High Resolution PDw-TSE of the ankle with the use of a flexible high density receive array at 7Tesla.

Fredy Visser[1,2], Mies Korteweg[1], Michel Italiaander[1], Peter Luijten[1], and Dennis Klomp[1]
[1]7 Tesla, UMC, Utrecht, Utrecht, Netherlands, [2]Philips Healthcare, Best, Brabant, Netherlands

Introduction:
Standard clinical musculoskeletal imaging (MSK) relies heavily on T1w, T2w, and PDw Spin Echo (SE) based sequences. Turbo Spin Echo (TSE) is the preferred implementation for optimal Signal-to-Noise (SNR) and efficiency per unit time. The preferred sequence contrast for the assessment of articular cartilage, ligaments and tendons is a PDweighted TSE (PDw-TSE) with or without fat suppression [1].
Over the years there is a contiguous drive in MSK towards more image detail. On clinical scanners ranging from 1.0 up to 3.0Tesla the maximum in terms of resolution within acceptable scan times is reaching its limits. For gradient echo based sequences it has been shown that 7T with its intrinsic high SNR has the potential to meet the requirements for more resolution. However, TSE imaging has proven to be very challenging at higher fields [2] because of high specific absorption rates (SAR), the use of multiple pulses in a short time frame, short T2 components and RF receive and transmit in-homogeneity.
The aim of the present study is to develop a high resolution multi slice PDw-TSE sequence with optimal image contrast and high SNR. The sequence should cover the whole ankle and allow sub-millimeter lesion detection in cartilage and detailed assessment of ligaments and tendons.

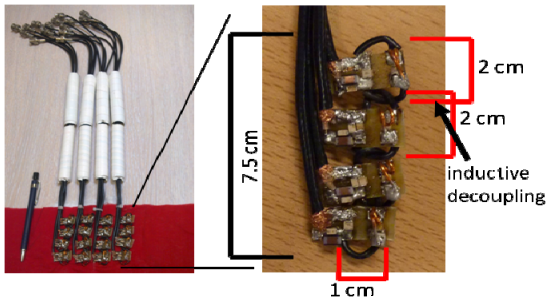

Fig. 1 *Left, open version of single sided array of 16 elements Right, zoomed in ona single strip of 4 elements*

Fig. 2 *Coronal high resolution PDw TSE image of a right ankle, 200µm pixel, 1mm slice thickness, TR/TE 4918/22ms*

Methods:
Imaging was performed on a 7T scanner (Philips Healthcare) using a flexible 32 (2x16) channel high density micro loop array [3] for receive (fig 1) combined with a single channel volume coil for transmit (Nova Medical). A coronal multi slice PDw-TSE sequence covering the ankle joint was implemented with the following scan parameters; acquisition pixel size of 0.2x0.2 mm^2, interpolated by zero-filling to 0.09x0.09 mm^2, 27 slices of 1mm slice thickness, FOV 90x90x53 mm^3, TR/TE 4918/22ms, turbo factor 3, linear k-space order, echo spacing 10.8ms, SENSE factor 2.2, total scan time 11:23 min. Standard refocusing pulse angle sweep was used consisting of a 180^0 followed by two 160^0 refocusing pulses for optimal image contrast between cartilage and synovial fluid. Two signal averages (NSA) were used to reduce FID artifacts by alternating the phase between first and second average. Homogeneity correction was applied based on the receive coil sensitivity. As modeling the SAR of the ankle in the volume coil was not performed we have used the available head model. To stay within the very conservative chosen SAR limits a repetition time of 4900ms was selected. The coil sensitivity reference scan was made at relative high resolution of 3.0mm^3. Five healthy volunteers were scanned ranging in age from 26 to 37 years, all volunteers gave written informed consent as approved by the institutional review board of our institution. The image quality and the assessment of cartilage and ligaments was scored on a 5 point scale ranging from poor-excellent.

Results:
A multi slice PDw-TSE sequence is successfully implemented on a 7T scanner. The FOV and gap of 1mm between 27 successive slices (90x90x53 mm) give sufficient coverage of the ankle joint. The in-vivo experiments show high quality images (*Figure 2*). The SNR in the middle of the ankle is sufficient at this resolution, image contrast between synovial fluids and articular cartilage is rated as good, the assessment of lateral and collateral ligaments is excellent due to the ultra high resolution. The artifact level is acceptable even though some of the images show mild motion artifacts due to the relative long scan time of over 11min. and the ultra high in-plane resolution. The homogeneity algorithm based on the coil sensitivity encoding needed for the SENSE reconstruction results in homogeneous signal intensity over the FOV. Additional transmit/receive in-homogeneities caused by standing wave properties at 300 MHz does not give a problem as the size of the object stays well within the wavelength of the proton resonance.

Conclusion:
With the present study we have shown that a routine clinical PDw-TSE sequence is well feasible at 7Tesla. Image quality, including the assessment of cartilage was rated good-excellent. The combination of the high SNR at 7Tesla and 32 channel high density flexible receive array has the potential to make the next step forward in High Resolution musculoskeletal imaging. The SENSE capabilities of the high density micro receive array are not utilized to the full extend. Higher SENSE factors are possible, reducing scan times towards more commonly used acquisitions times at lower field-strength. Fat suppression by means of a pre-pulse can be added to the sequence at the cost of SAR resulting in longer scan times, alternative fat suppression techniques should be investigated to overcome this problem. Implementation of the SAR model for the ankle would allow shorter scan time and/or increase the number of slices within the same TR.

References:
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