Reproducibility of dGEMRIC in the Human Knee Joint at 1.5 T

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INTRODUCTION

The cleavage of cartilage proteoglycans (PGs) is one of the first signs in the degenerative process of articular cartilage [1]. The delayed gadolinium enhanced MRI of cartilage (dGEMRIC) technique is sensitive to the cartilage PGs [2], and thus can detect the aforementioned changes. While the technique has been applied in various in vivo human studies, information on the reproducibility of dGEMRIC is very limited. In this study, we investigated the long term reproducibility of the dGEMRIC measurements at different joint surfaces in asymptomatic volunteers at 1.5 Tesla.

METHODS

Ten physically active asymptomatic volunteers (5 female, 5 male) with a mean age of 31.7±6.4 (range 25-47) years and body mass index of 25.3±3.5 (range 22-34) kg/m^2 were recruited. The volunteers had no history of knee injury or surgery and no knee-related symptoms. The dGEMRIC experiment was repeated three times with an average interval of five days between scans. To minimize diurnal variation in cartilage thickness the volunteers were imaged each time at the same time of the day within 2 hours. The flexion angle and rotation of the knee was controlled by stabilizing the ankle to a fixed position with a leg holder and by using a custom-made inflatable cushion to fix the joint within the knee coil.

Intravenous administration of 0.2mM/kg of Gd-DTPA^{2-} (Magnevist, Schering, Berlin) was followed by a 90-minute delay and T1-mapping using a single-slice inversion recovery fast spin echo sequence (TR=1800ms, TE=13ms, TI=1600, 800, 400, 200, 100 and 50 ms, ETL=5, 3-mm slice thickness and 0.36×0.36mm in-plane resolution) at 1.5 T with approximately 10.5min imaging time per series. The dGEMRIC measurement was performed from a single sagittal slice through the center of the lateral femoral condyle and from the center of the patella in the axial plane. Cartilage was manually segmented by a single radiologist into superficial and deep ROIs at different topographical locations of the femur, tibia and patella (Fig. 1). The absolute reproducibility, as measured by root-mean-square (RMS) coefficient of variation (CV_{RMS}), and the relative reproducibility, as determined by intraclass correlation coefficient (ICC), was evaluated both for the entire bulk cartilage of each joint surface in the slice and separately for each ROI at different topographical locations.

RESULTS

The reproducibility results are given in Table 1. The reproducibility for bulk dGEMRIC was 4.2% (ICC: 0.95), 5.5% (0.87) and 4.8% (0.97) for femoral, tibial and patellar cartilage, respectively. The reproducibility of superficial and deep cartilage ROIs at various topographical locations ranged between 5.2-12.9% (ICC: 0.45-0.93) for femur, 5.8-9.3% (0.45-0.91) for tibia and 4.7-8.3% (0.94-0.98) for patella. Twenty out of 22 ROIs showed a CV_{RMS} less than 10%.

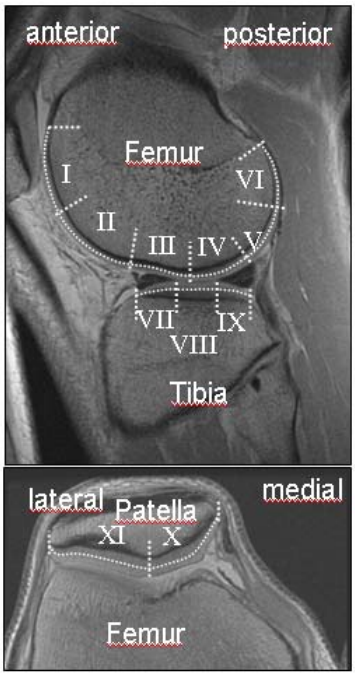

Figure 1: Segmental division of femoral, tibial and patellar cartilage surfaces. Cartilage thickness was divided into superficial (s) and deep halves (d) as indicated by the dotted line. Nomenclature for segments I-XI are given in Table 1.

Table 1: T1 relaxation time (dGEMRIC) of all subjects at first imaging session (mean±SD), RMS coefficient of variation and intraclass correlation coefficient (ICC) for superficial and deep cartilage segments in the femur, tibia and patella. Cartilage surfaces with wrap-around artifacts were excluded from analysis.

#	Segment	Layer*	dGEMRIC (ms)	CV_{RMS} (%)	ICC
	Lateral Femoral Condyle				
I	anterior aspect of trochlea	s (n = 9)	415 ± 48	6.1	0.92
		d (n = 9)	464 ± 62	9.2	0.89
II	posterior aspect of trochlea	s (n = 9)	389 ± 63	7.1	0.93
		d (n = 9)	455 ± 66	9.9	0.91
III	anterior central part	s (n = 10)	449 ± 61	7.0	0.86
		d (n = 10)	460 ± 71	9.1	0.68
IV	posterior central part	s (n = 10)	538 ± 40	5.2	0.84
		d (n = 10)	554 ± 53	7.2	0.45
V	anterior posterior part	s (n = 10)	452 ± 52	8.7	0.77
		d (n = 10)	515 ± 63	6.8	0.90
VI	posterior posterior part	s (n = 10)	362 ± 46	11.9	0.51
		d (n = 10)	398 ± 65	12.9	0.67
	Lateral Tibial Condyle				
VII	anterior part	s (n = 10)	419 ± 69	9.3	0.88
		d (n = 10)	456 ± 39	8.3	0.76
VIII	central part	s (n = 10)	436 ± 62	7.5	0.90
		d (n = 10)	521 ± 46	5.8	0.75
IX	posterior part	s (n = 10)	411 ± 51	6.2	0.91
		d (n = 10)	509 ± 40	7.4	0.45
	Patella				
X	medial aspect	s (n = 8)	398 ± 79	7.6	0.95
		d (n = 8)	479 ± 100	8.3	0.94
XI	lateral aspect	s (n = 10)	438 ± 94	4.7	0.98
		d (n = 10)	527 ± 123	7.0	0.97

* s=superficial 50% of tissue; d=deep 50% of tissue

DISCUSSION

The present results show mostly good long term reproducibility, on the average 5% for bulk ROIs covering all the visible cartilage in a single joint surface and 8% for smaller segments. Significant variation, however, was observed between topographical locations. The poorest reproducibility was observed for the most posterior part of the femoral condyle (~13%), which is probably most susceptible area to inaccuracies in joint rotation. The highest reproducibility was reported for the patella, which is relatively immune to rotation inaccuracies in the axial plane, has minimal in-plane curvature at the location of the imaged slice, has the largest ROIs and shows the least diurnal variation [3]. Previously, dGEMRIC has been reported reproducible within 10-15% in a limited number of subjects with up to two months interval between dGEMRIC scans [4]. With the aid of a leg holder and systematic positioning approach, as performed in the present study, a better reproducibility can be achieved.

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