Quantification of Pancreatic and Hepatic Fat using Gradient Echo MRI – Comparison of a Spatial-Spectral Excitation Technique with In/Opposed-phase Imaging

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Introduction: Fatty infiltration of the pancreas (lipomatosis) and the liver (steatosis) occurs in several metabolic disorders like obesity, cystic fibrosis and diabetes[1,2]. Data from several studies indicate that increased visceral and hepatic fat content and especially pancreatic lipomatosis is associated with insulin resistance[3]. Furthermore, it has been suggested that a lipid overload in pancreatic tissue impairs the insulin secretion of the islets of Langerhans[4]. Several MRI methods are capable to assess lipids in tissue: The most commonly use the frequency shift between water and fat resonances to generate in-phase (IN) and opposed-phase (OP) images. Unfortunately, these techniques are prone to relaxation effects (T1 and T2*) affecting the contribution of water and lipid signals to the images. Goal of the present study was the quantification of pancreatic and hepatic fat content using fat-selective spectral-spatial imaging and the comparison of the gained results with an IN/OP method. In this context variability of T2* in the pancreas and liver was assessed by multi-echo imaging, and related effects on fat quantification were estimated.

Materials and Methods: Twenty-three volunteers with an elevated risk for diabetes mellitus type 2 were examined on a 1.5 Tesla whole body clinical scanner. Pancreas and liver fat content was quantified with two different gradient echo techniques: one uses a spectral-spatial excitation technique which combines chemical shift selectivity with simultaneous slice-selective excitation[5]. The other technique is based on double-echo chemical shift gradient echo imaging (see ***Figure 1***). For both techniques, fat content was calculated in regions of interest positioned in three pancreatic regions (caput, corpus, cauda) and the liver. For fat selective imaging with spectral-spatial excitation, signal intensity was quantified by using adjacent pure adipose tissue for the pancreas and subcutaneous fat for the liver as reference. The "in-phase/opposed-phase" approach was evaluated by calculation of the fat fraction of the total signal intensity.

To accurately quantify the fat fraction $FF_{IN/OP}$ the effect of tissue relaxation (T1 and T2*) on water and lipid signal was addressed. Considering the short TR and the large flip angle of the IN/OP sequence, the effect of tissue T1 relaxation on water and lipid signal was addressed. To consider the T2* decay between IN and OP images, T2* correction was performed by calculating T2* using a fat saturated breath-hold 2D multi-echo gradient echo sequence.

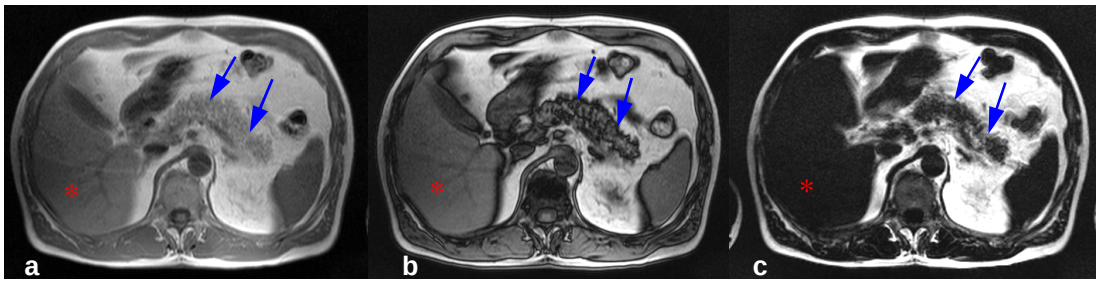

Figure 1: Pancreatic fat content assessed in a volunteer with pancreatic lipomatosis (arrows) and normal liver (star)
(a) in-phase, (b) opposed-phase *(TR 85 = ms; TE = 2.38 ms opposed-phase, 4.76 ms in-phase images flip angle 70°. Number of slices: 10, slice thickness: 10 mm)*
(c) spectral-spatial fat-selective *image (TR = 41 ms, TE = 16 ms, 192 x 256 matrix, FOV 285 x 380 mm², slice thickness: 10 mm).*

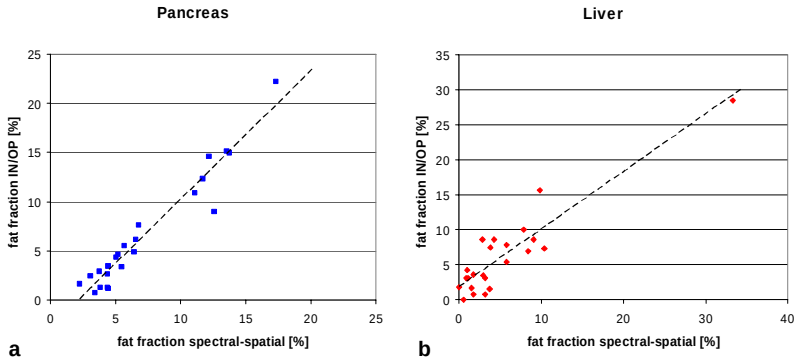

Figure 2: Relationship between fat content *gained with IN/OP-technique and spectral-spatial fat-selective imaging was studied using the Pearson correlation coefficient:* ***(a) pancreas*** *r = 0.96 (p < 0.0001),* ***(b) liver*** *r = 0.92 (p < 0.0001).*

Results: Pancreatic and hepatic fat quantification was feasible in all participants by both methods. The fat content calculated with the fat-selective spectral-spatial gradient echo sequence correlated well with the fat fraction determined with the in-phase/opposed-phase imaging: pancreas r = 0.96 (p < 0.0001), liver r = 0.92 (p < 0.0001) (see ***Figure 2***). In-phase/opposed-phase imaging revealed a pancreatic fat content between 0.7 and 22.2 % (mean: 6.6 ± 5.8 %) and a hepatic fat content between 0 and 33.3 % (mean: 5.3 ± 6.9 %). The fat-selective spectral-spatial gradient echo sequence revealed a pancreatic lipid content between 2.3 and 17.3 % (mean: 7.3 ± 4.3 %) and a hepatic fat content between 0 and 28.5 % (mean: 6.2 ± 6.1 %).

Discussion: Both applied strategies for fat-assessment have inherent advantages and disadvantages. In contrast to the in-phase/opposed-phase method, the fat-selective spectral-spatial gradient echo sequence offers no soft tissue contrast of water-containing parenchyma organs. A general problem of the pancreatic fat quantification are partial volume effects of the surrounding abdominal fat which could falsify the obtained fat fraction. Other than the liver, the cranio-caudal dimension of the pancreas is quite small so that slice- and ROI positioning must be done with care.

The presented results suggest that both methods are a reliable tool for pancreatic and hepatic fat quantification. However, regarding the usefulness in clinical routine fat-selective spectral-spatial imaging seems to be a more promising approach since it offers solid values without major T1 or T2* corrections. Especially with regard to metabolic disorders such as diabetes mellitus both methods could be useful for estimation of supplementing diabetes risk factors.

References:

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