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DIFFERENT IMAGING MODALITIES FOR ASSESSMENT AND ANALYSIS LIGAMENTOUS INJURIES OF THE KNEE

Saleh Ahmed Alammari [1], Moath Ibrahim Alzapni [2], Zaid Awad Alshammari [3], Rashed Raja Alshammari [4], Mohammad Abdulaziz Altraifi [5], Abdulrahman Fahad Alluhaybi [6], Abdulaziz Sorour Sorour[7]

[1-7] University of Hail, Faculty of Medicine, Saudi Arabia.

Abstract:

To assess human articular cartilage tissue functionality by serial multi parametric quantitative MRI (qMRI) mapping as a function of histological degeneration. Forty-nine cartilage samples obtained during total knee replacement surgeries were placed in a standardized artificial knee joint within an MRI-compatible compressive loading device and imaged in situ and at three loading positions, i.e. unloaded, at 2.5 mm displacement (20% body weight [BW]) and at 5 mm displacement (110% BW). Using a clinical 3.0 T MRI system serial T1, T1ρ, T2 and T2 maps were generated for each sample and loading position. Histology (Mankin scoring) and biomechanics (Young's modulus) served as references. Samples were dichotomized as intact (int, n = 27) or early degenerative (deg, n = 22) based on histology and analyzed using repeated-measures ANOVA and unpaired Student's t-tests after log-transformation. For T1ρ, T2 and T2*, significant loading-induced differences were found in deg (in contrast to int) samples, while for T1 significant decreases in all zones were observed, irrespective of degeneration. In conclusion, cartilage functionality may be visualized using serial qMRI parameter mapping and the response-to-loading patterns are associated with histological degeneration. Hence, loading-induced changes in qMRI parameter maps provide promising surrogate parameters of tissue functionality and status in health and disease. Synthetic MRI is able to simultaneously acquire conventional images and quantitative maps, and has the potential to reduce the overall examination time. It provides comparable image quality to conventional MRI for the knee joint, with the exception of the bone marrow. With further optimization, it will be possible to take advantage of the image quality of musculoskeletal tissue with synthetic imaging. Synthetic MRI produces images of good contrast and is also a time-saving technique. Thus, it may be useful for assessing osteoarthritis in the knee joint in the early stages.* ***Advantages of using 3.0 T****: 3.0 T imaging is of interest to the system thanks to the inflated man signal and better SNR.* ***SNR and Relaxation Time Considerations:*** *While it seems that 3.0 T imaging ought to give double the intrinsic SNR of imaging at 1.5 T, changes in each T1 associate degreed T2 relaxation times together with the dearth of optimized coils ends up in an SNR improvement of slightly but double.* ***Technical Considerations:*** *Technical concerns should be accounted for so as to optimize 3.0 T imaging.* ***Protocols:*** *Protocols are developed at 3.0 T tomography that show promising results for assessment of the knee.* ***Future direction:*** *(1) Isotropic Imaging: Isotropic or 3-dimensional (3D) imaging techniques leave the acquisition of identical voxels as opposition the usually non-heritable eolotropic voxels with 2-dimensional (2D) imaging. (2) UTE imaging: Human tissues contain many elements that have a large vary of T2 values. (3) T2 Mapping: T2 relaxation times for a precise tissue square measure usually constant, tissue pathology may end up in changes in these relaxation times. (4) T1rho Imaging: T1rho imaging, or spin lattice relaxation within the rotating frame, is feasible once the magnetization is "spin-locked" by a continuing RF field once being tipped into the crosswise plane. (5) Sodium: Sodium imaging, like T1rho imaging, has shown promise in mensuration proteoglycan content as a marker of early, symptomless OA.*

Keywords*: MRI, SNR, Bone Marrow, Directions, Diagnostic Tool, QMRI, Osteoarthritis Initiative.*

Corresponding author:
Saleh Ahmed Alammari,
University of Hail, Faculty of Medicine, Saudi Arabia.
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INTRODUCTION:

Magnetic resonance imaging (MRI), with its multi-planar capabilities and glorious soft-tissue distinction, has established itself because the leading modality for non-invasive analysis of the system [1,2,3,5,6]. It considered the highest imaging and diagnostic tool for the knee as a results of its ability to gauge a large vary of anatomy and pathology varied from ligamentous injuries to articular gristle lesions. Imaging of the knee needs glorious distinction, high resolution and also the ability to ascertain terribly little structures, all of which might be provided by man imaging. The event of advanced diagnostic man imaging tools for the joints is of accrued clinical importance because it has been recently shown that system imaging is that the most chop-chop growing field in man imaging, second solely to neuroradiology applications [7]. Currently, most clinical analysis of the system is performed at intermediate field strengths of 1.5 T or lower. High field systems, like 3.0 T, square measure currently changing into progressively obtainable for clinical use. Quantitative MRI (qMRI) techniques such as T2 and T1ρ mapping have therefore received considerable scientific attention. QMRI techniques are guided by the prospect of more standardized and objective tissue assessment and assess alterations of the extracellular matrix (ECM) constituents, thereby providing quantitative information on composition (beyond structure). However, these techniques' considerable inter- and intra-individual variability makes differentiation of early-to-moderate stages of degeneration challenging as these are characterized by only minor alterations in structure and composition. Among other changes cartilage degeneration is characterized by gradual reductions in mechanical stiffness throughout the entire sample depth resulting in increasing local strains (under constant stress) with progressive degeneration. Hence, biomechanics stimuli have been implemented within MRI scan protocols to assess cartilage tissue functionality: Recent approaches have used qMRI parameter maps to quantify the tissue's response to loading with promising results. We hypothesized that qualitative and quantitative loading-induced intra-tissue changes are related to tissue degeneration and may be used to improve the diagnostic accuracy of the qMRI parameters investigated.

Advantages of using 3.0 T

3.0 T imaging is of interest to the system thanks to the inflated man signal and better SNR. SNR could be a performance of the most flux strength, the quantity of tissue being imaged and therefore the radio-frequency coil used. Thus if the tissue volume imaged and coil used stay constant, the transition from 1.5 T to 3.0 T ought to end in double the intrinsic SNR. This increase in SNR then permits for up to fourfold quicker mage acquisition on multiple-average scans or double the resolution in one direction. Positive clinical applications abound. The rise in scan speed has the flexibility to supply for inflated patient comfort and output whereas the rise in resolution could prove valuable for the visualization of little structures. The rise in resolution and visualization of anatomy and pathology additionally offer the advantage of improved surgical designing. Shortly when the introduction of 3.0 T imaging capabilities many researchers began studies in an endeavor to research the anatomical and pathological accuracy of the new high field imaging systems compared to 1.5 T and lower field imaging systems. Various studies have incontestable the high accuracy and sensitivity and specificity of tissue anatomy and pathology within the articulation genus.

Technical considerations

Technical concerns should be accounted for so as to optimize 3.0 T imaging. The foremost apparent of those include: chemical shift, fat saturation, and radio-frequency power deposition. Since the resonant frequency of fat and water protons will increase linearly with the magnetic flux strength, chemical shift artifact with in the frequency secret writing direction are going to be double with 3.0 T as compared to 1.5 T, if imaging information measure is unbroken constant. A technique of correcting for the chemical shift artifact includes doubling the receiver information measure. A third technical thought is that of the radio-frequency power deposition. The radio-frequency power for excitation at 3.0 T is fourfold that at 1.5 T (1, three) thanks to the very fact that the resonant frequency at 3.0 T is double that at 1.5 T. several sequences utilized in system imaging, together with

quick spin-echo, have the potential for top radio-frequency power. The general deposition depends on the amplitude and range of radio-frequency pulses. The employment of speedy imaging sequences might cut back the radio-frequency power deposition.

Future directions

Isotropic imaging

Isotropic or 3 dimensional (3D) imaging techniques leave the acquisition of identical voxels as opposition the usually non- heritable eolotropic voxels with 2 dimensional (2D) imaging. With identical voxels comes the power to retrospectively reformat pictures into various planes letting higher visualization of oblique structures, for instance the anterior and posterior symmetrical ligaments.[8,9].

UTE imaging

Human tissues contain many elements that have a largen vary of T2 values. In tissues like the liver and nervous tissue, the spins usually have long T2 values. However, within the knee, ligaments, menisci, tendons, plant tissue bone and membrane have short T2 values that vary from many microseconds to tens of milliseconds [10]

T2 mapping

Another recent advancement within the field of MRI imaging is that of T2 mapping. Whereas T2 relaxation times for a precise tissue square measure usually constant, tissue pathology may end up in changes in these relaxation times. Even before symptoms arise, physiological changes within the animal tissue matrix begin happening.[11,12,13]

T1rho imaging

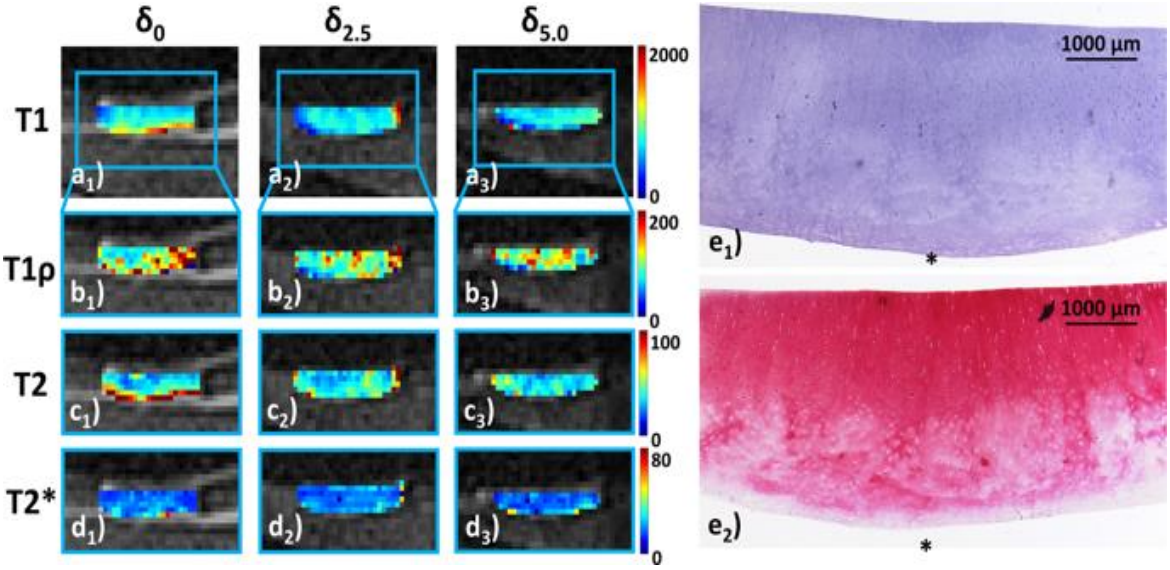
T1rho imaging, or spin lattice relaxation within the rotating frame, is feasible once the magnetization is "spin-locked" by a continuing RF field once

being tipped into the crosswise plane. It's a way of examining the slow interactions that occur between the static water molecules and therefore the animate thing atmosphere during which they live. Proteoglycan loss, AN early biomarker of degenerative joint disease (OA), leads to changes to the organic compound atmosphere which may be indicated in T1rho measurements. This system is in a position to amass valuable medicine in foin low frequency systems and initial studies have shown it to be a promising tool the study of early OA development [14, 15, 16]. T1rho imaging techniques will be utilized at each 1.5 T and 3.0 T field strengths, but depiction of proteoglycan loss is healthier optimized at 3.0 T thanks to the SNR increase.

DISCUSSION:

The most important finding of this study is that loading-induced changes in some serial qMRI parameter maps are related to histological degeneration and improve their diagnostic accuracy, which provides a solid scientific framework to assess cartilage functionality in future applications. Serial qMRI parameter maps under loading and corresponding histological sections of intact cartilage. QMRI parameter maps are displayed in the unloaded configuration δ0 (a1–d1) and at consecutive loading positions δ2.5 (a2–d2) and δ5.0 (a3–d3). T1ρ, T2 and T2* maps are displayed at higher magnification for better visualization ((b–d) framed in blue). In this sample, relatively homogeneous qMRI parameter distributions at δ0 remained largely unaltered at δ2.5 and δ5.0. Only for T1ρ, pre-existent slight focal signal heterogeneities changed a bit with loading. The first morphological image obtained of each series was used for qMRI parameter overlays. Entire sample width is 8 mm.

Corresponding histological sections revealed the absence of substantial structural surface or sub-surface alterations, while focal cell proliferation (only visible at higher magnification [not shown]) and moderate discoloration on proteoglycan staining were found. Hematoxylin/eosin (e1) and Safranin O staining (e2). MSS 3. Histological sections are displayed bottom-down in keeping with the orientation of the serial qMRI maps; hence, asterisks indicate the tissue's surface.



Disparate depth- and degeneration-dependent loading patterns were observed for T1ρ. Significant increases were found in the deep zone of deg samples only, although changes were similar, yet non-significant, in int samples. Opposite, yet non-significant changes were found in the superficial zone with T1ρ decreases in int samples and increases in deg samples. In absolute terms, changes in T1ρ were more pronounced in deg than int samples. These findings are in line with recent in-vivo data, as Souza et al. reported that changes in T1ρ are considerably larger in OA patients than controls16. However, they also observed significant decreases in the superficial and increases in the deep zone, irrespective of degeneration. Most likely, this discrepancy is secondary to doubtful patient allocation procedures based on radiographic evaluation, which is coarse and questionable when applied as reference measure. Additionally, T1ρ changes of the medial compartment are not linearly correlated with overall OA severity27, thereby further compromising this reference measure.

CONCLUSION:

MRI is accepted mutually of the foremost correct imaging modalities for assessment and analysis of the system whereas its advancement to 3.0 T high field imaging is changing into additional refined and established within the clinical realm. 3.0 T imaging systems supply either superior image resolution or shortened imaging times, each leading to many same blessings. A lot of promising analysis encompassing technical problems is being worn out order to permit 3.0 T imaging to succeed in its full clinical potential.

As analysis on optimization of 3.0 T high field imaging systems continues, the clinical world follows suit providing exquisite analysis of the system. The long run of 3.0 T imaging is bright as analysis increases to push the boundaries of this already outstanding imaging modality.

Several limitations are pertinent to this study including the generalizability of our results (i.e., the inability to directly compare our results with those obtained with different techniques or different MRI scanners. our subject selection process and no sub-compartmental analysis. While our study reports reference values for cartilage T2, it is important to note that cartilage T2 quantification is dependent on the type of MRI scanner, MRI field strength, radio frequency coil, MRI pulse sequence and T2 fitting method used. In addition, chemical shift misregistration errors may affect the quantified T2 values, especially toward the cartilage surface. Our study aimed to minimize any errors due to scanning and T2 fitting as the OAI has a rigid quality control protocol and by using identical T2 fitting models for all subjects. Also, while we attempted to reduce potential errors resulting from stimulated errors by excluding the first echo in the T2 fitting procedure, recent studies have proposed novel techniques for T2 quantification. Nevertheless, it is important to recognize that the results from our study are specific to the imaging and post-processing methods used. Since the cartilage T2 values are not standardized, directly comparing our results to those from other scanners and MRI pulse sequences may not be accurate. In addition, given the natural variation of T2 values, this reference database may not be able to precisely define which cartilage composition, as quantified by T2, would be considered “normal” and which would be considered early degeneration. However, developing a demographic-specific database is the first step toward a better interpretation of cartilage T2 values. Moreover, the differences in cartilage T2 between compartments and knees may represent a natural variation or differences in integrity; thus, compartment-specific

longitudinal monitoring may be required to better understand the evolution of degenerative disease.

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