Assessment of Inter-Operator Agreement in Manual Image-Segmentation of Femoral Cartilage

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Target audience:

Clinicians/researchers/imaging-scientists in study of cartilage via MRI.

Purpose:

MRI is a modality ideally suited for study of osteoarthritis (OA) not just for its non-invasive nature and lack of ionizing radiation but also due to the emergence of MR-based techniques for quantitative assessment of biochemical changes linked with onset of OA, such as T1, T2, and T1ρ relaxometry/mapping. Such quantitative assessment requires an image-based segmentation of the tissue in interest which can be performed manually or semi-automatically using a computer program. Although manual segmentation by a single trained operator is still considered as the gold-standard, it is very unpractical due to its time-consuming nature, which would typically require multiple operators in manual-segmentation approach as consequence. Therefore, it is imperative to first develop a methodology for objective assessment of the level of agreement prior to such segmentation task can be divided up among different operators without undue bias. In this study we present purely geometrical attributes of segmentation as a means to assess the inter-operator agreement (rather than subsequent mapping values from the segmentation).

Methods:

Twenty healthy-volunteer knees (mean 29 yrs; range: 19-38) using a clinical 3T MR-scanner (Philips Medical Systems, Best, Netherland) for T2-mapping of articular cartilage that is usually associated with the OA disease in knee. One knee from each volunteer was scanned for equal numbers of left/right knees utilizing a dedicated knee-coil and 31 sagittal slices with 140-mm field-of-view (FOV) and 3-mm slice-thickness in 512 x 512 image-matrix. The scan for T2-mapping was performed with 7 different echo times (TEs: 13-91 in step of 13 ms) for each volunteer. Image-segmentation of cartilage was carried out independently by two operators (K and N) with an extensive experience in musculoskeletal-MRI (13 and 12 yrs, respectively) using a custom processing tool prepared in Matlab (MathWorks, Natick, MA, USA) and the same TE-set of images for a given subject. Upon completion of manual tracing of cartilage boundary on each slice, the processing tool automatically performed the placement of an arch-center by assuming cartilage as a circular ring for subsequent angular segmentations in step of 4-degree angular interval necessary for T2-value profile[1] generation along the cartilage from each slice. The agreement between the operators was then assessed via regression (correlation plot) and Bland-Altman[2] (BA or differences plot) analyses based on 3 geometrical aspects as defined in Fig. 1: radial distances to the arch-center (AC) and center of each angular segment (AS) from the upper left corner of image and the size of angular segment (pixel-#).

Results:

Graphical assessments of inter-operator agreement in the 3 geometrical aspects are shown in Fig. 2-4. The difference plot shows a scatter plot of operator-difference vs. operator-averaged values wherein a perfect agreement would be represented by a horizontal line over the entire range of the measured values at difference equal to 0. The mean-differences in the radial distances to AC and AS and size of each angular segment were -0.80 mm, -0.28mm, and 7.3 pixels (≈0.5 mm^2), respectively, where the negative sign denotes the fact that the value from operator-1 is smaller that that of operator-2.

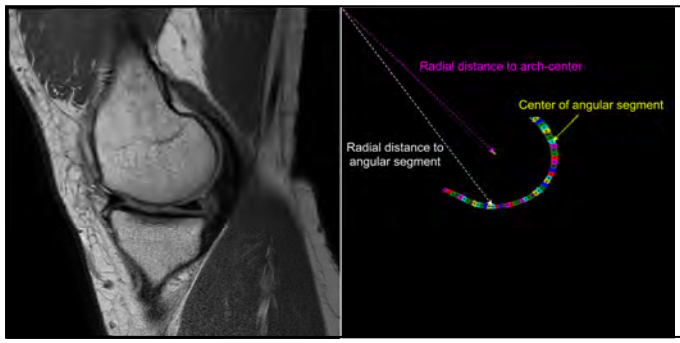

Fig.1: Sample image of knee-joint in sagittal view with TE=39 ms (left) and the corresponding manually-extracted cartilage and automatically-placed arch-center and color-coded angular segments along the extracted cartilage (right). Also shown are the definitions of the geometrical aspects used for assessment of inter-operator agreement.

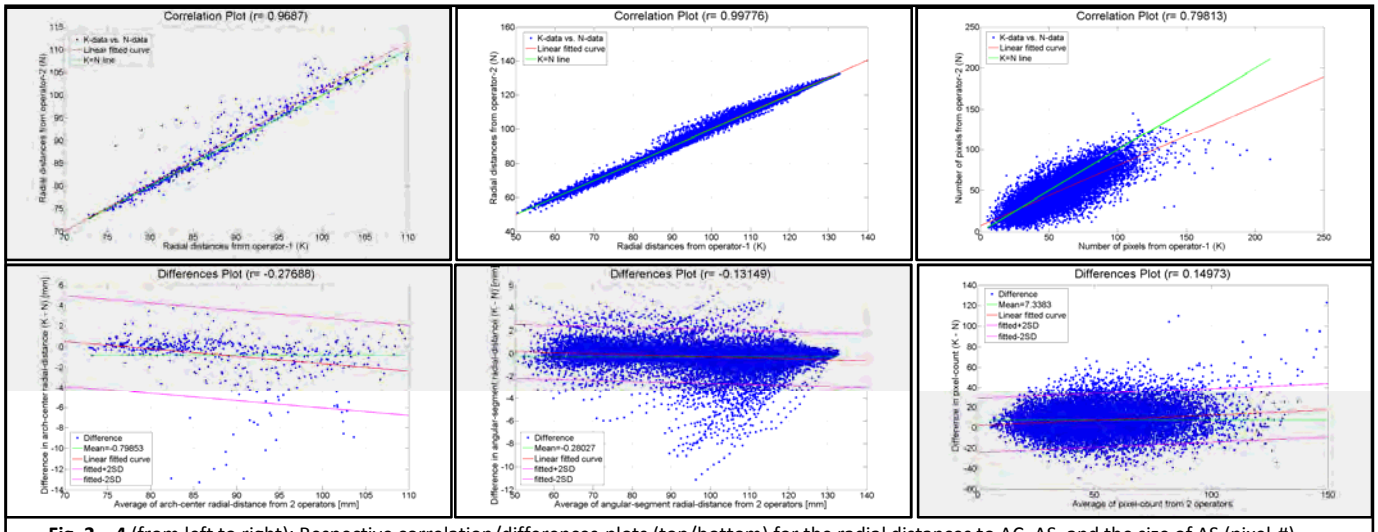

Fig. 2 – 4 (from left to right): Respective correlation/differences-plots (top/bottom) for the radial distances to AC, AS, and the size of AS (pixel-#).

Discussion:

Inter-operator assessment of image-based segmentation can be made unbiased by the underlying segmentation-based quantity (e.g., T2 or T1ρ value) when purely geometrical attributes of segmentation are utilized. When combined with BA-analysis, such assessment could provide a more insightful platform with which the user can evaluate any possible systematic trend in the inter-operator variances and make a decision on if the 95%-limits of agreement are acceptable (indicated by the pink ±2SD lines in BA-plots of Fig. 2-4, assuming the normal distribution) that are not easily obtainable with more commonly used regression approach.

Conclusion:

This study demonstrates a new approach of utilizing purely geometrical attributes (location & size) in conjunction with Bland-Altman analysis for assessing the inter-operator agreement in image-based segmentation, which allows the user to determine whether the limits of agreement are acceptable solely based on the anatomy of what is being studied rather than the subsequent segmentation-based quantity and can also be extended to semi-/automatic segmentation schemes.

References:

[1] Somers S, Pham P, Ghosh N, et al. A novel T2 mapping approach that can evaluate magic angle effect and T2 relaxation time in normal knee cartilage of patients from the osteoarthritis initiative. ISMRM 20th Annual Meeting & Exhibition, Melbourne, Australia, 2012. p.1387. [2] Altman DG and Bland JM. Measurement in Medicine: the Analysis of Method Comparison Studies. The Statistician 1983;32:307-17.