Quantitative Ultrasonic Properties of Prostate Cells

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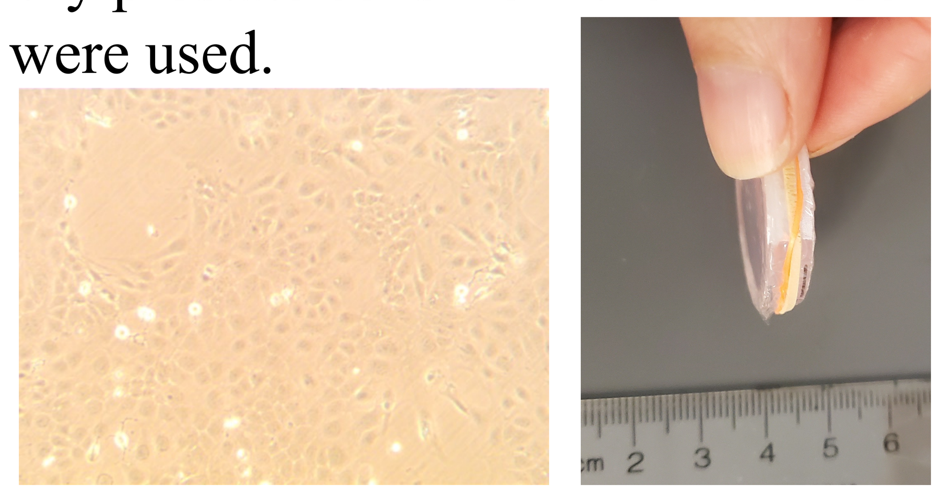
Abstract

This study explored the quantitative ultrasonic (QUS) properties of healthy prostate cells by determining attenuation, speed of sound, and backscatter. An archive of quantitative tissue properties will contribute to difference between cell types, possibly leading to a non-invasive way of detecting cancer through quantitative ultrasound.

Introduction

- In the United States, prostate cancer is the second leading cause of cancer death and the most diagnosed form of cancer in men.[1]
  - 1 in 5 US males will be diagnosed with prostate cancer during their lifetime.[1]
- Being able to detect prostate cancer early is important in preventing it from developing into more serious stages.
- It has been shown that healthy and malignant cells have differences in their QUS properties.[2]
  - Knowing these fundamental property differences is important in potentially using QUS to diagnose cancer.
  - Properties of speed of sound, attenuation, and backscatter were investigated.
- Healthy prostate cells from the PNT2 cell line were used.



Healthy Prostate Cells (PNT2) and pellet for SOS/ATTEN experiment

- A high-density cell pellet containing about 40 million cells was used to conduct the experiments.
- The trials were run in a water bath with a temperature between 32ºC and 33ºC

Acknowledgements

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[1] *Prostate cancer treatment (PDQ®)–health professional version. National Cancer Institute. (2021)* https://www.cancer.gov/types/prostate/hp/prostate-treatment-pdq

[2] *T.Ge4rtner, M. Zacharias, K.-V.Jenderka, H.Heynemann, and U. Cobet, Equipment independent ultrasound tissue characterization of human testis and prostate," Radiologe 38, 424-433 (1998).*

Methodology

- The speed of sound & attenuation experiment was run on the PNT2 cell line using 5, 10, and 15MHz unfocused paired transducers.
- Measurements of time at the start of the signal and amplitude, peak to peak, were recorded for the received signal in the presence and absence of the sample between the transducer.

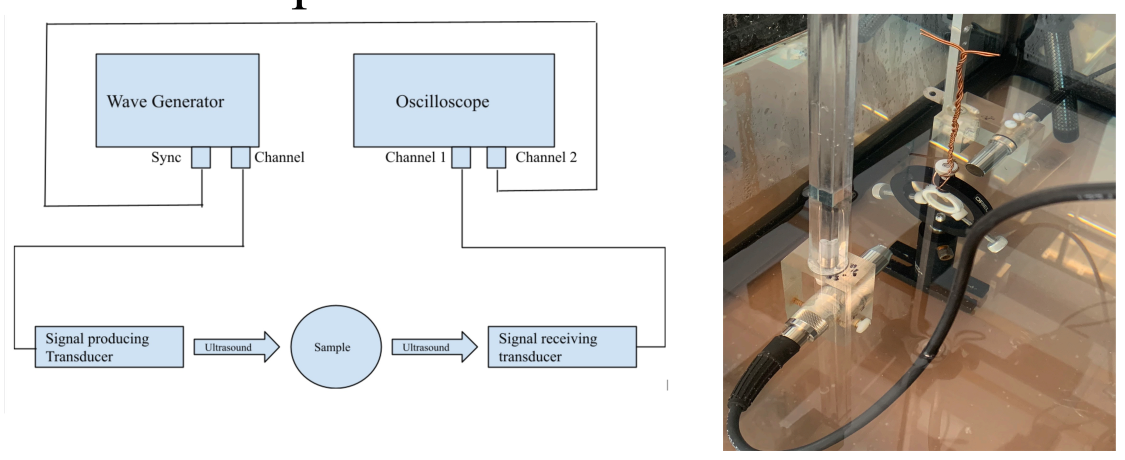

Figure 1 (a&b): Set up for the speed of sound and attenuation experiment.

- Speed of sound is calculated using:

$$C_s = \frac{C_W}{1 - \left(\frac{C_W \Delta t}{d}\right)}$$

Where Cs is the speed of sound in the sample, Cw is the speed of sound in the water, t is the difference in time between the water and sample path, and d is the thickness of the cell pellet.

- Attenuation is calculated using:

$$\alpha = \frac{20}{d}\log_{10}\left(\frac{A_0 T}{A}\right)$$

  - Where α is the attenuation, d is the thickness of the cell pellet, A_0 is the signal amplitude in water, T is the correction for the saran window, and A is the signal amplitude in the sample.
- The backscatter experiment was run on the PNT2 cell line using 5, 10, and 15 MHz focused transducers.
- The waveform of the signal produced by the cells was recorded at a range of frequencies and then processed in MATLAB alongside planar reflector waveform data.

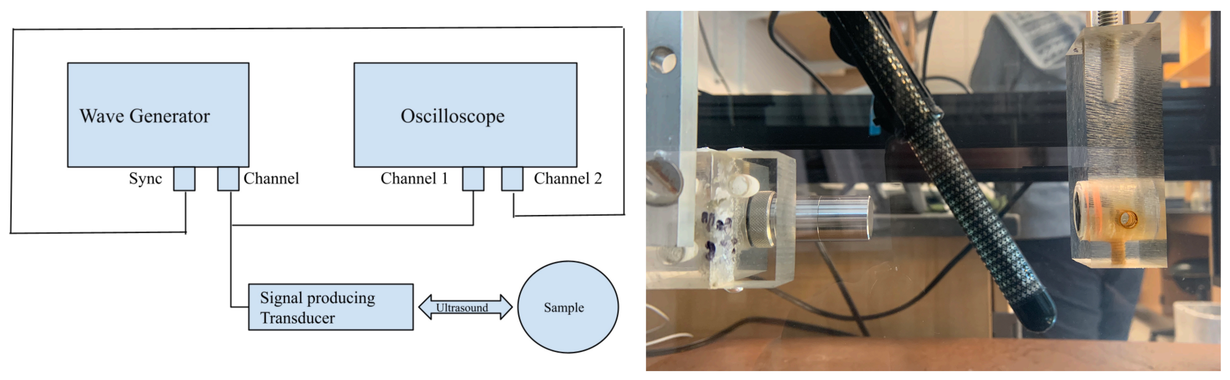

Figure 2 (a&b): Set up for the backscatter experiment.

- Backscatter is calculated using:
- **The BSC is calculated using the Power spectrum (V), transducer properties (T), frequency components (B), and beam profile (A) $\sigma_b = \frac{\langle V_g(\omega) V_g^*(\omega)\rangle}{c^2 |T(\omega)B(\omega)|^2 \iiint_\Omega |A(\vec{r},\omega)|^4 d\vec{r}}$ The transducer properties and frequency components are determined using a planer reflector, with reflectance R: $T(\omega)B(\omega) = \frac{V_p(\omega)}{R \iint_S A_0(\vec{r},\omega) dS}$**

Results

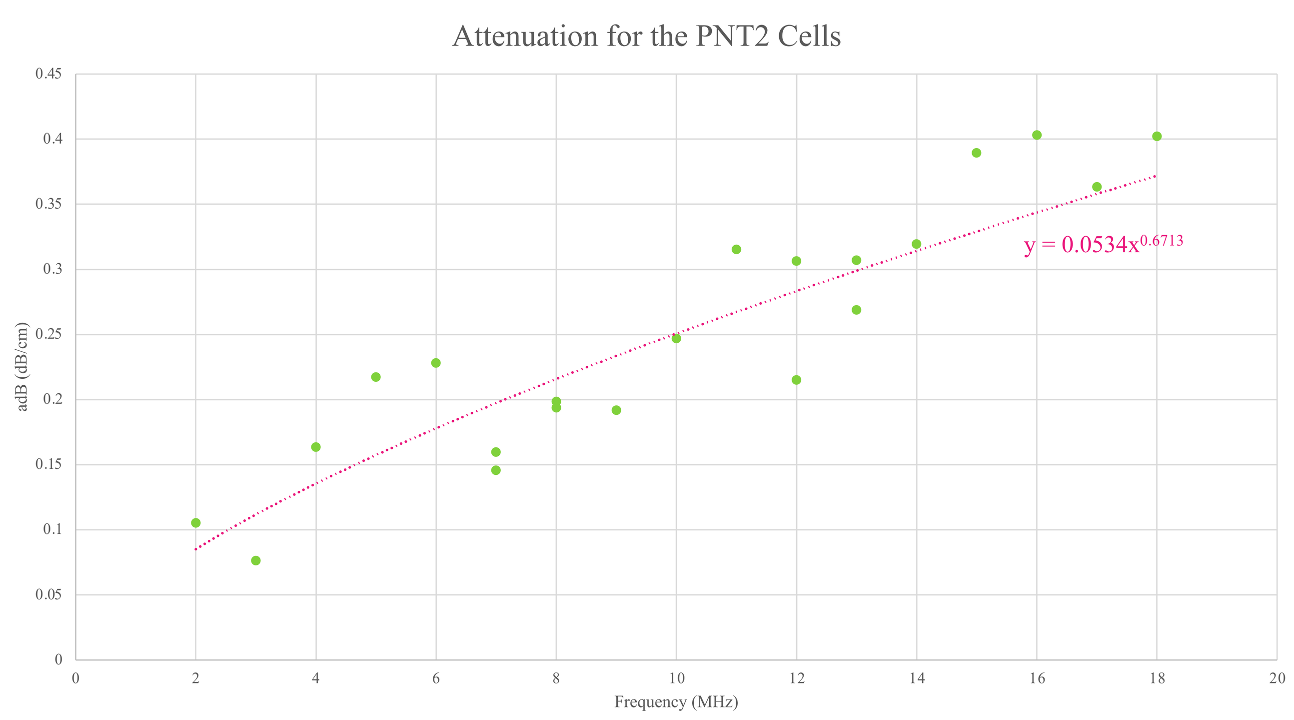

Figure 3: Attenuation increases in the healthy prostate cells as frequency increases. A power equation (red) were fit shows that attenuations is proportional to $f^{0.7}$, which is consistent with other power proportionalities for human tissue. The average attenuation/frequency is **0.027 +/- 0.009 dB/cm-MHz**

The **speed of sound** in healthy prostate cells remains constant across frequencies with a span of1522 m/s to 1524 m/s, and an average value of **1523.3 +/- 0.4 m/s**.

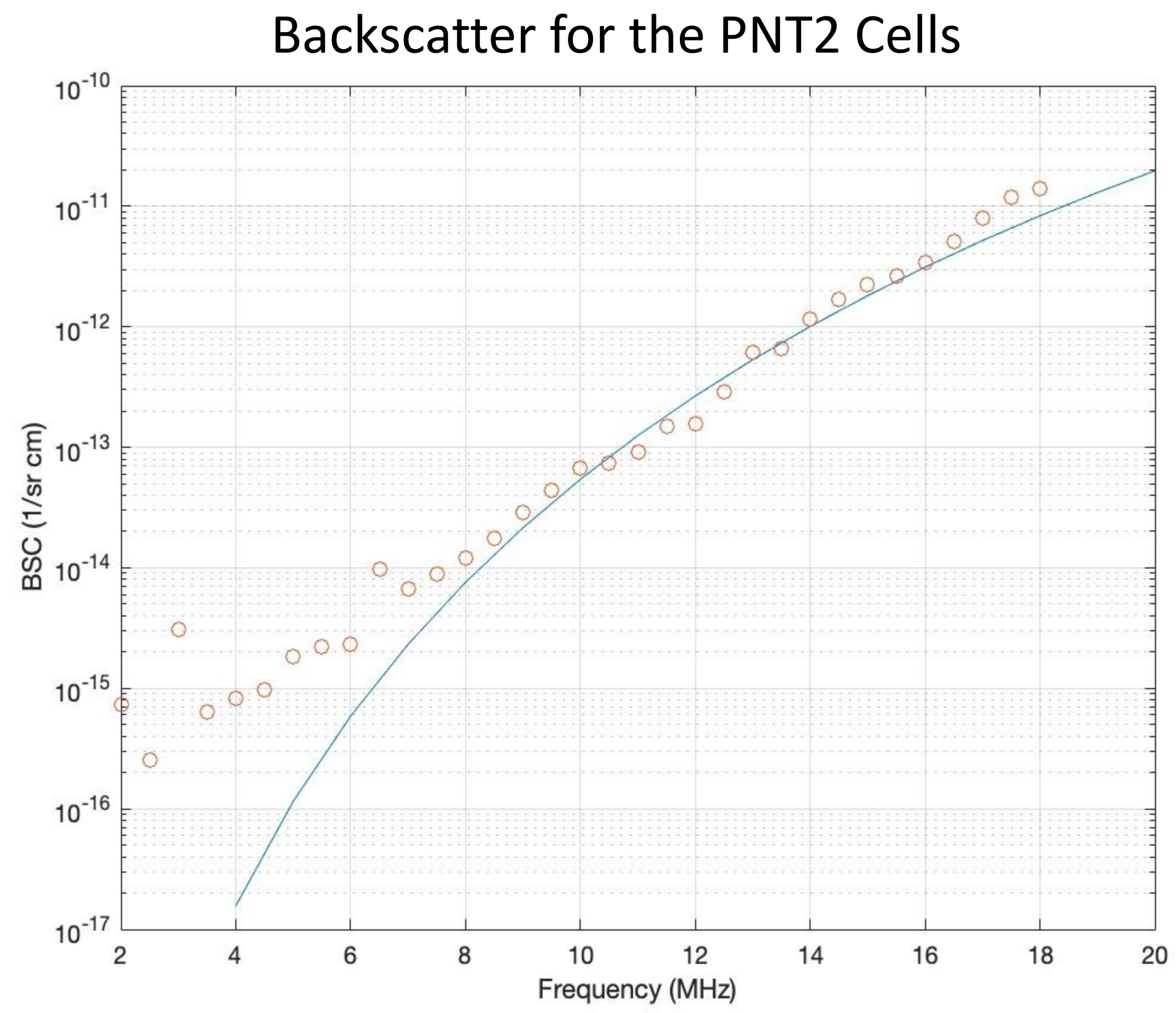

Figure 4: As frequency increases, the backscatter in the healthy prostate cells also increases. A comparison is made to theory for a spherical scatterer, showing agreement at higher frequencies. The cells have a diameter of ~20 microns which gives an expected peak backscatter at close to 75 MHz.

Conclusion

- Measurements of tissue properties for healthy prostate cells are consistent with theory and expected values for human tissue
- Future work will make similar measurements for malignant cells to provide comparisons.