Gray level co-occurrence matrix approach for T2 analysis of cartilage in knee osteoarthritis

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Target audience: Researchers and clinicians aiming to apply quantitative MRI techniques in osteoarthritis research.

Introduction:

MRI based osteoarthritis (OA) research has been a rapidly progressing front during the late years as several new techniques have emerged. T2 relaxation has been strongly linked to cartilage structure and degeneration. Calculation of second order textural features from T2 maps is a novel approach to refine relaxation time analyses [1]. In this abstract, we present a modified approach for detecting and characterizing OA by utilizing textural analysis on T2 relaxation time maps.

Materials and methods:

80 asymptomatic volunteers (50 female and 30 male, mean age 55.7 years (standards deviation, SD 13.85), body mass index 24.9 (SD 3.09)) and 41 symptomatic patients (27 female and 14 male, mean age 57.9 years (SD 8.57), body mass index 28.4 (SD 4.77)) were recruited into the study with permission from the local ethics committee. Asymptomatic volunteers were recruited via newspaper advertisement while patient were selected from the hospital registry based on a long term non-specific knee pain or referring to knee replacement surgery. Exclusion criterion included trauma, rheumatoid diseases, surgery, or underlying medical conditions that could affect the knee joint. Based on radiographic grade of osteoarthiris, subjects with early OA (K-L $\leq$ 2) were scanned on 3T Siemens Skyra clinical magnet and Siemens TxRx 15-channel knee coil (Siemens Healthcare, Erlangen, Germany). T2 relaxation time mapping was performed with a multi-slice multi-echo spin echo sequence (TR=1680ms, TE's(5)=13.8…69.0ms, ETL=5, FOV=160x160mm, matrix=384x384, thickness=3 mm).

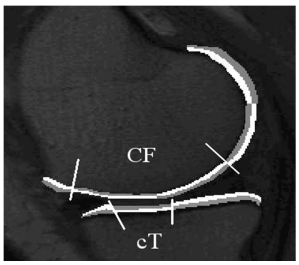

Figure 1: Segmentation scheme

T2 maps were manually segmented and fitted with an in-house developed segmentation and analysis tool (MATLAB, Mathworks Inc., Natick, MA). The segmentation scheme is presented in Figure 1. GLCM texture features [2] were calculated independently in parallel and perpendicular orientation for each region of interest (ROI). Instead of flattening the cartilage [1], we developed a method with orientations calculated independently point wise for each ROI. Orientations were determined such that the natural curvature of the articular surface was regarded as parallel and downright direction as perpendicular orientation. Results presented are provided from the weight-bearing region, central region on medial condyle (mCF) and medial central tibia (mcT), as early changes usually occur on these regions. Mean T2 values, entropy and contrast as determined by GLCM analysis, were calculated for these ROIs and compared between subject groups. Furthermore, the correlation between texture and mean T2 values were determined.

Results:

At mCF, the mean T2 values of ROIs did not differentiate subjects with early OA from asymptomatic subjects while T2 entropy was significantly higher in the patient group along both orientations (Table 1). At mcT, T2 values differed significantly between patients and volunteers but contrast parameter further increased the differentiation in parallel analysis orientation. Mean T2 values were mostly weakly correlated with structure parameters (Table 2), suggesting that GLCM analyses can provide complementary information on articular cartilage.

Table 1: GLCM and T2 results for asymptomatic and OA subjects.

			mCF, entropy				mcT, contrast			
		N	**Mean (SD)**	**95% CI**	**P[1]**	**P[2]**	**Mean (SD)**	**95% CI**	**P[1]**	**P[2]**
Parallel	Asymptomatic	80	2.74 (0.24)	2.69-2.80			0.46 (0.12)	0.44-0.49		
	Symptomatic	41	2.85 (0.24)	2.78-2.92	***.022***		0.58 (0.20)	0.52-0.65	***< .001***	
	K-L = 1	21	2.89 (0.20)	2.80-2.98	***.039***		0.57 (0.17)	0.49-0.65	***.015***	
	K-L = 2	20	2.79 (0.28)	2.66-2.92	*.690*	*.406*	0.60 (0.23)	0.50-0.71	***.001***	*.707*
Perpendicular	Asymptomatic	80	2.87 (0.26)	2.82-2.93			1.96 (0.58)	1.83-2.08		
	Symptomatic	41	2.97 (0.24)	2.90-3.05	***.043***		2.16 (0.73)	1.93-2.39	*.097*	
	K-L = 1	21	3.04 (0.24)	2.93-3.15	***.018***		2.16 (0.67)	1.85-2.47	*.393*	
	K-L = 2	20	2.90 (0.23)	2.79-3.01	*.914*	*.159*	2.16 (0.80)	1.78-2.54	*.411*	*> .999*
			mCF, contrast				**mcT, entropy**			
Parallel	Asymptomatic	80	1.38 (0.67)	1.23-1.52			2.44 (0.20)	2.40-2.48		
	Symptomatic	41	1.44 (0.67)	1.23-1.65	*0.611*		2.51 (0.28)	2.42-2.60	*0.114*	
	K-L = 1	21	1.47 (0.65)	1.17-1.77	*0.837*		2.54 (0.23)	2.43-2.64	*0.209*	
	K-L = 2	20	1.41 (0.71)	1.08-1.74	*0.975*	*0.959*	2.48 (0.32)	2.33-2.63	*0.735*	*0.742*
Perpendicular	Asymptomatic	80	2.15 (0.87)	1.96-2.35			2.88 (0.26)	2.82-2.94		
	Symptomatic	41	2.20 (0.89)	1.92-2.48	*0.804*		2.90 (0.33)	2.79-3.00	*0.755*	
	K-L = 1	21	2.17 (0.86)	1.78-2.57	*0.995*		2.93 (0.29)	2.79-3.06	*0.796*	
	K-L = 2	20	2.22 (0.94)	1.78-2.66	*0.953*	*0.986*	2.87 (0.38)	2.69-3.04	*0.984*	*0.797*
T2	Asymptomatic	80	47.8 (6.01)	46.5-49.1			36.2 (4.58)	35.1-37.2		
	Symptomatic	41	47.5 (5.75)	45.6-49.3	*.772*		38.2 (5.27)	36.5-40.0	***.030***	
	K-L = 1	21	48.2 (5.63)	45.6-50.7	*.965*		38.2 (4.48)	36.1-40.2	*.211*	
	K-L = 2	20	46.7 (5.94)	43.9-49.5	*.754*	*.720*	38.2 (6.11)	35.4-41.1	*.214*	*> .999*

mCF = central region on medial condyle, mcT = medial central tibia, K-L = Kellgren-Lawrence, SD = standard deviation, CI = confidence interval.
[1] P-value comparing each patient group with asymptomatic volunteers. [2] P-value comparing K-L 1 and K-L 2 groups.

Conclusion:

Texture analysis is a promising tool that can reveal underlying or additional information from T2 relaxation time maps and may detect cartilage degeneration more sensitively than mere mean T2 values from regions of interest.

Table 2: Pearson's correlation coefficients

	Parallel	Perpendicular
Entropy (CF)	0.253	0.175
Entropy (cT)	0.818	0.759
Contrast (CF)	0.219	0.245
Contrast (cT)	0.331	0.277

References:

[1] J. Carballido-Gamio et al. "Longitudinal Analysis of MRI T2 Knee Cartilage Laminar Organization in a Subset of Patients From the Osteoarthritis Initiative: A Texture Approach," Magnetic Resonance in Medicine, vol. 65, pp. 1184-1194, 2011.

[2] L.-K. Soh and C. Tsatsoulis, "Texture Analysis of SAR Sea Ice Imagery Using Gray Level Co-Occurance Matrices," IEEE Transactions on Geoscience and Remote Sensing, vol. 37, no. 2, pp. 780-795, 1999.