Ultrasound Needle Guidance for Hydrogel Injection During Cervical Cancer Brachytherapy

Group #18: Tracy Kao (Computer Integrated Surgery II)
Mentors: Carmen Kut, Younsu Kim, Dr. Akila Viswanathan, Dr. Emad Boctor
Mentor Affiliations: Johns Hopkins Hospital Department of Radiation Oncology, Medical Ultrasound Imaging and Intervention Collaboration Lab (MuSiiC Lab)

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Ultrasound-Compatible Female Pelvic Phantom for Hydrogel Spacer Injection during Brachytherapy Training

Group #18: Tracy Kao (Computer Integrated Surgery II)
Mentors: Carmen Kut, Younsu Kim, Dr. Akila Viswanathan, Dr. Emad Boctor
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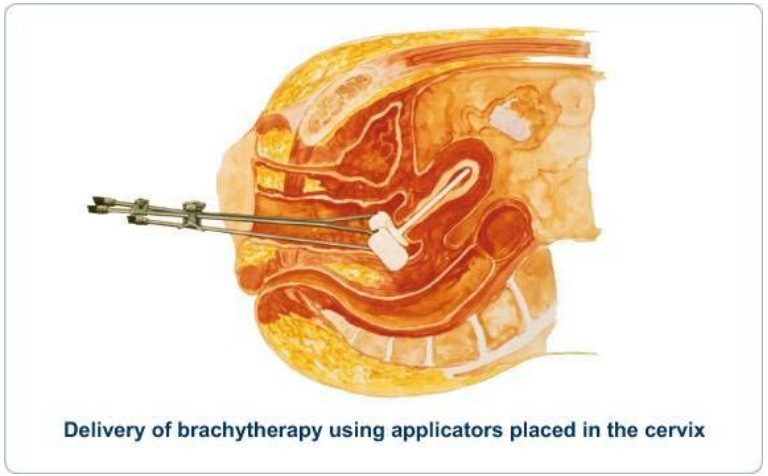
Clinical Need

- American Cancer Society estimates 4,170 women will die from cervical cancer in 2018.
- There is a clear need to **differentiate** the cervical tumor mass from surrounding normal tissues e.g. the rectovaginal septum during brachytherapy.
- In brachytherapy planning, it is routine practice to inject a hydrogel spacer to minimize radiation dose to normal anatomical structures. However, this is a challenging procedure, and **inaccurate needle placement can lead to complications such as accidental perforation of the bowel and rectum**.



Delivery of brachytherapy using applicators placed in the cervix

Problem Statement

We want to develop a method for more **precise localization and/or visualization** of the needle for hydrogel spacer injection under ultrasound image guidance during preparation of patient for brachytherapy procedure.

Problem Statement

~~We want to develop a method for more **precise localization and/or visualization** of the needle for hydrogel spacer injection under ultrasound image guidance during preparation of patient for brachytherapy procedure.~~

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.

“NEEDLE”

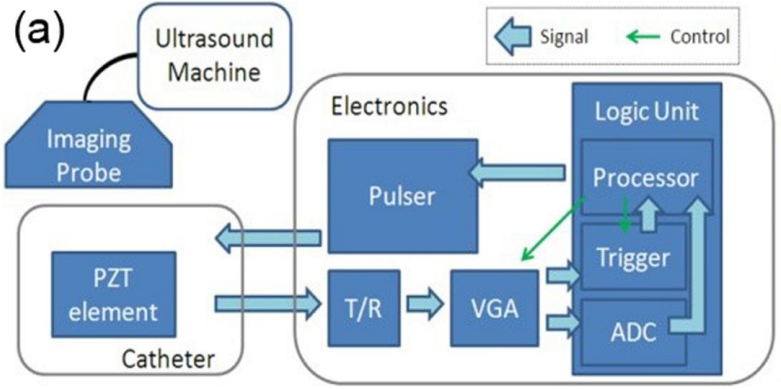
Original Approach and Progress

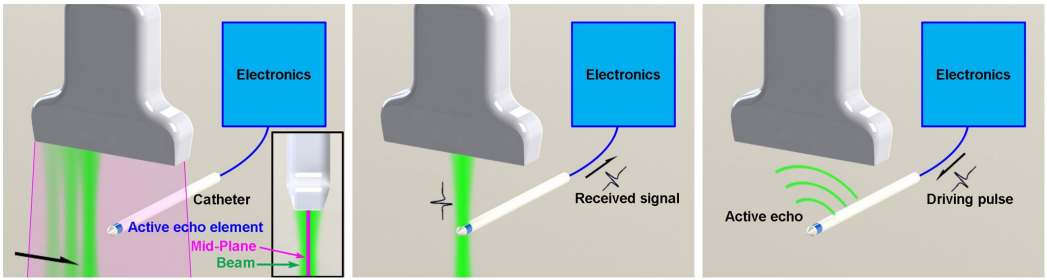
“PHANTOM”

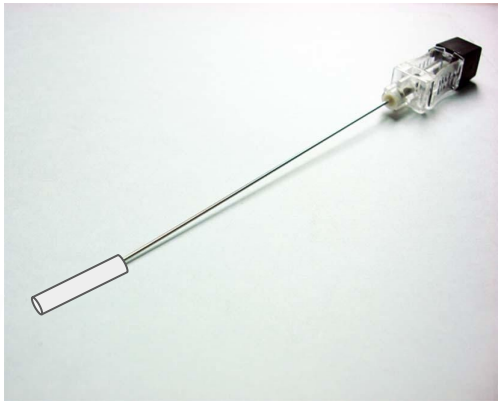
Updated Approach and Progress

Technical Approach

- Adapt Active Ultrasound Pattern Injection System(AUSPIS) for hydrogel needle application.
- Attach piezoelectric element to needle tip for active response to transducer.







NEEDLE

Deliverables & Milestones

- **Minimum:** (By 3/6/3018)
  - Documentation of specifications and initial design concepts.
- **Expected:** (By 3/29/2018)
  - **Development of a hydrogel injection needle prototype adapted for ultrasound compatibility.**
  - Documentation of working prototype design and process.
- **Maximum:** (By 5/10/2018)
  - Design and construction of phantom used to test adapted needle.
  - Documentation of phantom design, construction, and resulting test data.

- Clinical Observation & Clinical Need Evaluation (3/1/2018)
- Initial Design Sketch (3/6/3018)
- Documentation of Specifications and Conceptual Design (3/8/2018)
- **Working prototype that meets specified specifications (3/27/2018)**
- Documentation of working prototype (3/29/2018)
- Choice of compatible ultrasound system (4/5/2018)
- Output ultrasound image pattern (4/17/2018)
- Phantom Construction (4/24/2018)
- Documentation of Phantom Data(5/1/2018)
- Final Report and Presentation (5/10/2018)

Dependencies

* Level of deliverable affected based on previous plan

Level of Deliverable Affected*	Dependency	Proposed Solution	Important Dates	Alternatives	Status
Expected	Hydrogel Needle	Acquire from Clinical Consultant	3/8/3018	Use other needle.	Resolved as of 2/14/2018.
Expected	**Hardware Components**	**Provision by MuSiiC Lab.**	**4/5/2018**	**Place order as budget allows.**	**Provided but insufficient.**
Expected	Access to Lab Environment for Prototype Development	Provision by MuSiiC Lab	3/8/2018	Use currently available lab space.	Resolved as of 3/30/2018. .
Minimum	Compatible Ultrasound System	Provision by MuSiiC Lab (Prioritize TRUS)	4/5/2018	Use abdominal systems.	Resolved as of 4/14/2018.
Expected, Minimum, Maximum	Financial Resources	Propose budget to mentors.	3/6/2018	Finance by self.	Resolved as of 3/30/2018

Progress: Incomplete Prototype

Documentations for Completion

- Background Document on Clinical Need
- Needle Specifications and Conceptual Design
- Needle Manufacturing and Testing Plan

Lessons Learned

- Get a budget as early as possible.
- Always account for failure.
- Plan for more iterations and practice, especially with unfamiliar processes.

Updated Deliverables

Level	Item (and Date)
Minimum	• Documentation: Needle Design • Documentation: Phantom Design
Expected	• Documentation: Needle Manufacturing and Testing Plan • Documentation: Phantom Manufacturing and Testing Plan • Simple Phantom (Geometric Shape, Realistic Texture) • ~~Working prototype of Needle~~
Maximum	• Simple Phantom (Geometric Shape, Ultrasound Compatible) • Mold Used to Manufacture Phantom • Documentation: Phantom Manufacturing and Test Results • ~~Documentation: Needle Test Data~~

Milestones (Dates)

Completed

- Clinical Observation & Clinical Need Evaluation (3/1/2018)
- Discussed Project Goals with All Mentors (3/6/2018)
- Documentation: Initial Design Sketch of Needle (3/8/3018)
- Documentation: Needle Specifications (3/27/2018)
- Attempt 1st Needle Prototype (4/11/2018)
- Choice of Ultrasound System (4/14/2018)

Newly Added

- Further Clinical Observations (4/23/2018)
- Documentation: Phantom Design and Manufacturing Plan (4/23/2018)
- 1st Geometric Phantom (4/20/2018)
- 2nd Geometric Phantom (4/27/2018)
- Documentation: Phantom Test with Needle (5/4/2018)
- Documentation: Phantom Test Data on Ultrasound System (5/7/2018)
- Finalized Wiki Page with All Documentation (5/10/2018)

Approach

Phantom material: Soft Plastisol (mixed in ratio)

Mold material: Silicone (Mold); Glass; Aluminum

Acoustic Properties: Glass microbeads (of various concentrations)

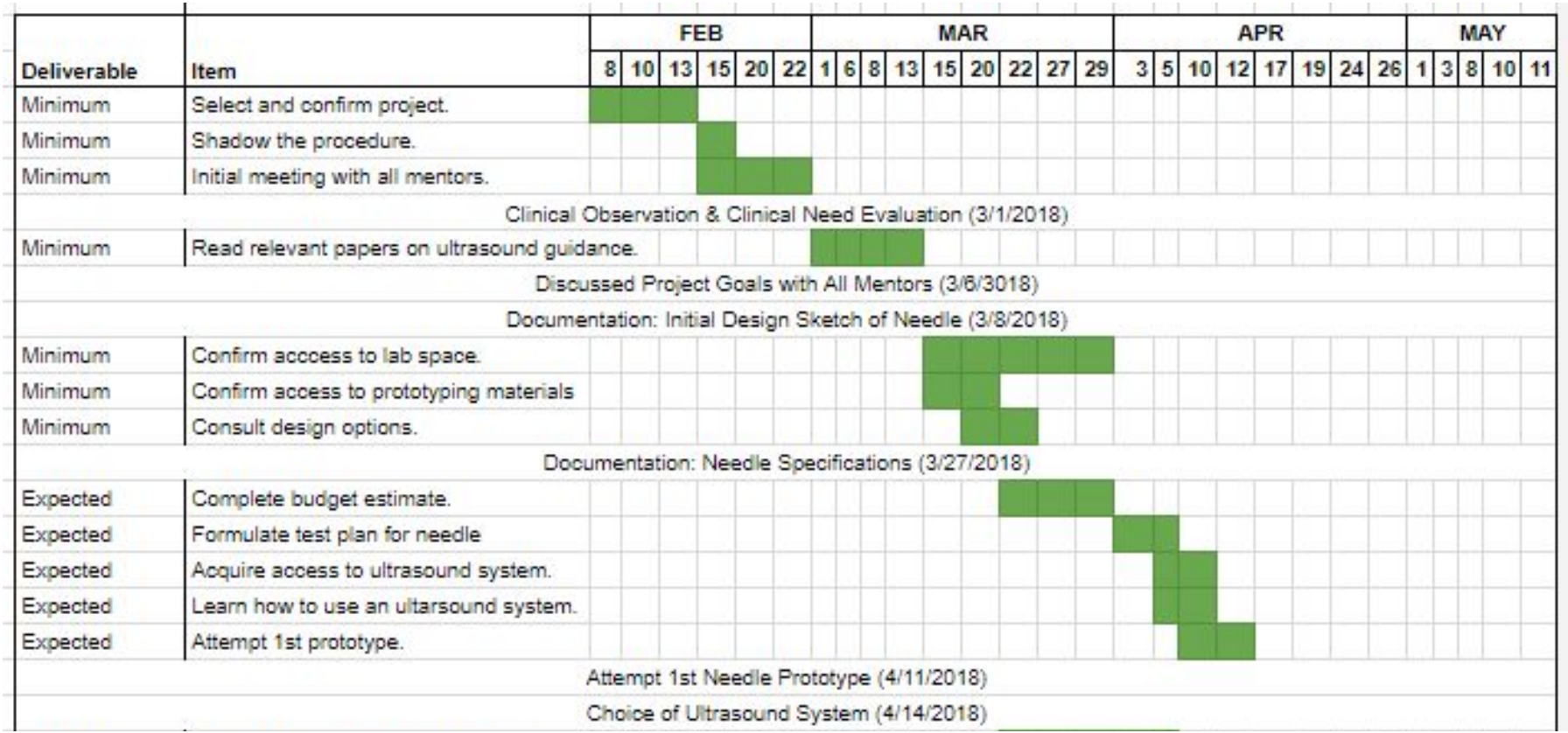
Environment: Hood with ventilation; temperature treatment of materials.

Phantom 1: Texture-Specific

Phantom 2: Ultrasound Compatible

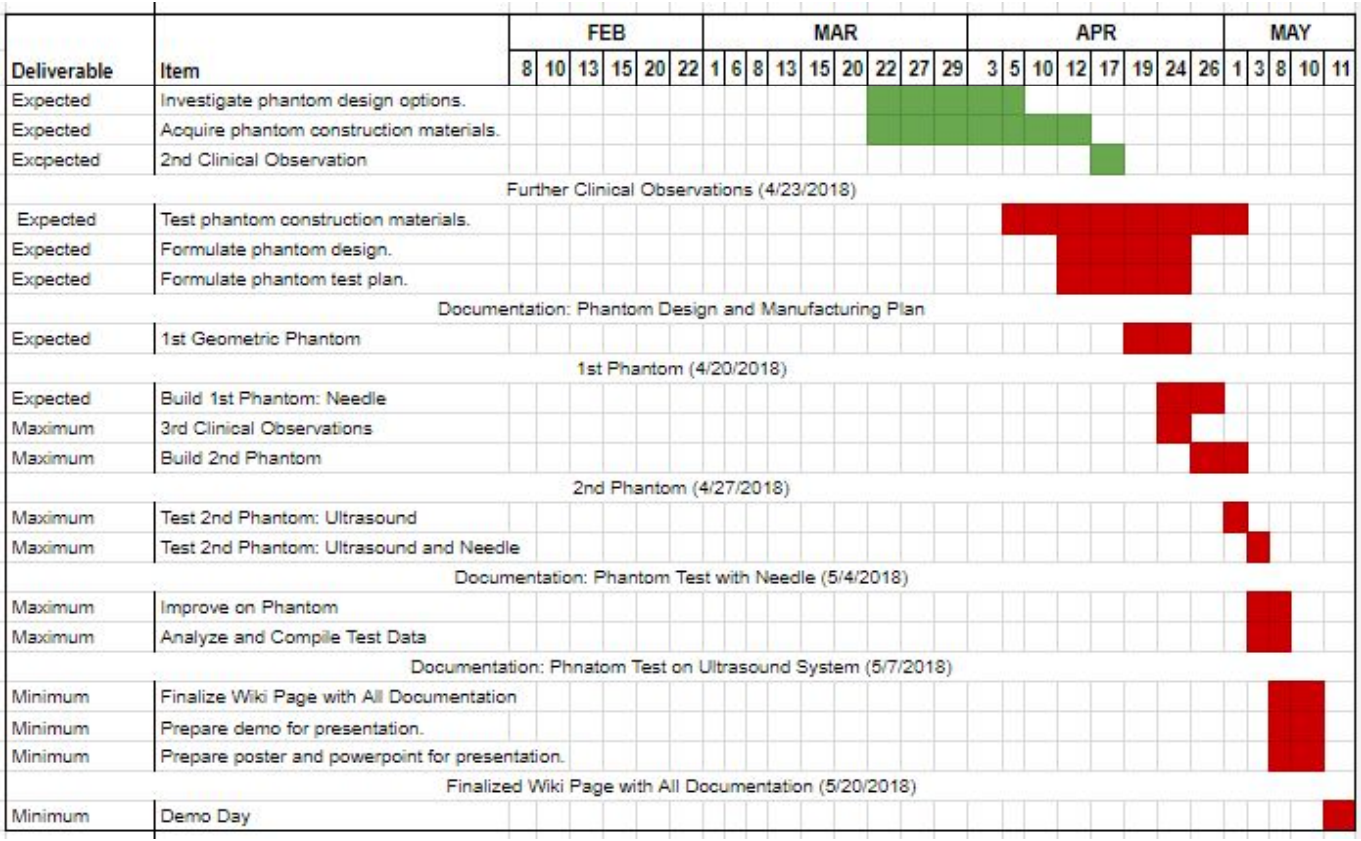
Testing: Ultrasound and Needle injection

Progress + Projected Timeline



Deliverable	Item	FEB						MAR								APR								MAY				
		8	10	13	15	20	22	1	6	8	13	15	20	22	27	29	3	5	10	12	17	19	24	26	1	3	8	10	11
Minimum	Select and confirm project.																												
Minimum	Shadow the procedure.																												
Minimum	Initial meeting with all mentors.																												
	Clinical Observation & Clinical Need Evaluation (3/1/2018)																												
Minimum	Read relevant papers on ultrasound guidance.																												
	Discussed Project Goals with All Mentors (3/6/3018)																												
	Documentation: Initial Design Sketch of Needle (3/8/2018)																												
Minimum	Confirm acccess to lab space.																												
Minimum	Confirm access to prototyping materials																												
Minimum	Consult design options.																												
	Documentation: Needle Specifications (3/27/2018)																												
Expected	Complete budget estimate.																												
Expected	Formulate test plan for needle																												
Expected	Acquire access to ultrasound system.																												
Expected	Learn how to use an ultarsound system.																												
Expected	Attempt 1st prototype.																												
	Attempt 1st Needle Prototype (4/11/2018)																												
	Choice of Ultrasound System (4/14/2018)																												

Progress + Projected Timeline



Deliverable	Item
Expected	Investigate phantom design options.
Expected	Acquire phantom construction materials.
Excpected	2nd Clinical Observation
	Further Clinical Observations (4/23/2018)
Expected	Test phantom construction materials.
Expected	Formulate phantom design.
Expected	Formulate phantom test plan.
	Documentation: Phantom Design and Manufacturing Plan
Expected	1st Geometric Phantom
	1st Phantom (4/20/2018)
Expected	Build 1st Phantom: Needle
Maximum	3rd Clinical Observations
Maximum	Build 2nd Phantom
	2nd Phantom (4/27/2018)
Maximum	Test 2nd Phantom: Ultrasound
Maximum	Test 2nd Phantom: Ultrasound and Needle
	Documentation: Phantom Test with Needle (5/4/2018)
Maximum	Improve on Phantom
Maximum	Analyze and Compile Test Data
	Documentation: Phnatom Test on Ultrasound System (5/7/2018)
Minimum	Finalize Wiki Page with All Documentation
Minimum	Prepare demo for presentation.
Minimum	Prepare poster and powerpoint for presentation.
	Finalized Wiki Page with All Documentation (5/20/2018)
Minimum	Demo Day

Dependencies

Level of Deliverable Affected	Dependency	Proposed Solution	Important Dates	Alternatives	Status
Expected, Maximum	Phantom Construction Materials (e.g. Plastisol, Microbead, Silicone, Metal and Glass Containers)	Use the materials available in lab space and purchase others as necessary.	4/20/2018	Purchase all materials needed. Minimize complexity of phantoms.	**Resolved** as of 4/14/2018
Expected, Maximum	Phantom Manufacturing Environment (Lab Space, Hood)	Use the BME Design Studio in Clark Hall	4/20/2018	Work on it outdoors.	**Resolved** as of 3/30/2018.
Expected, Maximum	Phantom Manufacturing Equipment (e.g. 3D Printing)	Use the BME Design Studio in Clark Hall	4/20/2018	Use Wyman Park Bldg. equipment	**Resolved** as of 4/11/2018.

Management Plan

I set meetings as needed with Carmen Kut (main mentor). We meet at least weekly and if necessary, bi-weekly.

Acknowledgement

My mentors: Carmen Kut, Younsu Kim, Dr. Akila Viswanathan, Dr. Emad Boctor have dedicated time, expertise, and financial resources to teach me how to carry out this project.

Additionally, Marc Morcos and Michelle Zwernemann have also provided valuable insight on phantom manufacturing.

Updated Reading List

Bair, R. J., Bair, E., & Viswanathan, A. N. (2015). A radiopaque polymer hydrogel used as a fiducial marker in gynecologic-cancer patients receiving brachytherapy. *Brachytherapy, 14*(6), 876-880.

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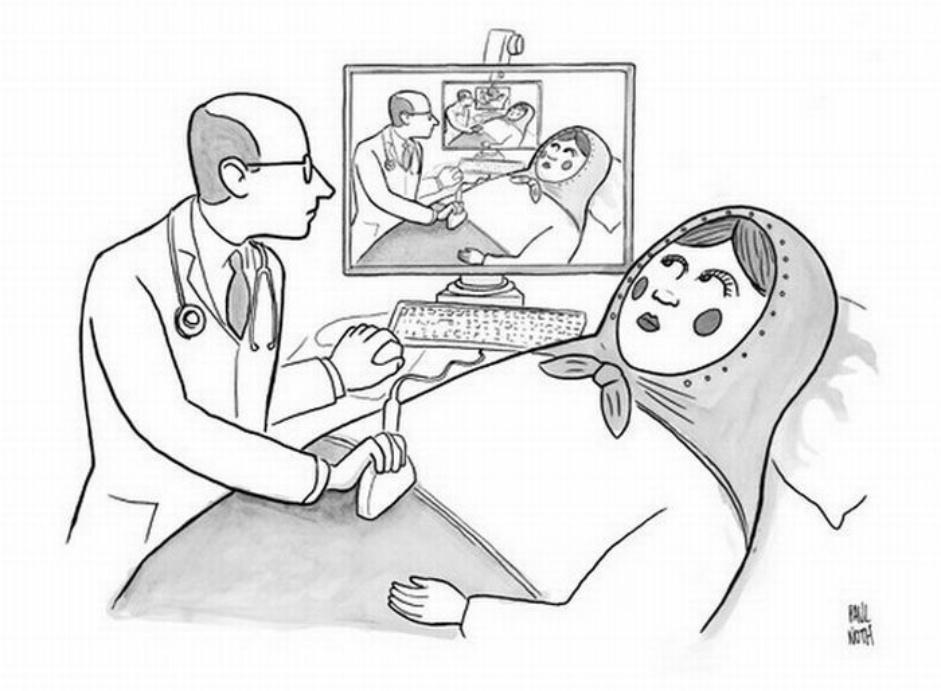

Thank you for listening!