Frequency-dependent compensation in H-scan Ultrasound for improved differentiation of benign and malignant breast tumors

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Aims: Tumor tissue microstructures produce diverse ultrasound scattering patterns, embedding frequency information in echo signals. H-scan Ultrasound visualizes these frequencies in the region of interest (ROI) by color-coding low frequencies as Red and high frequencies as Blue. However, high-frequency waves attenuate more severely during propagation, causing inaccuracies in H-scan analysis. To enhance H-scan performance in characterizing breast tumors, frequency-dependent attenuation compensation is essential.
Methods: This study utilized the H-scan technique with a frequency-dependent compensation (FDC) algorithm to analyze 100 groups of human breast tumors ultrasonic data (48 benign and 52 malignant, all confirmed by biopsy [1]). The frequency attenuation coefficient was estimated from peak frequency shifting with propagation depth. For the H-scan technique, matched Gaussian-Hermite filters isolated targeted frequency components based on the compensated spectrum.
Results: After applying the FDC algorithm, significant differences emerged: malignant and benign groups showed a highly significant difference ($p<0.01$) in the fraction of Blue pixels in the ROI, indicating high-frequency contents. Similarly, BI-RADS categories 3 and 5 exhibited a high significant difference ($p<0.01$) after FDC. Without FDC, no significant differences were observed.
Discussion & Conclusion: The significant differences in high-frequency components between compensated backscattered signals of benign and malignant tumors are closely linked to the scattering microstructures of breast tumors. Statistical results also indicated that high-frequency components in the ROI increased with higher tumor malignancy risk. Frequency-dependent attenuation compensation improves tissue characterization using H-scan, thereby offering more reliable indicators for distinguishing breast tumors with varying malignancy risks.

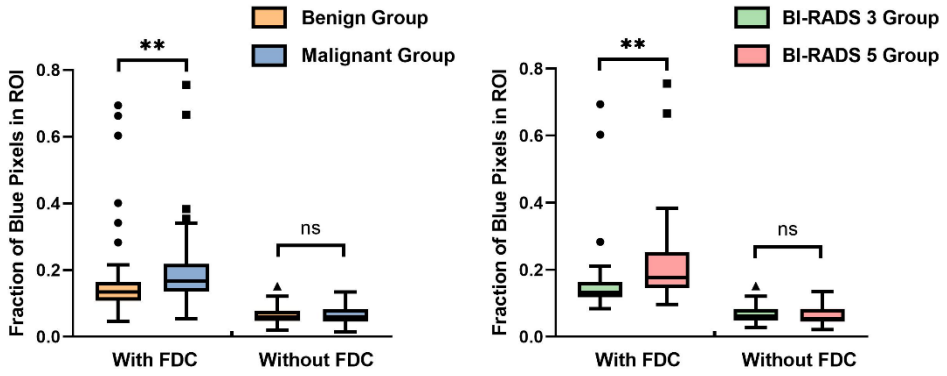

Figure 1. Blue Pixel Fraction in ROI: Malignant vs. Benign (Left) and BI-RADS 3 vs. 5 (Right). Note: * $p<0.05$; ** $p<0.01$; ns: No Significant Difference.

References:

[1] Piotrzkowska‐Wróblewska, Hanna, et al. "Open access database of raw ultrasonic signals acquired from malignant and benign breast lesions." Medical physics 44.11 (2017): 6105-6109.