Peripheral arterial imaging with a Continuously Moving Table Time-of-Flight View-Sharing technique

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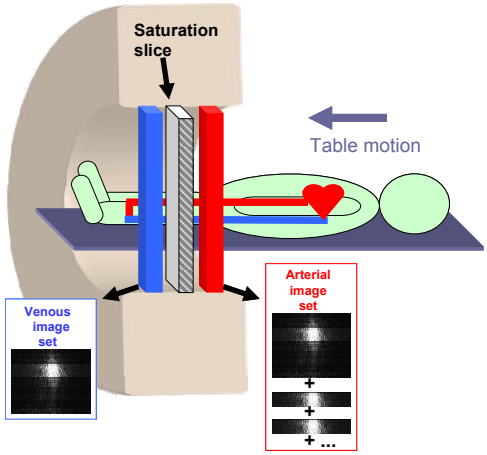

Fig.1: Acquisition scheme for CMT TOF arteriography: Two imaging slices were arranged around one saturation slice. Central k-space parts were sampled repeatedly for the arterial images.

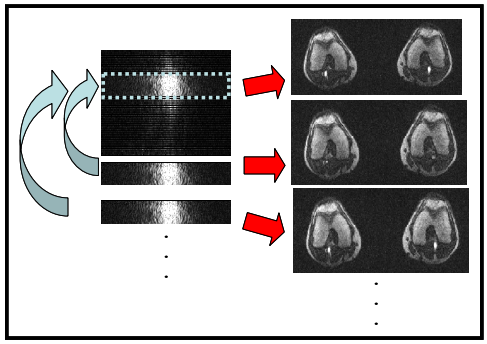

Fig.2: View sharing for reconstructing several arterial images per slice position. Replacing the central k-space in the fully sample k-space by 4 additional k-space centers leads to 5 arterial images per slice position with different arterial signal enhancement.

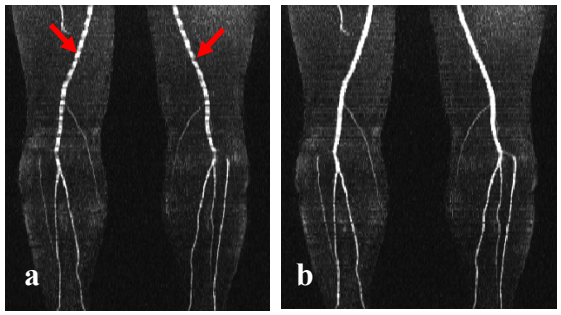

Fig.3: MIPs of arterial CMT TOF images using only one arterial image per slice position (a) or using additionally sampled k-space centers (b) for the compensation of signal variations in slice direction (arrows). Background was suppressed via subtraction of corresponding venous images.

References: [1] Korosec FR et al. *Magn Reson Med 1996*; 36:345-351. [2] Doyle M et al. *Magn Reson Med 1995*; 33:163-170. [3] Huff S et al. *Magn Reson Med, in press.*

Introduction Time-of-Flight MR Angiography (TOF MRA) is a commonly used non contrast enhanced technique for vessel visualization. To extend the spatial coverage of TOF arteriography, this study addresses the combination of axial 2D TOF imaging and Continuously Moving Table (CMT) acquisitions for imaging the peripheral arteries. Since arterial blood flow is highly pulsatile in the periphery, inflow in 2D axial slices and thus blood signal intensity in TOF images depends on acquisition time relative to the cardiac cycle resulting in unwanted signal variations in the final angiogram. To compensate for this artefact, a new CMT gradient echo sequence has been designed based on repeated acquisition of central k-space within the cardiac cycle for each slice position. Efficient suppression of pulsatile flow artifacts was achieved by view sharing and background signal was suppressed via image subtraction.

Methods For arterial CMT TOF imaging, two 2D axial imaging slices (thickness=4mm) were symmetrically arranged around the isocenter of the magnet (Fig. 1) and acquired in an interleaved manner (interslice gap= 7-fold imaging slice thickness). One saturation slice (thickness=10mm) was positioned between the two imaging slices canceling both arterial blood signal in the caudal imaging slice (venous image set) and venous blood signal in the cranial imaging slice (arterial image set). Further sequence parameters were: TR=11.11ms, TE=1.84ms, bandwidth=980Hz/Px, in plane resolution=1.25x1.25mm^2, Partial Fourier 6/8, GRAPPA Acceleration Factor=2 (24 reference lines). To compensate for signal variations caused by pulsatile inflow conditions, the central k-space of the arterial image, i.e. the GRAPPA reference lines, was sampled repeatedly n=4 times as illustrated in Fig. 1. The frequency of the excitation pulses was adapted to the table motion: During the interleaved CMT acquisition of one venous/arterial image pair (including the additional k-space centers) the same slice positions in the patient coordinate system were excited. Based on a view sharing principle, the additional k-space centers were used to reconstruct overall 5 arterial images per slice position as illustrated in Fig. 2. Each of the 5 reconstructed arterial images is thus characterized by different arterial signal enhancement, which is determined by the inflow of unsaturated blood during the acquisition of the respective k-space center. The corresponding venous image (identical position in the patient coordinate system) was subtracted from all arterial data. As a result, 5 subtracted image sets of the peripheral arterial system with suppressed background signal were obtained. The final TOF data set combined the subtracted images with the highest signal maximum which was further processed via maximum intensity projection (MIP). For 3 volunteers, the region from the proximal thigh to the ankles was acquired.
The sensitivity of arterial signal to pulsatile flow can also be reduced by increasing TR. A longer TR allows for more replacement of saturated blood spins within the imaging slices by inflow of unsaturated blood. Thus, for a fixed image resolution, the combination of TR and the number of additionally sampled k-space centers should determine the image quality in the presented approach. To evaluate, how these two factors compete, arterial CMT TOF imaging was performed again for one volunteer with the same total acquisition time but increased TR (18.51ms) and a reduced number of additional k-space centers (n=1).

Results and Discussion Since ECG-gated techniques can not be combined with CMT acquisitions the presented approach relies on a retrospective reconstruction of arteriograms. The proposed CMT TOF imaging strategy avoided signal variations in slice direction in TOF arteriograms of all volunteers which is clearly evident if the results of the new technique are compared to images obtained with the same sequence parameters but only one fully sampled k-space (exemplarily shown for one volunteer in Fig. 3). A comparison of resulting image quality between CMT TOF with longer TR and 1 additional k-space center versus short TR and 4 additional k-space centers is presented in Fig. 4. Vessel visibility is comparable, however small signal cancellations can be observed for the long TR approach (arrows, Fig. 4a). Note that image quality was considerably improved for long TR and reduced number of additionally acquired k-space centers (Fig. 4a) compared to standard methods without view sharing (Fig 3a). However, shorter TR and the acquisition of additional central k-spaces seem superior for efficient artifact suppression. In this context, the additional k-space data in combination with view sharing provide backup arterial images, if the fully sampled k-space is acquired at a time point in the cardiac cycle with low inflow or even reverse flow. Arterial CMT TOF imaging requires additional effort compared to venography, which has already been introduced in [3]. However, the presented acquisition pattern is a very time efficient strategy for the used view sharing principle, since additional acquisition time is only spent on arterial but not on venous imaging, for which the blood flow can be assumed as constant. Since the subject was continuously moved through the scanner during data acquisition, the temporal gap between the acquisitions of two spatially corresponding slices of the arterial and the venous image set was equal to the time needed for the acquisition of 7 imaging slice pairs. This timing strategy avoided sensitivity towards patient motion and provided excellent suppression of background signal via image subtraction.

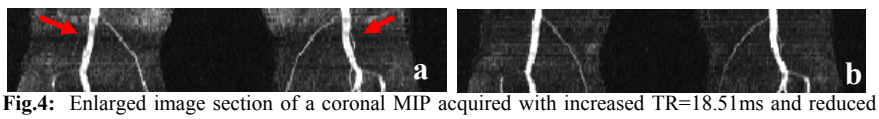

Fig.4: Enlarged image section of a coronal MIP acquired with increased TR=18.51ms and reduced number of additionally acquired k-space-centers (n=1) for arterial images (a) shows small signal cancellations compared to the short TR approach (TR=11.11ms, n=4) (b).