SEMINAR PAPER PRESENTATION

A training phantom for ultrasound-guided needle insertion and suturing

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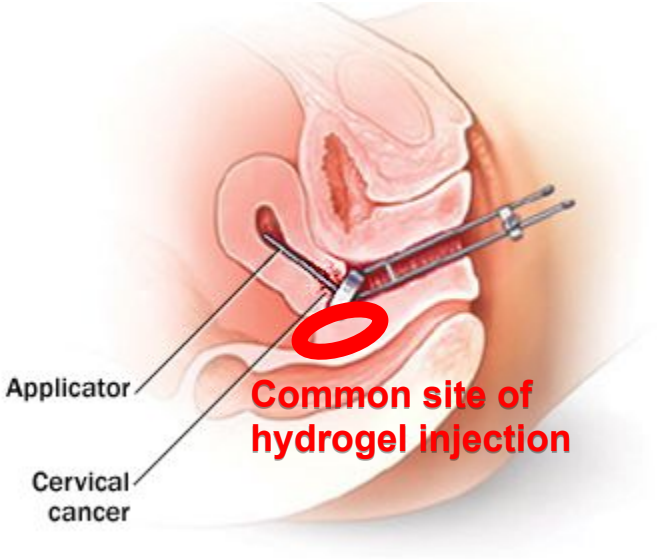
Citation:

Nattagh, Khashayar, et al. "A training phantom for ultrasound-guided needle insertion and suturing." *Brachytherapy* 13.4 (2014): 413-419.

Review of Project Goals

- There is a clear need to **differentiate** the cervical tumor mass from surrounding normal tissues e.g. the rectovaginal septum during brachytherapy.
- Placement of a hydrogel spacer to minimize radiation dose to normal anatomical structures is a challenging procedure, and **inaccurate needle placement can lead to complications such as accidental perforation of the bowel and rectum**.

We want to develop an **ultrasound-compatible phantom** to assist training on **localizing and visualizing a needle** for hydrogel space injection during the preparation of a patient for brachytherapy.



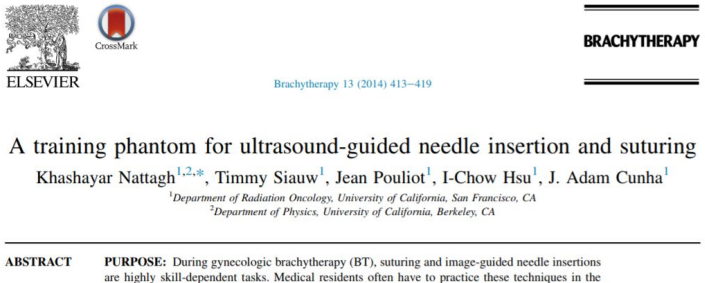
Rationale for Paper Selection

1.
Addresses the **same issue.**

2.
Detailed account of **construction process.**

3.
Framework for evaluating **strength and weaknesses.**

This will be very beneficial as a reference and point of **comparison** for this project's design and testing results.



ELSEVIER

Brachytherapy 13 (2014) 413–419

BRACHYTHERAPY

A training phantom for ultrasound-guided needle insertion and suturing

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ABSTRACT PURPOSE: During gynecologic brachytherapy (BT), suturing and image-guided needle insertions are highly skill-dependent tasks. Medical residents often have to practice these techniques in the

Paper Goals

UCSF Department of Radiation Oncology & Physics @BERKELEY

"The purpose of this study was to design and evaluate a gynecologic gelatin phantom to be used for gynecologic BT (brachytherapy) training."

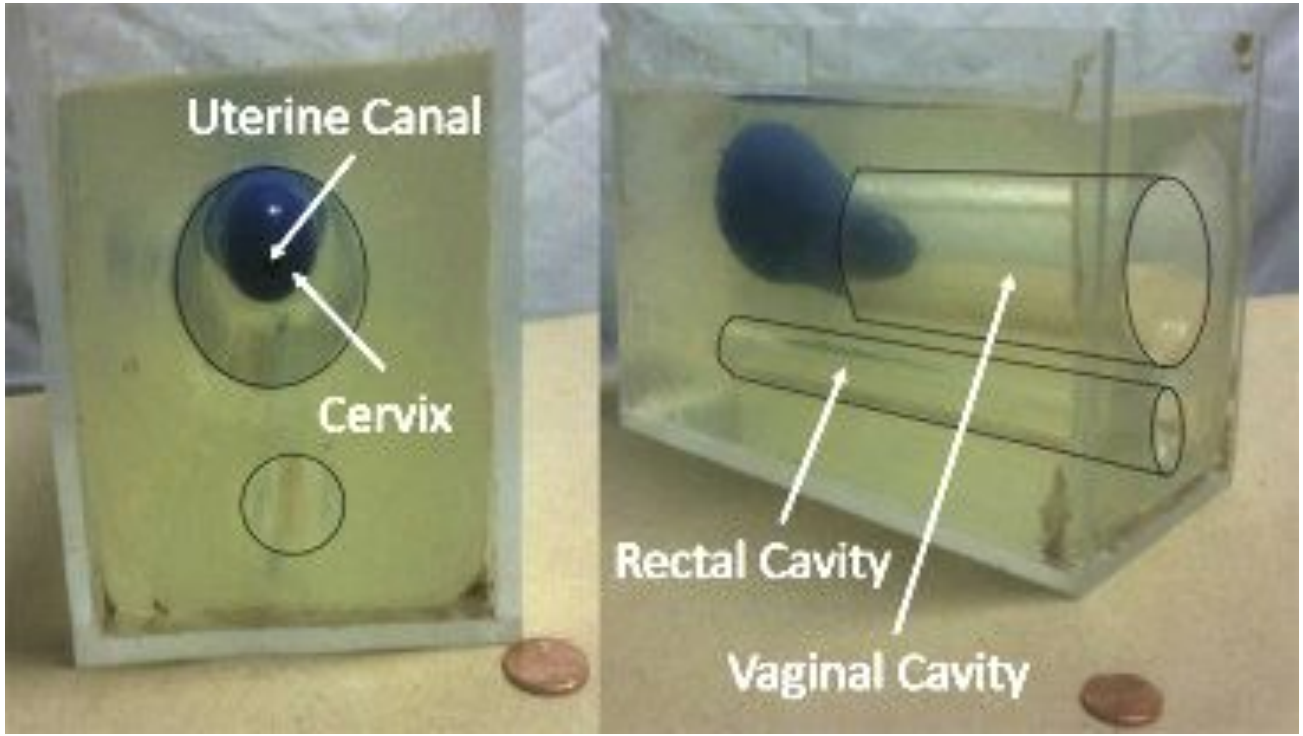
Significance: There are **no existing** gynecologic phantoms that can be constructed in a medical or research laboratory that is useful for training medical residents in gynecologic brachytherapy. This **improves on the traditional learning model,** where residents observe senior physicians within a very limited field of view in a limited number of cases with anatomical variability.

Uses: BT procedures such as the **transrectal US image-guided insertion of needles**, suturing the cervical lip, placing a suture on the vaginal wall to secure a BT tandem, etc.

Specifications:

- Transparent for external visualization
- Realistic contrast under computer tomography (CT)
- and ultrasound (US) imaging.
- Realistic tactile and material properties.
- Resistant to usage and storage.
- BONUS: Cheaper than the costly commercially available phantoms.

Resulting Product



Materials Used

Materials:

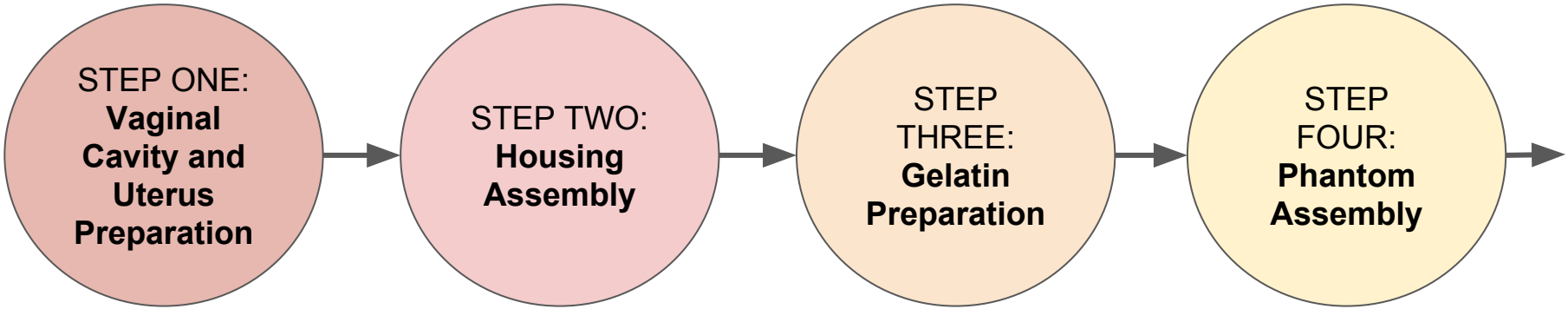
- 2x Acrylic sheet (20.3 cm × 12.7 cm × 0.6 cm).
- Acrylic sheet (10.8 cm × 21.0 cm × 0.6 cm).
- Acrylic sheet (10.8 cm × 12.7 cm × 0.6 cm).
- Acrylic sheet (13 cm × 15 cm × 0.3 cm).
- Cylinder (13 mm dia × 18 cm).
- Cylinder (6 mm dia × 15 cm).
- Cylinder (44 mm dia × 13 cm).
- Fast set acrylic bonding agent, SCIGRIPŽ (IPS Corporation, Gardena, CA).
- **Liquid rubber coating**, Performix Co. (Houston, TX).
- **Industrial grade porcine gelatin**, Sigma-Aldrich Corporation (St. Louis, MO).
- Clay.
- Plastic wrap.
- Water (2 L).
- 70% Ethanol solution.

Equipment:

- Drill.
- **Refrigerator (8°C).**
- Electric stove or similar heating source.
- C-clamps (size/s).
- Computer-aided design (CAD) software*.
- **3D printer*.**
- Stirring spatula.
- 2 L pot.
- Thermometer.

*Optional.

General Procedure: **Manufacture**



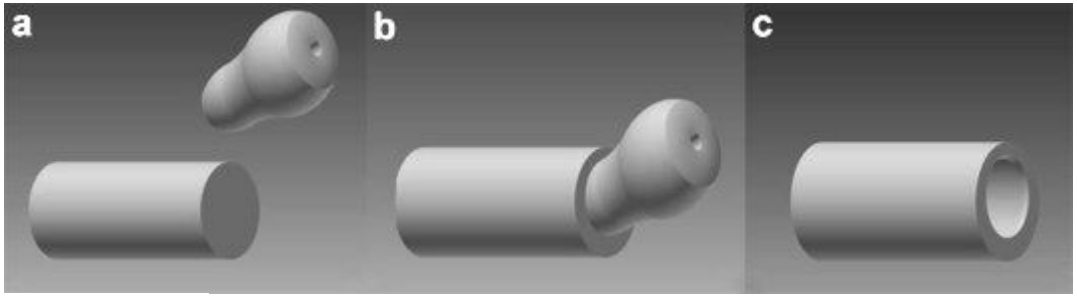
- CAD + 3D Print mold (ZP 150 High Performance composite printing material)
- Gelatin mix= 100 mL H_20:12 g gelatin, 50° C under stirring for over 10 minutes.
- 4.5 hour cooling and refrigeration (8°C).
- Rubber coating on Uterus.

- 5 sided acrylic box.
- Two holes at front for vaginal cavity and rectal cavity.
- Sealed with acrylic bonding agent and clay.

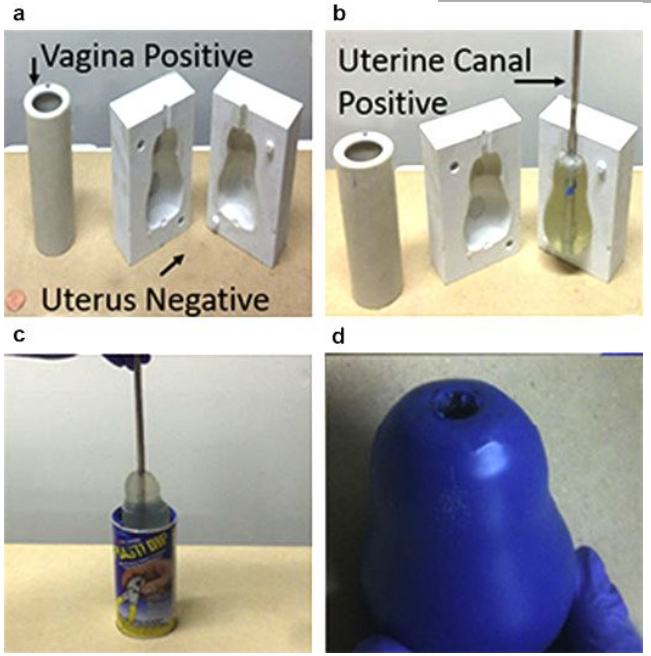
- Gelatin mix= 100 mL H_20:12 g gelatin, 50°C under stirring for over 10 minutes.
- 2 L of gelatin prepared.
- Can add thimerosal for longevity (optional).

- Structures suspended with tight seal in casing.
- Gelatin poured until uterus submerged.
- Cooled for 4 hours then refrigerated for solidifying.
- Structures removed manually and with water.

Images of Manufacturing Process

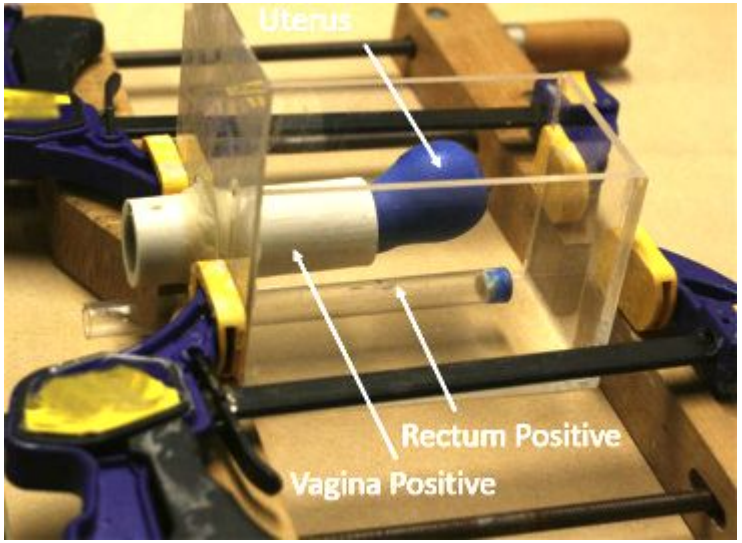


<< (*left*): CAD Models for Vaginal Cavity and Uterus

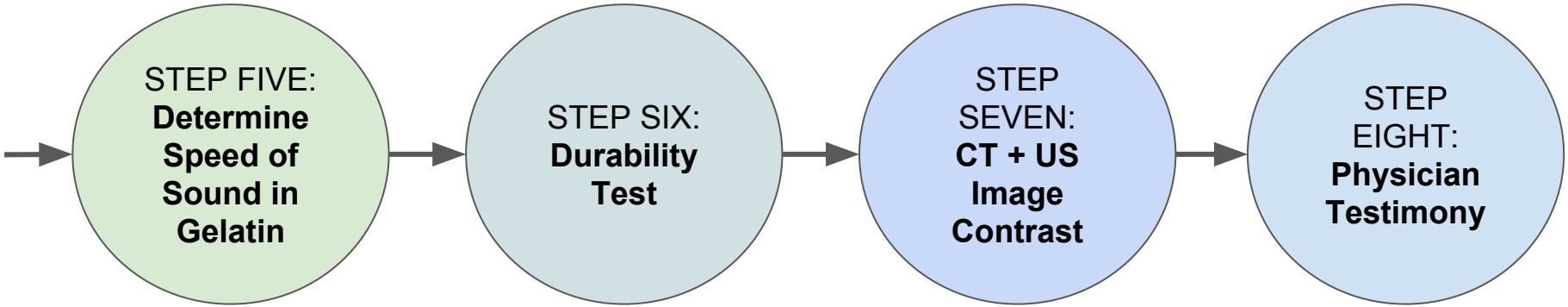


<< (*left top*): 3D Printed molds. (*left bottom*): Coating with Rubber

(*right*) >>: Set-up prior to gelatin insertion.



General Procedure: **Evaluation Strategy**



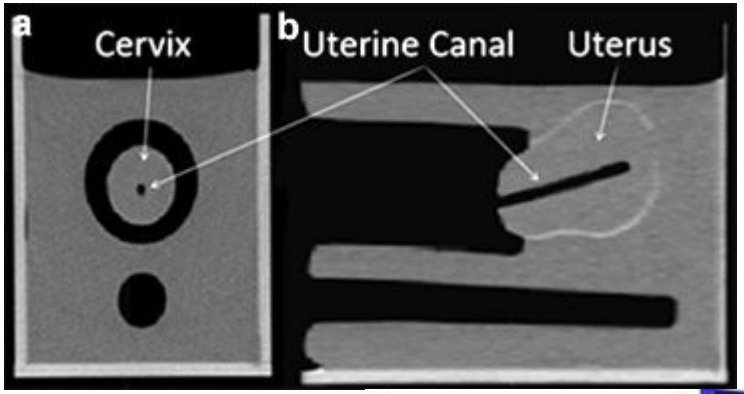
- Pulse echo measurements in water (500 PR Pulser).
- Sample cured gelatin of 5, 15, and 20 mm thickness.
- Placed between 2 ultrasound transducers 67 mm apart, 4.5 MHz center frequency.
- Analog input displayed on 54600 A oscilloscope

- Rectal wall: Transrectal US probe inserted and removed 50 times.
- Cervix: puncture wall 20 times with suture needles.
- Qualitative assessment: fissures/change in texture of gelatin.
- Longevity: Up to 2 mm of gelatin liquefaction.

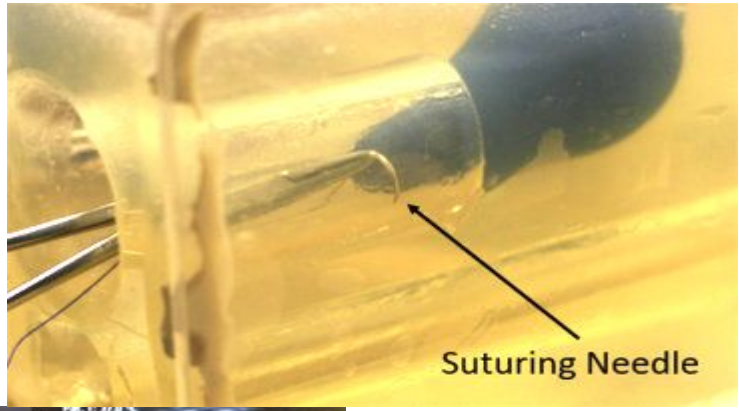
- Siemens SOMATOM Sensation spiral CT (120 kVp)
- BK Medical 2102 Hawk EXL transrectal US Probe
- Qualitative assessment of contrast.

- Used by attending BT physician to demonstrate gynecologic suturing and BT needle insertion to medical residents.
- Qualitative feedback.

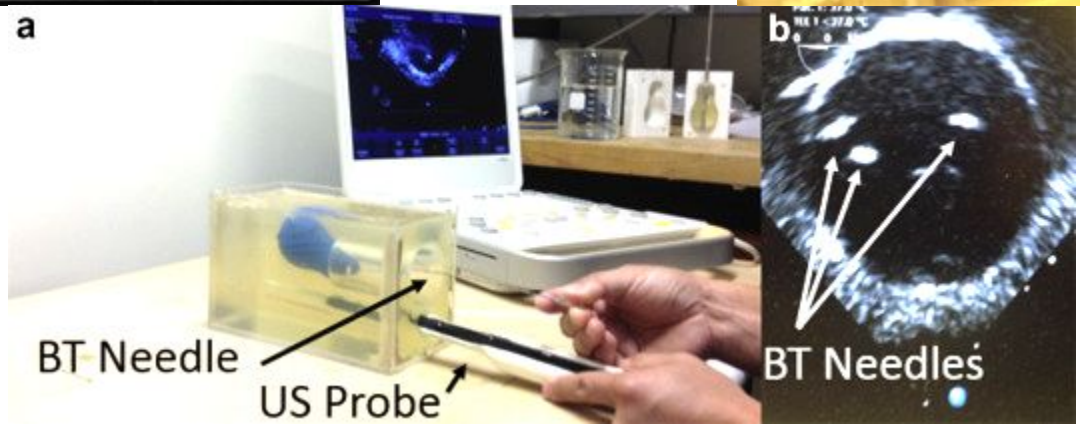
Images of Test Results/Evaluation



<< (*left)*: CT images of the phantom. Axial and sagittal cross sections.

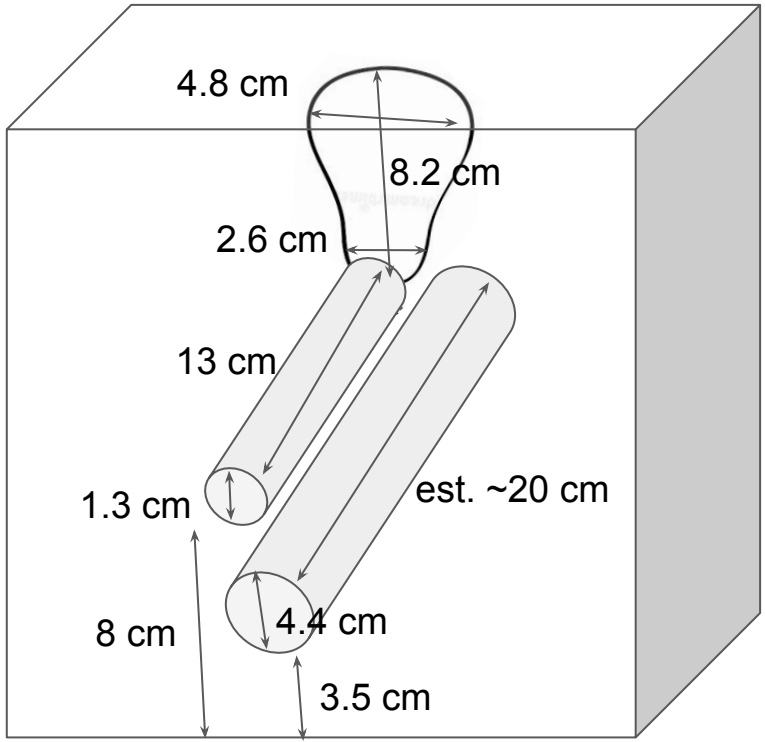


(*right)* >>: Attending brachytherapy physician testing phantom using transrectal ultrasound probe.



^^ (*top)*: Suturing needles were used repeatedly to test durability.

Results:



*"Medical students confirmed that the procedures with the phantom were **realistic**, the phantom helped **increase their skills** in GYN BT, and that they felt **more comfortable** in the operating room **after using the phantom**."*

Measured speed of sound in gelatin:

1495 ~ 1506 m/s

Medium	Velocity (m/sec)
Fat	1450
Water	1480
Soft tissue	1540
Kidney	1560
Blood	1570
Muscle	1580
Bone	4080

Discussion:

DURABILITY:

- Phantom lasted **2 weeks** in refrigeration (8°C). 2mg thimerosal:1 mL liquid gelatin extends lifetime to 6 weeks, but is a Level 3 Health Hazard (~CO, LH_2, $Ca(ClO)_2$, etc.)
- Probings on rectal wall show no degradations. Probing with suturing needle show **slight softening of texture** of phantom cervix. Needle tracks visible on subsequent ultrasound scans.

MANUFACTURE:

- Total Time: 3 hours of active participation and **2 days** including curing time.
- Material cost was **under $200**. Significant component was 3D printing.
- Phantom can be built without CAD/3D Printer through external sources. Alternatively, use sturdy pottery clay/traditional molding. *STL files available upon email request.

PHYSICIAN FEEDBACK*:*

- Suturing was similar to a real case; texture resembles human tissue. However, gelatin was **more fragile** than human tissue and didn't represent regular **uterine motion** during bimanual examination.

FUTURE ENDEAVORS**:**

- **Adjustable parameters**: Modifications of length/ shape, concentration of gelatin, choice of material.
- Possible improvements: Quantitatively determine **material properties** (e.g. acoustic and x-ray attenuation, propagation, backscatter)to adjust to achieve **optimal contrast** for multiple modalities.

Assessment

Purple: Paper
Brown: Design

Strengths	Weaknesses	Relevance
• Paper detailed for repeatability. • Recommended sources for 3D print and alternatives (clay). • Authors willing to provide STL files upon request. • Material used are compatible with medical/research lab environment. • Relatively low cost • Simple geometry.	• No quantitative analysis of imaging. • No detailed analysis of user study -- could compare outcomes. • Not durable (lifetime 2 weeks with refrigeration). • Long curing time. • Needle tracks visible on ultrasound. • No gradation in contrast for CT and ultrasound. • Geometry is not anatomically correct.	• Model phantom for project (standard). • Could look at multi-modality phantom model. • Evaluation protocol. • Adapt for hydrogel injection. • Consider a more durable material to resist reuse. • Can 3D print structures for molding. • Simple geometry is sufficient.

References:

Nattagh, Khashayar, et al. "A training phantom for ultrasound-guided needle insertion and suturing." *Brachytherapy* 13.4 (2014): 413-419.

“Physics of Ultrasound.” *Physics of Ultrasound - Wikiecho*, www.wikiecho.org/wiki/Physics_of_ultrasound.