INTRODUCTION

Bone bruises or marrow edema are present in up to 80% of acute anterior cruciate ligament (ACL) injuries (1), and have been associated with the severity and progression and pain of osteoarthritis (OA) (2,3). The increase in MR 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 (4). While these MR findings are common, little is known about the natural history and significance of these lesions. Some have suggested permanent cartilage injury overlying these bone bruises at the time of ligament injuries.

Quantitative assessment of bone bruises will allow us to better monitor the progression of bone and overlying cartilage injuries. Proton MR spectroscopic imaging (MRSI) is an advanced technique that provides non-invasive methodology for quantifying biochemical or metabolic changes, particularly changes of water and lipids, within regions of bone marrow edema. This technique can also study the differences in biochemical compositions of bone bruises at various stages of resolution. The goal of this study was 1) to develop 3D-MRSI techniques for quantification of water and lipids component in bone marrow of knee joint, and 2) to quantitatively assess biochemical compositions in bone marrow edema for patients with OA and ACL-injuries respectively.

METHODS

Sixteen patients with OA (n=8) or ACL tears (n=8) in knee joints who had bone bruise were studied. MR data were acquired at a 3T GE MR scanner. Point RESolved Spectroscopy (PRESS) volume selection was used to acquire 3D-MRSI data (TR/TE = 2000/38, phase encoding step = 8*8*8, nominal voxel size = 5*5*5mm = 0.125cc). The PRESS box was prescribed on axial or sagittal T2-weighted fat-suppressed images to cover bone marrow edema as much as possible and some normal-appearing bone marrow region as an internal reference for post-processing. Bone marrow edema was segmented automatically in T2-weighted fat-suppressed images based on a thresholding method. One region of interest (ROI) was defined in normal appearing bone marrow and the standard deviation (SD) of the signal intensity within that ROI was calculated. Regions with signal intensity 7 times higher than the SD with normal marrow ROI were defined as bone marrow edema. 3D contours were generated automatically and volumes of marrow edema were calculated. Spectral data were quantified using in-house developed software. 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 and contours for regions with significantly elevated water and/or unsaturated lipids were generated. The volumes of these abnormalities were calculated. A t-test was used to compare these volumes between patients with OA and ACL-injuries. The relationship between volumes of edema and elevated water and unsaturated lipids were examined using Spearman correlation.

RESULTS

Fig. 1(a) shows the spectral data for a healthy volunteer. Saturated lipids dominated the signal. Significantly elevated water and unsaturated lipids were seen in both patients with OA, Fig. 1(b) and with ACL-injuries, Fig. 1(c). The color overlay shows that the elevated water was coincident with edema spatially (in particular the region with highest signal intensity) while the elevated unsaturated lipids presented mainly in the peripheral regions of marrow edema (with less signal intensity) and extended outside the edema. The volume of elevated water correlated with the volume of edema significantly (R=0.798, P=0.0003). Patients with ACL-injuries tended to have larger volumes of elevated water and unsaturated lipids than patients with OA, but the difference was not significant, Table 1.

Table 1. Means±SD of volumes of edema, and elevated water and unsaturated lipids (in cm³). The difference was not significant.

<table>
<thead>
<tr>
<th></th>
<th>Edema</th>
<th>Water</th>
<th>UnSatLip</th>
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<tbody>
<tr>
<td>ACL</td>
<td>5.2±6.1</td>
<td>12.2±7.7</td>
<td>7.0±5.9</td>
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<tr>
<td>OA</td>
<td>2.8±2.5</td>
<td>8.5±3.5</td>
<td>3.6±1.5</td>
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DISCUSSION

Proton MR spectroscopy provides a non-invasive method to quantify metabolic levels in tissue. In this study, we have developed a 3D-MRSI protocol to study biochemistry changes in bone marrow for patients with OA and ACL-injuries. Using this method, we can objectively and quantitatively evaluate these bone lesions and derive their association with cartilage degeneration. Fig. 2 shows the T1ρ relaxation time mapping for a patient with ACL-injury (the one in Fig. 1(c)). Significantly elevated T1ρ was observed in the overlying cartilage of bone bruise. Follow-up studies are underway to examine the longitudinal changes of bone bruise and its overlying cartilage. 3D-MRSI provides spatial distribution of the biochemical changes in these lesions. In this series, unsaturated lipids are present predominately at the periphery of the lesion. Resolution of high water content with replacement of unsaturated lipids may be an indicator of bone bruise resolution. This distribution will be quantified in future studies. The results of this study may identify the significance and recovery of bone bruise, and hence, changes in treatment approaches such as pharmacological and surgical treatment.

REFERENCES


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