Echo time compensation adds robustnes to symmetrically sampled two point dixon imaging

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Introduction: In vitro symmetric two point Dixon (1) is complicated due to the temperature dependent resonance frequency of the water signal. To achieve 180 degrees difference between the water and fat components, it is thus necessary to adjust TE depending on the temperature of the object to be imaged. This problem becomes increasingly difficult in post mortem imaging since the temperature is undetermined at the time of imaging, and measurements of core temperature using a thermometer might be inappropriate. We propose a solution that first preforms a quick spectroscopy and then adjusts TE according to the result.

Materials and Method: Since only the water resonance frequency can be considered temperature variant, a model for the projection of the fat components onto the water component was constructed. This model is described in eq. 1 where *Δppm* is the difference between the main fat component and the water component, *t* is time, a_i and f_i is the relative amplitude and the frequency respectively of the fat components in a field of strength B_0. Amplitudes and frequencies from the six component model in (2) was used.

1. $s(t, \Delta ppm) = Re\{\sum_{i=1}^{n} a_i \exp(2\pi i \cdot t \cdot (f_i + \Delta ppm \cdot \gamma B_0))\}$

By measuring the difference between the main fat component and the water component, a graph of the difference between fat and water could be created using the model. A typical response is shown in the bottom right of figure 1. Every local minimum in this graph corresponds to a suitable OP echo time and every maximum an IP echo time. Thus it was possible to use the measured *Δppm* and a time vector to locate an optima TE for every examination.

To evaluate the method, two rat cadavers were stored at 4 degrees Celsius over the night. The cadavers were then imaged one and one after lying in room temperature. An image volume was then acquired using the second OP and the third IP echo times calculated using the method above. The first echoes were ignored due gradient strength imposed to resolution constrictions. The method was also evaluated in vivo under normal conditions, i.e. at body temperature. The result was analyzed by studying the doubled phase of OP. When doubled a true 180 degree difference between fat and water dominant tissue would result in a full 360 degree turn and give a continuous phase shift over the transition. To measure this effect a line was dawned over a fat/water interface and the double phase along that line was studied.

All data were captured on a clinical Philips Ingenia 3.0T (Philips Best, Netherlands). In vivo images used the anterior and posterior coils with a resolution of 0.75x0.75x0.75 mm, TEs 3.45/6.90 and TEs 3.62/7.24, TR 9.95 ms and a flip angle of 10 degrees. In vitro rat images were captured using the small extremities coil with a resolution of 0.42x0.42x0.42 mm, TEs 3.3/6.6, TR 15 ms and a flip angle of 10 degrees. Fat/water separation was performed using a modified version of the previously reported phase sensitive reconstruction method (3,4). The spectroscopy used to measure *Δppm* was made using a standard liver 1H-PRESS spectroscopy protocol with a single 20x20x20 mm voxel placed in a fat/muscle interface. The number of averages was reduced to eight and the TR set to 6000 ms.

Results: By measuring the *Δppm* between water and the main fat component of both rats it was found that the optimal TEs of OP/IP were 3.30/6.60 ms for the first rat to be scanned and 3.36/6.72 ms for the second. For the in vitro case optimal TEs proved to be 3.62/7.24 ms. Images of the double phases and fat/water images can be seen in figure 1. The phase transitions between fat and water tissue were also studied and it was found that the in vivo and in vitro images were closer to opposite phase after optimization using the model above. This effect is best seen in the first graph in figure 1 where a discontinuity can be observed on the blue line representing imaging with non-optimized TEs. Both in vivo and in vitro resulted in no observable discontinuities after optimization. The effect of the well-behaved phase was also beneficial during fat/Water reconstruction were convergence was reached faster. Visual inspection of the in vivo images also concluded that the one with optimized TE was sharper, see figure 1.

Discussion: The method described makes symmetric two point Dixon imaging feasible for any temperature. The reason for this is that these reconstruction methods assume a strict opposite phase between fat and water, and any divagation from this will increase the risk of reconstruction errors. This is especially important when going to high resolution imaging with longer TEs since any error will grow with time.

This manual method is easy to use since it only demands a fast spectroscopy measurement and a table with suitable echo times calculated using the method presented above. Even though the relative ease of the method an automated version would be preferable. The method also needs to be evaluated on several more subjects and objects with a wider range of body tempratures.

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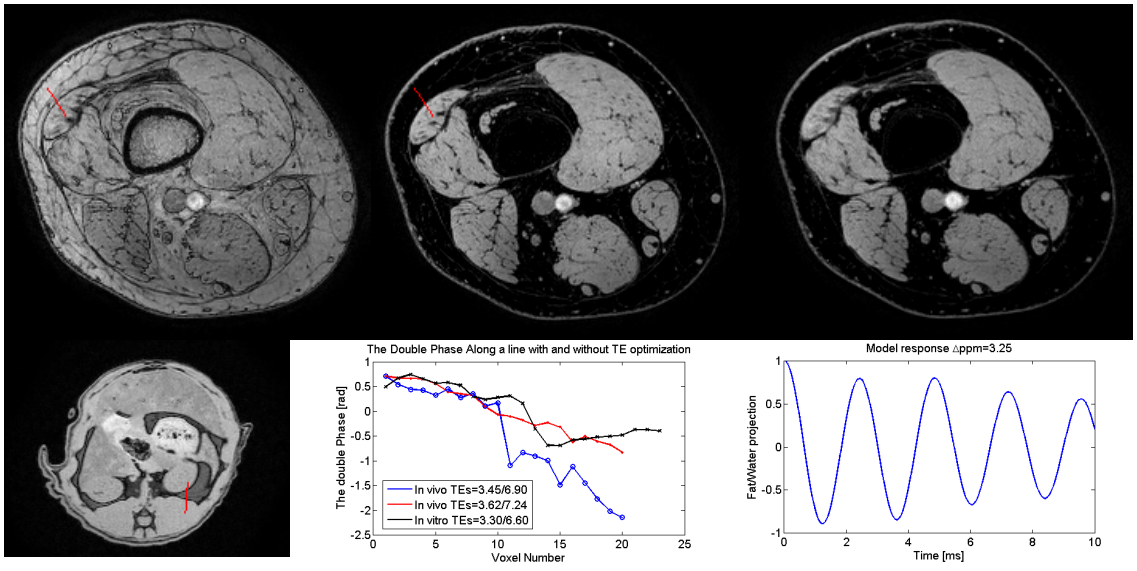

Figure 1 Top left shows a magnitude OP image from the optimized volume. Top middle shows a water image reconstructed using TE 3.62/7.24 ms. Top right is a water image from the TE 3.45/6.90 ms volume. Bottom left shows a magnitude OP image from the first of the scanned rats. Middle bottom shows the doubled phase along the line marked with red in the OP images; here a clear discontinuity can be se in the 3.45 ms dataset. Bottom right shows a typical response of the model above.