Spectroscopic Water-Fat Quantification in Human Kidney at 3T

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Introduction The prevalence of various kidney disorders is escalating in the United States, in parallel with the increase in obesity. Emerging data suggests the involvement of renal lipotoxicity in kidney diseases [1, 2]. However this hypothesis remains to be tested. Noninvasive ^{1}H magnetic resonance spectroscopy (MRS) has been used to measure fat content in liver, heart, pancreas, and skeletal muscle of human subjects [3, 4, 5, 6]. Unfortunately, ^{1}H MRS of kidney parenchyma has been hampered by technical difficulties such as respiratory motion, and subsequent contamination from perirenal or hilar fat. This contamination has precluded the establishment of nominal values for healthy subjects. The goal of this preliminary study was to establish normative values for renal cortical fat content in healthy volunteers by a respiratory-triggered TE-averaged non-water suppressed *in vivo* localized kidney ^{1}H MRS at 3T.

Methods Six healthy volunteers (5 female & 1 male; 5 Caucasians & 1 Asian, age: 31 ~ 57, 44.5±8.9, BMI: 17.5 ~ 42.6, 25.9±10.2) were consented to participate in this study. All measurements were performed with a 6-element SENSE cardiac coil or a body coil on a 3T MR scanner (Achieva, Philips Medical Systems, Cleveland, USA). A respiratory sensor was used to trigger the scan upon expiration, with trigger delay of 600-1200 ms. Three-plane respiratory-triggered high-resolution T_2-weighted anatomical images of kidney were acquired for voxel placement. Localized single-voxel MR spectra without water suppression were obtained using a respiratory-triggered PRESS sequence with TE-averaging from kidney parenchyma (four TE = 35~38 ms, ΔTE = 1 ms, TR = 2000 ms, bandwidth = 2000 Hz, sample points = 1024, voxel size = 10x10x10 ~ 10x10x25 mm^3, i.e., 1.0 ~ 2.5 ml, NSA = 16 per TE). A reference spectrum from the same voxel was acquired using the PRESS sequence with a single TE of 35 ms to correct for eddy current artifacts. Voxel placement included the maximal volume of cortical tissue feasible. Since water and lipid precess at different frequencies, the voxel displacement for water and lipid will complicate planning. Using the chemical shift displacement tool provided on Philips MRI scanner, specific effort was made to position both the water and the fat acquisition voxel away from hilar or perirenal fat (see Figure 1.). To demonstrate the importance of voxel placement, same scans were repeated for another voxel including fat-containing portion of the kidney hilum. In addition, ^{1}H spectroscopy was also measured from a bag of 500 mL Intralipid (30% IV Fat Emulsion, Fresenius Kabi, Uppsala, Sweden) placed underneath the volunteer in one exam to validate the quantitative measurement of fat content using this technique. All spectroscopy data were analyzed using AMARES (jMRUI 4.0) [7]. Phase correction for individual spectrum was performed before TE averaging using the reference scan.

Results The fat and water ratio of 28% was measured from the spectrum obtained from the 30% Intralipid phantom, thus assuring that the scans can generate quantitative data. No fat content was detected from kidney cortex in all six healthy volunteers. A representative renal cortical spectrum obtained from a healthy volunteer together with the voxel placement is demonstrated in Figure 1. The complete lack of detectable fat in the normal cortex may be used as a sensitive negative marker of lipo-accumulation. The importance of careful voxel positioning is seen in Figure 2 where substantial fat peak was detected from the same volunteer when the voxel placement purposely included some fat within the hilar region.

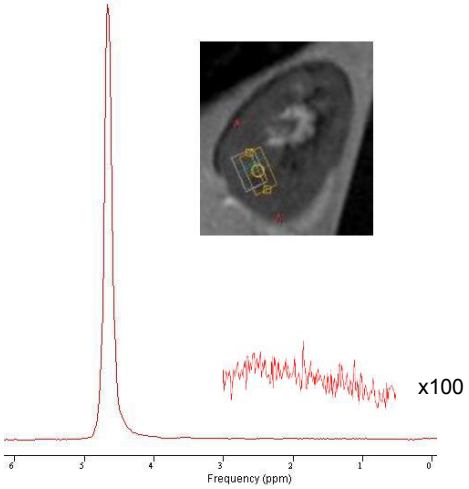

Figure 1. ^{1}H spectrum of kidney showing water peak and absence of fat peak when the placement of water (in yellow) and lipid (in white) voxels was away from hilar or perirenal fat. The spectrum magnitude is enlarged 100 times between 0.5 ~ 3 ppm.

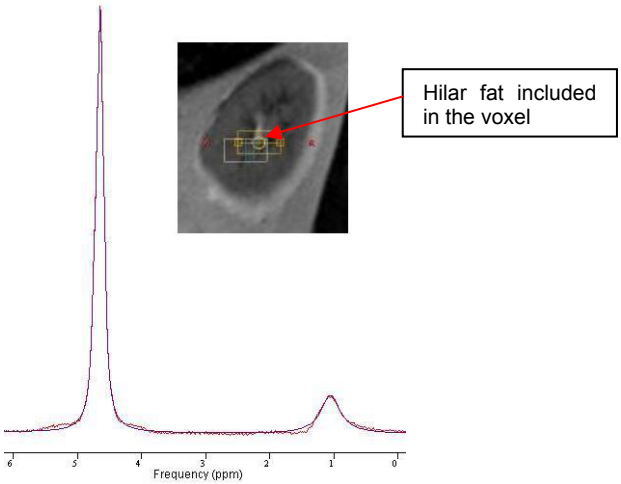

Figure 2. ^{1}H spectrum of kidney showing water and fat peaks when hilar fat was purposely included in the voxel. The measured spectrum (in red) can be fitted (in purple) using AMARES, therefore, fat content can be quantified.

Discussion The fat content may prove to be a very sensitive marker of kidney dysfunction since there was a complete absence of fat in ^{1}H spectroscopy of parenchyma of healthy kidneys. Voxel placement is crucial in the MRS measurement of kidney cortex. Any inclusion of perirenal fat or hilar fat would contaminate the results from the cortex. Due to the chemical shift difference between water and lipid, the selected volume will be different for these metabolites. Therefore voxel position for both chemical shifts should be confirmed if possible. Previous study has shown phase and frequency shifts in kidney spectra due to respiration [8]. In this study, respiratory-triggered spectra obtained from each voxel using different TEs demonstrated minimal variation. Nevertheless using this TE-averaging technique can potentially allow us to exclude the data with severe motion artifacts, as well as to reduce frequency modulation sideband artifacts from the large unsuppressed water peak.

Conclusions (1) Respiratory-triggered single-voxel PRESS technique with TE-averaging provides a feasible tool to noninvasively measure the fat content in human kidneys. (2) To accurately measure ^{1}H MRS of kidney parenchyma, it is important to reduce respiratory motion artifact and contamination from perirenal and hilar fat via a gating technique and precise voxel placement. (3) The method and the normative zero fat values established in this preliminary study will be used to study patients with various renal diseases resulting from lipotoxicity.

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