

SODIUM MR IMAGING AS A MARKER FOR ACHILLES TENDINOPATHY

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Introduction: In chronic Achilles tendinopathy, biochemical alterations precede macroscopic changes. Tendinopathy is usually accompanied by disaggregation of the microfibrillar bundles due to the greater quantities of water and PG, mainly, chondroitin sulphate A. An almost doubling of glycosaminoglycans (GAG) was observed in pathologic tendons [1,2]. By analogy with cartilage, sodium content should be higher in regions with GAG increase due to counter-ion mechanism between Na⁺ and negatively charged GAG chains [3]. The purpose of this study was to investigate the feasibility of sodium MR imaging in the diagnosis of Achilles tendinopathy.

Methods and Materials: Twenty healthy volunteers with no history of pain in the Achilles tendon (AT) (six males, fourteen females, mean age 38 ± 11 years) and eight patients (four males, four females, mean age 34 ± 11 years) with clinical findings of chronic Achilles tendinopathy were included in the study. Moreover, five fresh human cadaver lower legs from four different subjects (two males and two females, mean age, 51±13 years) were used. To acquire a sodium signal from the AT, a 3D-GRE (gradient echo) sequence optimized for sodium imaging was used. The length of the excitation pulse was set to 970 µs to avoid exceeding the specific absorption rate limit. The images were reconstructed in sagittal plane. The parameters of the 3D-GRE sodium sequence were set as follows: TE = 8.34ms; TR = 17ms; FOV = 199 × 199; slice thickness 3mm; flip angle 50°; 12 averages; and acquisition matrix 224 × 224 pixels. The total measurement time for sodium imaging, including flip angle calibration and localizers, was about 32 minutes. To calculate the signal-to-noise ratio (SNR) of each region of the AT, the mean sodium signal was divided by the standard deviation of noise, calculated from the same ROI on the "pure" noise images. To perform a biochemical analysis, samples from cadaver AT were taken from the MTJ (musculo-tendon junction), MID (mid region), and INS (insertion area) region according to segmentation of the tendon on MR images. Results are reported as micrograms of GAG per milligram of sample dry weight. A binary classification test was performed on the data to obtain the specificity and sensitivity of the method.



Fig. 1. Example images of 28y old healthy volunteer; the arrows point to centers of regions used for evaluation. (the scale represents signal intensity)



Fig. 2. Example images of 35y old patient with tendinopathy; the arrows point to centers of regions used for evaluation; SNR of AT is obviously increased.

in the sodium signal between healthy tendons and patients with Achilles tendinopathy in *in vivo* conditions. The correlation with the different GAG concentrations within the AT to sodium signal was shown in cadaver tendons. Notably, we observed several cases where a focal abnormality of the tendon shape was not associated with an abnormal signal increase on standard MR, but with abnormal values in all three parts of the tendon on sodium images. This may imply a higher sensitivity of sodium imaging for the detection of earlier stages of Achilles tendinopathy, and may provide a sensitive tool for the follow-up of patients after different therapies for the Achilles tendon. However, it is important to note that the correlation between GAG content and sodium signal measured in cadaver ankles should be viewed with caution, since post-mortem processes might cause the changes in biochemical composition of the tendon tissue.

References: [1] Fu SC et al, Clin J Sport Med. 2007;17(2):129-34 [2] Chard MD, Annals of the rheumatic diseases. 1994;53(1):30-4. [3] Trattnig S., et al., Radiology. 2010;257(1):175-84

Results: The median of sodium SNR in fifteen samples from the cadaver ATs was 9.6 (interquartile range [IQR]: 7.9-12.6). The median of GAG content assessed biochemically in fifteen samples from cadaver ATs was 1.7 (IQR: 1.3-2.7). The Pearson correlation coefficient between sodium SNR and GAG content was $r = 0.7135$ ($N = 15$). Mean bulk sodium SNR was 4.9 ± 2.1 in healthy controls and 9.3 ± 2.3 in patients with Achilles tendinopathy. The difference between the means was statistically significant ($p < 0.05$). When looking at the SNR changes regionally, the differences in SNR were also statistically significant in the INS and MID regions. The SNR in the MTJ was almost doubled in patients compared to healthy controls, in absolute value; ($p < 0.05$). At the sodium SNR equal to 7.5 (a threshold determined by ROC curve), the specificity of the method was 88.24%, and the sensitivity was 85.71%.

Conclusion: This work demonstrated the feasibility of sodium MRI to detect differences