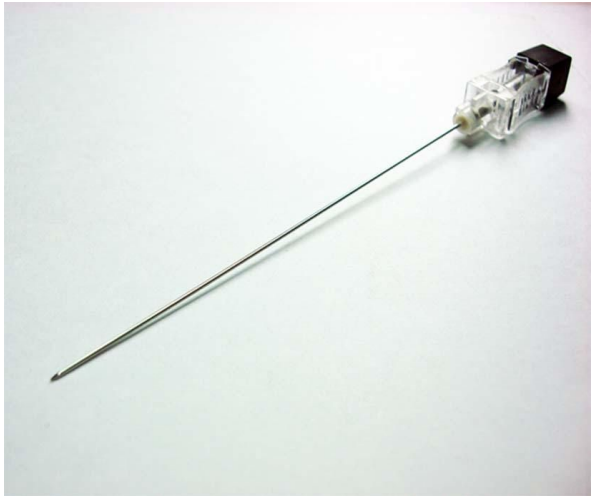
Ultrasound Needle Guidance for Hydrogel Injection During Cervical Cancer Brachytherapy

Tracy Kao (Computer Integrated Surgery II)
Mentors: Carmen Kut, Dr. Emad Boctor, Dr. Akila Viswanathan, and Younsu Kim

Objective

To develop a **needle prototype** for hydrogel injection during a brachytherapy procedure that is compatible with existing ultrasound systems.



Main skills employed:

Hardware, familiarity with electronics

Clinical Need

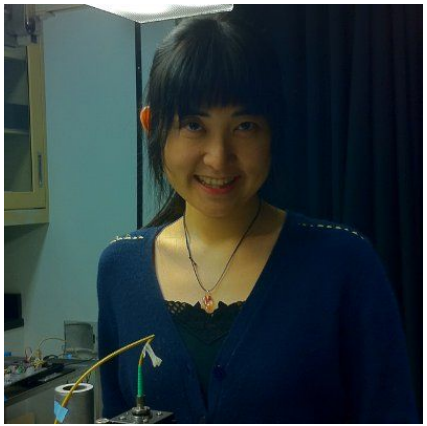
- Unlike early-stage disease, **locally advanced cervical cancer** has finite survival times and cannot be cured by surgery alone (with a high relapse rate at 30%).
- Recent data have repeatedly and consistently shown the benefit of administering **brachytherapy** following external beam radiotherapy (EBRT) to prolong survival and to improve patient outcomes (when coupled with chemotherapy)
- 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 injection under ultrasound image guidance during preparation of patient for brachytherapy procedure.

Mentor Team & Roles



Carmen Kut

Main Mentor

Dr. Emad Boctor

Technical Consultant

Dr. Akila Viswanathan

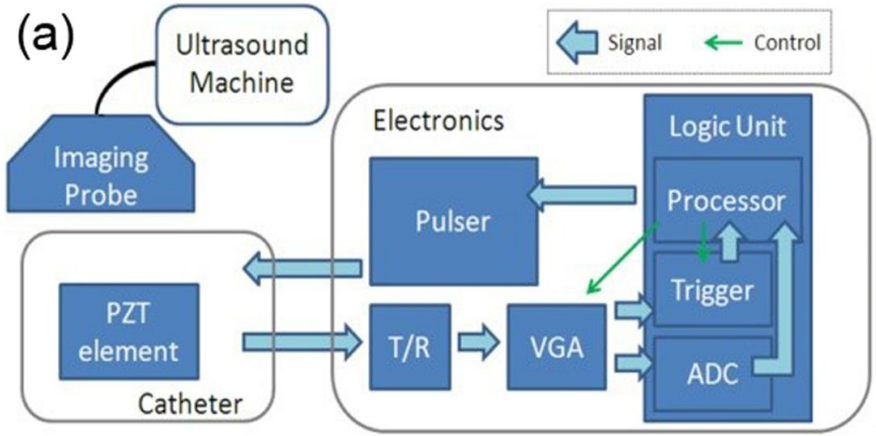
Clinical Consultant

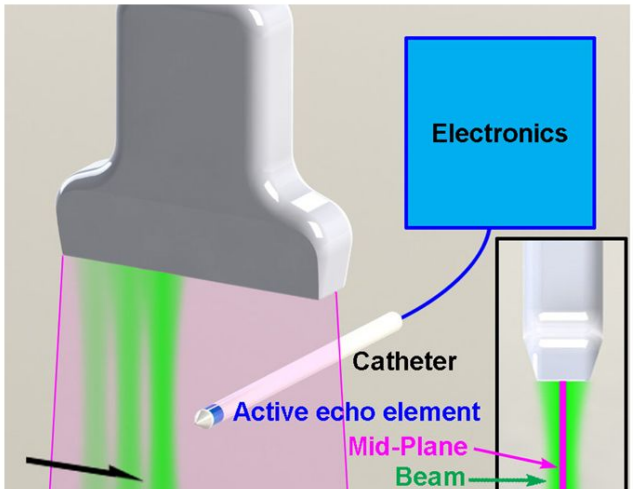
Younsu Kim

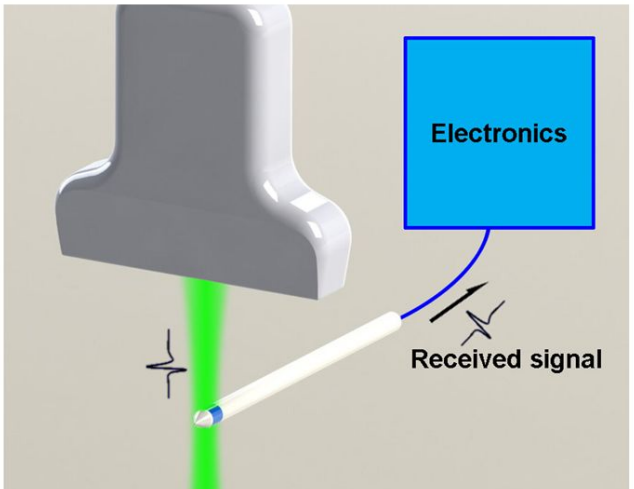
Technical Resources

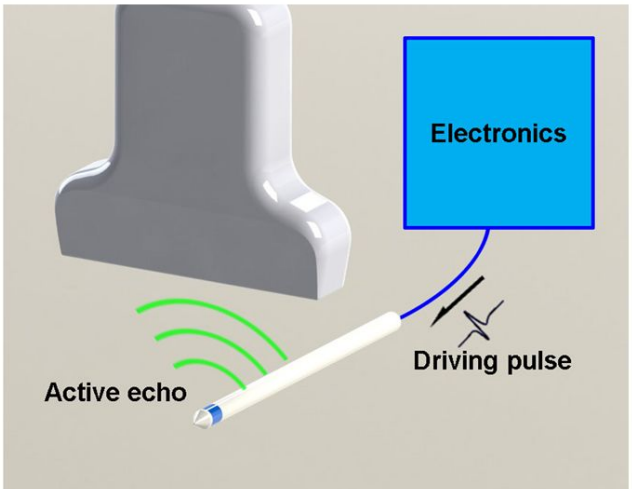
Technical Approach

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



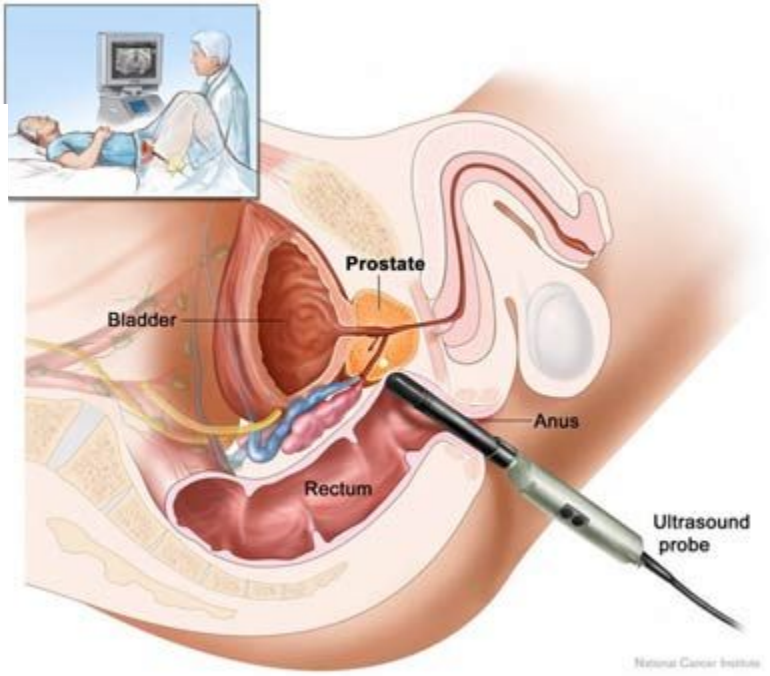




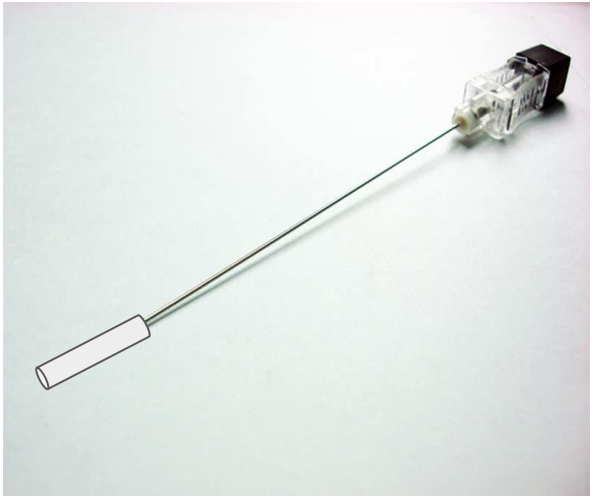


Technical Approach (cont’d)

- Use of Trans-Rectal Ultrasound System (TRUS).



Integrated System



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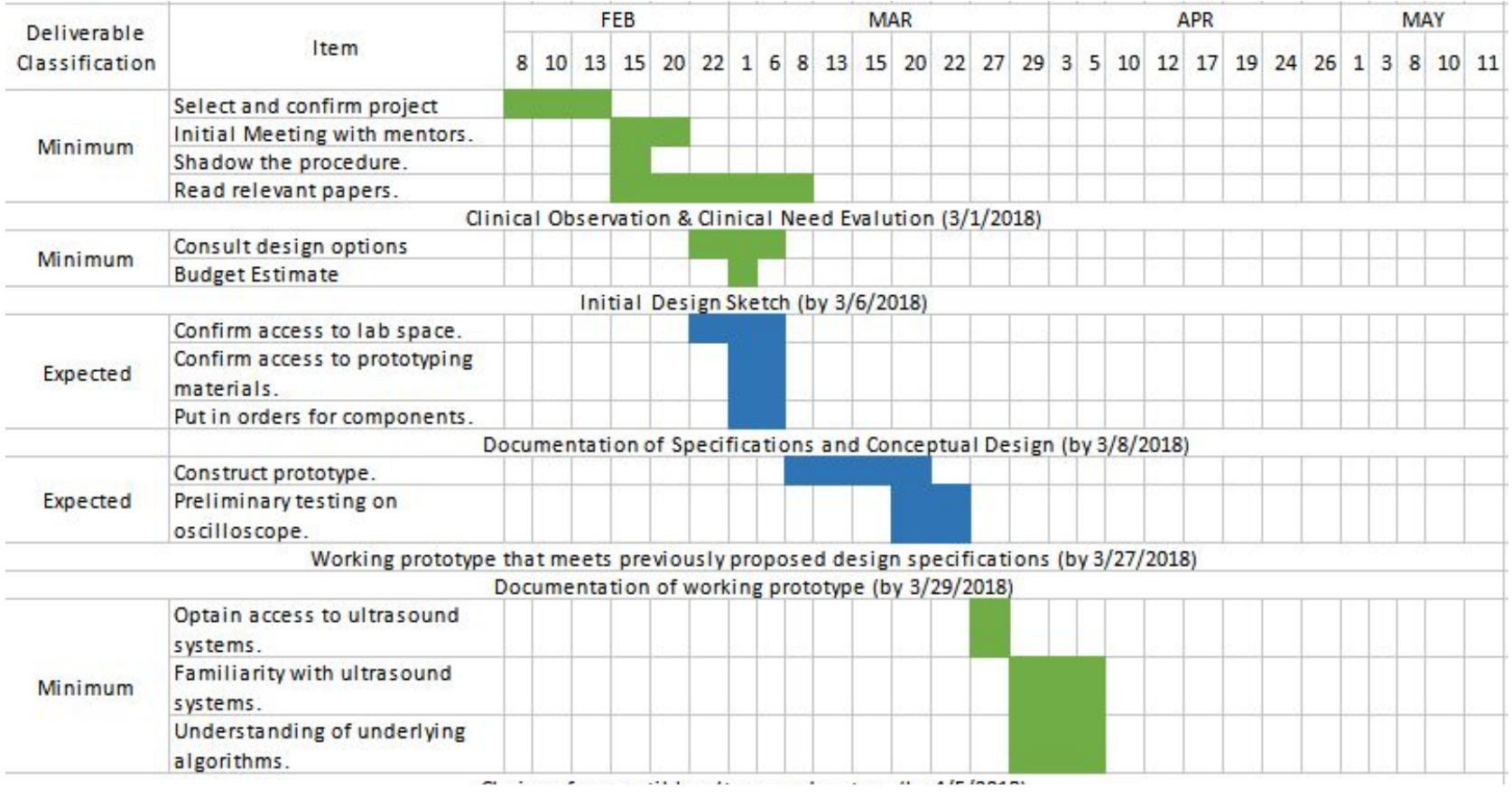
Deliverables

- **Minimum:** (Expected by for part I:3/6/3018, for part II: 4/5/2018)
  - Informed understanding of the clinical need.
  - Familiarity with underlying principles of ultrasound technology.
  - Ability to operate a relevant, existing ultrasound system.
  - Documentation of specifications and initial design concepts.
- **Expected:** (Expected by 3/29/2018)
  - Development of a hydrogel injection needle prototype adapted for ultrasound compatibility.
  - Needle interfaces with existing electronics and research-use ultrasound system.
  - Documentation of working prototype design and process.
- **Maximum:** (Expected by 5/10/2018)
  - Selection of appropriate phantom(s) for testing and evaluating the prototype.
  - Construction of the phantom.
  - Documentation of phantom design, construction, and resulting test data.

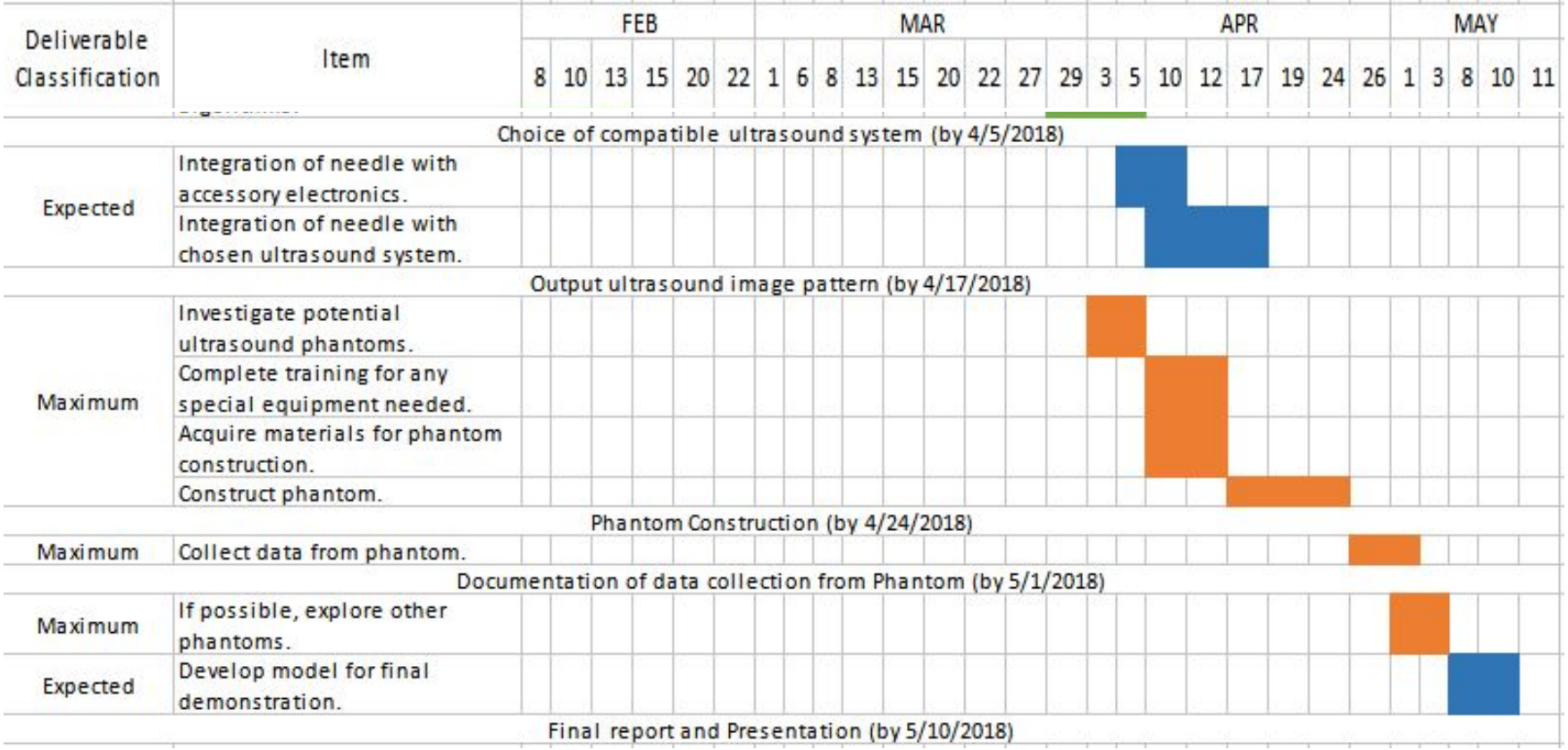
Milestones (and Deadlines)

- 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 (3/292018)
- 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)

Timeline


Deliverable Classification
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
Initial Meeting with mentors.
Shadow the procedure.
Read relevant papers.
Clinical Observation & Clinical Need Evalution (3/1/2018)
Minimum
Consult design options
Budget Estimate
Initial Design Sketch (by 3/6/2018)
Expected
Confirm access to lab space.
Confirm access to prototyping materials.
Put in orders for components.
Documentation of Specifications and Conceptual Design (by 3/8/2018)
Expected
Construct prototype.
Preliminary testing on oscilloscope.
Working prototype that meets previously proposed design specifications (by 3/27/2018)
Documentation of working prototype (by 3/29/2018)
Minimum
Optain access to ultrasound systems.
Familiarity with ultrasound systems.
Understanding of underlying algorithms.

Timeline (cont'd)



Dependencies

Level of Deliverable Affected	Dependency	Proposed Solution	Important Dates	Alternatives	Status
Expected	Hydrogel needle	Acquire from Clinical Consultant	Need by 3/8/2018	Use other needle.	RESOLVED as of 2/14/2018
Expected	Electronic Components	Provision by MUSiiC Lab.	Need by 3/8/2018	Place order in accordance with budget constraints	PARTIALLY RESOLVED as of 2/22/2018
Expected	Electronic Interface from AUSPIS	Provision by MUSiiC Lab.	Need by 4/5/2018	Build it myself.	Access confirmed as of 2/22/2018
Expected	Access to Lab environment for prototype development	Provision by MUSiiC Lab.	Need by 3/8/2018	Use currently available lab space.	Access confirmed as of 2/22/2018
Minimum	Ultrasound System and Compatible Algorithm	Provision by MUSiiC Lab. TRUS, in particular.	Need by 4/5/2018	Look for non-research abdominal probes with Radiation Oncology and Hopkins Simulation Center.	Access confirmed as of 2/22/2018

Level of Deliverable Affected	Dependency	Proposed Solution	Important Dates	Alternatives	Status
Maximum	Phantom Construction Materials	Purchase with budget.	Need by 4/12/2018	Purchase with own money. Or borrow from MUSiiC Lab	Not yet resolved.
Maximum	Phantom Construction Machinery/ Equipment	Provision by MUSiiC Lab, BME Design Studio, or Wyman Equipment after proper training.	Need by 4/12/2018	Make do with freely available equipment.	Currently doing training on multiple equipment.
Minimum	Mentorship	Weekly meetings if possible; otherwise, availability upon need.	Need by 2/21/2018	Rely on papers.	Have met with all mentors by 2/21/2018, confirming their roles in this project.
Expected	Financial Resources	Come up with budget at beginning of project, and attempt to get it processed through the mentors.	Need by 3/6/3018	Pay personally.	As of 2/20/2018.

Management Plan

E-mail communication with all mentors. Mentors available upon need.

Weekly meeting with main mentor (Carmen), flexible times.

Update all mentors when milestones are reached.

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.

Banerjee, R., & Kamrava, M. (2014). Brachytherapy in the treatment of cervical cancer: a review. *International journal of women's health, 6*, 555.

Bell, M. A. L., Kuo, N. P., Song, D. Y., Kang, J. U., & Boctor, E. M. (2014). *In vivo* visualization of prostate brachytherapy seeds with photoacoustic imaging. *Journal of biomedical optics, 19*(12), 126011.

Guo, X., Kang, H. J., Etienne-Cummings, R., & Boctor, E. M. (2014). Active ultrasound pattern injection system (AUSPIS) for interventional tool guidance. *PloS one, 9*(10), e104262.

Viswanathan, A. N., Damato, A. L., & Nguyen, P. L. (2013). Novel use of a hydrogel spacer permits reirradiation in otherwise incurable recurrent gynecologic cancers. *Journal of Clinical Oncology, 31*(34), e446-e447.

Zhang, H. K., Lin, M., Kim, Y., Paredes, M., Kannan, K., Patel, N., … & Boctor, E. M. (2017, March). Toward dynamic lumbar punctures guidance based on single element synthetic tracked aperture ultrasound imaging. In *Medical Imaging 2017: Image-Guided Procedures, Robotic Interventions, and Modeling* (Vol. 10135, p. 101350J). International Society for Optics and Photonics.

Thank you for listening.