Evaluation of individual versus average $T_2^*$ decay correction and single slice versus multislice sampling in the two-point Dixon method for liver fat quantification

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Purpose
Assessment of liver 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 $T_1$-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 $T_1$-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 $S_{IP}$ and $S_{IPB}$ are two in-phase images with TE=4.8 ms and 9.6 ms and $t$ 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 Whol) and single slice ROIs (FF Slice). Furthermore, a linear regression model was used to correlate FF Whol with FF Avg and FF Slice. Finally, a Blant-Altman analysis was performed to investigate the agreement between FF Whol and FF Slice.

Results
No significant difference was found between FF Ind and FF Avg ($p=0.5428$) or between FF Whol 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 Whol and FF Slice 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 ($r=0.9970$, $p<0.0001$) as well as between FF Whol and FF Slice ($r=0.9987$, $p<0.0001$). Although the mean difference between FF Ind and FF Avg using single liver ROIs was 1.24±2.11 (range: -0.14·84), the mean % difference was 33.86±32.89% (range: 0-113%). 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 Whol 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 Whol 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 Whol or FF Slice and 98% of measurements lied within the 95% limits of agreement.

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.

Algorithm:
(a) adjust IP images for $T_2^*$ relaxation using correction factor.
(b) calculate apparent fat content for both intermediate $H_{wt}$ ($\%Fat_{Ind}$ at 20° FA) and $T_1$-weighted ($\%Fat_{Ind,at70°FA}$).
(c) if $\%Fat_{Ind} AND \%Fat_{Ind,at70°FA} \leq 20$, then $\%Fat_{Ind} = \%Fat_{Ind,at70°FA}$.
otherwise $\%Fat_{Ind} = 100\% - \%Fat_{Ind,at70°FA}$.

References