Difference Image Ultra-Short Echo Time T2* Mapping Using a 3D Cones Trajectory

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Introduction: A variety of tissues are invisible using traditional MRI pulse sequences due to their extremely rapid transverse signal decay. To acquire sufficient signal to image these tissues, an Ultra-Short Echo Time (UTE) pulse sequence must be used. If an image with relatively long TE is subtracted from an image with UTE, then only tissues with extremely short relaxation times remain. When a series of these images is acquired using a range of TE values, a map of the T2* relaxation times in the tissue of interest may be created. Our methodology uses a special trajectory to acquire high resolution UTE images which are then post-processed to produce T2* maps to assess the condition of tendons and other traditionally invisible tissues. An application in the Achilles tendon is demonstrated showing a difference between healthy tendon and tendon degraded by scar tissue.

Materials and Methods:

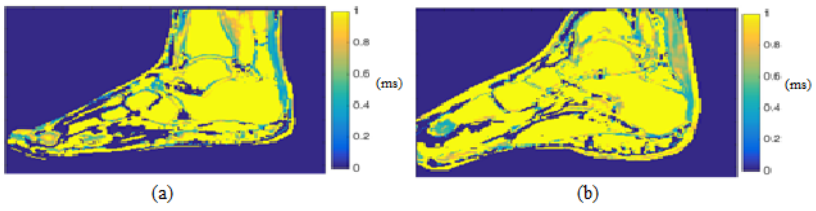
Image Acquisition: All images were acquired using a 3T Siemens TIM Trio system using an 8 channel combination foot knee coil. A 3D cones pulse sequence is used because it makes efficient use of gradient capabilities, maximizing gradient amplitude and slew rate, and is very SNR efficient. A hard RF excitation pulse with 160 μs duration was used with a flip angle of 10°. TR was 10 ms with TE values of 0.25, 0.5, 0.75, 1, and 5 ms for the series of images. FOV was 220x220x220 mm with 1 mm isotropic voxels. Readout time was 2 ms, the minimum possible to reduce T2 blurring while still providing adequate SNR for relaxometry measurements. Image reconstructions were conducted offline using MATLAB.

UTE T2* Mapping: After acquiring the images, post processing was performed on magnitude images in the following way.

1. A set of difference images was formed by subtracting the longest TE image from the shorter TE images.
2. The first difference image was thresholded and used to create a binary mask around the tissue of interest.
3. All of the difference images were multiplied by the binary mask to reduce computation time for determining relaxation times.
4. For each remaining non-zero voxel in the volume of interest, the signal intensities from each difference images were paired their corresponding TE value and a mono-exponential least squares fit was performed.

This process was used to compute UTE T2* maps of the ankle in both a healthy volunteer and a volunteer who had an ankle synovectomy.

Results and Discussion: The figure below shows the T2* maps comparing a healthy (a) and surgically repaired (b) Achilles tendon windowed to the same scale for comparison. The T2* values in the healthy volunteer across the tendon demonstrate excellent uniformity, providing some confidence in the estimates. Values in the healthy tendon range from 0.32 ms to 0.52 ms. Values in the injured tendon range from 0.5 to 0.74 ms, a notable difference that is easily detected when compared to the healthy tendon.



UTE T2* maps of the foot and ankle of a normal volunteer (a) and a volunteer who had undergone a synovectomy and surgical repair of the Achilles tendon (b). Excellent homogeneity in T2* values is seen in the healthy Achilles tendon (left), while areas of heightened T2* are evident in the areas of scarring in the image shown on the right.

Conclusion: Preliminary data from healthy and unhealthy Achilles tendon demonstrate this methodology can produce excellent in-vivo images of tissues, such as Achilles tendon, with extremely rapid T2* decay. Further, by acquiring UTE T2*maps of these tissues and differencing the images in the manner outlined, an accurate mapping of the T2* values within an unhealthy tendon can be determined. This tool may be extremely useful in characterizing certain types of injuries to tendon and other similar tissues with relatively short T2* values.

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