MOTION-TRACKING: FAST HIGH-RESOLUTION 2D MOTION QUANTIFICATION AND DEPICTION OF SHIVERING

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Introduction: Prolonged durations of examinations in stressful positions cause the human body to react by involuntarily shivering the region that is stressed. This ultimately affects signal acquisition, preventing sub-mm high resolution imaging in a short time. Here we present a novel technique using an adapted navigator to detect and quantificate shivering with high accuracy. The proposed method is used to find the best possible/comfortable position of hand for high resolution MR wrist imaging (with the arm in 'superman' position) at 7 T to enhance image quality.

Materials and Methods: 7 T hand/wrist imaging requires the patient's arm to be positioned in the stressful 'superman' position, as the space available aside the patient is insufficient to construct a transmit + high density receive array. This being the case, we tried using different positions of hand in 'superman' position (outstretched hand with the palm down, hand curved with the fingers around a tube and hand placed on a custom-made hand rest with the fingers resting on an inclined slope) to see which is the most comfortable for the patient and which causes least shivering (fig. 1).

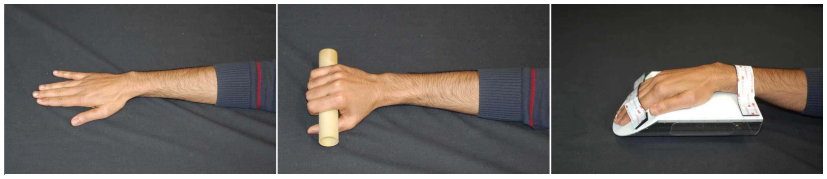

Figure 1. Shown are the three different hand positions used: Flat, holding a tube and lying on the rest.

For this purpose a contrast-agent filled sphere (T_1 ~15ms) was attached to the volunteer's hand (above the wrist). Using a radial FLASH sequence, 4 equidistant linear projections were acquired in a short time (TR 15ms, TE 4ms, 256 points/projection, α 68°). Undersampled images were generated from the projections using a non-uniform FFT [1] with a Kaiser-Bessel window. This measurement was repeated for a period of 1 min, after the patient lying in the specified position for 15 minutes. The temporal resolution for tracking the shivering is thus 60ms.

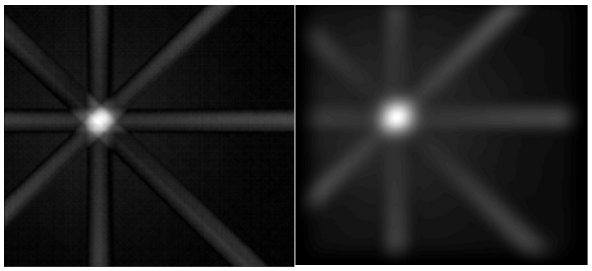

***Figure 2 Left**: Gridded image from 4 projections with the sphere visible. Due to strong undersampling, the image is affected with streaking. However, that does not have an impact on the cross-correlation (**right**).*

Detecting the motion was accomplished using cross-correlation of the reconstructed images with a cut-out image of the marker-sphere due to its low sensitivity to noise and high accuracy (standard error 61.2 µm [2]). The Fourier transform of individual radial projections over time were used to quantify the extent of motion, due to shivering.

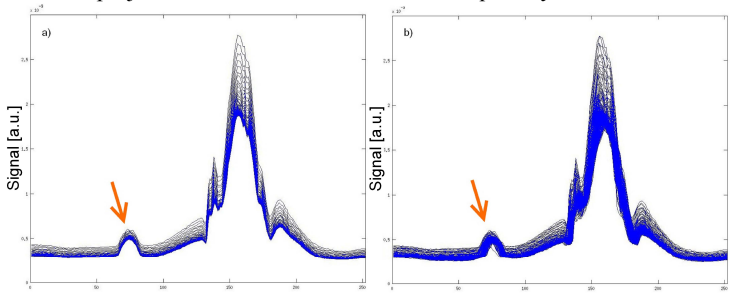

***Figure 3** The image shows each one radial projection through the sphere (arrow) and the hand. In the left case, almost no shivering occurred. The right plot shows a broadening of the peak, the shivering was distinct.*

Results and discussion: Fig. 2 shows the cross-correlation of the sphere with the reconstructed images. The broadening of the curve that represents the sphere in the Fourier transforms of the individual projections is shown in figure 3. As shown in fig. 4, least shivering was observed when the hand was placed above the hand rest. Placing the hand in the flat position causes more stress on the inner muscles, leading to shivering. While the hand in curved position (with the tube) was relatively more comfortable, shivering is higher than the flat position, as the fingers are not held tight. Movement or shivering in the fingers, in this case, translates to movement of the region of interest (i.e. wrist or metacarpal region). The motion in x (lateral) and y directions were considerably different. Identical results were obtained using the correlation (fig 2) as well as in the projection plots (fig. 4). While the use of hand rest is a compromise and improves the patient comfort to a small extent, the main stress in the study was from the 'superman' position itself.

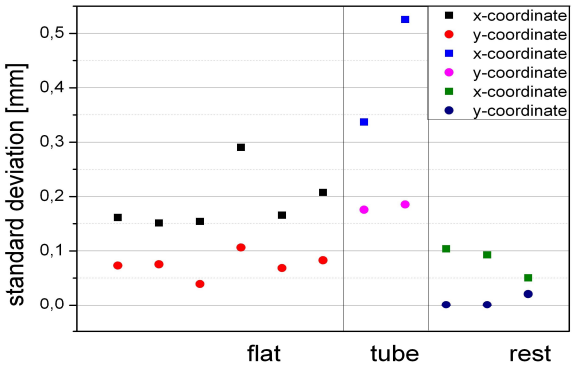

Figure 4. Comparison of the 3 different methods of hand positioning. The standard deviation of each measurement shown indicates the extent of shivering and is least when the hand-rest is used.

Conclusion: It is important to identify, measure and minimize stress and subsequent shivering, as images of extremely fine resolution cannot be acquired in the presence of trembling. A new method has been proposed to detect minute motions observed during shivering. The equidistant projections and high temporal resolution helps to give a measure of motion spread over the imaging plane in two different directions. As an example, the method has been used to find an optimum position for hand imaging in 'superman' position. The proposed method can be extended to other regions of interest in the human body to find optimum fixations for RF coils, accessories and to improve patient comfort.

References: [1] J. Song et. al., IEEE *Trans Biomed Eng*, vol. 56, no. 4, pp. 1134-1142, 2009. [2] A.J. Hopfgartner et al. ISMRM Proc 2012