Deep Learning Based Hip Abductor Muscle Segmentation and Association of Muscle Fat Fraction with Early OA Cartilage Degeneration Biomarkers

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Highlights: Manual segmentation of hip muscles is time consuming and laborious. This goal of this study was to develop a deep learning automatic segmentation pipeline to segment hip abductor muscles and find their associations with early OA cartilage degeneration biomarkers using voxel based relaxometry.

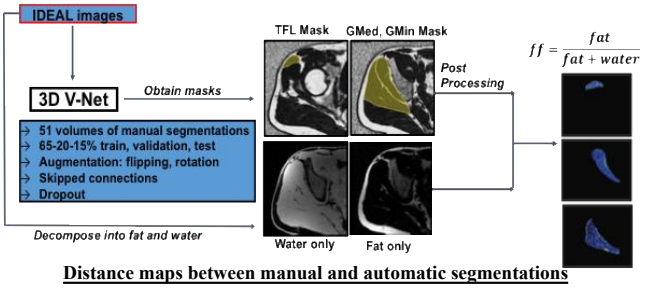
Introduction: Osteoarthritis (OA) affects over 30 million American adults, and has been recognized as a whole join disease, and includes pathological changes like cartilage degeneration, change in bone shape and muscle degeneration. In an effort to recognize the effect of OA on muscles, muscle atrophy and weakness around the hip have been studied and identified in hip OA. However, it remains unclear whether muscle weakness, is observed in hip OA in early stages and if it is linked to cartilage degeneration. This study aimed to develop an automatic segmentation method for hip abductor muscles and find their fat fraction associations with early stage hip osteoarthritis (OA) cartilage degeneration biomarkers.

Methods: This IRB approved, HIPAA compliant prospective study recruited 61 patients with evidence of hip OA or Femoroacetabular Impingement (FAI). Magnetic Resonance (MR) images were acquired for cartilage segmentation, $T_{1\rho}$ and T_2 relaxation times computation and grading of cartilage lesion scores. A 3D V-Net (Dice loss, Adam optimizer, learning rate=$1e^{-4}$, batch size=3) was trained to segment the 3 muscles (gluteus medius, gluteus minimus and tensor fascia latae). The V-Net performance was measured using Dice, distance maps between manual and automatic masks, and Bland-Altman plots of the fat fractions and volumes. Associations between muscle fat fraction and $T_{1\rho}$, T_2 relaxation times values were found using voxel based relaxometry (VBR). A p-value<0.05 was considered significant.

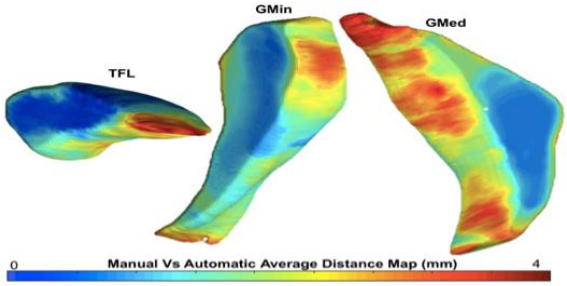
Results: The V-Net had a Dice of 0.90, 0.88 and 0.91 (GMed, GMin and TFL). The VBR results found associations of fat fraction of all three muscles in early stage OA and FAI patients with $T_{1\rho}$, T_2 relaxation times, indicating that there is a link between muscle degeneration and cartilage degeneration in early OA.

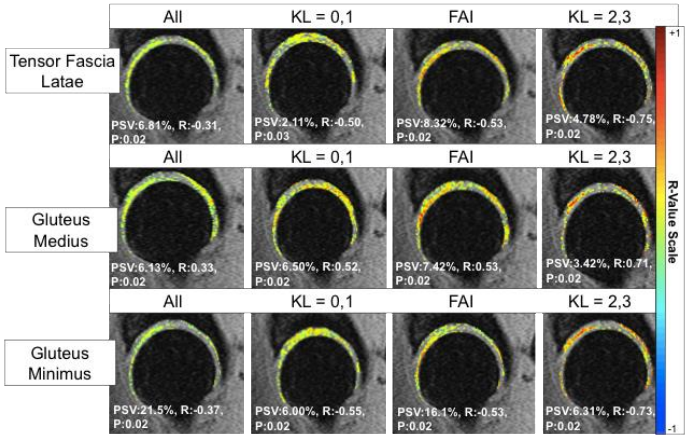
Conclusion: An automatic, reliable segmentation model was developed in this study and used to find associations between OA biomarkers and muscle fat fractions in early OA, providing targets for early intervention in treating OA non-invasively.

Automatic Muscle segmentation and Quantification pipeline



Distance maps between manual and automatic segmentations





R-value statistical parametric maps, showing the location of the voxels, percentage of significant voxels [PSV], mean partial Pearson correlation [R] and mean P-value [P], that show correlation between the mean fat fraction in the (rows, top-bottom) Tensor Fascia Latae (TFL), Gluteus Medius (GMed), Gluteus Minimus (GMin) muscle and $T_{1\rho}$ relaxation times in the hip acetabular and femoral cartilage in the (columns, left-right) whole patient cohort, patients with early OA, patients with Femoroacetabular Impingement (FAI) and patients with advance OA.