Lipid Percentage Measurements using Three-Point Dixon Method

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Introduction

The Dixon technique [1] is based on echo time-encoding method, and mostly known as an alternative to frequency selective and inversion recovery techniques for fat suppression. To overcome the sensitivity to field inhomogeneity 3-point Dixon technique was developed [2,3]. Although these methods were originally devised for fat-suppression, they also can be used to measure the amount of fat in a tissue, specifically the fat content within the liver or the skeletal muscle that play a major role in metabolic disorders such as type-2 diabetes [4,5]. In this study we investigated the repeatability, reproducibility, and accuracy of the 3-Point Dixon sequence in estimating true fat volume ratios using a fat-water phantom.

Theory

Fat and water protons resonate at slightly different frequencies by virtue of the 3.5 ppm chemical shift between them. At 1.5 Tesla, fat and water protons fall alternately in and out of phase with each other every 2.2 ms. The two-point Dixon method uses this time dependent phase shifts between water and fat to separate the signals from fat and water selectively which may be used to measure the fat content of different tissues. The three-point Dixon method uses another in-phase acquisition (shifted by 2π) to correct for the B0 field distortions. This makes the technique immune to B0 inhomogeneities within the imaging volume. This can analytically be expressed in compact form as $S_n = \left(S_W + e^{in\omega_0 \Delta t} S_F\right) e^{i(n\omega_0 \Delta t + \phi_0)}$ where Δt is the time delay to create 180 degrees phase shift to achieve the Dixon encoding for n=0,1,and 2. S_W and S_F are the water and fat signals, respectively [2].

Methods

The phantom (fig 1) was constructed of 4 test tubes containing various fat contents (cooking oil and detergent mixture) and placed in a transmit-receive head coil and imaged on a 1.5T scanner (GE, Medical Systems, Milwaukee, WI.) Axial images were acquired using an FSE-based three-point Dixon technique with an online reconstruction algorithm. Three images are generated per slice: pure water, pure fat, and combined fat and water. Imaging parameters were TR= 500 ms, TE=42ms, ETL=4, 256 x 160 matrix. A single thick coronal slice (15mm) was used to cover the entire phantom thickness to avoid any variations due to the separation of fat and water in the phantom. The fat volume ratios calculated based on the signal intensities of fat, water and background noise. Then they were compared to the true fat volume ratios using correlation and t-test statistical analysis after the removal of a slight fat signal on each image. The root cause of this residual fat signal is currently being investigated.

Results

Fig 2 and 3 show a sample of water-only and fat-only images acquired. Each measurement was repeated 4 times by 2 operators, resulting in 8 values. The combined gage error was found to be 1.27% within 99% confidence. Then the correlation between the measured values and the actual phantom composition was investigated, as shown in Fig 4. The correlation coefficient was 99.5%.

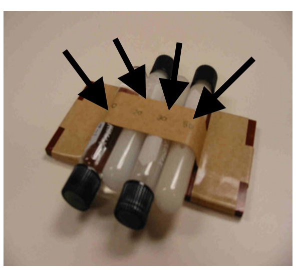

Figure 1

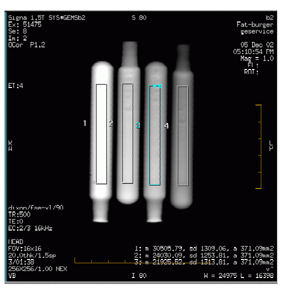

Figure 2

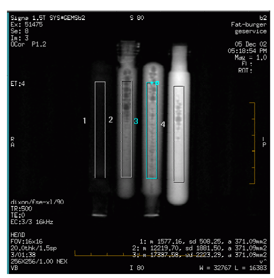

Figure 3

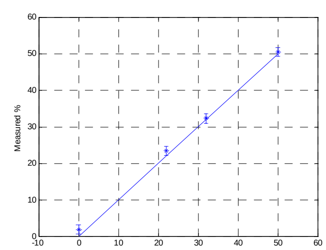

Figure 4

Conclusion

There is a strong correlation between the ratio of fat volume based on signal intensities taken by 3 point Dixon method and the true fat volume ratios in the phantom. 3-point Dixon method is a viable technique to measure lipid percentage within a tissue and has the potential to be very valuable in prospective studies in patients with diabetes and obesity.

References:

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