Evaluation of individual versus average T2* decay correction and single slice versus multislice sampling in the two-point Dixon method for liver fat quantification

C. Kirbas[1], E. Zalusky[1], S. Czerwinski[2], M. Lee[2], K. Liu[3], and J. G. Parker[1]
[1]Innovation Center, Kettering Health Network, Kettering, OH, United States, [2]Department of Community Health, Wright State University, Kettering, OH, United States, [3]Siemens Medical Solutions, United States

Purpose

Assessment of fat content in the liver is of interest in the evaluation of a spectrum of diseases including alcoholic steatosis and non-alcoholic fatty liver disease. Quantification of liver fat fraction using magnetic resonance imaging (MRI) has recently gained attention due to its lack of ionizing radiation exposure and non-invasiveness [1, 2]. One popular MRI method to quantify liver fat fraction is the two-point Dixon method using in-phase (IP) and out-phase (OP) images [1]. The method uses a correction factor for T_2* decay which is calculated as an average over 10 healthy volunteers. In this study we used a variation on the Dixon-based method [2] and evaluated the difference between using individual correction factors calculated for each subject and an average correction factor. We also evaluated the accuracy of fat fraction calculation using a ROI's from a single slice versus multiple slices.

Materials and Methods

Subjects: Forty-six healthy subjects (21 male and 25 female; mean age=53 years; range:13-80 years) participated in the study. An informed consent was signed by each subject prior to the scan. ***Scanning Procedure***: All experimental data were acquired using a Siemens MAGNETOM Avanto 1.5T MRI scanner (Siemens Medical Systems, Erlangen, Germany). MRI of the liver was performed using a breath-hold dual-echo T1-weighted gradient echo sequence with a 6-mm slice thickness, 0 mm section gap, 256×240 matrix, and repetition time (TR) of 155 ms. Dual-echo spoiled gradient recalled images were acquired with TE=2.4 ms (OP) and TE=4.8 ms (IP) and flip angles of 70° and 20° to generate T1-weighted and intermediate-weighted images, respectively (Figure 1). A pair of single slice IP images with TE=4.8 ms and TE=9.6 ms were also acquired to calculate individual correction factors for T_2^* decay. ***Fat Fraction Calculation***: We used the algorithm developed by Irwan et.al. [2] for the calculation of liver fat fraction. IP images were corrected for T_2^* relaxation using equation 1 where S_{IPA} and S_{IPB} are two in-phase images with TE=4.8 ms and 9.6 ms and τ is the echo time difference between the two images. We calculated fat fraction using individual correction factors as well as an average correction factor for the group, as suggested by Irwan et al. We also used ROIs sampled from the entire liver (5-10 slices) as well as from one slice (i.e. slice showing the most liver tissue). Figures 2A and 2B show example ROIs for a single slice and the corresponding color-coded fat fraction slice respectively. ***Statistical Analysis***: A paired t-test was performed to evaluate the difference between fat fractions calculated using an individual correction factor (FF_{Ind}) and an average correction factor (FF_{Avg}). A second paired t-test was performed to evaluate the difference between fat fractions calculated using whole liver ROIs (FF_{Whole}) and single slice ROIs (FF_{Slice}). Furthermore, a linear regression model was used to correlate FF_{Ind} with FF_{Avg} and FF_{Whole} with FF_{Slice}. Finally, a Blant-Altman analysis was performed to investigate the agreement between FF_{Whole} and FF_{Slice}.

$$S_{IPCorrected} = S_{IPA}\sqrt{\frac{S_{IPA}}{S_{IPB}}} = S_{IPA}e^{\frac{\tau}{T_2^*}} \quad (1)$$

Algorithm:

(a) adjust IP images for T_2* relaxation using correction factor.

(b) calculate apparent fat content for both intermediate H_{wt} ($\%Fat_{Hwt}$ at 20° FA) and T1-weighted ($\%Fat_{T1wt}$ at 70° FA).

$$\%\,fat = \frac{S_{IP} - S_{OP}}{2S_{IP}} x100\%$$

(c) if $\%Fat_{Hwt}$ AND $\%Fat_{T1wt} \leq 20$, then $\%FF = MIN[\%Fat_{Hwt}, \%Fat_{T1wt}]$
if $\%Fat_{Hwt}$ AND $\%Fat_{T1wt} \geq 20$ AND $\%Fat_{Hwt} \leq \%Fat_{T1wt}$, then $\%FF = \%Fat_{Hwt}$,
otherwise $\%FF = 100\% - \%Fat_{Hwt}$

Results

No significant difference was found between FF_{Ind} and FF_{Avg} (p= 0.5428) or between FF_{Whole} and FF_{Slice} (p= 0.8901). The mean values of FF_{Ind} and FF_{Avg} using whole liver ROIs were 7.16 ±3.52 and 7.39±3.54 respectively and the mean values of FF_{Ind} and FF_{Avg} using one slice ROIs were 7.17 ±3.16 and 7.38±3.18 respectively. A strong correlation was found between FF_{Ind} and FF_{Avg} (r=0.9570, p<0.0001) as well as between FF_{Whole} and FF_{Slice} (r=0.9987, p<0.0001). Although the mean difference between FF_{Ind} and FF_{Avg} using whole liver ROIs was 1.24±2.11 (range: 0-14.84), the mean % difference was 33.86±32.89% (range: 0-131%). This indicated that even though the group mean did not change significantly between FF_{Ind} and FF_{Avg}, there were significant differences on an individual basis. We did not see the same trend between FF_{Whole} and FF_{Slice} (mean difference: 0.307±0.29; range: 0.02-1.6). The Bland Altman analysis indicated that there is good agreement between FF_{Whole} and FF_{Slice} regardless of the correction method used. The 95% limits of agreement between the two correction methods ranged approximately from -5 to 5 on either FF_{Whole} or FF_{Slice} and 98% of measurements lied within the 95% limits of agreement.

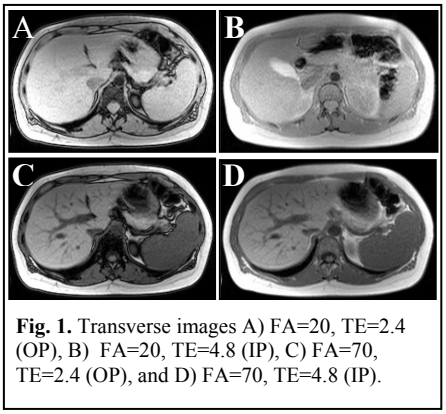

Fig. 1. Transverse images A) FA=20, TE=2.4 (OP), B) FA=20, TE=4.8 (IP), C) FA=70, TE=2.4 (OP), and D) FA=70, TE=4.8 (IP).

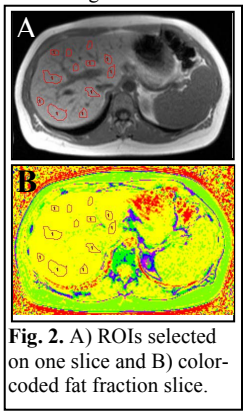

Fig. 2. A) ROIs selected on one slice and B) color-coded fat fraction slice.

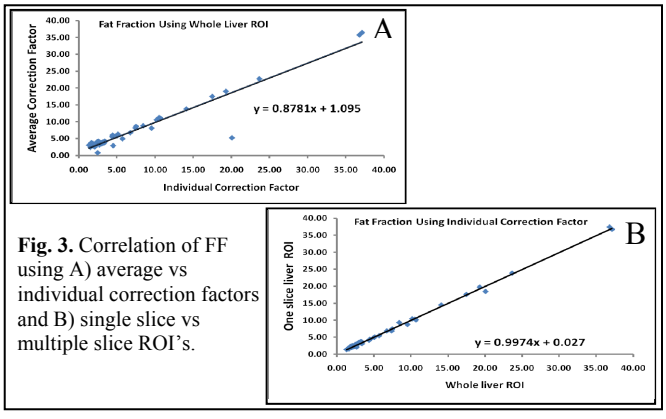

Fig. 3. Correlation of FF using A) average vs individual correction factors and B) single slice vs multiple slice ROI's.

Conclusion

In this study we investigated the effects of using individual as well as average correction factors in the calculation of liver fat fraction using a Dixon-based method. It was found that overall there was not a significant difference between the two methods, but that there could be large differences at the individual level, especially when the fat fraction was small. We also investigated whether obtaining ROI's throughout the whole liver was necessary or ROI's from a single representative liver slice was sufficient. It was found that there was not a significant difference between the two methods overall or at the individual level. In the future work, we will include MR spectroscopy (MRS) of the liver, which is considered as the gold standard in quantifying liver fat content, and compare our findings with liver MRS measurements.

References

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