High Frequency Backscatter Measurements of Bovine Tissues with Unfocused and Focused Transducers

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Abstract: In order to improve resolution of ultrasonic imaging, high frequency scanners which are employed in the range 20 MHz to 50 MHz are needed. As a result, it is critical to obtain data on ultrasonic scattering and attenuation in this frequency range. At these high frequencies, it is not feasible to make scattering measurements with unfocused transducers; therefore focused transducers are needed. Using the standard substitution method to calculate the backscatter coefficient, as is used with unfocused transducers, yields erroneous results for focused transducers. The assumption that the reflected echo from a perfect reflector in the far field can be calculated as though the transducer acted like a point source is not valid for focused transducers. Therefore, a method is presented for focused transducers where the flat reflector is substituted by a particulate reference medium whose backscatter coefficient is well known and documented. As a validation study, measurements are made with 10 MHz focused and unfocused transducers. Preliminary backscatter results at 10 MHz indicate a good agreement with previous work. For bovine myocardium, a backscatter coefficient of $6.35 \times 10^{-5} \pm 0.02 \text{ mm}^{-1} \text{ sr}^{-1}$ was obtained for unfocused transducer and $4.1 \times 10^{-4} \pm 0.11 \text{ mm}^{-1} \text{ sr}^{-1}$ for the focused transducer. These measurements will be extended up to 30 MHz using focused and unfocused transducers for bovine myocardium, kidney, and liver.

Introduction

The ultrasonic backscatter coefficient, as a function of frequency, is a useful parameter in describing the scattering efficiency of a material. In clinical ultrasound, the backscattered echoes in the frequency range 1-20 MHz are used to analyze biological tissues. However, there is a need to explore ultrasound imaging at a higher frequency range in order to improve image resolution and quality. High frequency measurements of backscatter have been conducted on blood (2). For frequencies greater than 20 MHz, focused transducers are needed to ensure adequate signal-to-noise ratio since high frequency unfocused transducers have reduced SNR due to small aperture sizes to keep measurements fairly close to the transducer. This paper explores backscatter measurements from bovine tissues at 10 MHz using focused and unfocused transducers. The methods described in this paper will be used to extend the backscattering measurements up to 30 MHz and comparisons will be made between focused and unfocused transducers.

Methods

Two methods are employed to measure the backscatter coefficient from biological tissues. The first method is the standard substitution method developed by Sigelmann and Reid (1). Formulation of equations can be found in reference 1. This method has become an acceptable method for the absolute measurement of backscatter and is used by many investigators in blood and biological tissue measurements. This method is a narrowband approach for measuring the backscattering coefficient from a volume of scatterers. The absolute backscattering coefficient in this sample volume is obtained by measuring the backscattered power and normalizing it to the power reflected from a perfect plane reflector. Normalizing the power eliminates the measurement of incident intensity and transducer characteristics. This method can be used for flat transducers only since it is based on the assumption that the power from the reflected echo from the perfect reflector can be calculated assuming that the transducer acts like a point source emanating energy confined in a cone bounded by the -3dB beamwidth of the transducer.

A second method (2) is used for focused transducers, since the assumption that the echo from a flat reflector can be calculated by assuming that the transducer acts like a point source does not hold. It has been shown that for focused transducers, the flat reference reflector can be replaced by a particulate reference medium whose backscattering characteristics are either well known or well-documented (2). One such particulate medium is red blood cell suspensions of low hematocrit. The red cells are tenuous scatterers and well-dispersed in the suspension by constant stirring throughout the measurements. The backscattered power is obtained from the reference red cell suspension of
a low hematocrit and the biological tissue in the same insonified region under the same experimental conditions.

Therefore, in order to determine the backscattering coefficient of the tissue, measurements of the ratio of the scattered power values from the medium and the reference medium using the focused transducer and the backscattering coefficient of the reference medium are needed.

Materials and Experimental Methods

Bovine tissues and porcine whole blood were obtained from local slaughterhouses. The tissues were immediately placed in saline after excision. Experiments on the tissues were performed within 6 hours of excision. EDTA solution was added to the porcine blood to prevent clotting. The blood was centrifuged to separate the red blood cells from the plasma and other cells. The red cells were then washed twice by saline solution. A solution of 6% hematocrit red cells was prepared as the reference medium.

The experimental set-up is shown in figure 1. The unfocused 10 MHz transducer has a diameter of 4.9 mm and transition region at 40 mm. The focused 10 MHz transducer, Panametrics A-327R, has a 9.5mm diameter and is focused at 50 mm. All experiments were done at room temperature.

Results and Discussion

Three different specimens of bovine myocardium and blood samples from two different animals were obtained for this preliminary study. For each blood sample, five-hundred backscattering rf signals were acquired and the corresponding rms values were calculated. A mean rms value was then obtained and used for the backscattering calculations. For each bovine tissue, several rf lines were collected over the tissue and averaged. The backscatter coefficient was calculated for bovine myocardium at a frequency of 10 MHz using focused and unfocused transducers. The attenuation coefficient at 10 MHz was measured to be $0.89 \pm 0.07$ nP/mm, which agrees with previous results (3). The backscatter coefficient obtained with the unfocused transducer yielded a value of $6.35 \times 10^{-4} \pm 0.02$ mm$^{-1}$ sr$^{-1}$ and a value of $4.1 \times 10^{-4} \pm 0.11$ mm$^{-1}$ sr$^{-1}$ with the focused transducer. More experiments will be carried out at 10 MHz and above to 30 MHz to compare obtained values of backscatter coefficient of bovine tissues in order to determine the frequency dependence of backscatter at very high frequencies.

References