Elastography Liver Stiffness Estimates From Two Phase Samples

R. C. Grimm[1], A. Manduca[2], and R. L. Ehman[3]
[1]Mayo Clinic, Rochester, MN, United States, [2]Mayo Clinic, United States, [3]Mayo Clinic

Introduction

Recently, Wang [1] has shown that two phase samples are adequate to generate stiffness estimates in phantom and breast experiments. This paper studies the possibility of generating stiffness estimates in liver elastography experiments from two phase samples. Acquiring only two phase samples is only justified if the vast majority of the applied energy is occurring at a single frequency. Any excitation at higher harmonics will superimpose shorter wave lengths onto the sample and artifactually lower the stiffness estimates.

Methods

Data from ten consecutive clinical studies [2] using a multi-coil receive array were reprocessed to generate stiffness estimates using two or four phase samples. A temporal FT was used to extract the 60Hz signal from the four phase sample data sets. Since the first two phase samples from the four phase data set are temporally separated by $\pi/2$ they can be combined as the complex wave field. The first phase sample is taken to be the real part and the second sample is taken to be the imaginary part of the wave field. The scans were performed on a GE 1.5T scanner using a 2D gradient echo pulse sequence. Four axial slices with four phase samples sensitized to through plane motion were obtained in each study. An acoustic driver with a passive actuator was used to mechanically excite the liver at 60Hz.

Results

To determine the validity of the single frequency assumption, 8 phase samples were acquired within a breath hold using a SENSE reduction factor of 2. Figure 1 shows the temporal FT processing of the wave images. No significant motion is seen in the higher harmonics eliminating the concern about contamination of the fundamental frequency. Signal in the DC term requires that the inversion process removes this signal. With three or more phases samples this can be accomplished with a temporal FT. In this work a spatial least squares was used to remove the DC in the two phase case. Stiffness estimates for the two and four phase cases are compared in Figures 2 and 3. The results from the stiffness maps for the two methods are linear with a slight underestimation obtained from two phase sample data set due to the root 2 lower SNR.

Conclusions

Acquisition of two phase samples $\pi/2$ apart provides the same information for single frequency data as four phase samples and is only limited by SNR considerations. Reduction in the number of phase samples halves the time needed for acquisition of 2D data sets and reduces the chances of unwanted patient motion. Unfortunately, 2D inversion techniques are inherently limited by their inability to distinguish waves traveling obliquely to an imaging plane. Moving to 3D analysis will allow for the characterization of these oblique waves. However, the need to acquire images during breath holds or respiratory gating can make the acquisition of 3D data sets prohibitively long. Limiting the phase steps needed for valid stiffness estimates will move 3D liver scans closer to clinical application.

References [1] Wang et al. Phys. Med. Biol. 53:2181-2196 (2008). [2]Yin M et al. Clin Gastroenterol Hepatol 5(10):1207-1213 (2007).

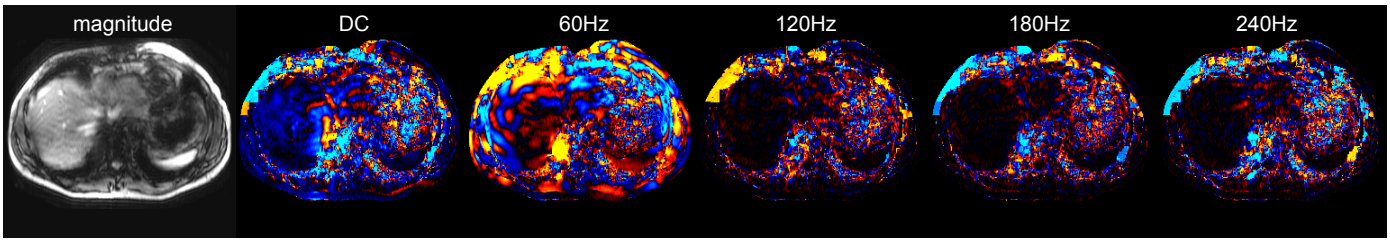

Figure 1: A temporal FT from eight phase samples obtained in a breath hold show signal only in the DC term and at the driving frequency of 60Hz. There is no significant signal in the higher harmonics.

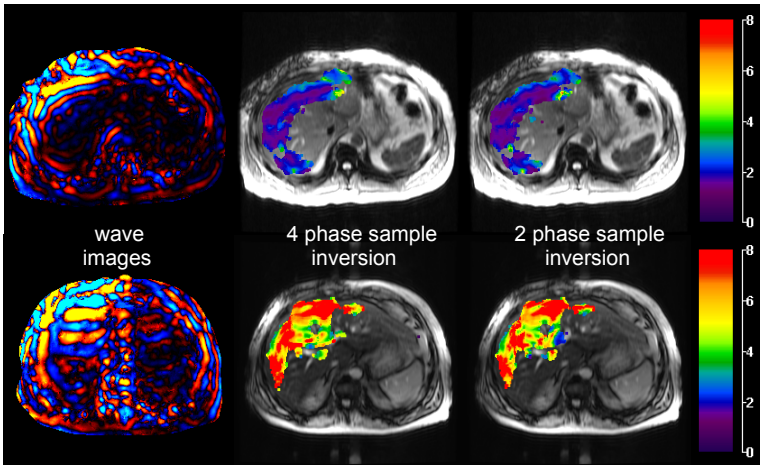

Figure 2: Wave images and stiffness estimates overlaid on to the corresponding images from two clinical studies. The stiffness estimates show nearly equivalent results between the two techniques.

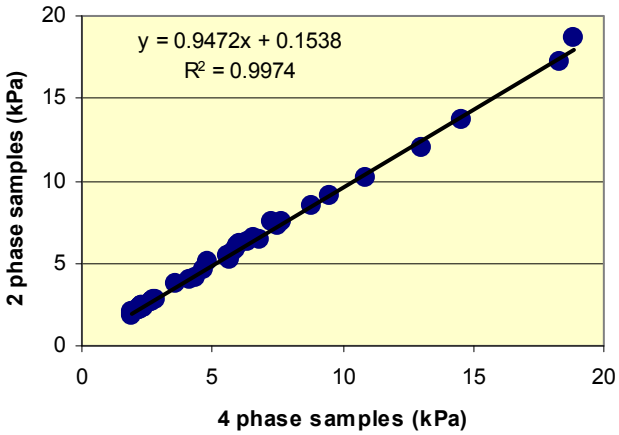

Figure 3: Stiffness estimates in an ROI from each slice obtained using 4 phase samples and 2 phase samples. The lower SNR in 2 phase processing causes slightly lower estimates.