Examining the Accuracy of Dual Echo B_0 Map for Field Inhomogeneity Correction with the Application of gagCEST in Articular Cartilage at 3T

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INTRODUCTION:

Chemical Exchange Saturation Transfer (CEST) is a molecular MRI methodology which can detect the presence of endogenous macromolecules [1]. Recently, gagCEST was developed to quantitatively assess glycosaminoglycans (GAGs) that may indicate the presence of early cartilage degeneration [2]. This technique is based on asymmetry in the CEST spectrum around 1ppm where OH protons resonate. Because the OH resonance frequency is similar to that of water, it is very sensitive to B_0 field inhomogeneity [3], which can result in widely differing results with small shifts in the CEST spectrum. Conventionally, an entire CEST spectrum with high spectral resolution is sampled to match the actual minimum signal with the water frequency. This will give rise to a long acquisition time. To deal with this problem, a B_0 map is used to find the field inhomogeneity [4]. The purpose of this abstract is to compare the B_0 inhomogeneity determined by both the minimum point in CEST spectrum and B_0 map and their effects on gagCEST results.

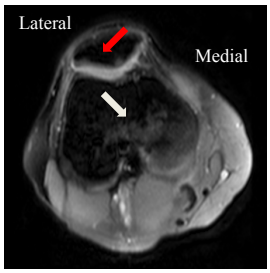

Fig. 1: Right knee of a patient with tricompartmental cartilage fibrillation (red arrow) and an abundance of hematopoietic marrow (white arrow).

MATERIALS AND METHODS:

Image Acquisition Ten clinical knee patients (42±8 years) were scanned in a 3T MRI system (Achieva, Philips) using an 8-channel knee coil. A multi-shot turbo spin echo sequence with fat suppression was employed to achieve high resolution proton density weighted images (FOV=160x160mm^2, matrix size=256x256, slice thickness=4mm, TR/TE=1000/7ms, TSE factor=12, NSA=2). The pre-saturation pulse power was around 1.2μT with a total duration of 460ms. The CEST spectrum was acquired with 33 offsets from 4ppm to -4ppm in intervals of 0.25ppm. A S_0 image without pre-saturation pulse was acquired. Five dual echo B_0 maps with ΔTE of 1ms, 2ms, 4ms, 8ms and 10ms (the largest ΔTE available in the scanner) were also acquired.

Image Analysis The CEST spectra were fitted with a 12th order polynomial through a least-squares approach, using the IDL programming environment (ITT, CO). Based on the generated coefficients, the CEST spectra were interpolated into 16001 offsets with an offset resolution of 0.001ppm. A B_0 frequency shift map was calculated based on the minimum value of the CEST spectra. It was compared with the five dual echo B_0 maps. The CEST spectra were shifted using both the B_0 frequency shift map and the five B_0 maps to observe their effects on gagCEST analysis. The magnetic transfer ratio asymmetry (MTR_{asym}) was defined by $MTR_{asym}(1.0ppm)=S_{sat}(-1.0ppm)/S_0-S_{sat}(+1.0ppm)/S_0$.

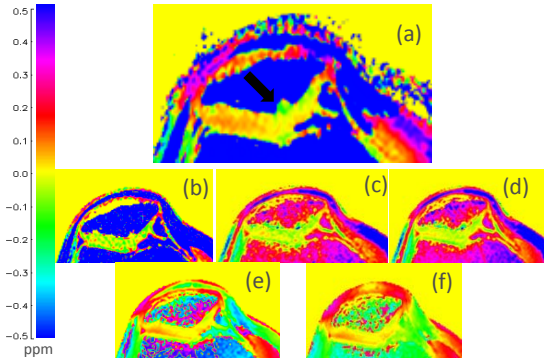

Fig. 2: B_0 frequency shift map (a) and five dual echo B_0 maps with ΔTE=1ms, 2ms, 4ms, 8ms, 10ms (b, c, d, e, f). As the ΔTE of the B_0 map increases, the frequency shifts in the cartilage region (black arrow) exhibit a closer pattern to B_0 frequency shift map.

RESULTS AND DISCUSSION:

One patient with tricompartmental cartilage fibrillation (red arrow) and an abundance of hematopoietic marrow (white arrow) is shown (Fig. 1, Right knee). Fig. 2 examines the correspondence of the B_0 frequency shift map and the five dual echo B_0 maps. Fig. 2a shows the B_0 frequency shift map calculated from the minimum value of CEST spectra. For the gagCEST study, only the cartilage area (black arrow) is examined. The frequency shift of other areas (patella et al.) can be seen as artifacts because of low signals and thus noisy CEST spectra resulting in errors in detecting minimum values. B_0 maps with ΔTE=1ms, 2ms, 4ms, 8ms, 10ms are shown in Fig. 2b, c, d, e, f respectively. As ΔTE increases, the frequency shifts in cartilage area exhibit a closer pattern to the B_0 frequency shift map (~0.1-0.2ppm laterally, ~0ppm medially). Because the frequency shifts are below 0.3ppm, the phase wrap will not appear even with 10ms ΔTE. Fig. 3 shows the MTR asymmetry curve in the cartilage region. The spectra were corrected using the B_0 frequency shift map as well as the B_0 maps. B_0 map corrections with ΔTE=1ms, 2ms, 4ms, 8ms, 10ms are displayed in different colors from top to bottom. B_0 frequency shift map correction is shown in black as the standard. There is a tendency that with higher ΔTE, the MTR_{asym} curves become more similar.

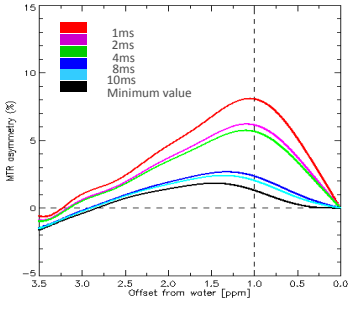

Fig. 3: MTR asymmetry curve in the cartilage region. The spectra were corrected by both B_0 frequency shift map and five dual echo B_0 maps. The ΔTE increases in order from top to bottom. There is a tendency that with higher ΔTE, the MTR asymmetry curves corrected by B_0 maps are getting more similar to the one corrected by B_0 frequency shift map.

CONCLUSIONS:

In this study we demonstrated that with proper ΔTE B_0 maps we are able to make reliable B_0 inhomogeneity corrections to CEST spectra. This can be used to calculate more accurate MTR asymmetry value in gagCEST experiments which are very sensitive to CEST spectra centering. With a better B_0 map acquisition, an entire CEST spectrum is not necessary and total scan time can be reduced which enables gagCEST to be more feasible for clinical use.

REFERENCES:

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