UTSouthwestern
Harold C. Simmons
Comprehensive Cancer Center
Radiation Oncology

Developing a Novel 3D Print-Based Phantom to Facilitate Ultrasound-Guided Interstitial Gynecologic Brachytherapy Simulation Training

Z. Xiong, D. Parsons, Y. Zhong, B. Gannavarapu, C. Nwachukwu, M. Folkert, X. Jia, P. Medin, K. Albuquerque, B. Hrycushko, T. Chiu

Department of Radiation Oncology, University of Texas Southwestern Medical Center, Dallas, TX

JULY 12–16 2020 VIRTUAL
Improving Health QUALITY, Increasing Global IMPACT
JOINT AAPM | COMP MEETING
EASTERN TIME [GMT-4]

INTRODUCTION

High dose rate (HDR) brachytherapy is a well-established treatment for cervical cancer, with favorable cost, toxicity, and quality of life profiles. an interstitial procedure is necessary in these situations. This type of procedure often requires intensive training or accumulated experience to achieve ideal needle placement for desire a dose distribution.

Although not a substitute, the gynecologic brachytherapy simulation labs could be beneficial in supplementing experience from patient caseloads for physicians. Medical physicists and the rest of the brachytherapy team can also benefit from familiarity in equipment handling and treatment planning as well as in determining failure modes and effects.

To establish a successful training program requires a simulation environment and sufficient training equipment. Although there are phantoms for many different anatomic regions, there is no suitable commercial gynecologic ultrasound compatible phantom on the market for an interstitial procedure. An intensive literature search revealed no robust in-house gynecologic phantom for an interstitial procedure. In the clinic, a phantom of this nature would be useful for training medical and physics residents in gynecologic brachytherapy, which requires suturing and the ultrasound-guided insertion of needles into the cervix.

AIM

To design and manufacture a cost effective gynecologic phantom to support training opportunities to improve procedure proficiency in ultrasound-guided interstitial gynecologic brachytherapy.

METHOD

- Two materials were tested and evaluated for material selection for gynecologic phantom fabrication, Ecoflex 00-30 silicone, and PVC.
- The phantom was designed in Autodesk Inventor, and comprised of a simulated rectum, vagina, cervix, uterus, bladder, and surrounding tissue.
- Each component was cast in 3D printed molds using an EVO22 3D printer (Airwolf 3D, CA) with acrylonitrile-butadiene-styrene (ABS) filament.
- The phantom's durability, longevity, fabrication time, material cost, and ultrasound image quality were determined.
- The ultrasound-guided gynecologic interstitial brachytherapy simulation study was implemented using a BK 3000 ultrasound system with an E14CL4b transrectal probe for the phantom imaging evaluation.
- The phantom should be transparent to allow external visualization of the suturing process, it should look realistic under ultrasound imaging, it should have realistic tactile and material properties, and it should be reusable. **Figure 1** shows the designs of each major component inside the phantom.

RESULTS

A material speed of sound test was performed using a BK3000 ultrasound system for 10 mm and 30 mm thick slabs of Ecoflex 00-30 silicone and PVC plastic in a water bath. The accuracy of the slabs was controlled using 3D printed molds. Due to the known designed, ultrasound distance measurements were made and the speed of sound was estimated. These are shown in **Table 1**, in which PVC has closer acoustic properties to soft tissue and was chosen for the final phantom design.

The final phantom design was 20x20x10 cm3 using PVC. Anatomic structures were distinguishable on ultrasound images. The rectum, vaginal wall, and uterus were identified as hyperechoic while the water filled bladder was hypoechoic. The thickness of rectum and vaginal walls were measured at 11 and 12.2 mm, respectively. A complete phantom may be fabricated in 2 to 3 hours with material cost for each phantom estimated at $102. Reusable casting accessories are approximated at $108.

The vagina cavity, rectum and bladder inserts were created by using Mold Star 30 silicone. These inserts were designed to hold up the cavity shapes while casting the surrounding tissue using PVC, which are blue components in **Figure2 (B)**. 3D printed ABS molds were made to cast the uterus and rectum with PVC embedded with fine stone powder to create US speckle, shown in **Figure 2(A).** Lastly, PVC was cast into an acrylic casting box until the final phantom height is reached.

Figure 3(A) shows the phantom before the inserts are demolded. The uterus canal was designed at 30 degrees in this prototype. **Figure 3(B)** shows the using ultrasound image for phantom image evaluation.

The ultrasound scans are shown in **Figure 4**. The geometry accuracy was verified and the phantom features highly distinguish with hyperechoic boundaries.

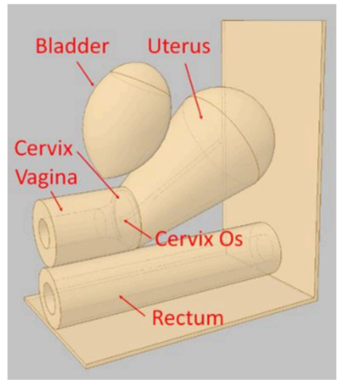

Figure 1: Phantom design containing anatomic simulated rectal cavity, vagina, cervix, uterus, bladder, and surrounding tissue.

Table 1 Speed of sound test results

	Distance (mm)			
Ground Truth	10	30		
	Measured Distance (mm)			
Silicone	15.1	45.7		
PVC	10.9	32.6		
	Estimated Speed of Sound (m/s)			
Silicone	1019.9	1010.9	1015.4	6.3
PVC	1412.8	1417.2	1415.0	3.1

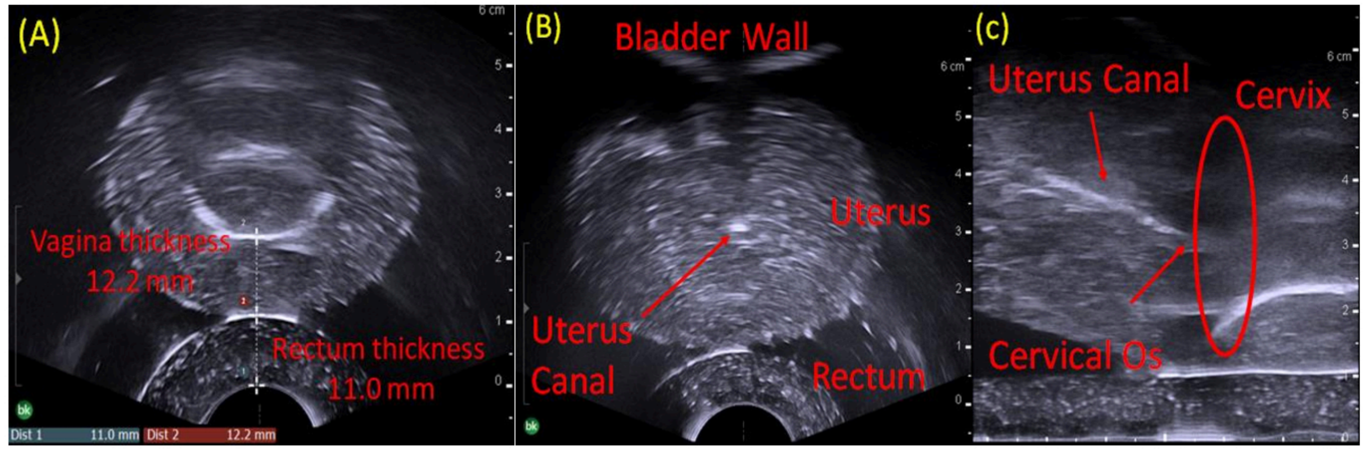

***Figure 4(A).** Geometry verification on rectum and vagian wall thickness. **Figure 4(B)** Axial cross-section of uterus taken with a transrectal ultrasound probe. The uterus and rectum wall show up clearly. The uterus canal shows up as bright line on the US. The bladder wall is also distinguishable. **Figure 4(C)** shows longitudinal view of the ultrasound image, and the junction between vagina, cervix and uterus.*

RESULTS

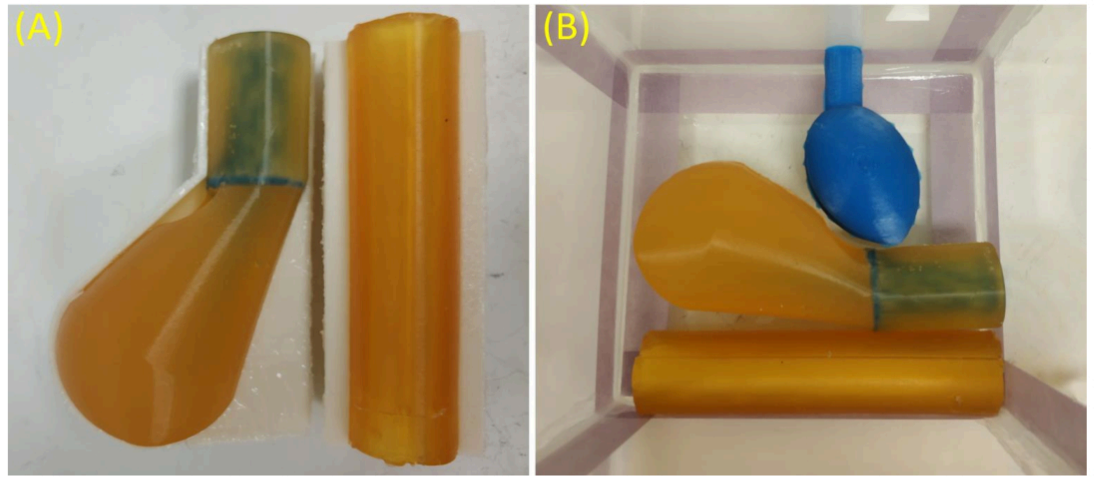

***Figure 2:(A)** Fabricated rectum and combination of uterus, vagina, and cervix components by silicone and PVC; **Figure 2 (B)**. Position of components of gynecologic phantom in an acrylic casting box.*

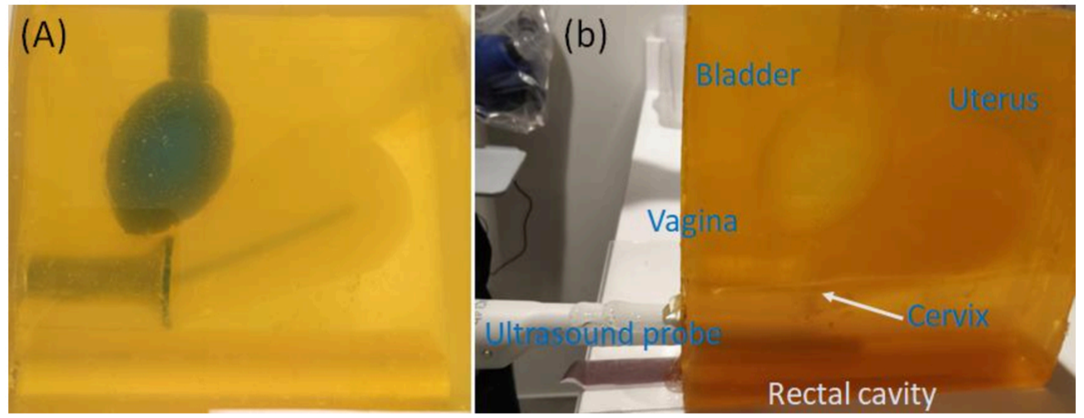

***Figure 3: (A)** The gynecologic components cast by PVC until it reached the final phantom design (20x20x10 cm3); **Figure 3 (B)** the rectum, bladder, vagina and cervix positive were removed, and the bladder was filled by water and using a transrectal ultrasound probe for the phantom imaging evaluation.*

CONCLUSIONS

A novel low-cost ultrasound-based gynecologic phantom was developed by casting PVC into 3D-printed molds. The proposed educational gynecologic phantom is an ideal, cost-effective platform for building confidence in fundamental interstitial brachytherapy procedural skills as a supplement patient caseloads.

CONTACT INFORMATION

Email: Zhenyu.Xiong@utsouthwestern.edu