Towards Ultrasonic Detection of Acoustic Windows for Transcranial Doppler Ultrasound and related Procedures

Presenter: Tony de Souza-Daw

RMIT University, Vietnam
Hanoi University of Science and Technology

Temporal Ultrasound Window

Temporal Ultrasound Window – Axial Scanning Plane

Temporal Ultrasound Window – Coronal Scanning Plane

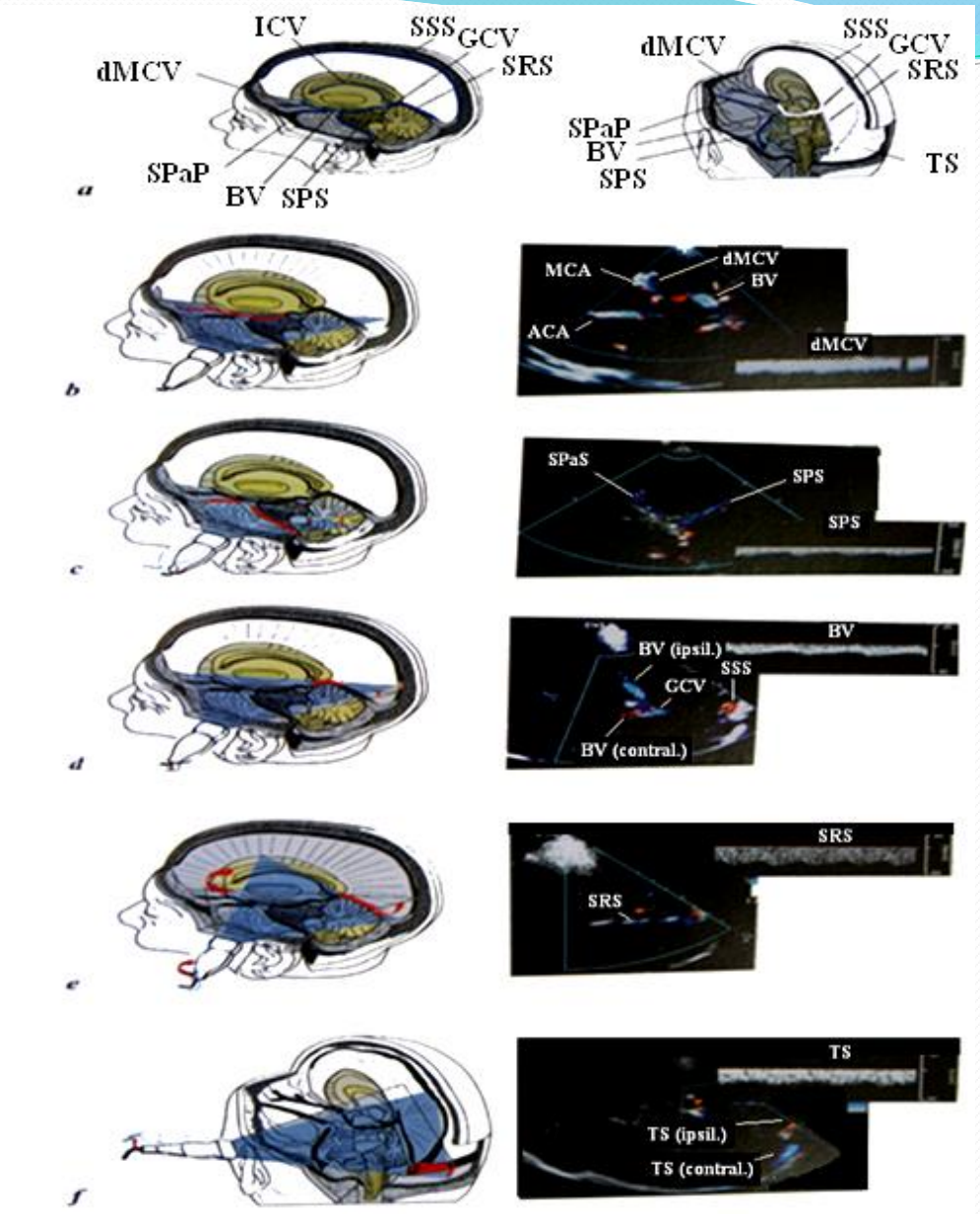
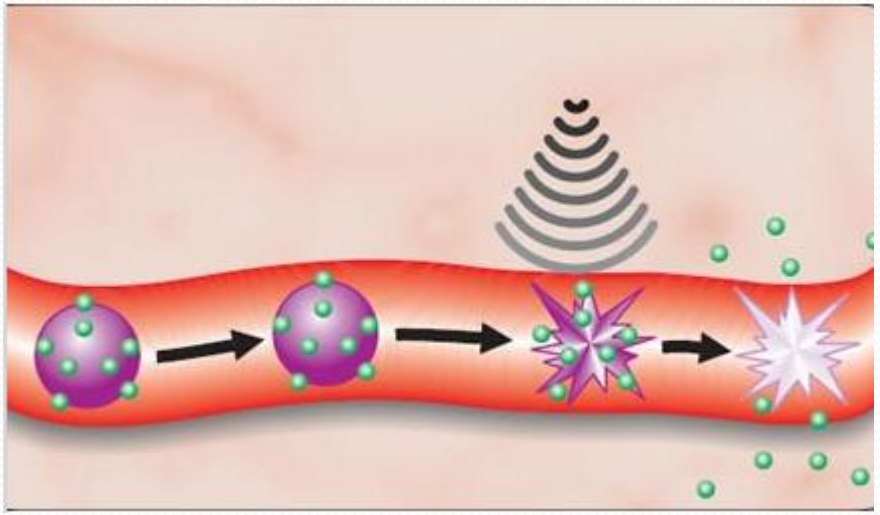


Figure 2-4 Venous Anatomy and Examination[1]

[1] Replicated from R.W. Baumgartner, Handbook on Neurovascular Ultrasound, Frontiers of Neurology and Neuroscience Volume 21, Karger, 2006, Page: 185

Significant Developments in Ultrasound Research

- Attach To Diseased Cells For Identification (molecular imaging)
- TCD ultrasound enhanced tPA induced thrombosis
- Targeted Drug Delivery
- Gene Delivery



Phillips (2009) www.phillips.com; Drug Delivery

Previous Work

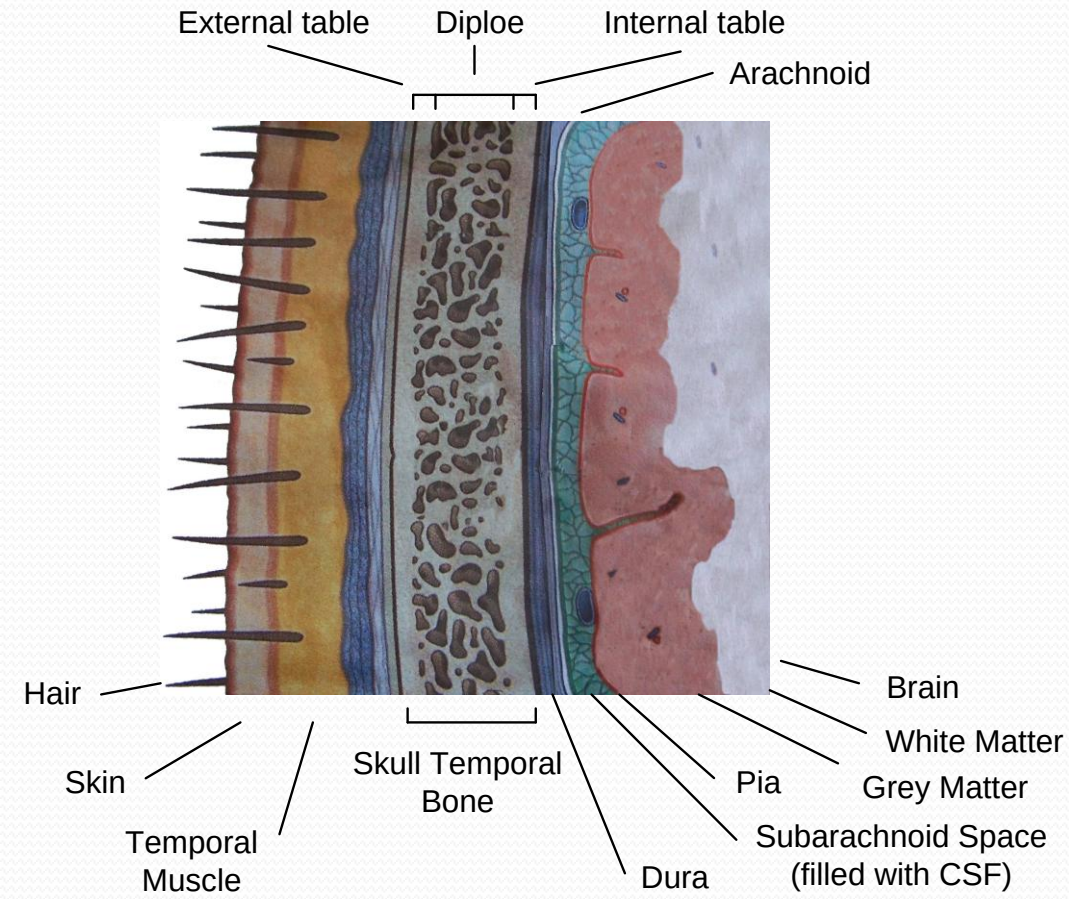
- Transcranial Acoustic Windows Detection on Ultrasound Phantoms

- Acoustic Charartertistic of Ultrasound contrast agent

Current Work

- Transcranial Acoustic Windows Detection on Sheep

Acoustic Window Anatomy



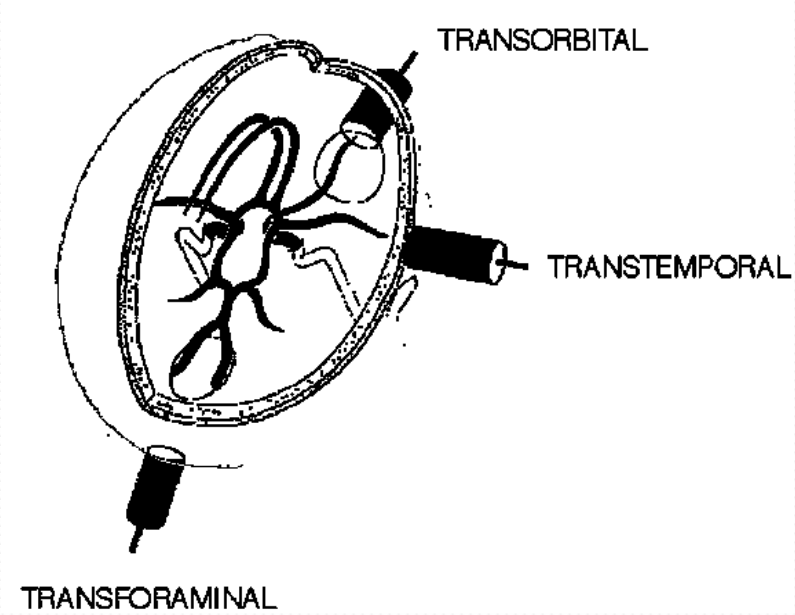


Figure 2-5 Human Head Anatomy Cross-Section
Adapted from R. L. Drake; W. Vogl; A. W. M. Mitchell; Gray's Anatomy for Students, Elsevier Inc., 2005, ISBN: 0808923064 Page: 794

Adapted from K.A. Fujioka, C.M. Douville, Anatomy and freehand examination. In Newell DW, Aaslid R:

Transcranial Doppler, Raven Press, New York, 1992

Acoustic Propagation

$$R(f,d) = T^2(f).D^2(f,d).A^2(f,d).S(f)$$

where R is the ultrasound response, S is the acoustic backscatter of the medium, A is the attenuation, T is the transfer function of the acoustic transducer and D is the acoustic diffraction. The temporal bone caused the most scattering.

(2)

Attenuation-Velocity Product

$$attenuation\ velocity = \alpha(f)/t = \alpha_0 f^n (d_1 - d_2)/t$$

$$BUA = \log_{10} \frac{R_{ref}(f)}{R_{sample}(f)} + \log_{10}(T_{rs}T_{sr}),\ dB$$

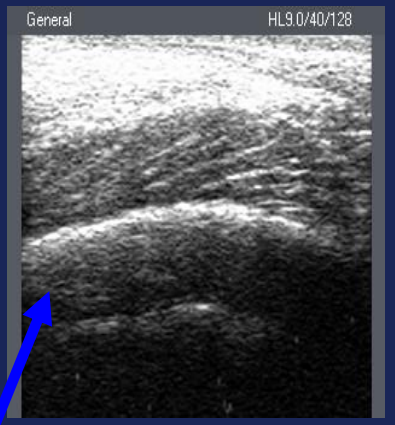
TABLE I

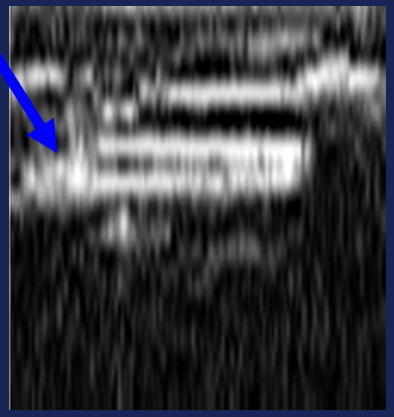
TRANSCRANIAL ACOUSTIC PROPERTIES

Media	Speed of Sound (ms^{-1})	Attenuation ($dBcm^{-1}MHz^{n}$)	Speed of Sound Attenuation Product
Scalp	1550-1630	0.5-1.7	775-2771
Bone	1740-4080	1-11	4080-44850
CSF	1510	0.0023	3.4
Brain	1545	0.3-0.85	463-1313

n ranges from one in soft tissue (scalp, brain) and approaches two for hard tissue and liquid (bone, CSF).

Skull





Jaw

Brain

Hardware Schematics

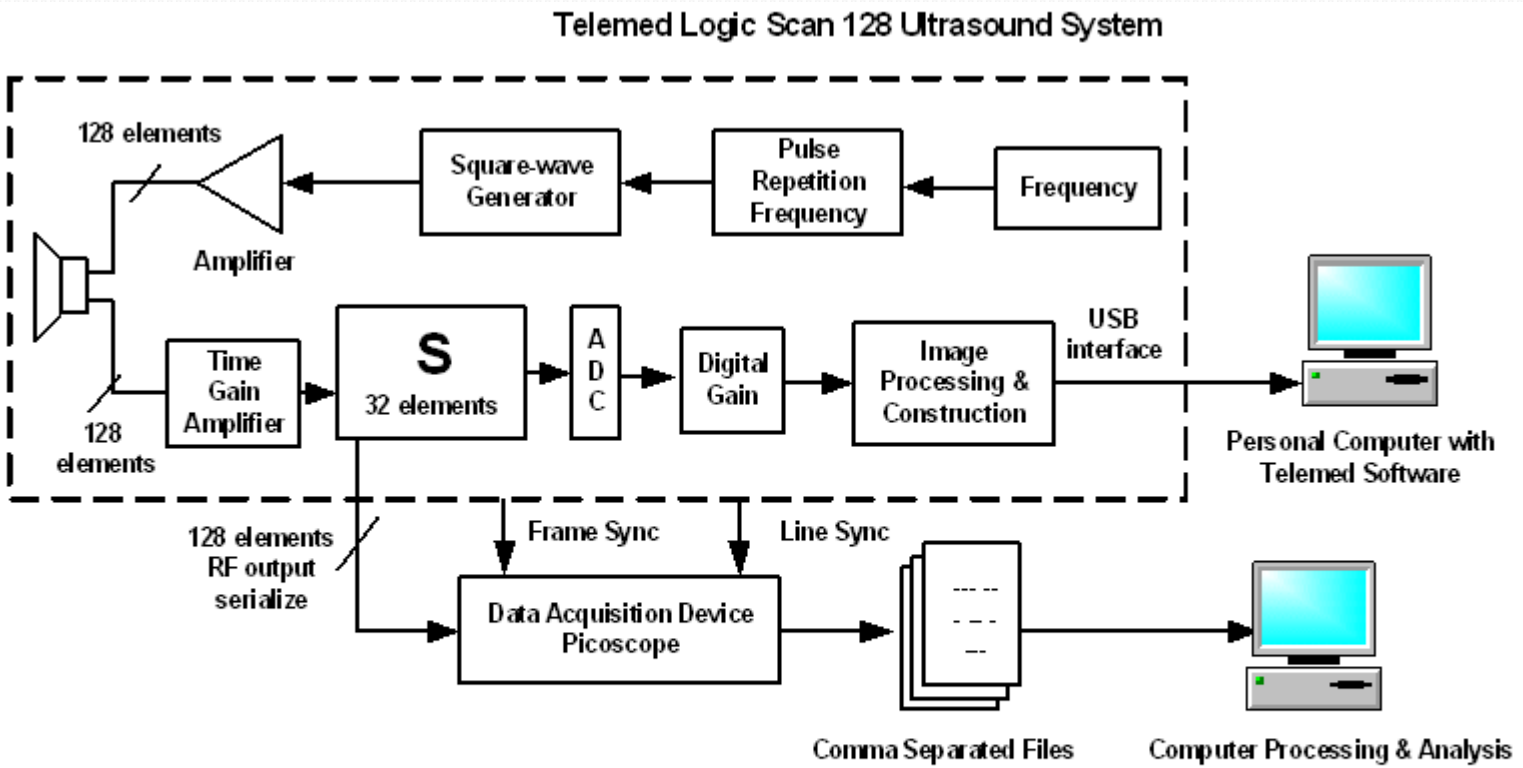
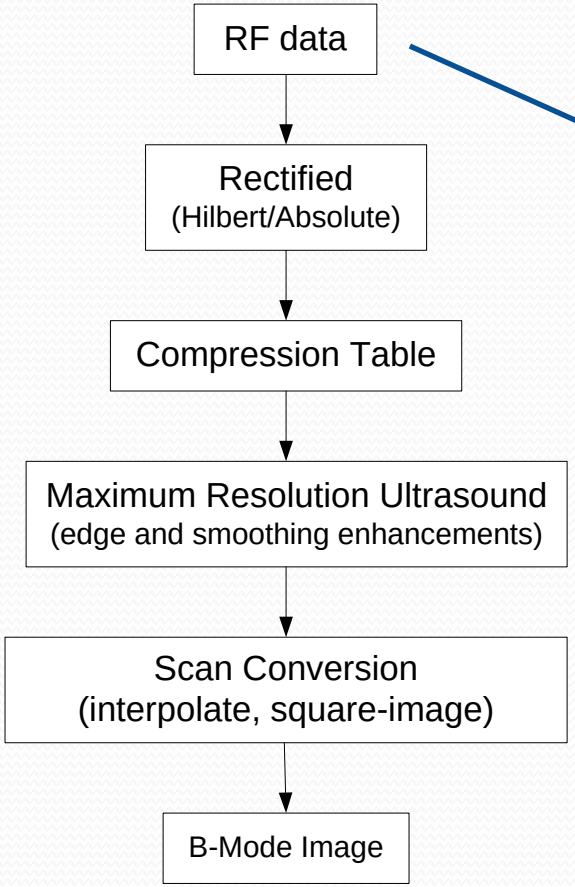


Figure 1. Experiment Setup

Block diagram of a B-Mode Signal Process



$$BUA = \log_{10} \frac{R_{ref}(f)}{R_{sample}(f)} + \log_{10}(T_{rs}T_{sr}),\ dB$$

Attenuation-Velocity Image

Results

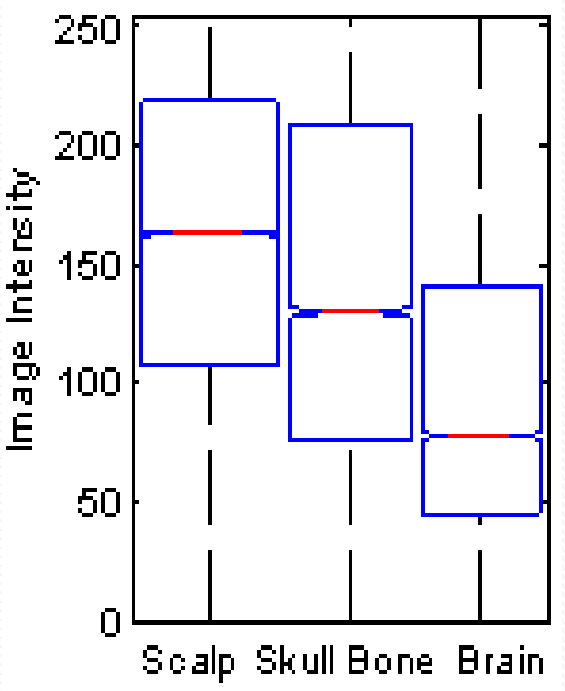


Figure 5. Ultrasound B-Mode Response of the Cross-section of an ovine Transcranial Region

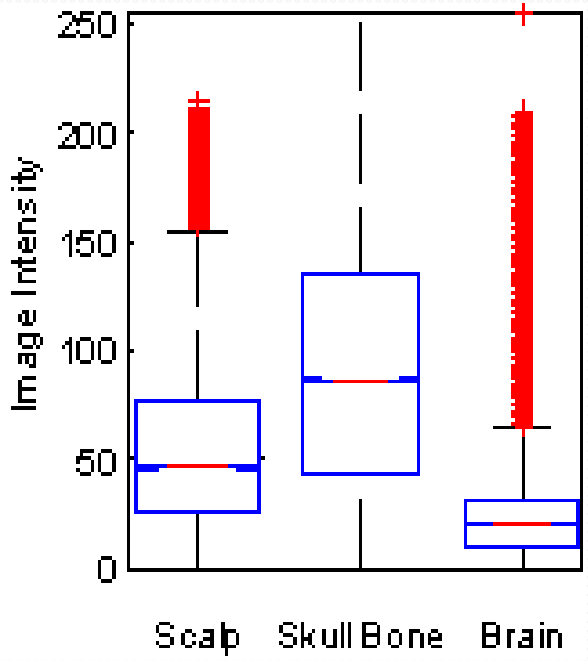


Figure 6. Broadband Ultrasound Attenuation-Velocity Response of the Cross-section of an ovine Transcranial Region

Discussion

- Ovine (Sheep) != Human Anatomy

Ovine generally have denser skulls, and in some species, their jaw bone perturb up in front of the temporal bone, hindering ultrasound penetration of the temporal bone.

However, the technique under investigation of pre-scanning the temporal for suitable acoustic window is anticipated to reduce the distance between experienced TCD operator versus non-experienced TCD operators; this will improve the reliability, repeatability and reproducibility of the procedure.

Conclusion

- The TCD acoustic window response has some distinguishable features, although the features are not always recognizable.

- Early Acoustic Window Detection could significantly improve the procedure for strokes, brain surgery and brain diseases.

Acknowledgements

Author: Tony de Souza-Daw
Email: tony.desouza-daw@rmit.edu.vn

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Questions?

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4. **de Souza-Daw, Tony, et al.** Comparison of Transcranial, Scalp-to-Brain, Layered Phantoms. *Ultrasound in Medicine and Biology.* August 2009, Vol. 35, 8S, pp. S3-0066.
5. **de Souza-Daw, Tony, et al.** Cross-Sectional Human Tissue Equivalent Phantoms. *Engineering and Physcial Sciences in Medicine and the Australian Biomedical Engineering Conference.* November 2009.
6. **de Souza-Daw, Tony, et al.** Dilution Media Effects on Proteinaceous Ultrasound Contrast Agents. *Proceedings of 2009 International Symposium on Bioelectronics and Bioinformatics.* 9-11 December 2009, pp. 45-48.