Ultrasound Imaging of Brain Shunts

Checkpoint Presentation

Team 1

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Overview

- Project Summary
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- Progress: Imaging
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Project Summary

Problem: Brain shunts suffers from high incidence of occlusion that the in-grown tissues block the CSF flow.

Project Goal: Use external US probe, together with photoacoustic excitation to image occlusions and brain shunts inside the skull.

Original Deliverables

- Minimum – without skull
  - Design and build a ultrasound friendly brain phantom and insert the shunts. (Done)
  - Preliminary test of US probe for reflected PA signal detection. (Done)
  - Collect and process the data of the occlusion with brain phantom into delayed image. (Done)

Original Deliverables

- Expected – with skull
  - Collect and process the data of the occlusion into delayed image. (Done)
  - Capability to distinguish shunts, tissues and fluids. X
  - Demonstrate PA imaging of shunts with different levels of occlusion. (In progress, will be done in this week.)

Original Deliverables

- Maximum
  - Demonstrate real-time PA imaging through the skull of shunts with different levels of occlusion X
  - Monitor clearing of the shunt

NEW Deliverables

- Maximum
  - Visualization of fiber end point
  - Delayed monitoring (due to data collection time of DAQ)
    - Approaching of the fiber to the occlusion
    - Accumulation of occlusion

Phantom Construction

Two parts : Brain & Skull

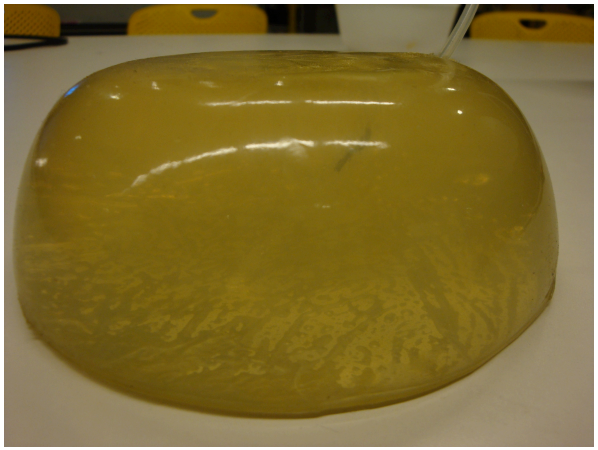
- Brain part : model the environment of the brain
  support the shunt tube

- Skull : model the real effect of bone on US imaging
- 3D printer not available
- 3DP service will miss the best time to do the post-processing

Phantom Construction

What we did …

- Several simple shaped phantoms …



Pure gelatin phantom
(Very Stiff)

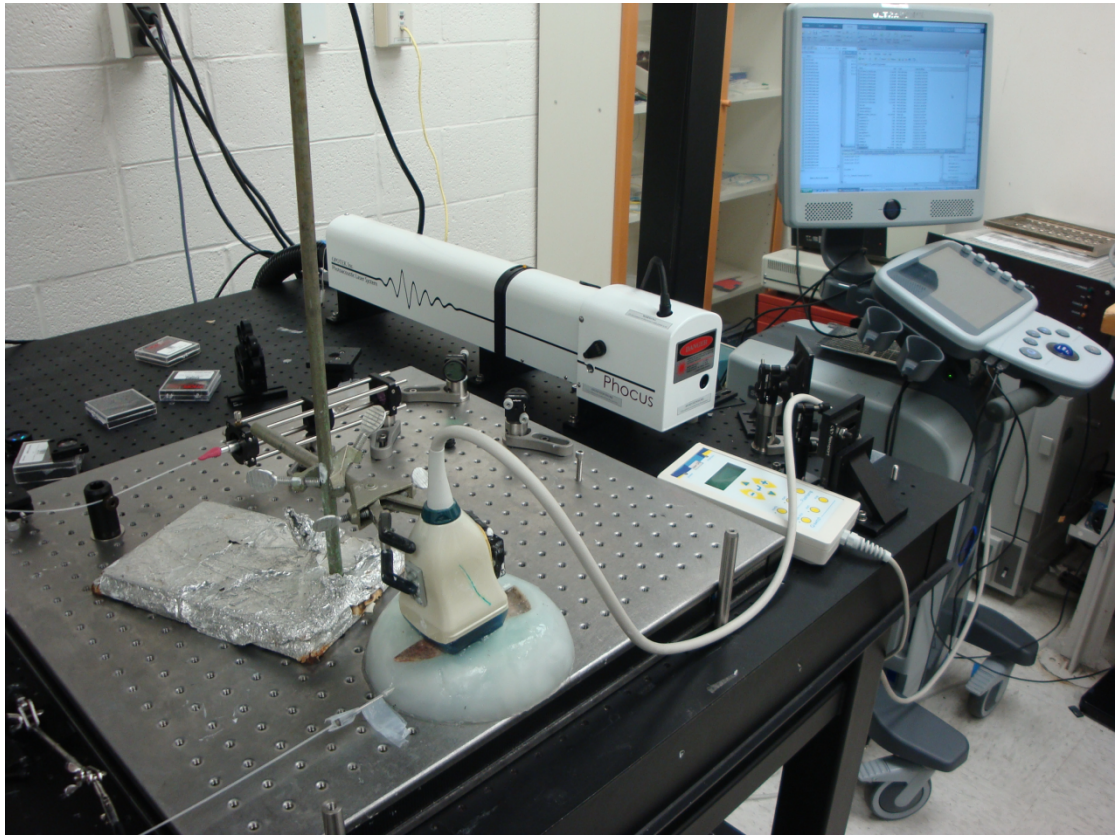
Gelatin and Fiber phantom
(Relatively soft, Tissue-like)

Phantom Construction

What we are using now …

Progress: Imaging

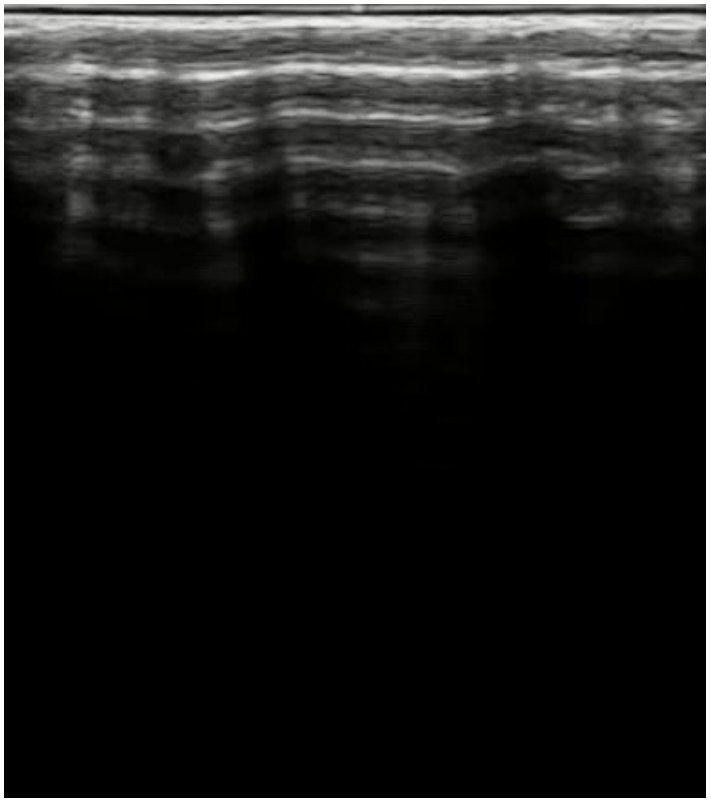
- Ultrasound generation
  - laser
- Data collection
  - Sonix Touch & DAQ
- Data processing
  - Beamform
- Image formation



Progress: Imaging

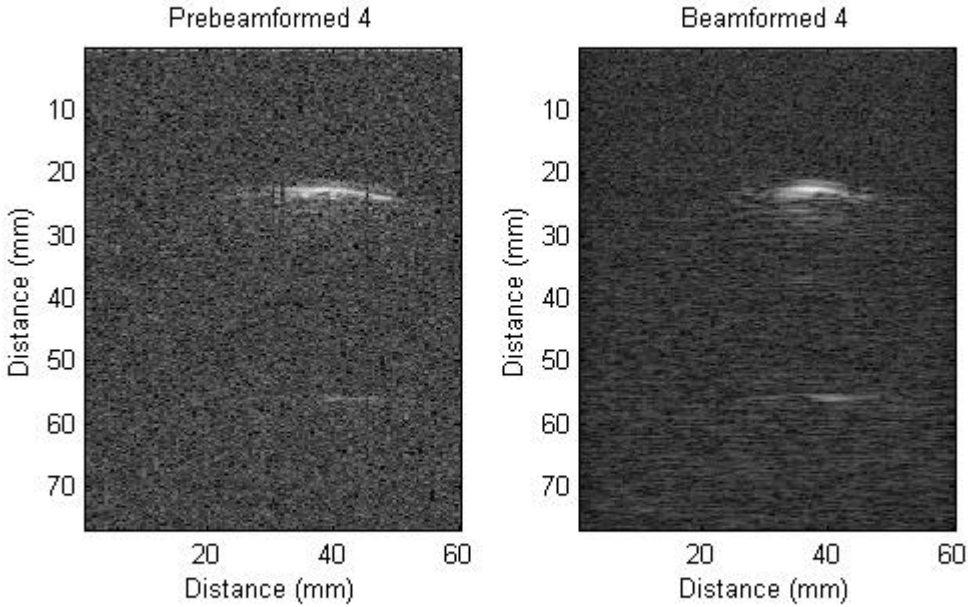
Progress: Imaging

- Test with bones of different thickness
  - Thin piece of bone (2mm)



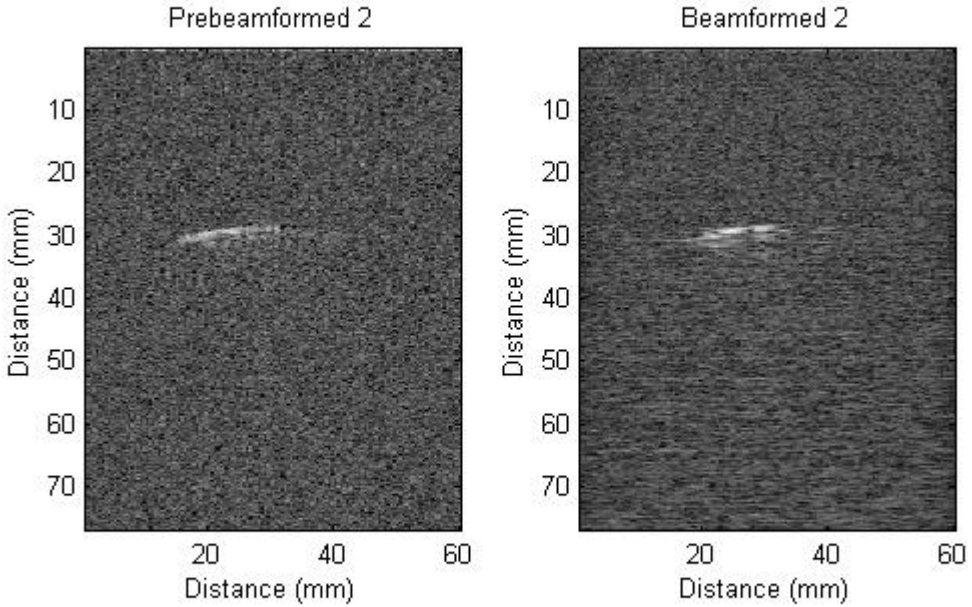
Progress: Imaging

- Test with bones of different thickness
  - Thin piece of bone (2mm)
  - Laser energy: 0.75mJ
  - Distance: 2mm



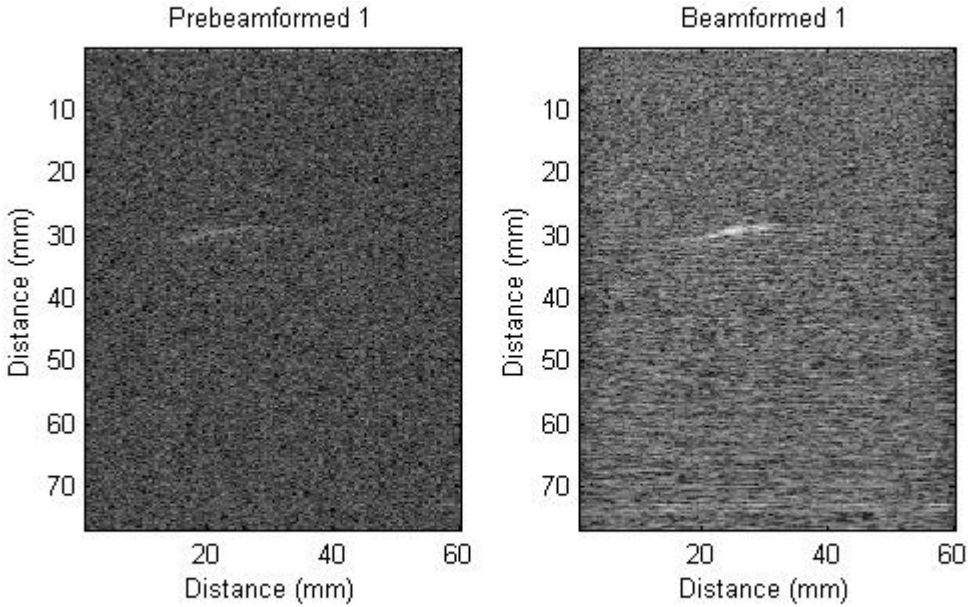
Progress: Imaging

- Test with bones of different thickness
  - Thicker piece of bone (4mm)
  - Laser energy: 0.75mJ
  - Distance: 2mm



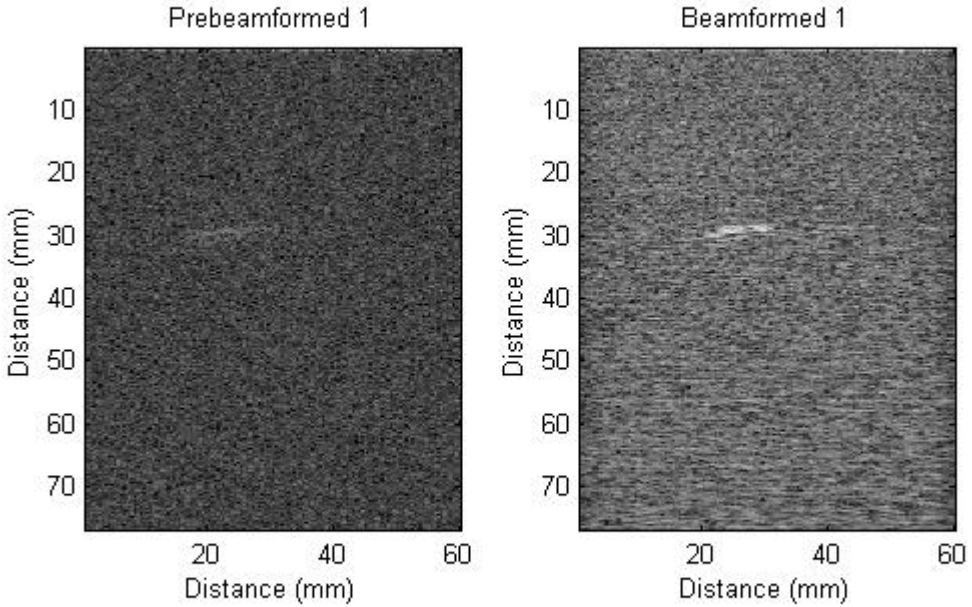
Progress: Imaging

- Test with distance between the fiber and the occlusion
  - Bone thickness: 4mm
  - Laser energy: 0.75mJ
  - Distance: 5mm



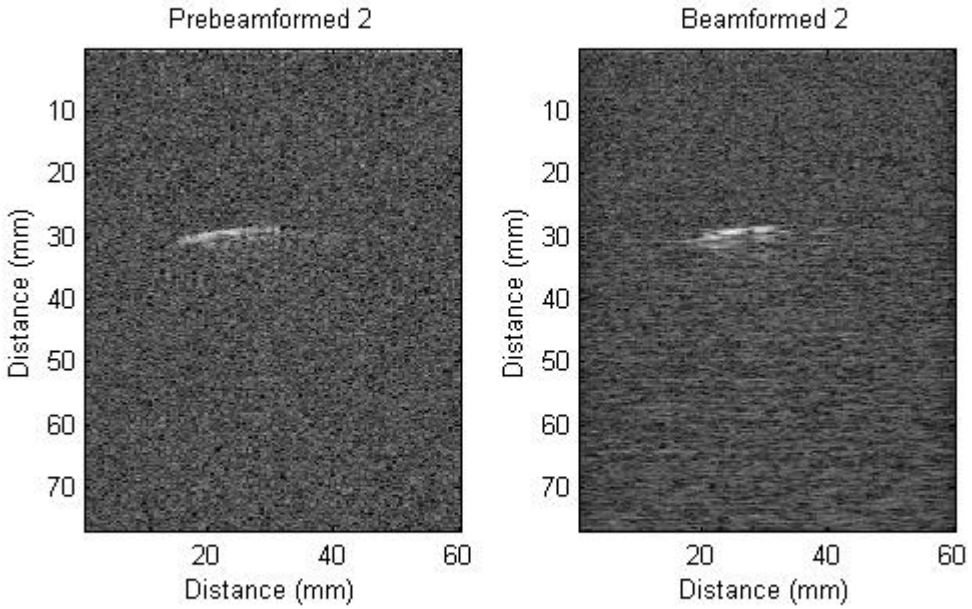
Progress: Imaging

- Test with distance between the fiber and the occlusion
  - Bone thickness: 4mm
  - Laser energy: 0.75mJ
  - Distance: 10mm



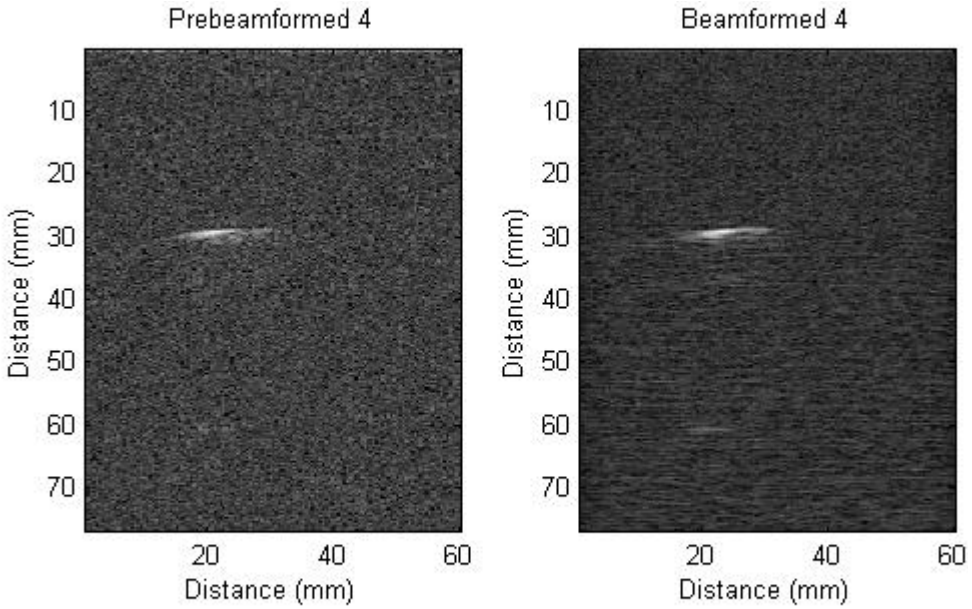
Progress: Imaging

- Test with different sizes of occlusion
  - Bone thickness: 4mm
  - Laser energy: 0.75mJ
  - Distance: 2mm
  - Size: previous



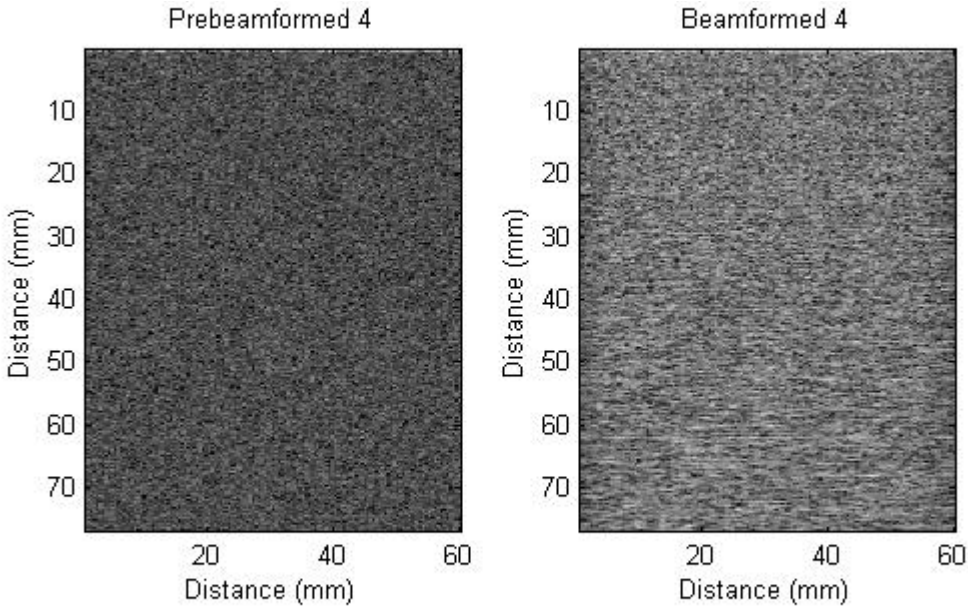
Progress: Imaging

- Test with different sizes of occlusion
  - Bone thickness: 4mm
  - Laser energy: 0.75mJ
  - Distance: 2mm
  - Size: twice the thickness of previous



Progress: Imaging

- Test with different sizes of occlusion
  - Bone thickness: 4mm
  - Laser energy: 0.75mJ
  - Distance: 2mm
  - Size: no occlusion



Progress: Imaging

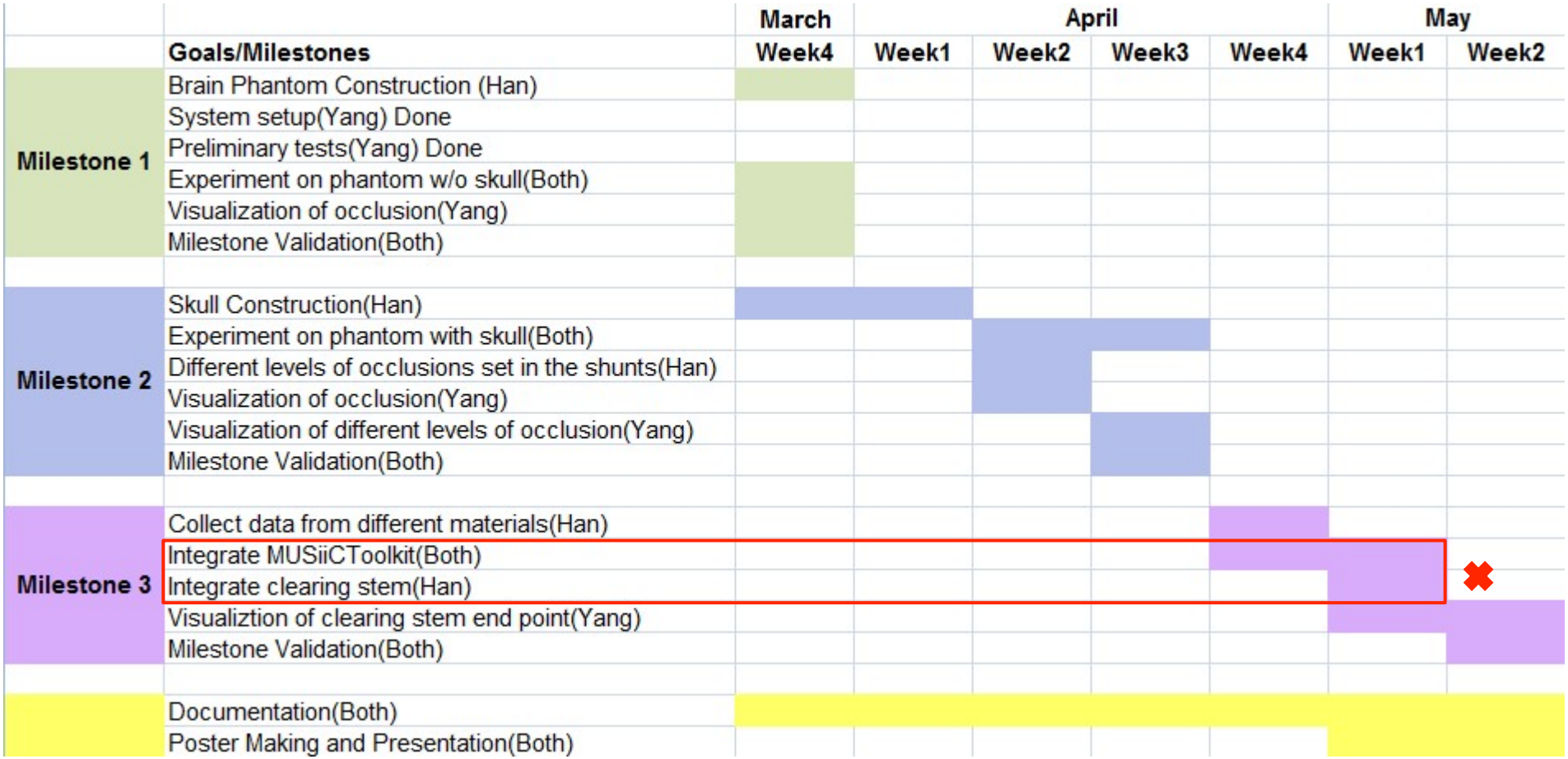
- Problem
  - Bones get harder for ultrasound as time goes on.
  - Borrowed human bone is not usable.
  - Real-time monitoring is not realizable due to the hardware limitation.

- Next step
  - Change the position of the probe from perpendicular to aligned with the shunts
  - Inject tiny pieces of occlusion with a needle and collect the image into movie
  - Delayed monitoring

Revised Timeline Version 1

		March	April				May	
	Goals/Milestones	**Week4**	**Week1**	**Week2**	**Week3**	**Week4**	**Week1**	**Week2**
Milestone 1	Brain Phantom Construction (Han)							
	System setup(Yang) Done							
	Preliminary tests(Yang) Done							
	Experiment on phantom w/o skull(Both)							
	Visualization of occlusion(Yang)							
	Milestone Validation(Both)							
Milestone 2	Skull Construction(Han)							
	Experiment on phantom with skull(Both)							
	Different levels of occlusions set in the shunts(Han)							
	Visualization of occlusion(Yang)							
	Visualization of different levels of occlusion(Yang)							
	Milestone Validation(Both)							
Milestone 3	Collect data from different materials(Han)							
	Integrate MUSiiCToolkit(Both)							
	Integrate clearing stem(Han)							
	Visualiztion of clearing stem end point(Yang)							
	Milestone Validation(Both)							
	Documentation(Both)							
	Poster Making and Presentation(Both)							

Revised Timeline Version 1



Revised Timeline Version 2

		March	April				May	
	Goals/Milestones	**Week4**	**Week1**	**Week2**	**Week3**	**Week4**	**Week1**	**Week2**
Milestone 1	Brain Phantom Construction (Han)							
	System setup(Yang) Done							
	Preliminary tests(Yang) Done							
	Experiment on phantom w/o skull(Both) Done							
	Visualization of occlusion(Yang) Done							
	Milestone Validation(Both) Done							
Milestone 2	Skull Construction(Han)							
	Experiment on phantom with skull(Both)							
	Different levels of occlusions set in the shunts(Han)							
	Visualization of occlusion(Yang) Done							
	Visualization of different levels of occlusion(Yang)							
	Milestone Validation(Both)							
Milestone 3	Collect data from different materials(Han)							
	Delayed monitoring							
	Visualiztion of clearing stem end point(Yang)							
	Milestone Validation(Both)							
	Documentation(Both)							
	Poster Making and Presentation(Both)							

Milestone Validations

Milestone	Original plan	Revised plan I	Revised plan II	Status
Phantom construction	2/28	4/8		Done
Preliminary test	2/28	3/27		Done
Visualization of occlusion w/o skull	3/18	3/29		Done
Visualization of occlusion with skull	4/15	4/22		Done
Visualization of different level of occlusions	4/15	4/22		Done
Visualization of the fiber end point	5/10	5/10	5/10	In progress
Delayed monitoring	5/10	5/10	5/10	In progress

Dependencies

Dependency	Resolved by	Resolved	Fallback plan	Influences
Access to Dr. Boctor's lab	3/11	Yes		All the milestones
Laser system back	3/18	Yes		All the milestones
Jello phantoms	3/26	Yes		Milestone I
PVA phantoms	3/31	Yes		
Skull construction	4/8	Yes (Revised)	Borrow a piece of skull	Milestone II
Data collection training	2/27	Yes		Milestone I
Training of laser	3/27	Yes		Milestone I

Reading list

Phantom Construction

- Parastoo Farnia, Alireza Ahmadian, Alireza Khoshnevisan, AmirHossein Jaberzadeh, Nasim Dadashi Serej, Anahita F. Kazerooni: An efficient Point Based Registration of Intra-operative Ultrasound images with MR images for computation of brain shift; a Phantom Study. 33rd Annual International Conference of the IEEE EMBS Boston, Massachusetts USA, August 30 - September 3, 2011
- Sean Jy-Shyang Chen1, Pierre Hellier2, Jean-Yves Gauvrit4,5,6, Maud Marchal3, Xavier Morandi4,5,6, and D. Louis Collins: An Anthropomorphic Polyvinyl Alcohol Triple-Modality Brain Phantom based on Colin27. McConnell Brain Imaging Centre, Montreal Neurological Institute, McGill University, Montreal, Canada
- Ronald O. Bude, Ronald S. Adler: An Easily Made, Low-Cost, Tissue-Like Ultrasound Phantom Material. J Clin Ultrasound 23:271 – 273, May 1995.
- Frederic Bevilacqua, Dominique Piguet, Pierre Marquet, Jeffrey D. Gross, Bruce J. Tromberg, and Christian Depeursinge: In vivo local determination of tissue optical properties: applications to human brain. 1 August 1999/ Vol.38, No.22/ Applied Optics.
- Brian W. Pogue, Michael S. Patterson: Review of tissue simulating phantoms for optical spectroscopy, imaging and dosimetry. Journal of Biomedical Optics 11(4), 041102 (July/August 2006).
- A N Yaroslavsky, P C Schulze, I V Yaroslavsky, R Schober, F Ulrich and H-J Schwarzmaier: Optical properties of selected native and coagulated human brain tissues in vitro in the visible and near infrared spectral range. Phys. Med. Biol. 47(2002) 2059-2073.
- K J M Surry, H J B Austin, A Fenster and T M Peters: Poly(vinyl alcohol) cryogel phantoms for use in ultrasound and MR imaging. Phys. Med. Biol. 49(2004) 5529-5546.
- Matteo Gatto, Gianluca Memoli, Adam Shaw, Neelaksh Sadhoo, Pierre Gelat, Russell A. Harris: Three-Dimensional Printing (3DP) of neonatal head phantom for ultrasound: Thermocouple embedding and simulation of bone. Medical Engineering & Physics 34(2012) 929-937.

Reading list

- Photoacoustic and Ultrasound imaging

- Limng Nie, Xin Cai, Konstantin Maslov, Alejandro Garcia-Uribe, Mark A. Anastasio, Lihong V. Wang, "Photoacoustic tomography through a whole adult human skull with a photon recycler", Washington University, Department of Biomedical Engineering, St. Louis, Missouri 63130.
- H. J. Kang et al., "Software framework of a real-time pre-beam-formed RF data acquisition of an ultrasound research scanner," Proc. SPIE 8320, 83201F (2012).
- N. Kuo, H.J. Kang, D.Y. Song, J.U. Kang, E.M. Boctor, "Real-time Photoacoustic Imaging of Prostate Brachytherapy Seeds Using a Clinical Ultrasound System", *Journal of Biomedical Optics, 17(6)*, June 2012.
- P. J. Stolka, H.-J. Kang, and M. B. Emad, "The MUSiiC toolkit: Modular Real-Time Toolkit for Advanced Ultrasound Research," MIDAS Journal, (2010)
- H.-J. Kang, P. J. Stolka, and M.B.Emad, "OpenITGLinkMUSiiC toolkit: A Standard Communications Protocol for Advanced Ultrasound Research," MIDAS Journal, (2010)
- M. Fink, "Time reversal of ultrasonic fields-Part I: Basic principles". *IEEE Trans. Sonics Ultrason. 39(5), 555–566 (1992).*
- J.-L. Robert, M. Burcher, C. Cohen-Bacrie, and M.Fink, "Time reversal operator decomposition with focused transmission and robustness to speckle noise: Application to microcalcification detection". *J. Acoust. Soc. Am., 119:3848-3859 (2006).*

Thank you !