

SNR IMPACTS THE ACCURACY AND PRECISION OF KNEE ARTICULAR CARTILAGE T2 RELAXATION TIME MEASUREMENTS

B.J. Dardzinski¹, E. Schneider²

¹Merck Sharp & Dohme Corp., West Point, PA USA

²Imaging Institute, Cleveland Clinic, Cleveland, OH USA and
SciTrials LLC, Rocky River, OH

The authors have no conflicts with the work reported in this study.

MRI Assessments of Cartilage

- Morphological MRI
 - Insensitive to early stage cartilage lesions
 - Outerbridge I – softening / swelling
 - Unexposed (no risk) and Incidence (at risk, no symptoms or ROA) have equal incidence of early defects (WORMS <5)
- T2
 - collagen integrity, [GAG], orientation dependent
- T1 (dGEMRIC)
 - [GAG] charge-based, orientation independent
- T1rho
 - collagen integrity, [GAG], orientation dependent (less than T2)

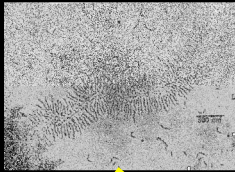
T2 Assessments

- Are not absolute
- Values are:
 - Spatially dependent
 - Knee positioning (magic angle)
 - Cartilage plate
 - Cartilage zone
 - MR System Dependent
 - Magnetic Field Strength
 - Refocusing flip angle
 - Acquisition sequence
 - Analysis method
 - Image noise, particularly last echo

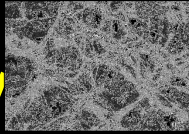
Introduction

- OAI opted for 3T
 - Increased SNR allowed higher spatial resolution
- In 2003:
 - Not many 3T MR systems
 - Only one knee coil (USAI)
 - However other options in development
 - Pilot study to evaluate impact two different knee coils
 - Similar transmit design (similar excitation / refocusing pulses)
 - Different detection design (different SNR)

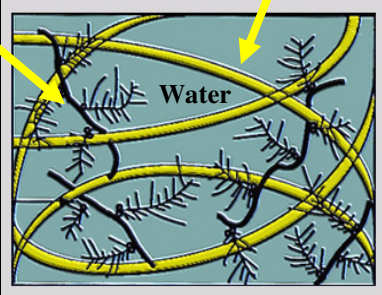
Structure of Articular Cartilage



Proteoglycans

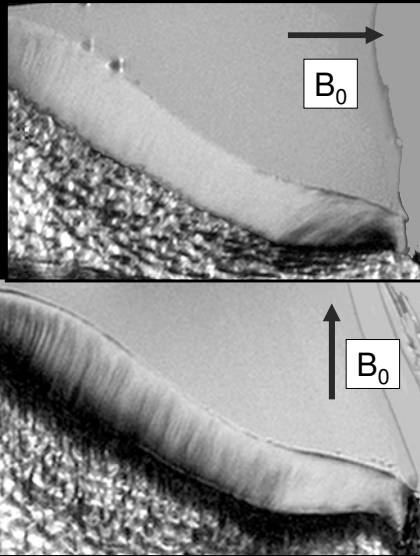
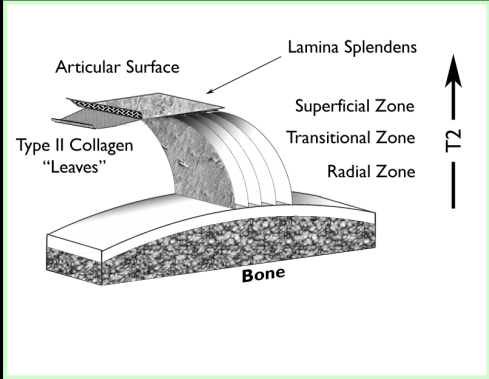


Type II Collagen Matrix



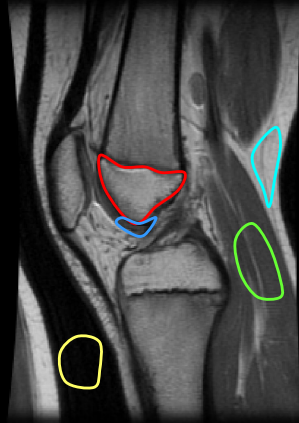
Fiber reinforced composite matrix

Effect of Collagen Orientation on MR Signal Intensity



Images courtesy of Doug Goodwin, MD
Dartmouth Medical School

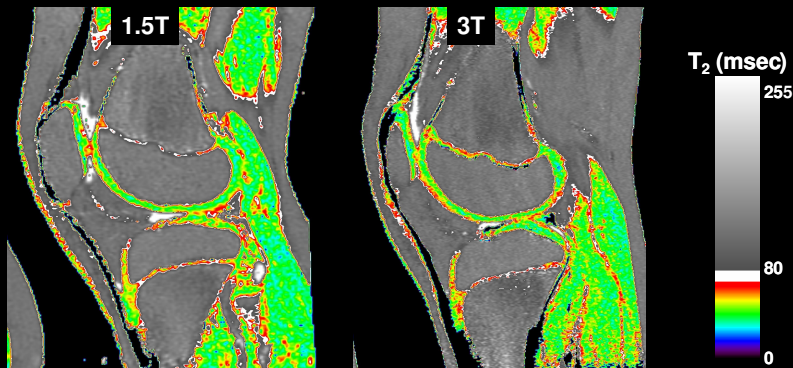
SNR 1.5T vs. 3T



ROI	SNR (BW = 125)			SNR (BW = 250)		
	1.5T	3T	Ratio	1.5T	3T	Ratio
Bone	53	109	2.1	61	95	1.6
Cartilage	22	46	2.1	29	45	1.6
Fat	74	132	1.8	84	112	1.3
Muscle	26	42	1.6	31	44	1.4

$$SNR = \frac{S}{\sigma_n}$$

T2 Map Comparison 1.5 vs. 3 Tesla



T2 Comparison

ROI	1.5T	3T
Bone	123 ± 5	122 ± 7
Cartilage	50 ± 6	43 ± 5
Muscle	39 ± 4	38 ± 6
Fat	123 ± 9	128 ± 6

Objective

- Determine the accuracy and precision of cartilage T2 measurements using two different RF Coils
 - Similar transmit (quadrature)
 - Dissimilar receive (quadrature vs 8 channel phased array)

QTR vs. QT8PAR

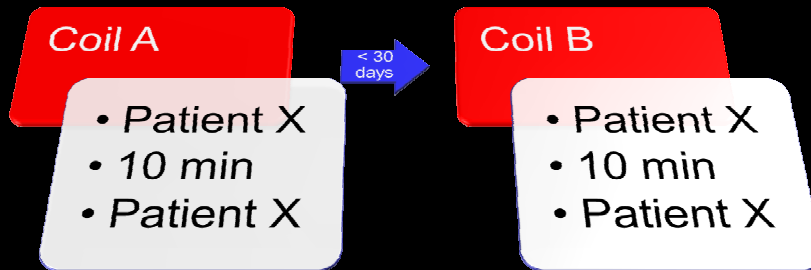


Inner height	180 mm
Inner width	190 mm
Inner Circumference	580 mm
Equivalent diameter	184 mm



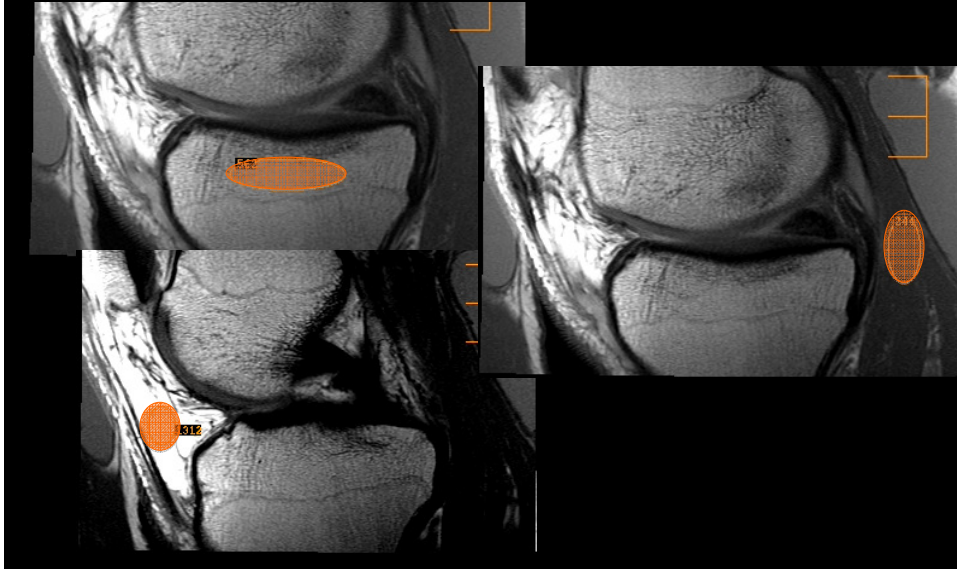
Min inner height	130 mm
Min inner width	140 mm
Inner Circumference	420 mm
Equivalent diameter	134 mm
Thigh/Calf inner height	180 mm
Thigh/Calf inner width	185 mm

Methods

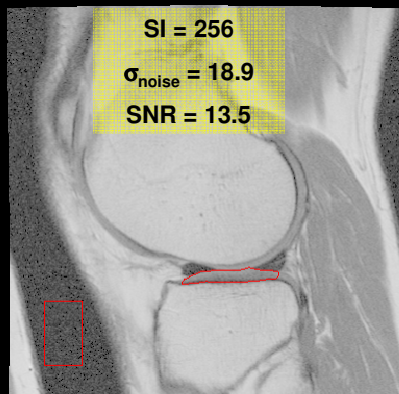


10 subjects (3 men) 52.2 yrs, 28.2 BMI
12 knees (6 progression, 6 incident)
10 femoro-tibial joints were eligible

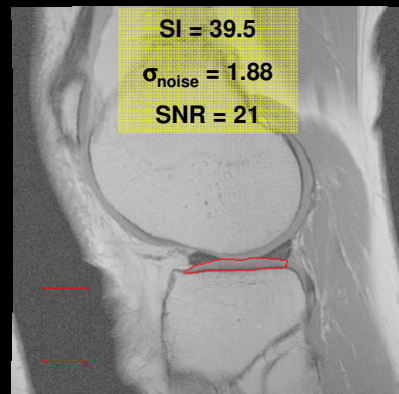
ROIs for SNR Calculation



SNR @ 10 msec Echo Time Tibial Cartilage



QTR

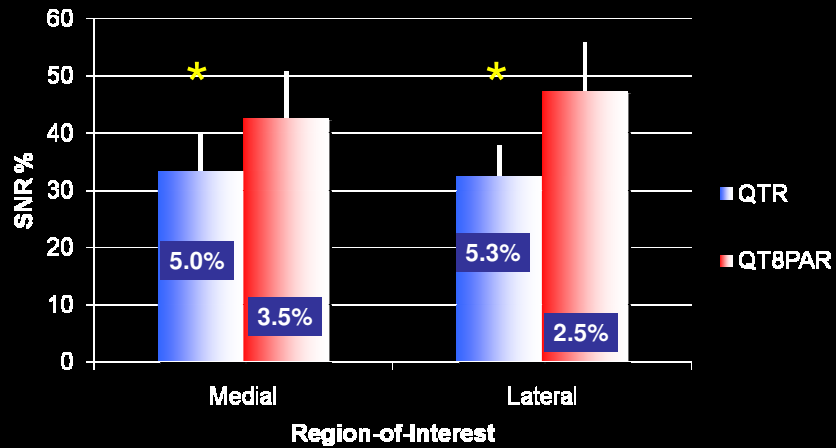


QT8PAR

SNR @ 70 msec echo time

Tibial Marrow

Mean ± SD



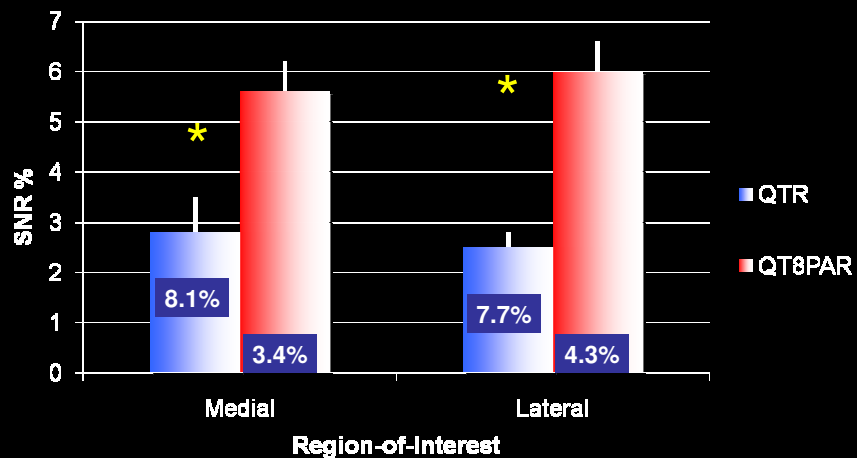
* = P < 0.001

RMS CV %

SNR @ 70 msec echo time

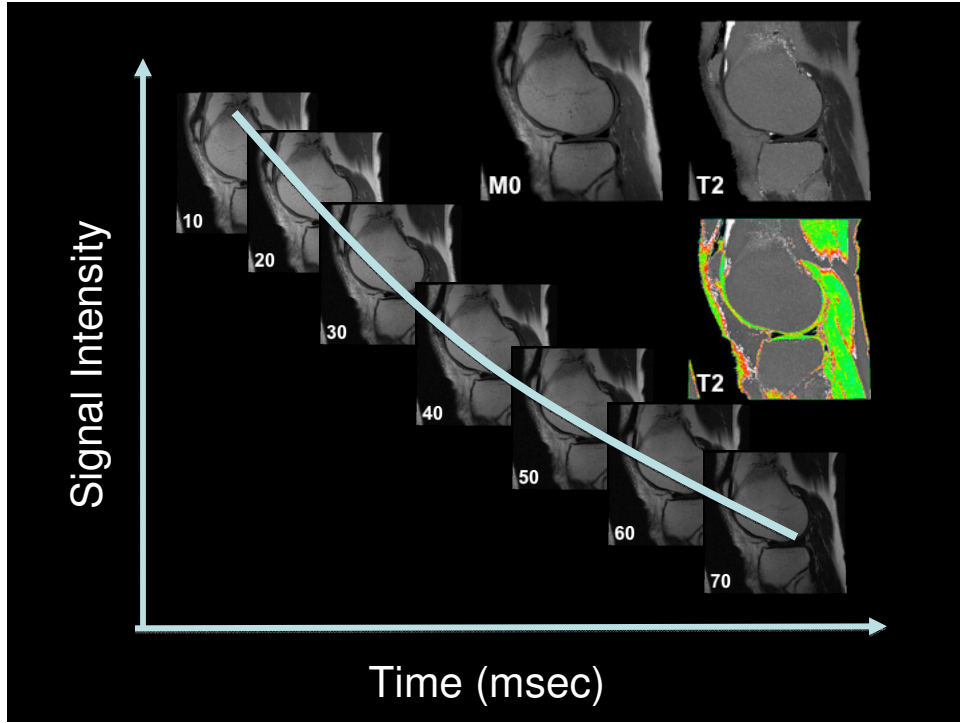
Tibial Cartilage

Mean ± SD

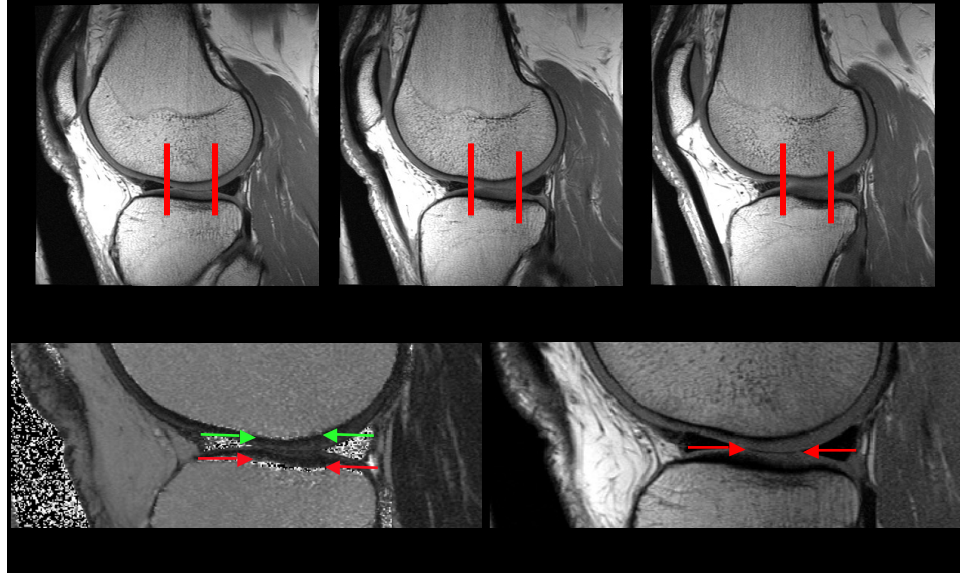


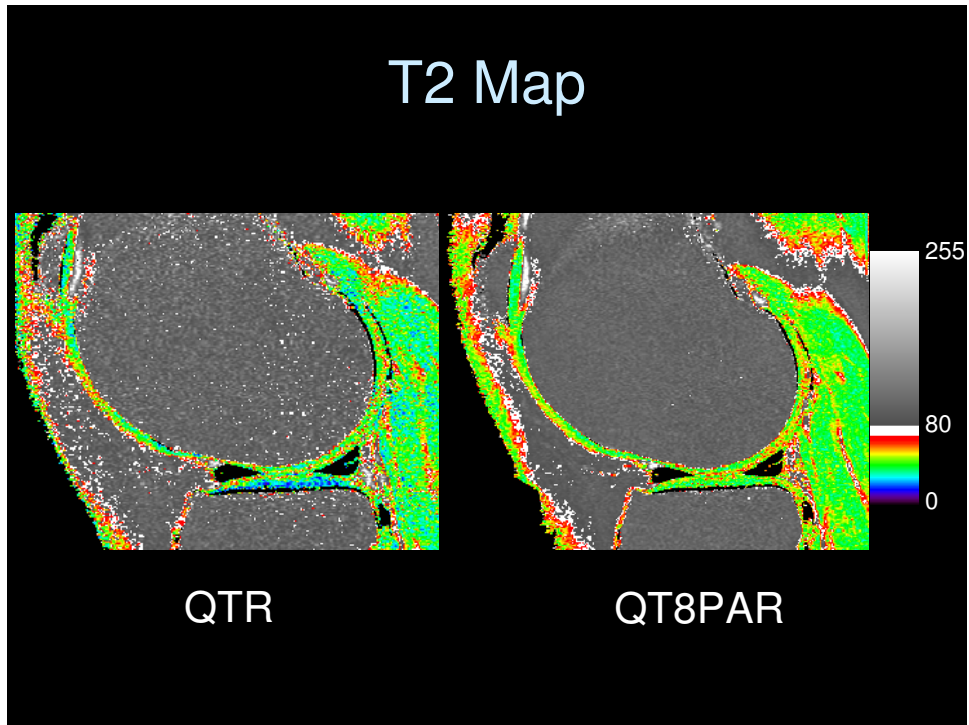
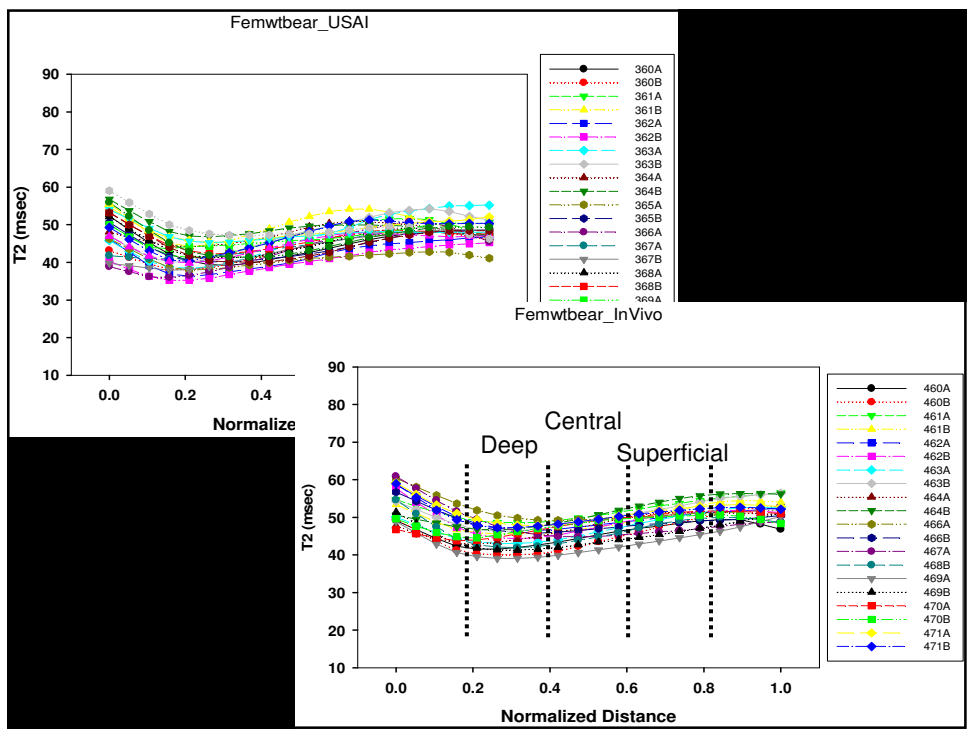
* = P < 0.001

RMS CV %



Weight Bearing Region ROIs for T2 Comparison

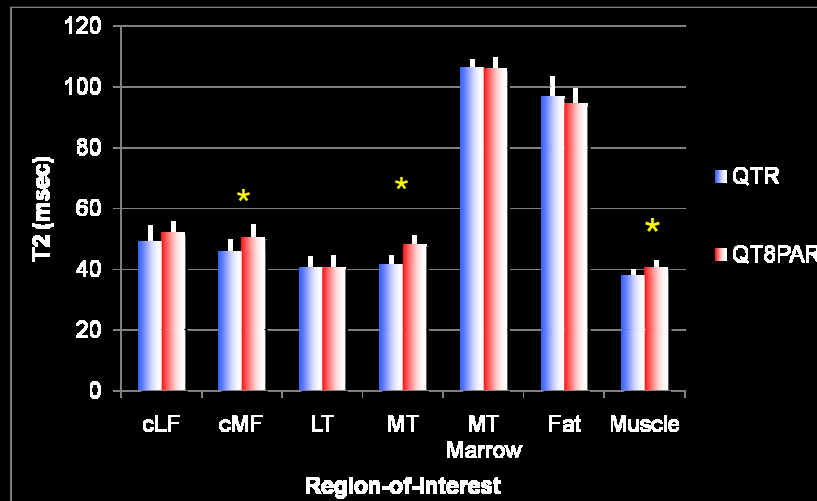




* = P < 0.001

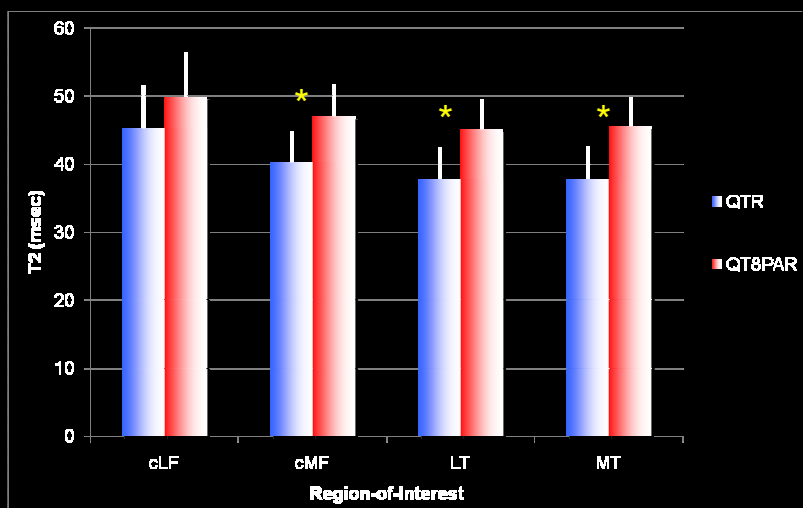
T2 Relaxation

Mean ± SD



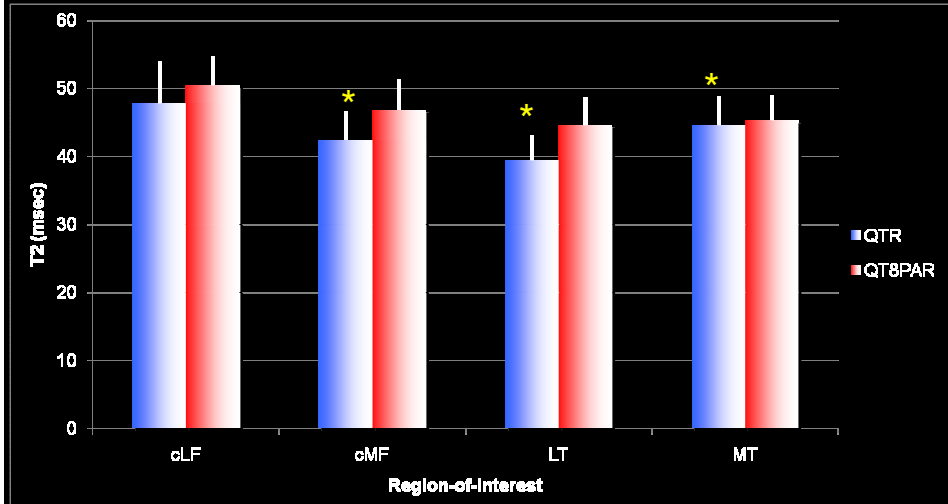
* = P < 0.001

Deep Zone



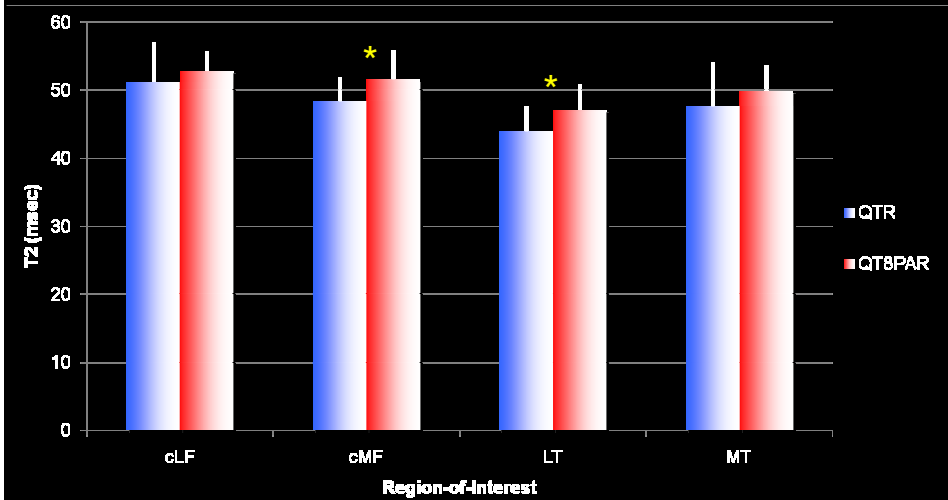
* = $P < 0.001$

Central Zone

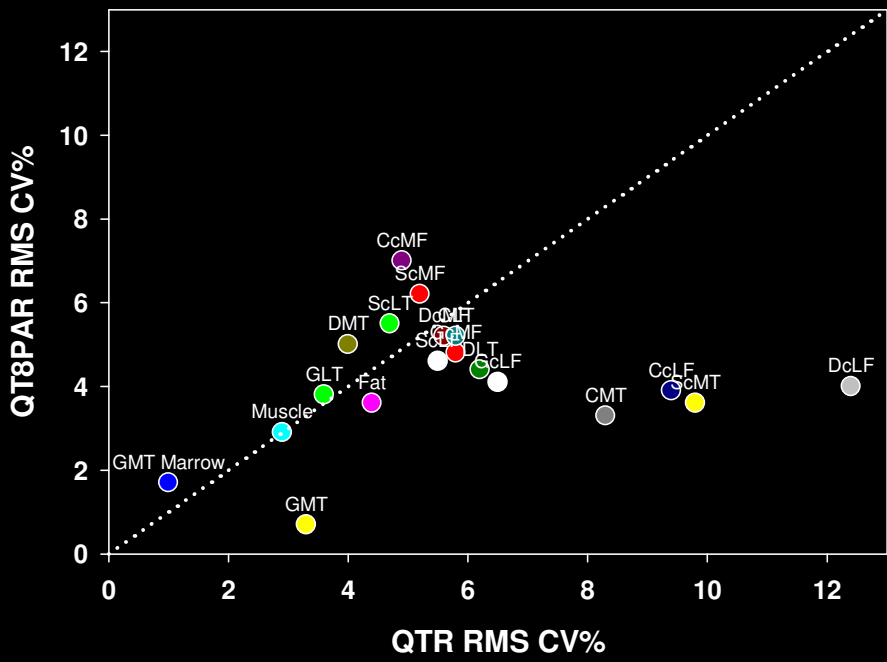
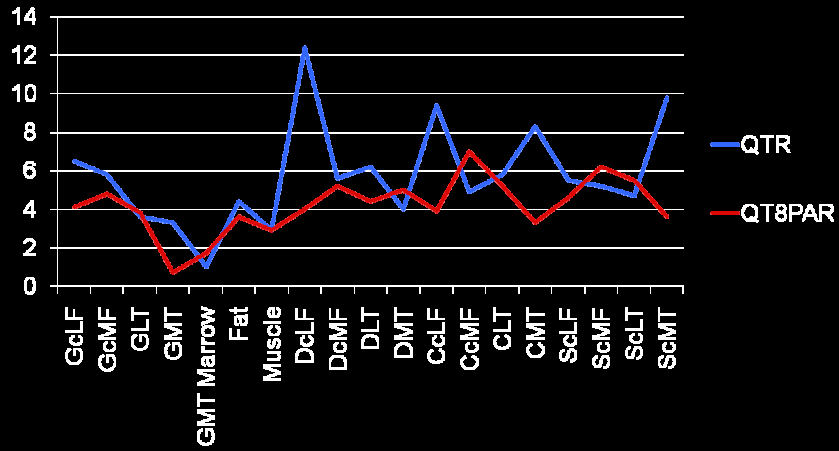


* = $P < 0.01$

Superficial Zone



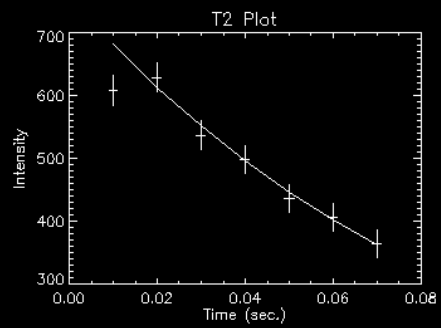
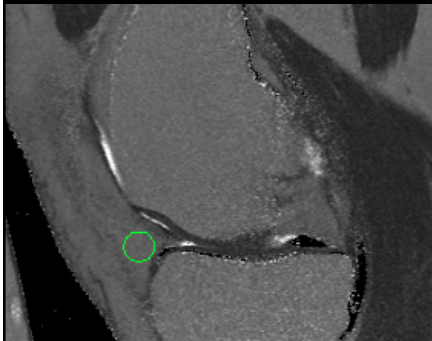
RMS CV (%)



Some Caveats on T2

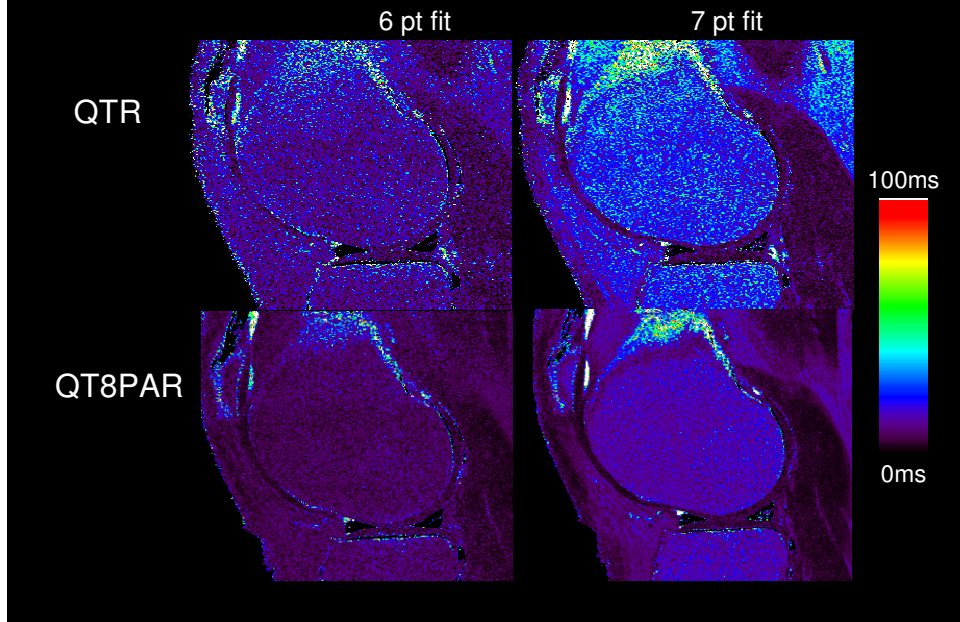


T2 Example - Infrapatellar Fat Pad

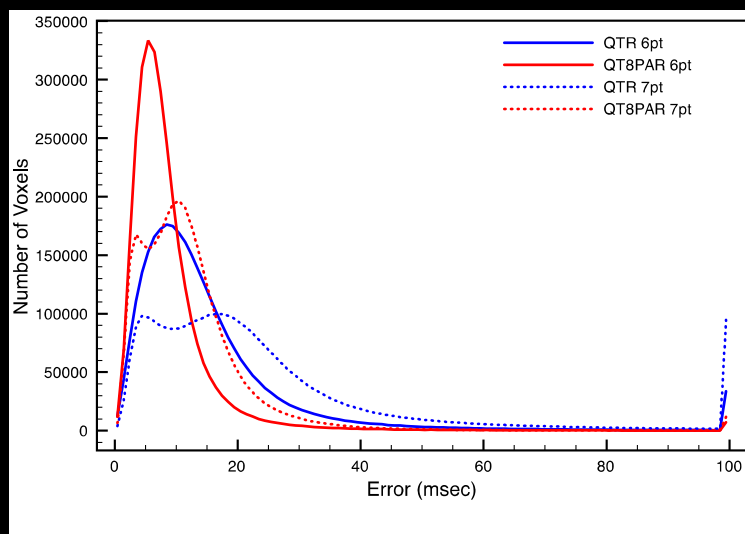


94.7 ± 6.5 msec

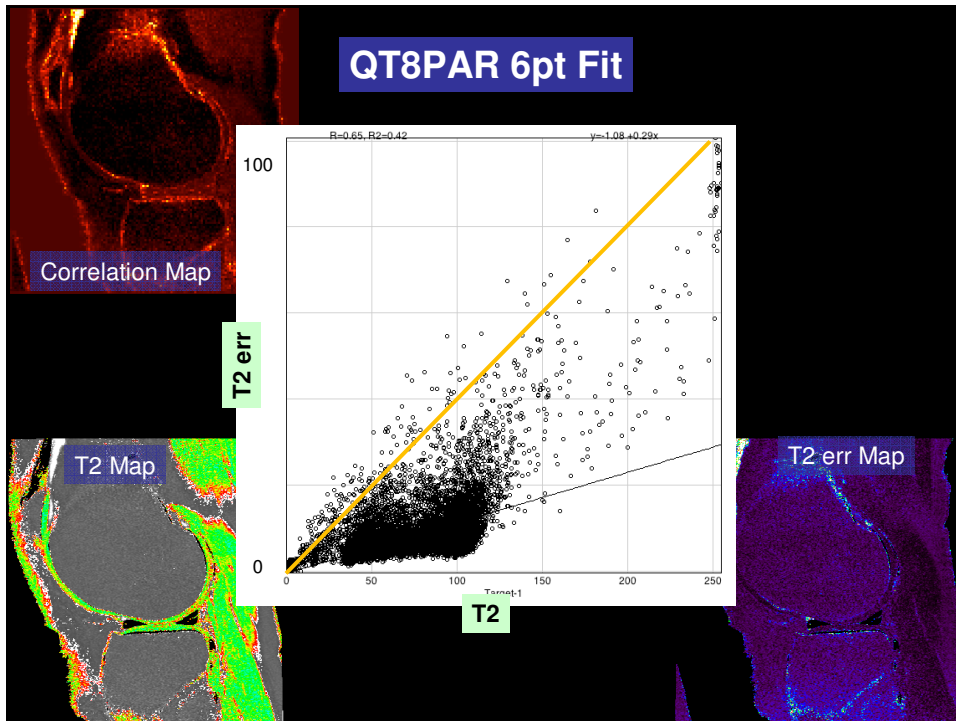
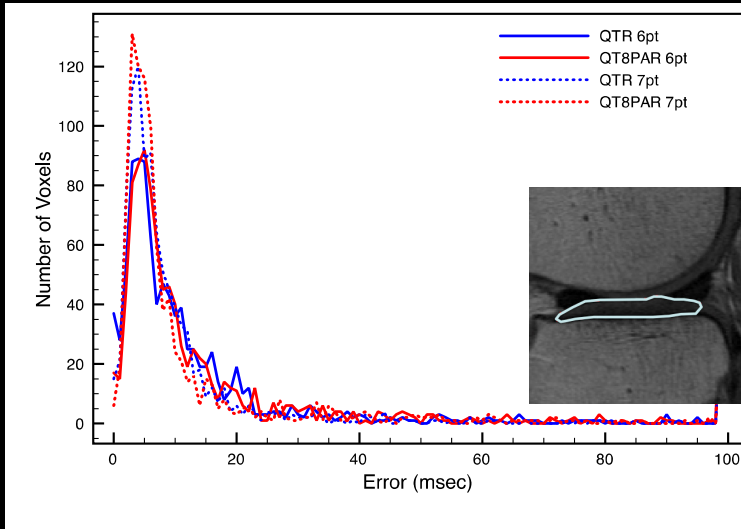
T2 Error Maps



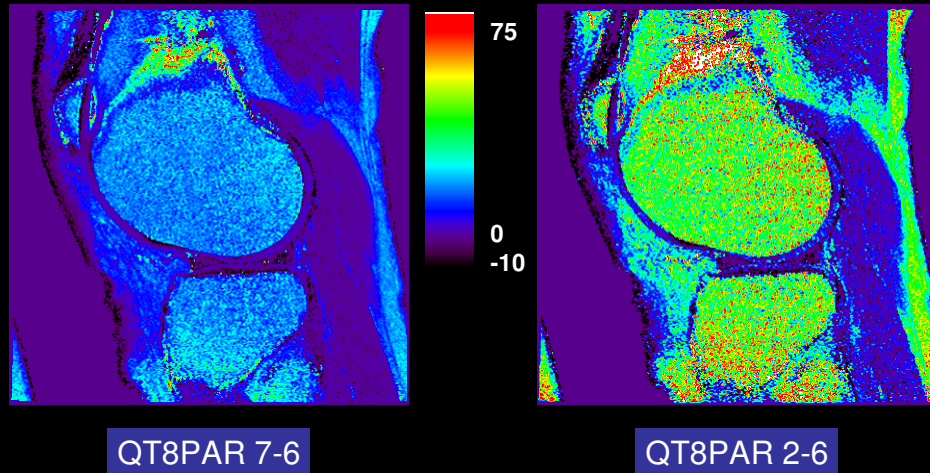
Whole Knee T2 Error



Tibial Cartilage



T2 Differences



Findings

- SNR higher in QT8PAR
- Global T2 longer with QT8PAR
 - cMF (45.9ms/50.7ms)
 - MT (41.6ms/48.2ms)
 - muscle (37.9ms/40.7ms)
- T2 precision better with QT8PAR
 - cLF, cMF, and infrapatellar fat

Findings

- Due to anatomy, T2 values differ spatially
 - cLF has the longest value (52ms)
 - LT has the shortest (40.6ms)
- SNR can vary spatially depending upon coil
- With higher SNR, significantly longer T2 values
 - Deep cartilage T2 values were most affected
- T2 changes with SNR can be larger than the impact of changing magnetic field strength

What does this mean for analyzing the OAI data?

- Same USAI QTR coils
 - Used from 2004 – early 2012
- Failing quality assurance
 - No replacements have been available for past 2yrs
 - Replaced with InVivo QT8PAR
 - Spring 2012

T2 Summary

- Monitors rotational freedom of water motion
- Sensitive to both collagen integrity, [GAG] in cartilage
 - hydration
- Orientation dependent
- Equipment, acquisition and analysis dependent
 - Analysis precision – varies with plate and zone
 - (0.5-2% RMS CV%)
 - Measurement precision – varies with plate and zone
 - (3.3-10.9% RMS CV%)
 - Include quality control ROIs
 - Accommodate for noise in analysis

T2 values are higher in disease, possibly sensitive to early OA

- Reversible (exercise)
- Small changes, 1-3ms
- Higher T2 in
 - Knee Pain
 - Cartilage or meniscal defects
 - Weaker quadriceps muscles
 - Increases with age, but no diff in rate of change with early OA

T2 in Clinical Research

- Pair the acquisition and analysis
 - Ensure accuracy and sensitivity to change with phantoms
- Perform within subject comparisons for longitudinal change
- Use an intrinsic reference tissue (if possible)
 - Cartilage in a different compartment
 - No gold standard
- Tailor the acquisition to the clinical question
 - cartilage repair vs. OA vs. deep cartilage change due to trauma
- Difficult to perform meta-analyses

Acknowledgments

- The OAI and this pilot study are conducted and supported by NIAMS in collaboration with the OAI Investigators and Consultants
- The research reported in this abstract was supported in part by contracts N01-AR-2-2261, N01-AR-2-2262 and N01-AR-2-2258
- We are grateful to the Ohio State University and Memorial Hospital of Rhode Island OAI study teams for recruitment of the study subjects and acquisition of the MR exams