Ultrasound Imaging of Brain Shunts

Computer Integrated Surgery II, Spring 2013

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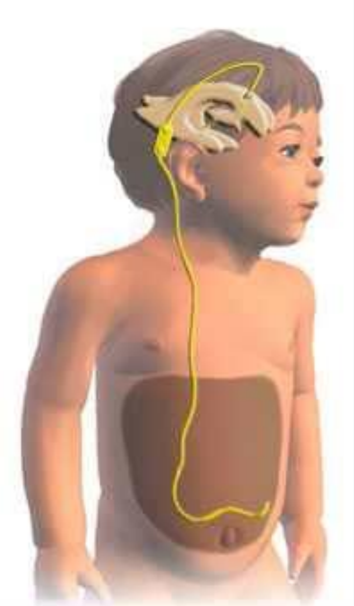
Introduction

- A new technology to image the occlusion in brain shunts is proposed.
- Several PVA-C phantoms that can mimic a human brain are built.
- Feasibility of this method using PA excitation has been demonstrated.
- Different levels of occlusion can be detected.
- Distance between the fiber end and the occlusion can be distinguished.
- The clearing procedure can be monitored in a delayed way.

Ultrasonography is an ultrasound-based diagnostic imaging technique widely used for visualizing body structures. But it has trouble in penetrating bone, which limits its use in brain imaging because of the existence of the skull. This motivates us to find a way to break this limit.

The Problem



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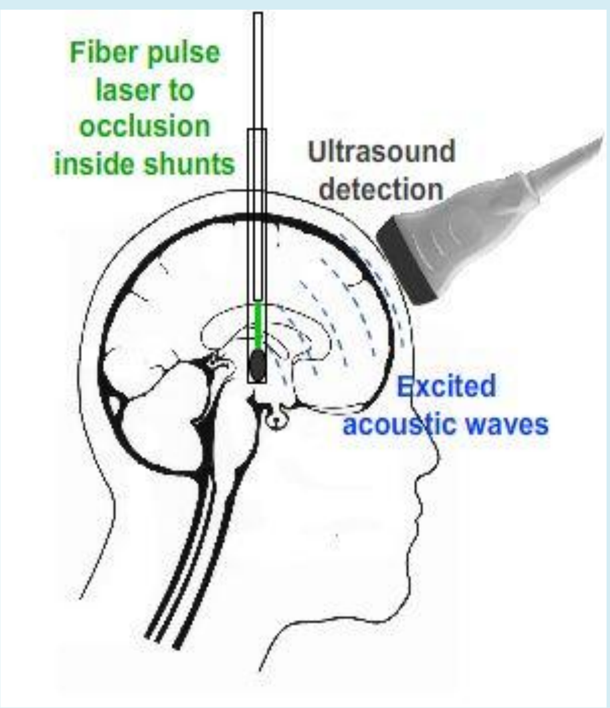
- Hydrocephalus is serious brain disease caused by excessive CSF accumulates in the ventricular space. It can only be treated in a surgical way.
- According to statistics, every year, only 30% of the 40,000 shunt-related operations performed in the US are the patient's first surgery. The medical cost for replacement or revision is $ 700 million per year.
- This fact reveals that, though brain shunt is a very mature surgery, high failure rates still cannot be avoided. Also, the replacement or revision cannot guarantee to avoid the failure in the future.
- Clearing system provides a easier and faster way to treat the failure due to the occlusion. It uses a shunt clearing stem that can be inserted into the shunt to remove the brain tissue.
- As the clearing procedure needs be visualized and the results needs to be verified, a system that can achieve visualization is necessary.

The Solution

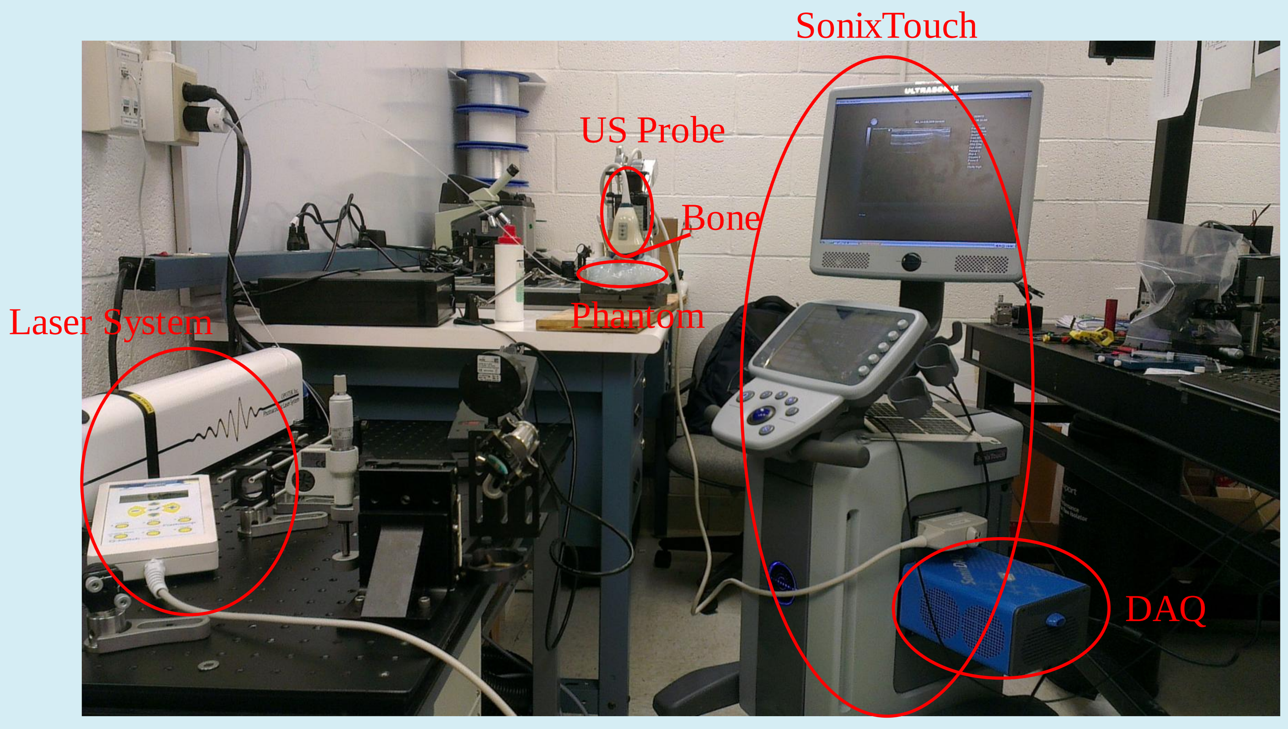
- To conquer this weakness of ultrasound, the laser system is integrated with the ultrasound system.
- Working principle specification:

  A high frequency pulses of light is launched onto the occlusion. The energy of the light absorbed by the occlusion will convert into heat, which makes the molecules become thermally excited. Then, the pressure variations caused by radiation of the heat will propagate as ultrasound waves in the occlusion. So that it can be detected by ultrasound probe.



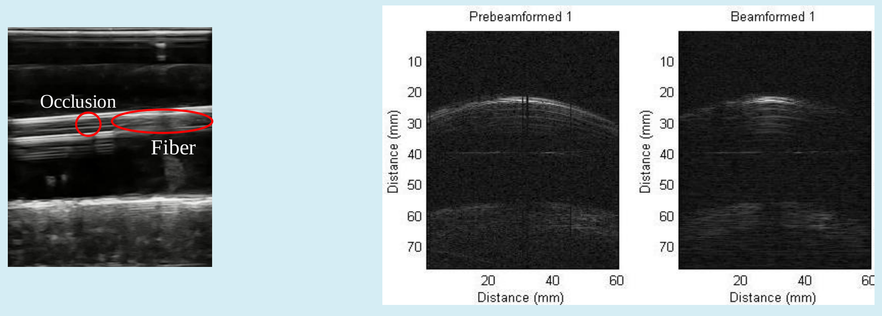
- Feasibility demonstration

1. The the brain shunt mimicking plastic tube containing water and occlusion is inserted into the brain phantom horizontally. The probe is put in aligned with the shunt. (B-mode and PA)
2. Two pieces of bone (2mm / 4mm) are inserted between the phantom and the probe in separate times. (B-mode and PA)
3. Different sizes of occlusions are inserted in the shunt without changing other setup. (PA)
4. Different distances between the fiber and the occlusion are set. (PA)
5. A metal needle is tied up with the fiber. (PA)

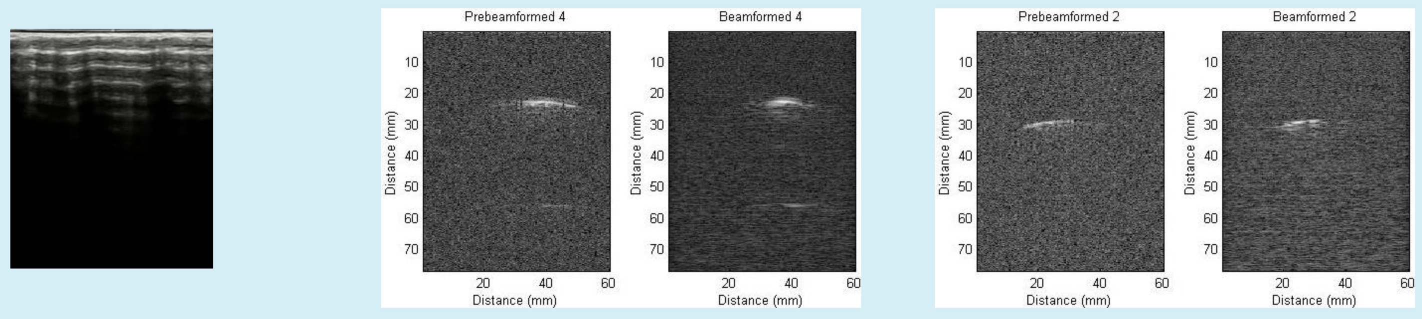


System setup

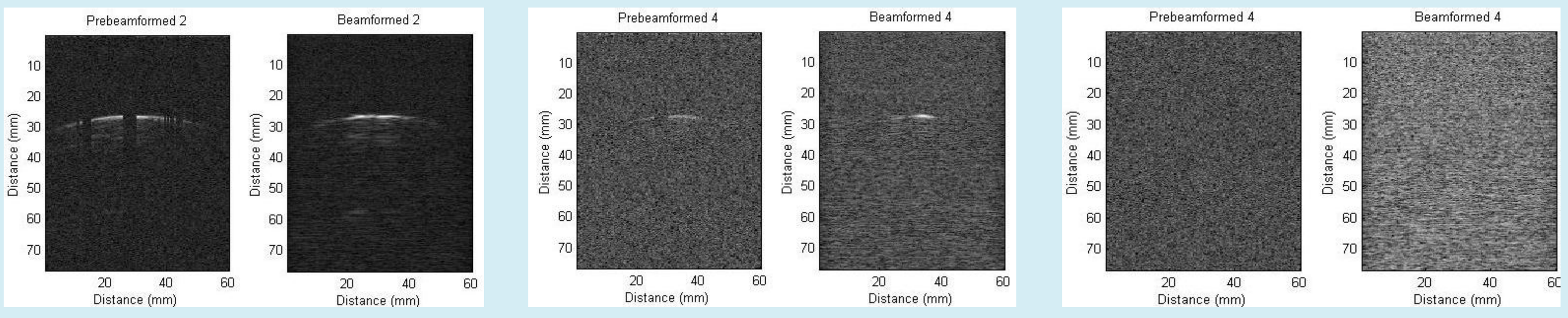
Outcomes and Results



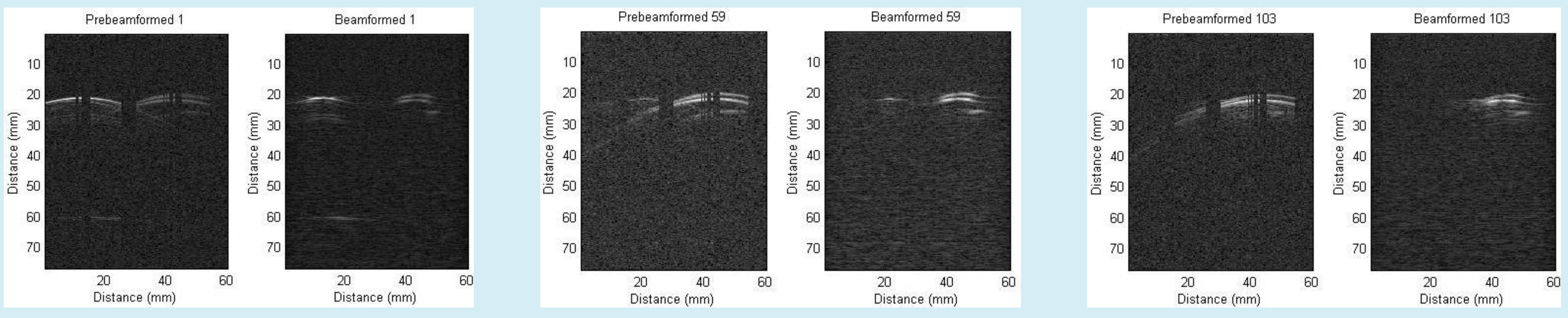
B-mode image of occlusion and fiber in the shunts (Left); PA image of occlusion without skull (Right).



B-mode ultrasound image with 2mm pig bone (Left). PA image with 2mm (Middle) and 4mm (Right) pig bone.



PA image of 4mm thickness occlusion with 2mm pig (Left), 1.5mm thickness (Middle), and no occlusion (Right).



PA image of occlusion and fiber end point with a distance of 20mm (Left), 12mm(Middle), 5mm(Right)

Future Work

- Specified energy of fiber end point need to be detected for real human skull.
- Minimize the time delay to realize real-time PA imaging.

Lessons Learned

- Backup plans for unexpected situations
- Feasibility checking before in starting stage
- Timely communication with advisors

Credits

- All authors contributed equally to the final execution and implementation of the project

Support by and Acknowledgements

- Thanks to Prof. Taylor and Dr. Boctor for their helpful guidance and financial support through the project.
- Special thanks to Behnoosh Tavakoli for her continuous help and advise.