Influence of Knee Positions on T2, T2* and dGEMRIC Mapping in Porcine Knee Cartilage

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Introduction

Knee imaging using quantitative MR imaging techniques, such as delayed gadolinium enhanced MRI of cartilage (dGEMRIC), T2, T2* and T1rho has achieved great advancement in non-invasive assessment of physiological compositions and degenerative changes of the articular cartilage [1,2]. In most clinical studies, those quantitative MR assessments were performed with the knee in extension position. Influence of knee positions during MR imaging, such as flexed knees, on quantitative MR assessments has been scarcely investigated, even though knee positional change may cause substantial change of intra-articular biomechanical environment or magic angle effects. The purpose of this study is to examine influence of knee flexed positions on cartilage assessment by T2, T2* and dGEMRIC using cadaver porcine femoral-tibial joints.

Materials and Methods

Seven knee joints were harvested en block with intact capsule and surrounding muscle from juvenile pigs, and were imaged using 1.5T MR imaging system (Siemens, Germany). Before imaging, a small cylindrical bone defect was made at the medial and lateral femoral condyle as a fiducial mark (arrows in Fig 1), to enable reproducible identification of the same imaging plane and the definitions of regions of interest (ROIs) in the following imaging sequences. First, sagittal T2 maps and T2* maps were obtained in the medial and lateral femoro-tibial joints, with the knee extended position (Position A: flexion 0°and the femoral shaft in parallel to B_0) and the knee flexed position (Position B: flexion approximately 40°and the femoral shaft oriented 40° to B_0). Then, sagittal dGEMRIC maps after equilibration in 1mM Gd-DTPA^{2-} for 3 hours, were obtained in the same imaging plane and knee positions (Position A and B). In addition, sagittal T2, T2*, and dGEMRIC maps with the knee extended (flexion 0°) and the femoral shaft oriented 40° to B_0 (Position C) were obtained in two knees, to evaluate the isolated influence of magic angle effect. T2 and T2* maps were calculated using mono-exponential fit from 2D multi-spin echo sequences (TR=4000ms, 10 echoes between 18.7-187 ms, voxel size 0.5X0.5X3.0mm) and 2D multi-gradient echo sequences (TR=1500ms, 9 echoes between 10-72.96ms, voxel size 0.5X0.5X3.0mm), respectively. dGEMRIC maps (T1 time) were calculated from inversion recovery fast spin echo sequence (TR=1800ms, TE=14ms, TI=50-1680ms, ETL=5, voxel size0.5X0.5X3.0mm).

In each mapping at knee Position A, three ROIs were manually defined on the femoral cartilage (Fig 1); ROI 1 was covered by the anterior meniscus at the weight-bearing area and parallel to B_0, ROI 2 and 3 were free from the weight-bearing area and oriented 25° and 50° to B_0, respectively. Placement of the three ROIs in the mappings at knee Position B and C were matched to the ROIs at knee Position A, using the fiducial mark. T2, T2*, and dGEMRIC values with knee extension and knee flexion in each ROI were compared using a paired t-test.

Results

In comparison of the quantitative values at Position A and B, all of T2, T2* and dGEMRIC values showed similar changes according to location of the ROIs (Table 1); As compared with the values at extension, T2, T2* and dGEMRIC values at flexion 40° tended to increase in ROI 1 and tended to decrease in ROI 3, with more remarkable change on the medial side. There was a statistically significant increase of T2 value at flexion 40° in ROI 1 ($p<0.05$) on the lateral femoro-tibial joint. In two knees imaged at Position C, T2, T2* and dGEMRIC values showed substantially less increase in ROI 1 and less decrease in ROI 3 than those changes at Position B.

Conclusion

From the results at Position C (knee extended and the femoral shaft oriented 40° to B_0), substantial changes of T2, T2* and dGEMRIC values in response to knee flexion may be caused from both change of intra-articular biomechanical environment and magic angle effects [3]. Our results may suggest that quantitative MR measurements allow intra-articular biomechanical assessment in association with knee flexion, after excluding factors of magic angle effects. Clinically, attention should be paid on knee positions, to achieve reliable assessments of the knee cartilage with quantitative MR measurements, in comparative or longitudinal studies.

References

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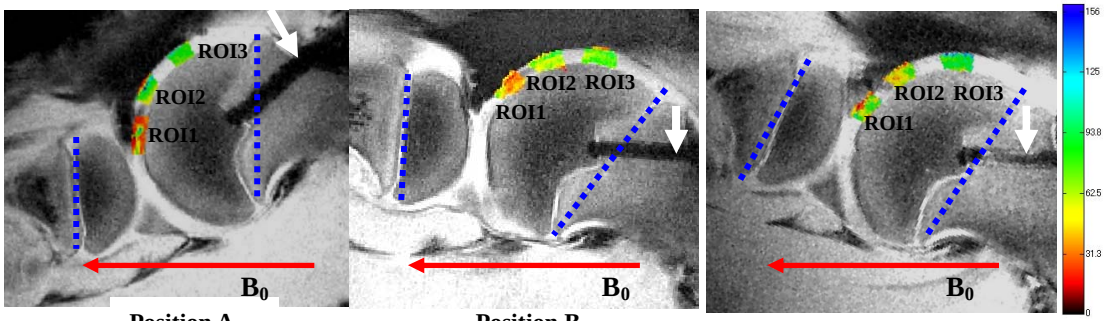

Position A Position B Position C

Fig 1: Sagittal T2* maps at Position A (flexion 0°and the femoral shaft in parallel to B_0), at Position B (flexion 40°and the femoral shaft oriented 40° to B_0) and at Position C (flexion 0°and the femoral shaft oriented 40° to B_0). Arrows indicate fiducial marks. Dots lines are perpendicular to the femoral and tibial shaft.

Table 1: T2, T2* and dGEMRIC values in each ROI (mean±SD) at knee flexion 0°(Position A) and flexion 40°(Position B) (N=7)

		T2 value (ms)			T2* value (ms)			dGEMRIC (ms)		
Side	Zones	Flex 0°	Flex 40°	Change(%)	Flex 0°	Flex 40°	Change(%)	Flex 0°	Flex 40°	Change(%)
Medial joint	ROI 1	85.0±17.1	94.6±14.4	16.0±33.3	33.4±10.3	42.3±10.7	33.4±35.3	142.7±92.9	178.3±115.3	32.0±34.4
	ROI 2	95.4±18.3	95.4±16.5	0.9±7.7	49.3±12.0	54.7±9.6	13.3±12.2	234.7±104.6	232.4±119.1	7.7±44.1
	ROI 3	104.6±27.9	87.7±17.6	-13.7±15.6	59.3±17.7	47.9±12.6	-16.9±15.7	261.9±114.4	213.1±136.8	-15.9±39.0
Lateral joint	ROI 1	88.6±11.8	105.9±15.8	20.3±16.7	36.9±7.0	43.7±6.0	21.3±22.5	162.1±64.4	179.7±72.8	9.9±15.3
	ROI 2	80.0±25.5	78.6±16.1	8.0±44.5	36.1±20.5	44.3±14.0	37.9±39.5	163.1±133.4	169.1±124.1	13.3±62.2
	ROI 3	103.9±26.7	96.7±23.6	-3.9±22.9	43.4±16.9	43.7±15.7	8.7±41.1	274.3±89.1	246.1±78.6	-9.7±14.2

Changes were calculated as (Flex 40°- Flex0°)/ Flex0°*100