Water and lipids quantification in bone marrow edema using 3D MRSI techniques at 3T: A preliminary study

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INTRODUCTION

Severity and progression of osteoarthritis (OA) is associated with bone marrow edema induced by injury and OA-related changes (1). Bone marrow edema is characterized by ill-defined areas of high signal on short inversion time inversion-recovery (STIR) images and/or on fat-saturated T2-weighted images. This increase in signal has been attributed to a number of factors, such as abnormal trabeculae, bone marrow necrosis, swelling of fat cells, marrow bleeding and marrow edema (2). Proton MR spectroscopy provides a non-invasive method to quantify metabolic levels, however, its application in bone marrow has been sparse (3,4). The goal of this study was to examine the feasibility of using 3D MR spectroscopic imaging (MRSI) to quantify water and lipids changes in bone marrow edema for patients with OA or acute knee injury.

MATERIALS AND METHODS

Three healthy volunteers and seven patients with OA or knee injury who showed bone marrow edema were studied. Among the patients, three had acute knee injuries with anterior cruciate ligament (ACL) or medial collateral ligament (MCL) tears, four had early osteoarthritis which we considered as chronic knee injuries. MR data were acquired at a 3T GE Excite Signa MR scanner using a quadrature knee coil. Point RESovled Spectroscopy (PRESS) volume selection was used to acquire 3D-MRSI data (TR/TE=2000/38, phase encoding step=8*8*8, nominal voxel size = 0.13 – 0.7 cc) and the PRESS box was prescribed on axial or sagittal T2-weighted fat-suppressed images to cover bone marrow edema as much as possible. Bone marrow edema was manually segmented based on T2-weighted fat-suppressed images and volume of bone marrow edema was calculated using software developed with IDL (RSI, Boulder, CO). The spectral data were constructed, corrected and fitted with Voigt models using in-house developed software (5.6). Water at 4.7 ppm, unsaturated lipids at 5.4 ppm and saturated lipids at 0.9-1.3 ppm were estimated for each voxel. The 3-D metabolic images were resampled with sinc interpolation and contours for regions with significantly elevated water and/or unsaturated lipids, defined as metabolic levels more than five times the standard deviation of noise, were generated using IDL The volumes of these abnormalities were calculated for each patient. In addition, to address the decrease of saturated lipids, the ratio of water to saturated lipids, and unsaturated lipids to saturated lipids were calculated for each voxel. The 3-D metabolic images of ratio index, defined as log(ratio+1), were resampled with sinc interpolation and median ratio index within edema contours were estimated for each patients.

RESULTS

Fig. 1 shows the spectra for a healthy volunteer (a), a patient with OA (upper in b) and a patient with acute knee injury (ACL tear, lower in b). Saturated lipid peaks at 1.3 ppm dominated signals in controls. Significantly elevated water and decreased saturated lipids were seen within the region of edema in both patients. Elevated unsaturated lipids were also shown in the patient with acute injury, and it extended outside the region of edema. Table 1(a) illustrates average volumes of bone marrow edema, elevated water and elevated unsaturated lipids, and Table 1(b) shows the median values of log ratios of water to saturated lipids and unsaturated lipids to saturated lipids for patients with acute injury and OA respectively. Significant correlation was found between volumes of elevated water and volumes of bone marrow edema in all seven patients, with R^2=0.78 and P-value=0.039.

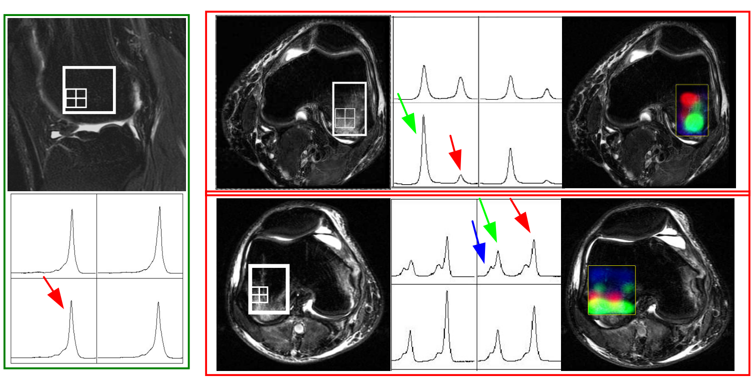

Fig. 1. Spectral data for (a) a healthy volunteer; (b) patients with OA (upper) and with acute knee injury (lower). Red: saturated lipids; Green: water; Blue; unsaturated lipids.

Table 1.

(a) Mean±STD of volumes of edema and elevated water and unsaturated lipids (in cm^3)

	Edema	Water	UnSatLip
Acute	25.4±28.0	15.5±13.2	9.3±9.9
Chronic	7.5±8.2	8.6±5.2	3.3±2.3

(b) Mean±STD of log ratios within edema

	Log (Water/SatLip)	Log (UnSatLip/SatLip)
Acute	0.30±0.29	0.04±0.04
Chronic	0.37±0.18	0.03±0.02

CONCLUSIONS AND DISCUSSION

This study shows the feasibility of using *in vivo* 3D-MRSI to examine changes of water and lipid components associated with bone marrow edema in acute and chronic joint disease. Elevated water correlates with edema both in location and volumes, while elevated unsaturated lipids may extend outside the region of edema. Patients with acute knee injury tend to have more elevated unsaturated lipids but a larger cohort of patients is warranted to examine if spectral patterns are different between patients with chronic OA and with acute injury. Longitudinal studies are underway to investigate the potential of MRSI data in bone marrow as a marker of OA progression. Correlation between MRSI data and histological findings in bone marrow edema will be also studied in the future using biopsies obtained from patients undergoing total knee arthroplasty.

REFERENCES

1. Felson DT, et al., Ann Intern Med 2003,139(5 Pt 1):330-336.
2. Zanetti M, et al. Radiology 2000, 215(3):835-840.
3. Jensen KE, et al, Dan Med Bull 1992, 39: 369-90.
4. Bao S., et al, Magn Reson Imaging 1999, 17:1203-10.
5. Nelson SJ. Magn Reson Med 2001. 46(2):228-39.
6. Li X, Nelson SJ. Proc IEEE EMBS 2003: 482-5.

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