Comparison of 2- and 3-Point Dixon Techniques in RF- and Readout-Shifted FSE Sequences

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Introduction

Different implementations of the Dixon technique (1) have been used to quantify fat and water in various parts of the human body. In most applications, the 3-point Dixon technique with B_o correction is preferred over simple suppression methods because of its robustness in the presence of B_o inhomogeneities (2). It is also superior to the saturation techniques from an SNR standpoint, offering an equivalent of 2-2.7 signal averages.

More recently, a 2D FSE version of the Dixon technique has been described (3), where it was suggested that shifting the acquisition window may be preferred to shifting the RF pulses, in order to meet the CPMG criterion. Although generally less robust than the 3-point counterpart, the 2-point Dixon technique with phase unwrapping (4,5) has the advantage of shorter scan time, and with fewer acquisitions, can be less susceptible to misregistration artifacts in the fat/water component images.

The purpose of this work is to compare the 2- and 3-point Dixon techniques in both RF- and readout (RO)-shifted versions of the 2D FSE sequence, and to evaluate the effects of transverse relaxation on measurement accuracy. Fat (proton density) fractions are compared in several regions of the calcaneus (heel bone), where T_2* varies considerably (6).

Theory

Errors in the measurement of fat fraction when using the 2-point Dixon technique (RF-shifted) can be approximated to first order:

$$fat\ fraction \approx F\left(1-\frac{\tau}{2T'_{2f}}\right)+W\left(\frac{\tau}{2T'_{2w}}\right) \qquad [1]$$

where F and W are true fractional fat and water proton densities, τ is half the period of fat-water frequency separation, and T_{2f}' and T_{2w}' are T_2' of fat and water, respectively. If the readout window is shifted instead, T_2's are replaced with T_2*s ($1/T_2^* = 1/T_2' + 1/T_2$). The following equation holds for the 3-point techniques:

$$fat\ fraction \approx F\left(1-\frac{\tau}{T'_{2f}}\right) \qquad [2]$$

The measurement error for fat fraction, therefore, is the result of signal loss from fat T_2' (or T_2*) in the 3-point scheme, while for the 2-point, the error includes contributions from the water component. Equations for water fraction are similar, with F's and W's interchanged.

Materials and Methods

The 2D FSE sequence was modified to allow either shifting of the readout window or the refocusing pulses. In the first embodiment, the position of the readout windows were allowed to be shifted by 0, τ and 2 τ (τ = 2.3ms) from the original Hahn echo positions (readout-shift). In the second, the positions of the 180° RF pulses were shifted such that the Hahn echoes are displaced relative to the readouts (RF-shift).

Both sequences were used to scan the right calcaneus of a 35-year-old male volunteer on a 1.5T GE Signa scanner equipped with Echospeed gradients (TR/TE=3000/25, ETL=16, FOV=20cm, 256x256, 5mm thick). Following 2- or 3-point phase unwrapping, their respective fat and water component images were obtained as described by Ma, et al (7), and the fat fractions computed.

Results and Discussion

Figure 1 shows the fat/water component images, along with the locations where measurements were made. Fat fractions of the regions are shown in Table 1. Although the measured values were similar between both 3-point Dixon techniques, Table 1 reveals the potential problems with the 2-point schemes. In regions where transverse relaxation time is short, fat (and water) fraction will be erroneous due to the signal loss incurred during the dephasing period τ. The data show that in regions with increased cancellous bone density, where susceptibility effects reduce T_2' (T_2*), errors are increased. Whereas in the RF-shifted sequence, the loss is a T_2' effect, the effect is exacerbated in the RO-shifted version since the loss is caused by T_2* decay. Of particular interest is muscle, where T_2 (and therefore T_2*) is considerably shorter than T_2'. Because T_2' is relatively long, error is small in the 2-point RF-shifted scheme; however, short T_2* causes much greater error in the RO-shifted technique. Due to the averaging effect among the two in-phase time points (4), and the lack of cross-contamination between the two components (Eq.2), both 3-point Dixon techniques are less prone to errors and yield similar results.

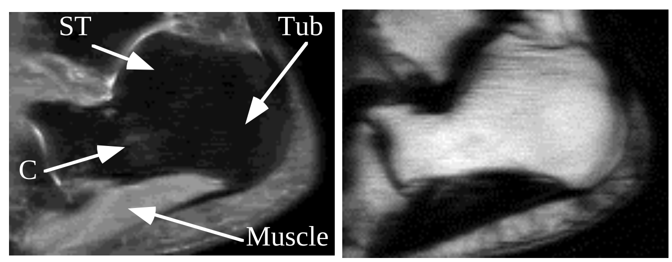

Fig. 1 Water (left) and fat (right) component images of the calcaneus. (ST=subtalar; Tub=tuber; C=cavum calcanei)

Table 1 Fat fraction measured with the 3-point, RF-shifted FSE (2nd column), and percentage differences as measured with the other techniques. Percentages shown in columns 3-5 are relative to column 2. (RO = readout-shifted)

	Fat %	3pt RO	2pt RF	2pt RO
Least dense (C)	83	-0.3 %	-5.4 %	-7.3 %
Medium dense (Tub)	88	-1.4	-6.4	-9.8
Most dense (ST)	86	-0.4	-8.3	-10.3
Muscle	5.5	+0.0	+3.4	+67.7

Conclusion

Two- or three-point Dixon techniques incorporated into a 2D FSE sequence allow rapid computation of fat/water component images. However, the two-point scheme, particularly its readout-shifted version, is prone to significant errors when T_2* is short. Both implementations of the 3-point technique yielded good fat/water separation.

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