Fast Vessel Scout Imaging based on Continuously Moving Table acquisitions of projection data

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Introduction: MR-Angiography (MRA) of the peripheral arterial vasculature is typically based on a contrast enhanced (CE) multistation bolus-chase approach [1], which requires good synchronization of data acquisition, table motion and arterial passage of the contrast agent bolus. These challenges imply the need for careful planning and optimized workflow for the consecutive acquisitions of the multiple stations (sub-FOVs). Prior knowledge of the vessel geometry would thus be desirable to aid positioning of the individual sub-FOVs, to provide adequate vascular coverage, and to avoid edge artefacts of overlapping sub-FOVs in regions of interest. The application of a fast non CE vessel scout prior to the CE MRA examination can be a helpful tool, which addresses these issues and requires only short additional scan time. This study presents the implementation of a peripheral vessel scout based on Continuously Moving Table (CMT) acquisition of projection data with Time-of-Flight (TOF) contrast. The variation of arterial TOF signal during the cardiac cycle was exploited to enhance blood-background contrast.

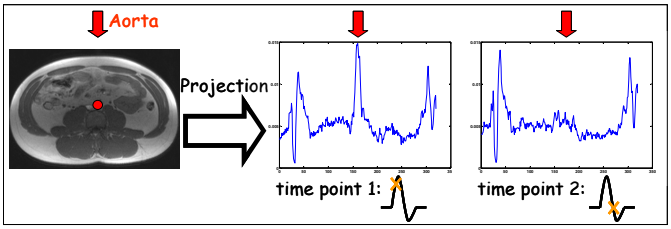

Fig.1: 1D projections of a slice at the level of the abdominal aorta show different signal enhancement at vessel locations (red arrows) depending on the level of inflow of unsaturated blood (marked orange in a pulse wave profile), i.e. the time point of acquisition within the cardiac cycle.

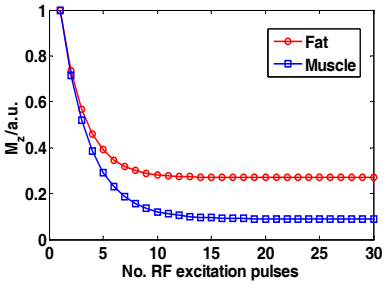

Fig.2: Longitudinal magnetization as a function of the applied RF pulses simulated for the applied parameters.

Methods: For fast visualization of the peripheral arteries, 1D projection data from the feet to the pelvis were acquired in 6 healthy volunteers on a 1.5T system (Magnetom Avanto, Siemens, Medical Solutions, Erlangen, Germany) using a RF spoiled gradient echo sequence. MR signal of 2D axial slices was received *n* times for each slice position without phase encoding and during continuous motion of the patient table. 1D Fourier transformation was performed to derive *n* projections per slice position. Sequence parameters for the interleaved multislice CMT acquisition were: *n*=63, image resolution readout: 320, FOV=400x260mm^2, slice thickness=5mm, 3 slices per package, bandwidth=180Hz/Px, patient table velocity=9.3mm/s, TR=25.64ms, TE=3.95ms, and flip angle=45°. During data acquisition, venous inflow was saturated, the frequency of RF excitation pulses was adapted to the table motion [2], and surface receiver coil elements were dynamically switched on and off during table motion to improve overall SNR. Due to the high pulsatility of the arterial blood flow, the vessel signal in the reconstructed projection data can vary considerably for different projections. For each projection, the inflow (i.e. time point in the cardiac cycle) determines the arterial signal intensity and can result in more or less prominent arterial signal enhancement (Fig. 1, arrows) while tissue and background signal remain constant. It is thus possible to isolate the arteries by exploiting these signal differences by subtracting projections with identical slice positions but a temporal gap of multiple TR. As a result, locations with signal variations (arteries) are detected while background signal (fat, muscle) is canceled. However, care has to be taken to ensure that background signal has reached the steady state to proved constant signal levels for all projections. This is theoretically fulfilled after the application of approximately 25 excitation pulses for the presented sequence parameters (simulated in Fig. 2). Acquired data was processed by calculating all possible $(n\text{-}25)^2$ differences $\Delta I(i,j) = |I_i - I_j|$, i,j = [1,n-25] of projections with assumed steady state for background signal, and by detecting the maxima of the difference intensities $\Delta I(i,j)$ iteratively for each leg (Fig 3). The signal intensities max($\Delta I(i,j)$) in Fig. 3 represent the maximum found in the difference of all possible projection combinations (i,j). High intensities are visible as band structures in the plot and can be assigned to one projection i with prominent peaks and the other projection j with low signal at arterial positions. These band structures were isolated by histogram thresholding for each slice position and the detected max($\Delta I(i,j)$) reconstructed to the final vessel scout image using a sum of squares combination. The search of maxima in subtracted projections was restricted to an area 2cm within the body margin, which was found via thresholding in the gradient of projections.

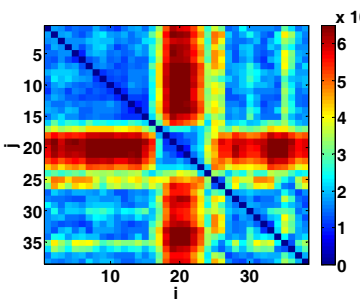

Fig.3: Maxima of the difference intensities max($\Delta I(i,j)$) for all possible projection combinations.

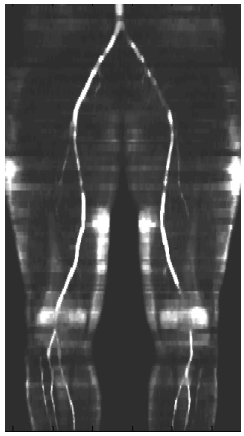

Fig.4: Vessel scout based on CMT acquisition of projection data.

Results and Discussion: An arterial scout image of a healthy volunteer based on the introduced CMT projection acquisition is presented in Fig. 4. Total acquisition time was 2:14min, which was needed for the coverage of 125mm longitudinal FOV. For all volunteers, the aortic bifurcation, small sections of the internal iliac arteries, as well as the femoral and the popliteal artery were clearly depicted in the abdomen and the upper leg. Furthermore, three arteries of the lower leg and their branching point from the popliteal artery are visible. Thus, the presented approach allows for a fast visualization of the main structures of the peripheral arterial system in a moderately short scan time without the need for contrast agent. Projection data has already been used to extract the time point in cardiac and respiratory motion cycle during data acquisition to replace ECG gating devices [3]. In these studies, changes in projection signal intensity were detected resulting from heart or abdominal wall motion. In the presented work, changes in blood flow conditions were not eliminated but exploited to isolate the arterial vasculature. The outer body parts were excluded from the search for optimal differences of projections. During CMT acquisitions the local magnetic field is changing continuously and even in the steady state, there may be signal differences in projections at body margins, which would also result in signal peaks in subtracted projections. These peaks can be very prominent since they can be assigned to the subcutaneous fat, which appears bright in T1-weighted images. Thus, these signals compete against the arterial peaks, requiring this further post processing step for improvement of vessel visualization in scout images. For the presented scout technique, the time (*n* x TR) has to exceed the duration of one cardiac cycle to guarantee the acquisition of at least one projection per slice position with high and one projection with low arterial signal. This condition was fulfilled by the chosen sequence parameters, whereas not the minimal TR for a single slice measurement was used, but a TR which was used to full capacity in the performed multislice-experiment. Since ECG triggering is not an option for CMT MRA, the presented CMT arterial vessel scouts relies on data post processing. In this study, the acquired data was directly used to derive the vessel scout image. Another potential approach would be the processing of projection data according to simultaneously acquired ECG data, which was tested for comparison. However, the ECG data based scout images had lower blood-background contrast. This was due to the fact, that the presented approach extracts the optimum achievable contrast with the acquired projections and is not affected by small variations in the cardiac cycle as it is the case in an ECG approach. A further advantage over ECG post processing techniques is, that there is no need for an external device, which improves patient comfort and reduces preparation time.

References: [1] Goyen M et al. *Radiology 2003*;227:277-282. [2] Ludwig U et al. *MRM 2006*;55:423-430. [3] Kim WS et al. *MRM 1990*;13:25-37.