Effect of Flip Angle on Fat Quantification by Dixon Techniques

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Introduction

Dixon imaging techniques allow the separation of fat and water components of a signal using numerical modeling of measurements taken over a range of echo times (TE). The classic Dixon technique uses two measurements at specific TEs (1) although later variants can use measurements at arbitrary TEs (2,3).

The quantification of fat using Dixon methods is important clinically as it can potentially give a rapid way to assess fat infiltration with high spatial resolution (4,5). One of the constraints of body imaging, where this approach may be of most benefit (e.g. liver) is that the scan must be complete within a 20 second breath-hold. This means the TR must be relatively short and so there may be strong T1-weighting in the resulting images. Consequently the amplitude A of each component is a function of the repetition time TR, flip angle α and longitudinal rate of recovery T1 as given by Eq 1 (6,7)

$$A \propto \frac{(1-\exp(-TR/T1))\sin\alpha}{1-\exp(-TR/T1)\cos\alpha} \qquad [1]$$

Note that the Ernst angle, $\cos\alpha_E = \exp(-TR/T1)$, which gives the maximum signal, is not necessarily the same for each component. Therefore the fat fraction, defined as $F = A_{fat}/(A_{water}+A_{fat})$, should be expected to be a function of flip angle. Substituting from Eq 1 produces an expression for the dependence of the fat fraction on flip angle.

Methods and Results

As part of a clinical liver protocol, patients were imaged using a multiple echo spoiled gradient echo sequence on a Siemens 1.5T Symphony scanner as follows: TR 122 ms, α =15, 30, 50, 70 & 90° , TE 2.3 & 4.6 ms, matrix 256×160, bandwidth 500 Hz/pixel, scan time 20 s. Fat and water amplitudes were estimated by the 2-point Dixon technique and used to calculate the fat fraction. Figures 1 and 2 shows typical results from a patient with fatty infiltration of the liver. The fat fractions were plotted as a function of flip angle (Figure 3). Curve-fitting was performed to estimate values for T1; the values for fat and water were in the range 200-300ms and 800-1000ms, respectively. The T1-corrected fat fraction was obtained by extrapolating the curve to $\alpha \to 0$.

Fig 1 shows images at TE 4.6 ms for α =15 & 90°.

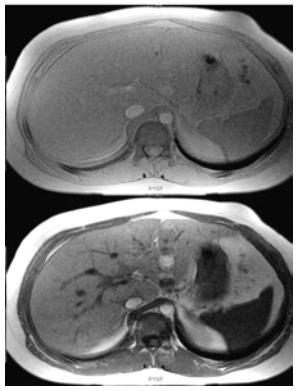


Fig 2 shows the fat fractions at α =15 & 90°.

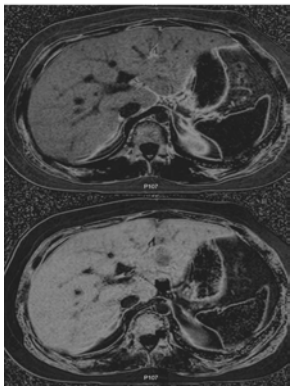
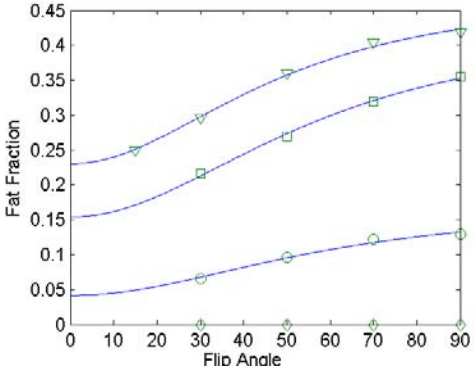


Fig 3 shows the fat fraction *vs* flip angle and best fit curves for three patients with different levels of fatty infiltration.



Discussion

The present study has found that fat quantification using Dixon techniques can be affected by T1-relaxation. Low flip angles and long TRs are required to reduce these effects or otherwise curve-fitting may be used to obtain T1-corrected estimates of the fat fraction.

References **(1)** Dixon W. Simple proton spectroscopic imaging. Radiology 1984;153:189 **(2)** Glover G. Multipoint Dixon Technique for Water and Fat Proton and Susceptibility Imaging. J Mag Res Imag 1991;1:521 **(3)** Reeder SB, Wen Z, Yu H, Pineda AR, Gold GE, Markl M, Pelc NJ. Multicoil Dixon Chemical Species Separation With an Iterative Least-Squares Estimation Method. Magn Reson Med 2004;51:35 **(4)** Kovanlikaya A, Guclu C, Desa C, Becerra R, Gilsanz V. Fat Quantification Using Three-point Dixon Technique: In Vitro Validation. Acad Radiol 2005;12:636 **(5)** Kovanlikaya A, Mittelman SD, Ward A, Geffner ME, Dorey F, Gilsanz V. Obesity and fat quantification in lean tissues using three-point Dixon MR imaging. Pediatr Radiol, 2005;35:601 **(6)** Fram EK, Herfkens RJ, Johnson GA, Glover GH, Karis JP, Shimakawa A, Perkins TG, Pelc NJ. Rapid Calculation of T1 Using Variable Flip Angle Gradient Refocussed Imaging Mag Reson Imaging 1987;5:201 **(7)** Wang HZ, Riederer SJ, Lee JN. Optimizing the Precision in T1 Relaxation Estimation Using Limited Flip Angles. Magn Reson Med 1987;5:399