3D SURFACE MAP ANALYSIS OF dGEMRIC CHANGES IN THE KNEE

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Background

The 3D distribution and variance of glycosaminoglycan (GAG) concentration in knee cartilage is not well known. The 3D surface rendering techniques could in theory to be used to visualize, monitor and quantify the 3D distribution and focal changes of (GAG) concentration in cartilage in dGEMRIC (Delayed Gadolinium enhanced MR) images. In this work we present the results of our study where we used this technique in monitoring the changes and the 3D distribution of (GAG) before and after a Marathon.

Objectives

The aim of this study was test the utility of 3D image analysis techniques in studying the 3D changes in the dGEMRIC (delayed Gadolinium Enhanced MRI of Cartilage) Index distribution in the human knee

Methods

3D segmentation and rendering of the cartilage surface using the techniques descried by Tamez-Pena [1] was applied to 3D dGEMRIC images of the knee. After computing the dGEMRIC Index for each voxel (313 um x 313 um x 3mm) from the 3D SPGR acquisition, the cartilage was segmented. The median value across the surface normal was mapped into each point of the 3D surface. To compare several dGEMRIC acquisitions of the same knee measured at different time points, a surface to surface registration algorithm was used to compute the point to point correspondence between dGEMRIC acquisition pairs. The point to point correspondence was then used to generate a 3D paired analysis of the dGEMRIC data. The mean difference and the standard deviation of the difference were calculated. The delta map was also analyzed to extract the area statistical significant changes between time point pairs. The delta map approach was used to analyze dGEMRIC data from five female marathon runners, ages 24-39, imaged at 3T at 4 time points: 3 days prior to the race, then 1 day, 1 week, and 6 weeks after the race [2]. The Volunteers were injected IV with 0.2mM/Kg Magnevist (Berlex Imaging, Wayne, NJ) and asked to walk for 10 mins to facilitate contrast penetration into the cartilage. dGEMRIC images were acquired 90 min post injection using a 3D IR sequence with TS/TE = 6.5ms/2.7ms, and TI = 2.1,0.8,0.4,0.2,0.13s. T1(Gd) maps were generated with a pixel-by-pixel 3-parameter T1-fit routine using the Levenberg-Marquardt method. Three regions were evaluated in each of medial and lateral compartments: the central zone of the femoral condyle, the tibia plateau, and the posterior section of the femoral condyle.

Results

Figure 1 shows the 3D rendering of the femur cartilage for a subject before and after the marathon. Figure 2 shows the z-map (change in T1 divided by the standard deviation of the difference). The local standard deviation of the difference of the delta map was used to compute the area of significant dGEMRIC changes. Significant changes were defined as regions whose absolute z value was greater than 2.5 ($p<0.013$). Figure 3 shows the change of the aggregated positive and negative changes of the area of affected cartilage after the marathon. On average 14% of the medial condyle tissue showed a change in the dGEMRIC Index one day after running. After 1 week the affected area was reduced significantly and area measurements six week after running showed that the cartilage tissue returned to its pre-marathon stage as seen in Figure 4. The results also showed that degree of dGEMRIC change varied between subjects and regions within the knees.

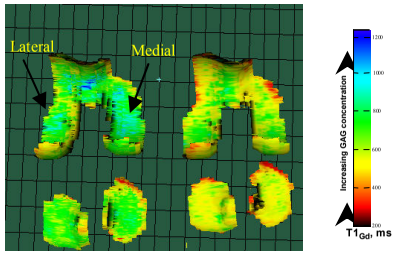

Figure 1. 3D surface T1 maps of the pre marathon (left) and the post marathon (right).

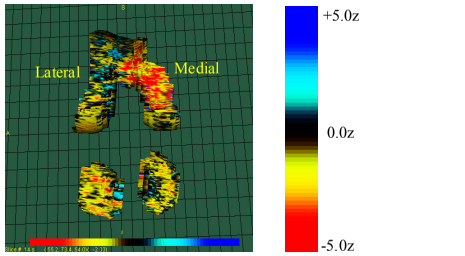

Figure 2. z-maps of the difference between the pre and post marathon analysis.

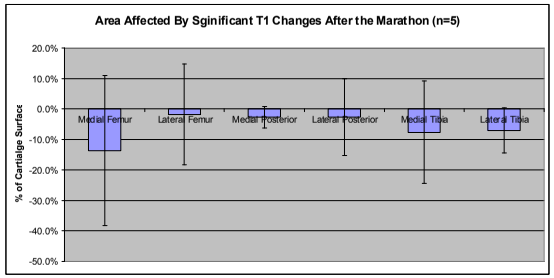

Figure 3. Area of cartilage affected by significant changes in the T1(Gd) values after running a marathon. The error bars represents the 95% Confidence Intervals.

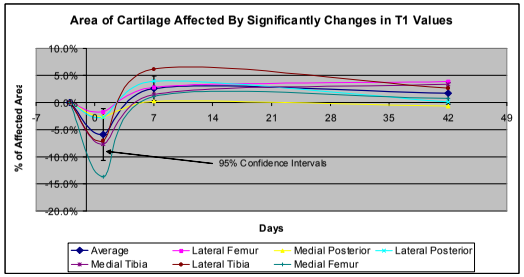

Figure 4. Evolution of the area affected by significant T1(Gd) change as measured by the 3D delta map.

Discussion

The 3D rendering technique presented in this work provides an analytical tool to quantitatively measure and visualize the spatial changes in the dGEMRIC Index in all knee joint cartilage plates. This approach supplements the currently utilized 2D analysis for the evaluation of dGEMRIC changes in the knee. Although, the full validation of this technology is still under way, the use of this technique in monitoring of changes from pre to post marathon on five volunteers yielded promising results. Larger studies will be needed to better understand the effect of marathon running on the biochemical components of knee cartilage.

References

1.Tamez-Pena J *et.al.* "Knee Cartilage Extraction and Bone-Cartilage Interface Analysis from 3D MRI Data Sets", SPIE, 2004
2.Williams A. *et. al.* "Effects Of Running A Marathon on dGEMRIC Of The Knee", OARSI 2005.