GlycoCEST using FISPCEST

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\textbf{Introduction:} In vivo and non-invasive measures of hepatic and muscular glycogen are needed to effectively study diabetes and metabolism in humans and animals. C13-MRS methods have been shown to accurately measure glycogen levels; however, C13-MRS suffers from relatively poor spatial resolution and is not available on the majority of clinical MRI scanners. More recently, glycogen’s inherent CEST effect has been proposed as an alternative to C13-MRS\textsuperscript{1}. While this initial “GlycoCEST” work is promising, the in vivo utility of the GlycoCEST technique is limited because of the long acquisition times (1-3 hours) for quantitative CEST-MRI acquisitions. In this study, we have developed and optimized a rapid GlycoCEST acquisition using our recently developed FISP-CEST technique\textsuperscript{2} to obtain quantitative glycogen CEST spectra in phantoms and in vivo livers in 15-45 minutes.

\textbf{Methods:} A single, 5-second spectrally selective CEST pulse train consisting of 50 x 100ms Gaussian pulses (BW=27.4 Hz) was combined with our rapid FISP-CEST acquisition scheme (Fig. 1). The rapid FISP imaging sequence (TR/TE=1.9/0.95ms, matrix=128x128) used a $\alpha$-2-TR/2 preparation and was acquired with centric encoding to preserve the glycogen CEST contrast. A series of 81 CEST images were obtained, with a 30 sec delay between each image, for \textit{in vitro} bovine glycogen phantoms (50mM, 100mM, 200mM) on a 9.4T Bruker BioSpec\textsuperscript{3} by varying the frequency of the CEST pulse from -4 ppm to 4 ppm in 0.1 ppm increments. The mean image signal amplitude from an ROI was measured for each phantom to generate CEST-spectra. The CEST spectra were analyzed with a new polynomial fitting technique (separate abstract) by first shifting the minima of each spectra (i.e. direct saturation of water) to 0 ppm for $B_1$ by varying the frequency of the CEST pulse from -4 ppm to 4 ppm in 0.1 ppm increments. The mean image signal amplitude from an ROI was measured for each phantom to generate CEST-spectra. The CEST spectra were analyzed with a new polynomial fitting technique (separate abstract) by first shifting the minima of each spectra (i.e. direct saturation of water) to 0 ppm for $B_1$ correction. The positive (right-side) and negative (left-side) halves of the CEST spectra were then fit to separate 12th order polynomials. The overall CEST effect was then determined analytically by integrating the area between the two curves. An initial \textit{ex vivo} experiment was also performed on an excised liver from a 22 week-old SHROB rat.

\textbf{Results:} Phantom results from our rapid glycogen CEST acquisition are shown in Figures 2 & 3. As expected, the CEST sensitivity increases with increasing $B_1$, and the CEST effect (area between the model curves) appears to increase almost linearly with glycogen concentration at $B_1=2\mu$T (Fig. 2). Scans of an \textit{ex vivo} Spontaneously Hypertensive Obese rat (SHROB) (Fig. 3) clearly shows a similar glycogen CEST effect at 1ppm as well as the direct saturation of hepatic fat at -3.5ppm as expected in this animal model. Biochemical analyses of the glycogen concentration in this liver are pending.

\textbf{Discussion:} We have developed a rapid glycogen CEST acquisition and analysis methodology that provides quantitative, glycogen CEST spectra in ~40 minutes, and individual data points in ~6 seconds which is 50-100 times faster than other such acquisition schemes previously reported, with little to no loss in CEST sensitivity or unintended saturation as compared to Spin Echo-CEST acquisitions (data not shown). These CEST spectra are capable of sensitively measuring glycogen levels over the typical physiologic range. In addition, the initial ex vivo liver results also suggest that this rapid acquisition will provide an improved \textit{in vivo} assessment of hepatic and intramuscular glycogen levels as this imaging technique offers improved temporal and spatial resolution in comparison to C13-MRS.

\textbf{References:}

\textbf{Acknowledgements:}
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