhexidine gluconate or topped with a layer of 10% povidone-iodine can prolong the shelf life of a phantom for at least 24 days. However, it is possible that the change in color delayed the observer's ability to recognize microbial growth on these phantoms, creating a source of error. Bleach also allowed the phantom to last longer at room temperature, but it created small air bubbles that blocked ultrasound wave transmission, thus making the phantom unusable.

While refrigeration prolongs the usability of the phantoms, these appliances create dehumidifying conditions which can cause the phantoms to desiccate leading to degradation of the quality of ultrasound imaging that can be obtained with them. Our study utilized tight-fitting lids on all 40 samples to reduce the effects of desiccation as well as contamination. Condensation was observed on the lids of all refrigerated samples by the end of the 1st month of observation, suggesting that the phantoms were beginning to dry out. Without the lids, it is likely that the phantoms will desiccate more quickly. For smaller phantoms that easily fit into containers with lids, this may not provide such a large obstacle. However, for larger or oddly shaped phantoms, obtaining lids for protection against the effects of desiccation may not be feasible.

This study has several limitations. Our phantoms were covered and stored immediately after creation. It is not known how the use of phantom for an educational session will affect microbial growth. Presumably, the use of phantom would accelerate microbial growth, limiting the interval it can be stored before subsequent use. In addition, we did not evaluate the effect of various concentrations of the additives on shelf life. The concentrations that we used in this study far exceeded the typical concentrations that are used when these compounds are added to food.

Conclusion

We have shown that refrigeration is the best way to preserve gelatin-psyllium hydrophilic mucilloid fiber ultrasound phantoms, extending the life of the phantom for close to 6 weeks with many additives extending this even longer. When refrigeration is not possible, adding 4% chlorhexidine gluconate to the phantom mixture or topping the phantom with a layer of 10% povidone-iodine can allow the phantom to last at least 3 weeks.

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Conflicts of interest

There are no conflicts of interest.

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