Using the Electrical Impedance Spectrum to Classify Brain Pathologies Causing Elevated Intracranial Pressure

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Introduction & Research Question

How does the impedance spectrum correlate with varying intracranial pressure (ICP) conditions?

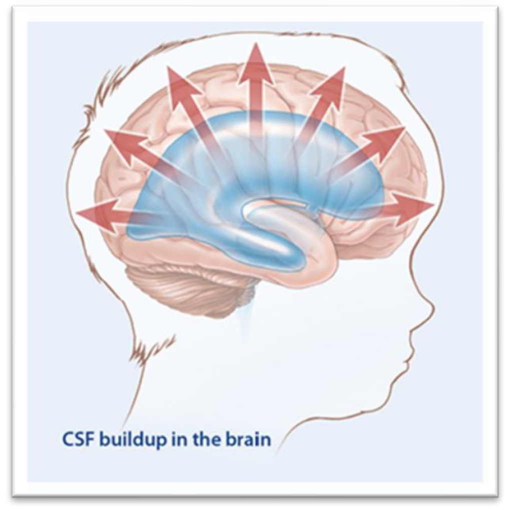


Figure 1. Accumulation of CSF causing elevated ICP

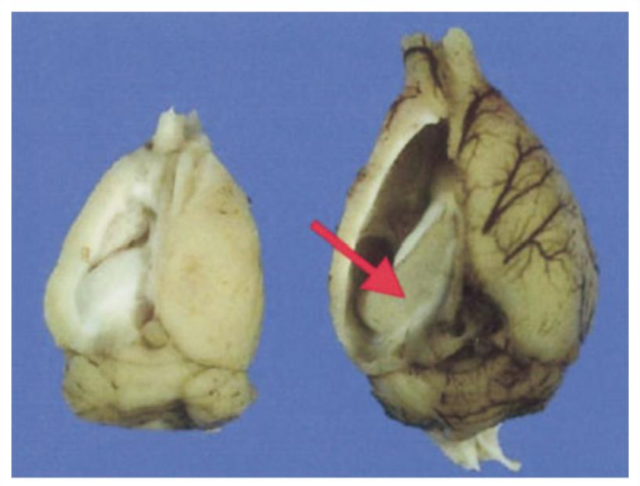


Figure 2. Normal vs hydrocephalic rat brain showing severe thinning of the cerebrum, displacement of hippocampus, and atrophy of white matter [1]

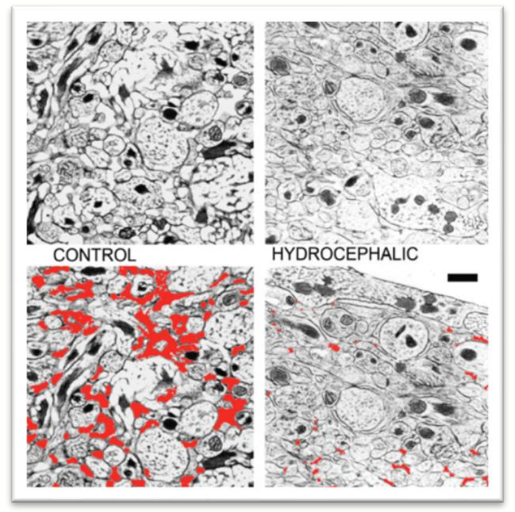


Figure 3. Brain tissue compression within the extracellular space as pressure and volume increase, decreasing extracellular fluid [2]

Project aims are to provide research for the development of more reliable and less invasive techniques for monitoring ICP in patients with intracranial shunts.

Materials & Methods

Materials:

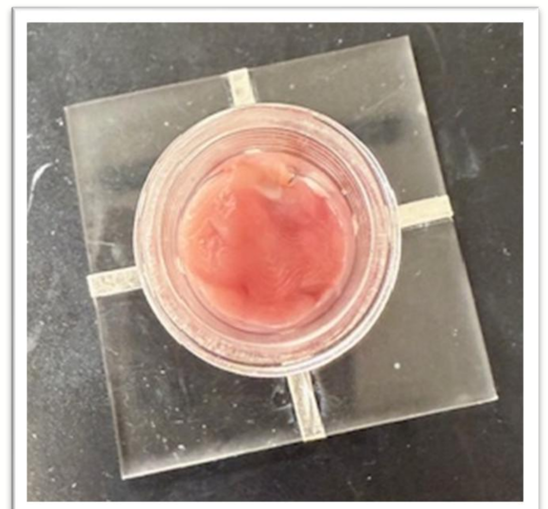
- Porcine Brain Tissue
- 1kg load cell + HX177 Amplifier + Arduino
- Oscilloscope
- Function Generator
- 4 Electrodes
- Silver Foil

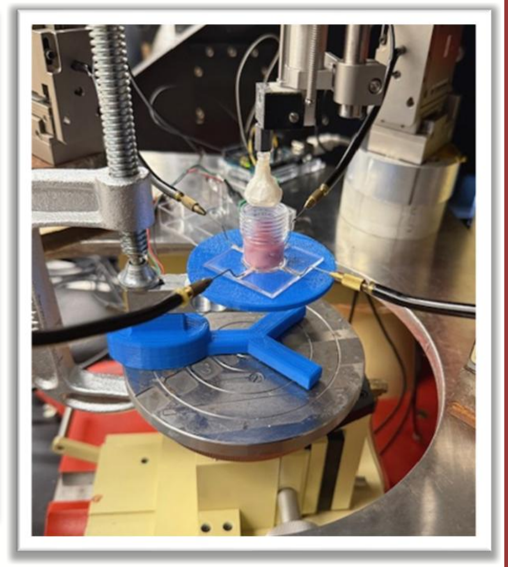
Experimental Parameters:

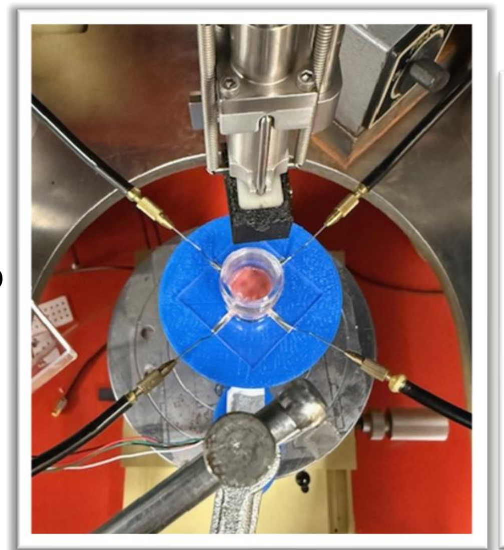
- 50 mV
- 1, 10, 100, 1k, 10k, 100k (Hz)
- 5, 10, 20, 30, 40 (mmHg)

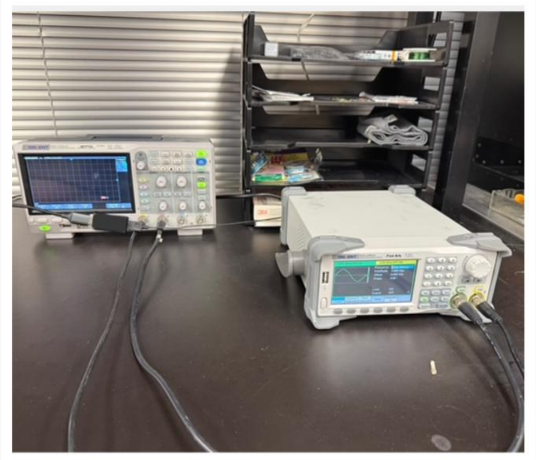
Methods

Porcine tissue was confined in a small dish and subject to compression. An Arduino-controlled load cell was used to obtain the specific pressure measurements. For each compression, voltage measurements were collected at the frequencies listed above using the 4-electrode method.









Results

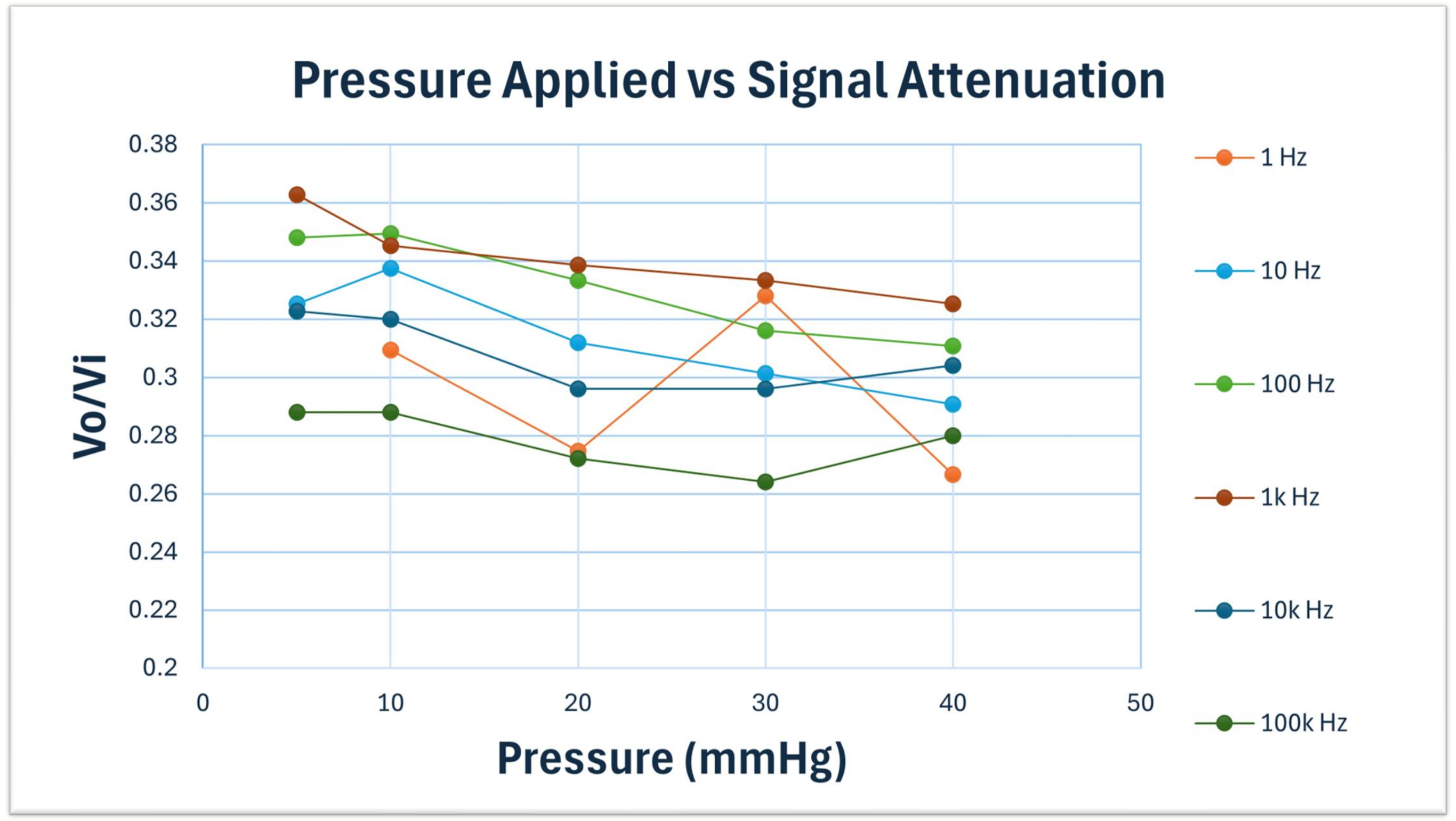


Figure 4. Plot of the signal attenuation for each frequency at each pressure measurement. Raw signals were filtered using a 3-point moving average. The peak-to-peak voltage was found and subsequently compared to the constant input voltage of 50 mV, yielding the attenuation. An extreme point for 1 Hz at 5 mmHg was removed from the dataset.

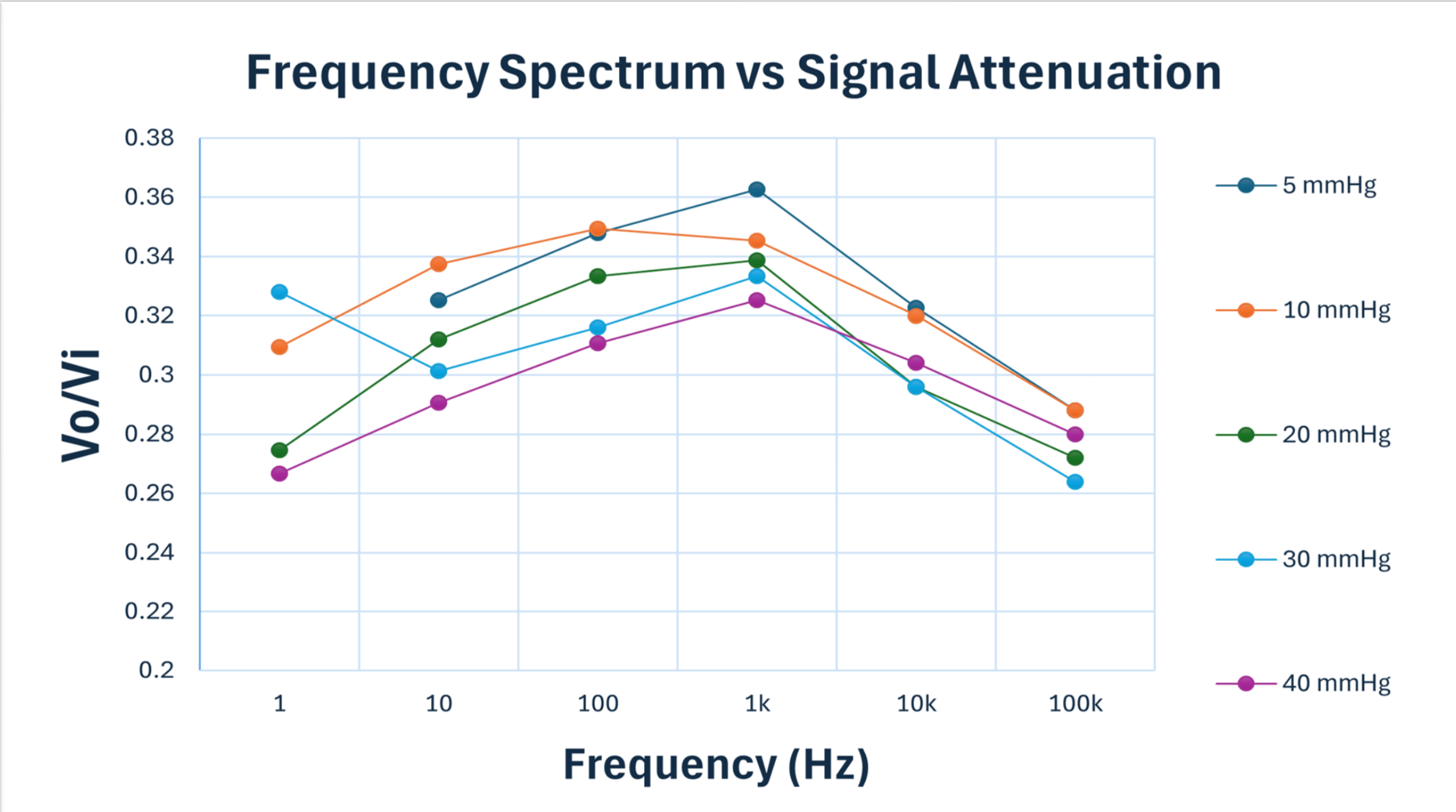


Figure 5. Plot of the signal attenuation for each pressure over different ranges of the frequency spectrum.

Conclusion

Overall, as pressure applied to the brain tissue increases so does the attenuation of the signal, which can be correlated to increasing impedance.

Results of this research show frequencies around 1k Hz to be most optimal in detecting pressure fluctuations, due to this frequency showing the largest change in output voltage compared to the input as pressure increased from 5 to 40 mmHg.

The smallest difference was found when using 100k Hz and 10k Hz, due to the frequency being higher and less subject to impedance changes.

The signal that had no noticeable trend was 1 Hz and could possibly be attributed to more noise while collecting measurements.

As such, impedance shows promise for ICP monitoring applications.

Future Directions

1. Performing similar tests with fresh brain tissue to more accurately model the mechanical properties of brain, such as compression and fluid constraint.
2. Improved signal noise-reduction for lower frequencies in the 1-10 Hz range.

Acknowledgements

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References

[1] M.R. DelBigio, M.J.Wilson, and T.Enno, "Chronic hydrocephalus in rats and humans: White matter loss and behavior changes, "Annals of Neurology, vol.53, no.3, pp.337–346, Feb.2003, doi: https://doi.org/10.1002/ana.10453.

[2]M.R. Del Bigio and T.L .Enno, "Effect of hydrocephalus on rat brain extracellular compartment," Cerebrospinal Fluid Research, vol.5, no.1, Jul.2008, doi:https://doi.org/10.1186/1743-8454-5-12.

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