Robust Image Registration for In-vivo Human Osteoarthritic Knees and Cartilage Specimens and Correlation Between In-vivo and Ex-vivo T1ρ

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Introduction: Along with the efforts of developing prevention strategies and new treatment methods for osteoarthritis (OA), there are increasing demands for early diagnosis and critical treatment monitoring of cartilage degeneration in OA. Quantitative MRI T1ρ relaxation times have been developed to detect early biochemical changes in cartilage matrix [1-2]. Previous studies correlated quantitative MRI T1ρ relaxation times with biochemical changes within cartilage matrix using specimens taken from total knee arthroplasty (TKA) [3-4], but no study has documented yet the relationship between in vivo and ex vivo T1ρ quantification in cartilage. The purposes of this study are to develop a robust registration algorithm between in vivo and ex vivo knee cartilage images and to evaluate the correlation between in vivo and ex vivo T1ρ relaxation time in human OA cartilages.

Methods: Eight patients (five women; mean age: 68±9 years) who were going to undergo TKA procedure due to severe OA were scanned before surgery. Eleven knee specimens from tibial-femoral joints were then resected and scanned with being positioned in the corresponding physiological orientation [2]. All scans were acquired using a 3T GE Signa MR Scanner with an 8-channel phased-array knee coil. The sagittal T2-w fat-saturated FSE images (TR/TE=4300/51 ms, FOV=14 cm for in vivo, 6-8 cm for ex vivo, matrix=512×256, slice thickness=2.5 mm, gap=0.5 mm), 3D sagittal high-resolution fat-saturated SPGR images (TR/TE=15.6/7 ms, flip angle=12, FOV=14cm for in vivo, 6-8 cm for ex vivo, matrix=512×512, slice thickness=1 mm, bandwidth =31.25 kHz, NEX=1), and sagittal T1ρ relaxation time mapping images (MAPSS) (TR/TE=9.0/3.5 ms, FOV=14 cm for in vivo, 6-8 for ex vivo, matrix=256×128, slice thickness=4 mm for in vivo, 2mm for ex vivo, BW=62.5 kHz, VPS=64, recovery time=1.2 s, TSL=0, 10, 40, 80 ms, FSL=500 Hz) were acquired. The cartilage lesions were graded on in vivo MRI images (MAPSS) (TR/TE=9.0/3.5 ms, FOV=14 cm for in vivo, 6-8 for ex vivo, matrix=256×128, slice thickness=4 mm for in vivo, 2mm for ex vivo, BW=62.5 kHz, VPS=64, recovery time=1.2 s, TSL=0, 10, 40, 80 ms, FSL=500 Hz) were acquired. The cartilage lesions were graded on in vivo MRI using modified Whole-Organ Magnetic Resonance Imaging Score (mWORMS) assessment [5]. T1ρ maps were reconstructed by fitting the T1ρ-weighted images voxel by voxel to the equation: S(TSL)∝exp(-TSL/T1ρ).

Results: The registration errors were similar in all compartments (0.1±0.04 mm). The mean T1ρ values of the ex-vivo specimens were significantly higher than in vivo T1ρ in the same regions (71.1±3.6 ms vs. 41.9±3.8 ms, p<0.0001). The in vivo T1ρ relaxation times showed a significant moderate positive correlation with ex vivo T1ρ values (R²=0.45, p<0.0001, Fig. 2). There was no correlation between in vivo mWORMS and the T1ρ differences of ex vivo and in vivo.

Discussion: The registration error was comparable to the image resolution, showing good registration between in vivo and ex vivo images. The significant elevation of T1ρ in specimens may be explained by potential damages during surgery, and/or hydration and biochemical exchanges and further degeneration during specimen preparation. No correlation between mWORMS and T1ρ differences indicated that the different of the in vivo and ex vivo T1ρ was not dependent on the degeneration status of the cartilage.

Conclusion: This study developed a robust registration algorithm for in vivo and ex vivo cartilage imaging. The ex vivo imaging of specimens are powerful tools to explore the link between imaging measures and biochemical analysis. As a non-invasive imaging technique, it would be critical to link the biochemical analysis with in vivo imaging measures.

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[2] Li et al., Osteoarthritis Cartilage, 2007

Figure 1. Cartilage of specimens (a) and in-vivo knees (c) was registered (e) before T1ρ relaxation time quantification (b, d).

Figure 2. Moderate correlation was found between in-vivo and ex-vivo human osteoarthritic cartilage.