CUBEQUANT T1ρ, QDESS T2, AND CONES SODIUM MEASUREMENTS ARE SUFFICIENTLY REPRODUCIBLE FOR IN VIVO CARTILAGE STUDIES

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PURPOSE: Osteoarthritis (OA) causes disability for 10% of the population over 60 and costs up to $60 billion each year1. Quantitative MRI parameters such as T1ρ, T2, and sodium have been shown to vary in OA patients or specimens by an increase of 30–120% for T1ρ, an increase of 5–50% for T2, or a decrease of 20–40% in sodium concentration2,3. T1ρ relaxation times have shown correlation to the depletion of proteoglycan (PG) content4, T2 relaxation times have shown correlation to collagen structure and water content in cartilage5, and sodium has been shown to correlate highly with glycosaminoglycan (GAG) in cartilage5. CubeQuant6 has been recently shown to calculate T1ρ, and Quantitative Double-Echo Steady-State (qDESS) has recently been shown to measure T2 without diffusion effects while also providing useful morphological images to distinguish fluid and cartilage7,8. In this work, we assess the reproducibility of the 3D quantitative MR techniques T1ρ mapping using CubeQuant, T2 mapping using qDESS and 3D cones sodium MRI.

METHODS: Acquisition: Five healthy volunteers (5M, mean age 28.8±5.5 years, mean BMI 23.3±3.8) were each scanned 24 hours apart for short-term reproducibility and approximately 4.5 months later for long-term reproducibility. IRB approval and informed consent were obtained. Images were acquired using a GE Discovery MR750 3T scanner (GE Healthcare, Waukesha, WI), a transmit-receive 8-channel knee coil (Invivo Inc., Gainesville, FL) and a custom-built proton/sodium dual-tuned coil.

Scan Parameters: CubeQuant T1ρ maps were acquired using a magnetization-prepared pseudo-steady-state 3D fast spin echo acquisition with 500 Hz spin-lock frequency pulse6. T2 maps were calculated from qDESS images7. Sodium images were obtained using a fast gradient-spoiled sequence with the 3D cones k-space trajectory9,10 (Table 1).

Analysis: T1ρ and T2 maps were generated using OsiriX and sodium signals were measured and normalized to the popliteal artery from a single slice in the lateral and medial compartments in the following 2D ROIs: anterior, central, and posterior femoral cartilage and anterior/posterior tibial cartilage as in Fig. 111. The coefficient of variation (CV) was calculated for each individual and ROI, and subsequently the root-mean-square CV (CV RMS) for each ROI, which demonstrates the reproducibility of a technique12.

Definitions of Variability: We define short-term intra-subject variability to be the variability from scanning the same subject on consecutive days, and long-term intra-subject variability to be the variability from scanning the same subject several months apart. The inter-observer variability is due to ROI differences between observers and intra-observer variability is due to ROI differences between different segmentation sessions. Adjacent slice variability is the variability between consecutive slices.

RESULTS: The short-term and long-term intra-subject reproducibility amongst the 10 ROIs, as expressed by the CVRMS, ranged between 2.7-8.6% and 4.6-9.0% for T1ρ mapping using CubeQuant, between 2.4-9.8% and 4.4-13.8% for T2 mapping using qDESS, and between 5.2-13.8% and 4.6-16.0% for 3D cones sodium MRI, respectively (Figure 2).

DISCUSSION & CONCLUSION: The average CVRMS values are comparable to other published literature CVs, which may range between 7-19% for T1ρ mapping13, 4-14% for regional T2 mapping13, and 6.9-11.3% for sodium sequences at 3T14. These CVRMS values are lower than most previously measured changes in OA patients, suggesting that CubeQuant T1ρ, qDESS T2 and 3D cones sodium MRI may be sufficiently reproducible for detecting changes resulting from osteoarthritis.

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