Diagnosing giant cell arteritis (GCA) with ultrasound center frequency shift (CFS)

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Giant cell arteritis (GCA) is a disease that casuses inflamation of larger blood vessels. This can for example affect the temporal artery, an artery supplying blood to the head and brain. GCA of the temporal artery results in symptoms such as headaches, dizziness, and problems with vision. If left untreated it can cause blindness, aneurysm and stroke. When a patient is suspected of having GCA, a biopsy is performed. During the biopsy a part of the temporal artery is surgically removed. Diagnosing GCA non invasively with ultrasound would be of benefit to the patient as it is less harmful and avoids risks associated with biopsy and can be performed at the bedside.

Determining the size of tissue particles can be a way of characterizing the tissue as healthy or diseased. This can be done with the use of ultrasound. The ultrasound pulse has a frequency spectrum with a certain center frequency. The center frequency of ultrasound echo is impacted by the size of the tissue particles reflecting the sound. When reflected, the ultrasound frequency spectrum will get a lower center frequency. The change in center frequency is larger for larger tissue particles and smaller for smaller tissue particles. The center frequency shift (CFS) is the measured center frequency compared to a reference frequency. The arrows in Figure 1 points out the the center frequency shift (CFS). The upper image is the spectrum from very small scatterers compared to the wavelength of the ultrasound (reference spectrum) and the lower image is the spectrum from large scatterers.

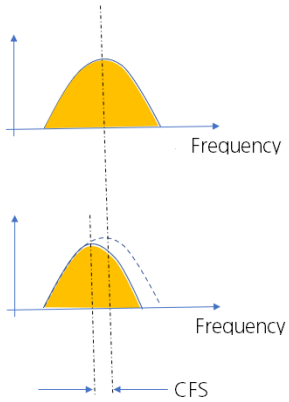

Figure 1. Center frequency shift (CFS) between a reference frequency spectrum (top) and the frequency spectrum in tissue (bottom).

The method has been evaluated in an ex vivo study showing promising results to differentiate GCA positive from GCA negative arteries. The next step is to eveluate the method in vivo. However, a difficulty when in vivo measurements are made, is that there is always some additional tissue between the transducer and tissue of interest. This additional tissue causes a gradual, depth dependant lowering of the ultrasounds center frequency, so called frequency attenuation. The purpose of this thesis was to study the frequency attenuation and how to compensate for it, so it does not influence the measurements from the tissue of interest. A graphical user interface was also developed as a tool to help clinicians with analysing the center frequency measurements and compensating for the frequency attenuation.

As a first step it was necessary to study the behaviour of the frequency attenuation, if it is linear and if the same general compensation can be done for all patients or if the compensation has to be done individually. For this purpose, the average of all patient's frequency attenuation in the tissue between the ultrasound transducer and the temporal artery was calculated and plotted. Figure 2 shows the average frequency attenuation of the patients +/-2 standard deviations. The frequency attenuation curve was compared to the frequency attenuation in a material designed to resemble tissue to determine which characteristics were due to tissue and which were due to the instrumentation.

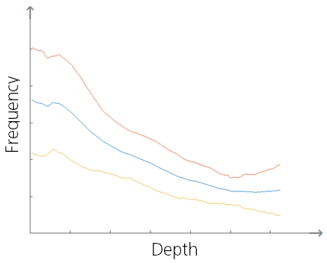

Figure 2. Center frequency attenuation vs depth in tissue.

The frequency attenuation was found to be approximately linear, however it varies between patients. It was concluded that it is not possible to use a standardized slope for all patients, because the variation

in frequency attenuation would affect the measured CFS too much. Instead, the frequency attenuation should be calculated individually for all patients.