Improving mobile protein level detection using mDIXON-based APT-MRI in bone marrow edema

Guang Jia[1], Wenbo Wei[1], Xiangyu Yang[1], David C Flanigan[2], Jochen Keupp[3], Jinyuan Zhou[4], and Michael V Knopp[1]

[1]*Department of Radiology, The Ohio State University, Columbus, OH, United States,* [2]*Department of Orthopedics, The Ohio State University, Columbus, OH, United States,* [3]*Innovative Technologies, Research Laboratories, Philips Research Europe, Hamburg, Germany,* [4]*Department of Radiology, Johns Hopkins University, Baltimore, MD, United States*

Introduction

Amide-proton-transfer MRI (APT-MRI) as a new protein-based molecular imaging technique has recently used in knee joint imaging (1), where bone marrow edema may high mobile protein levels due to inflammation (2). APT-MRI signal is normally quantified using the magnetization transfer ratio (MTR)-asymmetry at 3.5 ppm around the water resonance, namely, $MTR_{asym}(3.5ppm)$. However, it is shown that the fatty bone marrow results in an extra magnetization transfer (MT) signal at -3.5ppm, deteriorating the calculation of the APT signal at 3.5 ppm. Further, many regular fat suppression techniques, when used, may interfere with the the saturation pre-pulse in APT-MRI, which may result in an abnormally high signal at -3.5 ppm. A multiple gradient-echo DIXON (mDIXON) technique has been previously applied to water and fat separation without using any pre-pulse (3), which hitherto has not been used in APT-MRI of fat-containing tissue. This study is to evaluate the feasibility of applying mDIXON-based APT-MRI to a mobile protein level assessment in the bone marrow edema.

Material and methods

21 patients with knee injuries were imaged on a 3 Tesla MR system (Achieva, Philips Healthcare, Cleveland, OH) using an 8-channel knee phased array coil. Standard diagnostic images were used to identify bone marrow edema (BME). Both fat-suppressed APT-MRI and mDIXON-based APT-MRI were acquired with the center slices covering the BME mid-section.

Fat-suppressed APT-MRI was based on a single-slice single-shot fast spin-echo (TSE) sequence with selective fat suppression (TSE-SPIR). The saturation pre-pulse was composed of a train of sixteen 1800º block pulses, each with a pulse length of 29 ms and saturation amplitude of 172 Hz (4.1 μT). MT-spectrum was acquired using 33 saturation pre-pulse frequency offsets (-8 to 8 ppm, interval 0.5 ppm). S_0 was acquired using TSE image without saturation pre-pulse. The acquisition time was 3 min. A B_0 field map was acquired using a dual-echo mDIXON-2D-FFE sequence (TE1/TE2 = 1.5/4.1 ms) (4).

New mDIXON-based APT-MRI was based on a dual-echo 3D-FFE sequence (TE1/TE2 = 1.72/4.6 ms). Water-only, fat-only, in-phase, out-of-phase images as well as Dixon-type B_0 maps were extracted from the dual-echo mDIXON images. The same duration and power of the saturation pre-pulse were implemented. MT-spectrum was defined by six saturation pre-pulse frequency offsets. S_0 was acquired using 3D-FFE image without saturation pre-pulse. The acquisition time was 5 min. After B_0 field inhomogeneity corrections to the MT-spectrum, The $MTR_{asym}(3.5ppm)$ signal was calculated to estimate the mobile protein levels in bone marrow edema with the pixel-wised map display and ROI-based analysis.

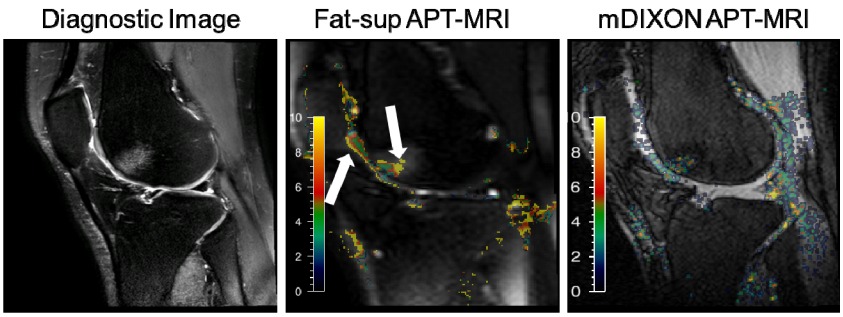

Figure 1. Comparison of two APT-MRI techniques of BME. Fat-suppressed APT-MRI overestimates $MTR_{asym}(3.5ppm)$ in the area close to bone marrow and fat tissue (marked by arrows). With this artifact removed, mDIXON-based APT-MRI shows an appropriate estimation of the $MTR_{asym}(3.5ppm)$ signal on the BME.

Results

Eight imaged knees were shown with bone marrow edema (6 in femur and 2 in tibia). On fat-suppressed APT-MR images, the abnormally high $MTR_{asym}(3.5ppm)$ signals (artifact) appeared in the border area close to bone marrow and fat tissue (Figure 1). This artifact was removed by mDIXON-based APT-MRI, by which the $MTR_{asym}(3.5ppm)$ map of BME shows elevated mobile protein levels only in the area close to the bone surface (Figure 2). The deeper BME area did not exhibit MRI-detectable mobile protein levels. The average $MTR_{asym}(3.5ppm)$ in the knee BME ROIs was 4.8% ± 5.5%.

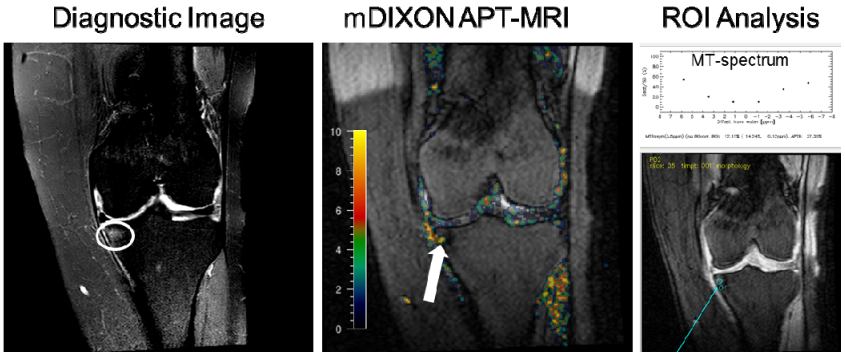

Figure 2. A subject with BME in the tibia bone marrow. A large BME area is highlighted on the diagnostic image. Only a small area close to the bone surface exhibits elevated mobile protein levels (arrow), with a $MTR_{asym}(3.5ppm)$ value of 12.1%. The deeper BME area is shown a lack of mobile protein levels.

Discussion

We demonstrate that the mDIXON-based APT-MRI technique can substantially improve non-invasive assessment of mobile protein levels in bone marrow edema. The proposed technique has the potential to be applicable to fat-containing tissue tumors, such as osteosarcoma, breast cancer, and fatty liver lesion.

References

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