A Multiple Species Separation Method Based On T1

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Introduction

In generalized Dixon techniques, phase differences due to chemical shift are used to separate signals from different species such as water, fat and silicon and so on [1-3].However, phase correction is almost mandatory in Dixon techniques to eliminate additional phase due to B0 inhomogeneity in order to get real water, fat images and so on. But phase correction is time consuming and unstable in many cases especially in mid-low MR system with large B0 inhomogeneity. To avoid phase correction, a novel multiple species separation method was introduced based on different T1 of species instead of chemical shift, it can be implemented using GRE, SE, TSE, EPI sequences and so on.

Methods

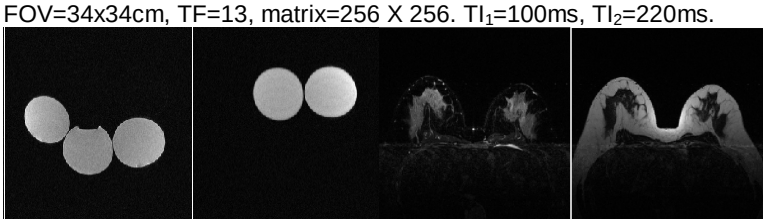
In MRI, Species like water, fat and silicon have different relaxation time, like T1. The main idea of this technique is introducing different signal intensity for each species by using different preparing pulse or excitation pulse, and then every species can be calculated by solving equation. For example, different TI values are used in IR technique, different flip angles are used in GRE sequence. Inversion recovery (IR) technique is taken for example here. The general signal formula for MRI with IR technique is (1), where $I_{\Sigma.TI}(x,y)$ is the image signal, $I_i(x,y)$ is the i species signal in equilibrium state, $E_i(TI)$ is the signal recovery factor of the i species on TI, it depends on imaging sequence type. Formula (1) illustrates that $I_i(x,y)$ can be separated if images with different TI are sampled, the number of images should be equal to or larger than the number of species, the matrix form of equation with different TI is (2), where $\bar{\mathrm{I}}_{\Sigma}(x,y)$ is vector form of image signal with different TI, and $\bar{\mathrm{I}}(x,y)$ is vector form of species signal.

$$I_{\Sigma.TI}(x,y)=\sum_{i=1}^{n} I_i(x,y)\cdot E_i(TI) \quad (1), \quad \bar{\mathrm{I}}_{\Sigma}(x,y)=\mathrm{E}\cdot\bar{\mathrm{I}}(x,y) \quad (2), \quad E_i(TI)=1-2\cdot e^{-\frac{TI}{T1_i}}+e^{-\frac{TR-TE_{last}}{T1_i}} \quad (3)$$

Different TI values are used here to introduce different image signal, so different species can be separated by solving $\bar{\mathrm{I}}$ in equation (2). Fig.1 (a) illustrates two sequences scheme for water fat separation image scanning, the 180 degree IR Pulse here is not used to null the fat signal like general IR fat suppression technique, so selection of TI time can be optimized to get images with good SNR. The SNR of water and fat images increases with the increasing of difference between TI_1 and TI_2. Fig.1 (b) shows the signal recovery curve and Fig. 1(c) illustrates the water and fat momentum at TI_1 and TI_2 immediately after they are tipped to the transversal plan by excitation pulse of the sequence. TSE sequence was selected for imaging where $E_i(TI)$ is represented in formula (3), [4]. Water and fat can be separated with data from these two sequences by solving equation (2).

Results

Images were acquired using the pulse scheme shown in Fig.1(a), Fig. 2(a) and 2(b) is from Magnetom C!, TE=24 ms, TR=1000ms, BW=60Hz/pixel, SL=5mm, FOV=22x22cm TF=9, matrix=256 X 256m, TI_1=40ms, TI_2=172ms. A phantom has five separate plastic bottles, three of them were filled with tap water, and the others were filled with cooking oil (fat). Water and fat images of breast from volunteer are shown in Fig. 2(c) and (d). The scanner is 1.5T (Siemens MR, Shenzhen), TE=71ms, TR=5600ms, BW=170Hz/pixel, SL=4mm, FOV=34x34cm, TF=13, matrix=256 X 256. TI_1=100ms, TI_2=220ms.



(a) (b) (c) (d)

Fig. 2(a) water image (0.35T), (b) fat image (0.35T), (c) water image (1.5T), (d) fat image (1.5T)

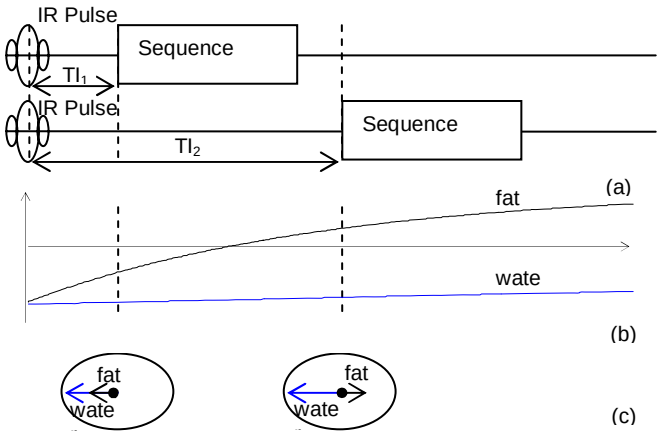


Fig.1(a). One example sequence pulse scheme of proposed method, (b).Recovery curve of water and fat signals and (c).Water and fat momentum in transversal plan at different TI time instant

Discussion

T1 relaxation time difference rather than chemical shift are used to separate difference species. Unlike general Multiple points Dixon method, this method need not to set different echo time for water, fat, silicon etc. to precess to different phase which will introduce additional phase caused by B0 inhomogeneity, as a result, phase correction (like phase unwrapping) is not necessary.The calculation of this method is quite simple and the result is stable. Other prepare scheme, like SR (saturation recovery) pulse can be used for this method, only $E_i(TI)$ has to be modified. The scan time of this method is longer than general IR technique, but the SNR of the resulted image is higher than the general IR technique. Long TI is not need needed to get a fat image with this technique.

References

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