CUBEQUANT T1RHO, QDESS T2, AND CONES SODIUM MEASUREMENTS ARE SUFFICIENTLY REPRODUCIBLE FOR *IN VIVO* CARTILAGE STUDIES

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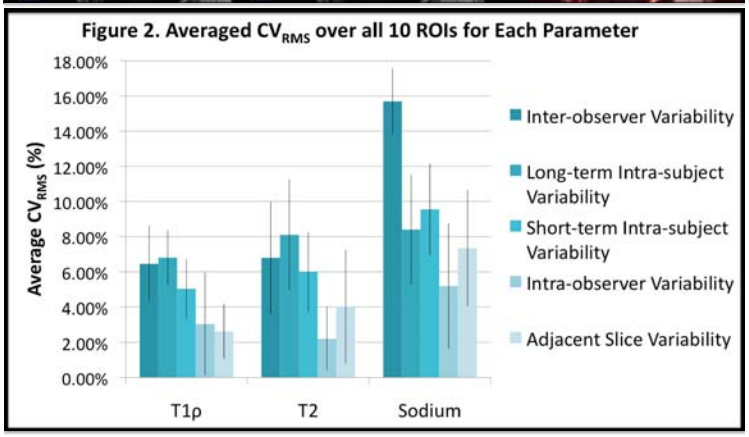
PURPOSE: Osteoarthritis (OA) causes disability for 10% of the population over 60 and costs up to $60 billion each year[1]. Quantitative MRI parameters such as $T_{1\rho}$, T_2, and sodium have been shown to vary in OA patients or specimens by an increase of 30–120% for $T_{1\rho}$, an increase of 5–50% for T_2, or a decrease of 20-40% in sodium concentration[2,3]. $T_{1\rho}$ relaxation times have shown correlation to the depletion of proteoglycan (PG) content[4], T_2 relaxation times have shown correlation to collagen structure and water content in cartilage[5], and sodium has been shown to correlate highly with glycosaminoglycan (GAG) in cartilage[3]. CubeQuant[6] has been recently shown to calculate $T_{1\rho}$, and Quantitative Double-Echo Steady-State (qDESS) has recently been shown to measure T_2 without diffusion effects while also providing useful morphological images to distinguish fluid and cartilage[7,8]. In this work, we assess the reproducibility of the 3D quantitative MR techniques $T_{1\rho}$ mapping using CubeQuant, T_2 mapping using qDESS and 3D cones sodium MRI.

Table 1: Scan Parameters

Sequence	TE (ms)	TR (ms)	FA (°)	Resolution (mm³)	Time
CubeQuant	1, 10, 30, 60	5.1	90	0.5x0.625x3	5:49
qDESS	9, 49	29	18, 35	0.625x0.625x3	9:20
Sodium	0.6	35	70	1.25x1.25x4	21:33

Figure 1. CubeQuant $T_{1\rho}$ Maps, qDESS T_2 Maps and 3D Cones Sodium Overlaid on DESS Low Proton Images in Lateral ROIs of a Healthy Volunteer.

Figure 2. Averaged CV_{RMS} over all 10 ROIs for Each Parameter



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 $T_{1\rho}$ maps were acquired using a magnetization-prepared pseudo-steady-state 3D fast spin echo acquisition with 500 Hz spin-lock frequency pulse[6]. T_2 maps were calculated from qDESS images[7]. Sodium images were obtained using a fast gradient-spoiled sequence with the 3D cones k-space trajectory[9,10] (Table 1).

Analysis: $T_{1\rho}$ and T_2 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. 1[11]. 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 technique[12].

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 CV_{RMS}, ranged between 2.7-8.6% and 4.6-9.0% for $T_{1\rho}$ mapping using CubeQuant, between 2.4-9.8% and 4.4-13.8% for T_2 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 CV_{RMS} values are comparable to other published literature CVs, which may range between 7-19% for $T_{1\rho}$ mapping[13], 4-14% for regional T_2 mapping[13], and 6.9-11.3% for sodium sequences at 3T[14]. These CV_{RMS} values are lower than most previously measured changes in OA patients, suggesting that CubeQuant $T_{1\rho}$, qDESS T_2 and 3D cones sodium MRI may be sufficiently reproducible for detecting changes resulting from osteoarthritis.

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