Continuously Moving Table Time-of-Flight Angiography of the Peripheral Veins

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Introduction

Time-of-Flight (TOF) imaging is one of the commonly used Non-Contrast-Enhanced Magnetic Resonance Angiography (NCE MRA) methods. To improve the limited coverage of TOF techniques, the aim of this study is the combination of axial 2D TOF and Continuously Moving Table (CMT) acquisitions. Two imaging strategies, both based on image subtraction, are presented and their applicability for peripheral vein imaging was tested in a study with 10 healthy volunteers.

Methods

The continuous change of the imaging volume during CMT acquisitions prevents reliable fat suppression on a chemical shift selective basis. For that reason, two acquisition strategies for Subtraction Moving Table (SuMo) TOF venography have been developed: In the 2-step method, an axial 2D single slice CMT acquisition of the whole extended Field of View (FOV) is performed twice in two separate scans: first, saturating the arterial blood signal (image set A) and second, saturating the arterial and the venous blood signal (image set B) [1]. For the 1-step method, image sets A and B are acquired simultaneously during a single table sweep. A special arrangement of two interleaved acquired imaging slices (slice gap = 7-fold imaging slice thickness) and two saturation slices (Fig. 1) results in suppression of the arterial blood signal in the caudal imaging slice (image set A), and the venous as well as the arterial blood signal in the cranial imaging slice (image set B). Image sets A and B of the 1-step method thus provide the same contrast properties as in the 2-step approach. For both CMT TOF methods subtraction of two images of set A and B, which are assigned to the same slice position in the patient coordinate system, yields images of the venous structure. Image quality of both SuMo TOF methods was assessed by region-of-interest (ROI) analysis of the signal-to-noise ratio (SNR) and the contrast-to-noise ratio between vein and muscle (CNR_{muscle}) as well as between vein and surrounding fat tissue (CNR_{fat}) in subtracted images and image set A for veins of the upper and lower leg in 10 healthy volunteers. The SuMo TOF methods

Fig.1: 1-step method for SuMo TOF venography.

Image set A   Image set B

were compared among each other and to a standard stationary 2D TOF multistation acquisition (3 stations with 51 slices each) using a paired Student's t-test. Additionally, two radiologists assessed the diagnostic quality of different parts of the venous system on a 4-point scale (0: not visible; 1: partially visible or impaired by major artefacts; 2: largely visible or impaired by minor artefacts; 3: fully visible without artefacts). Paired Wilcoxon's signed rank test was applied to compare the quality scores. For all experiments 2D CMT axial scanning was performed on a 1.5 T wholebody system (Magnetom Avanto, Siemens, Medical Solutions, Erlangen, Germany). Measurements were conducted with image acquisition in opposite direction to the venous blood flow using a RF spoiled gradient echo sequence and an empirically determined optimal flip angle of 45°. Further parameters were: TR=25ms, TE=3.95ms, $matrix$=208x320, $voxelsize$=1.3x1.4x4mm^3, $GRAPPA$ $acceleration$ $factor$ 2.
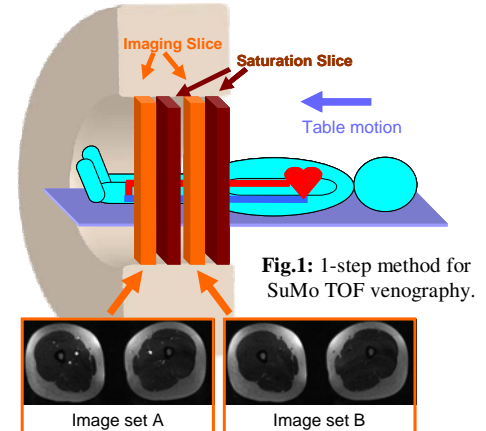
Results

Figure 2 presents the coronal Maximum Intensity Projection (MIP) of difference data obtained with the 2-step method and the 1-step method for SuMo TOF venography for one volunteer. Both methods provide peripheral vein imaging of good and comparable image quality with successful suppression of signal from stationary tissue and without contrast agent injection. The obtained spatial image resolution allows imaging of the small veins of the lower leg. ROI analysis demonstrated no statistically significant difference in terms of SNR, CNR_{muscle} and CNR_{fat} values (p>0.05) for the comparison of the two SuMo TOF techniques. Similar values for CNR_{muscle} and CNR_{fat} in the difference data confirm excellent performance of fat suppression by subtraction. If the multistation measurement and the image set A of both SuMo TOF methods are compared, CMT acquisitions provide higher SNR and CNR_{muscle} values, which are exemplarily illustrated in Fig. 3 for three representative veins. The advantage of the continuous table movement during data acquisition in terms of higher SNR and CNR_{muscle} was especially noticeable for veins with a small diameter and therefore less inflow effect for the standard TOF methods and statistically significant for the great saphenous vein and the anterior tibial vein (p<0.05) (Fig. 3). For the 1-step method image grading yielded mean scores of 2.7 and 2.8 for the proximal veins and 1.9 and 2.2 for the distal veins, respectively, whereas the 2-step method yielded scores of 2.6 and 2.4 for the proximal and 1.7 and 1.5 for the distal veins, respectively. For both observers the difference between both SuMo methods was statistically significant for the distal vessels in favour of the 1-step method.
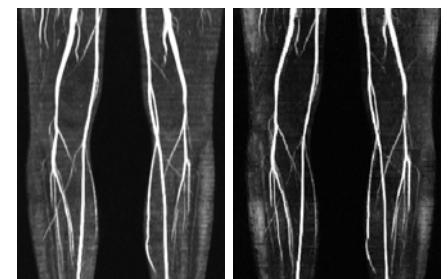

Fig.2: Coronal MIP of difference data: 2-step method (left), 1-step method (right).

Discussion and Conclusions

The feasibility of SuMo TOF techniques for peripheral vein acquisition was demonstrated in a study with 10 healthy volunteers. TOF SNR and CNR were increased by acquiring imaging slices in opposite direction to the venous blood flow. This beneficial effect was especially noticeable for the small distal veins with expected low blood flow velocity. A higher fraction of saturated spins is replaced by fresh spins from the outside of the imaging slice resulting in increased inflow enhancement and thus TOF signal. The presented 1-step method for SuMo TOF venography allows vein imaging for extended FOV within only one continuous scan. Sensitivity towards patient motion could be reduced in comparison to the 2-step method, since the temporal gap between the acquisitions of an image assigned to set A and an image of the same slice position assigned to set B is substantially reduced. This reduced influence of patient motion was also reflected by the image grading results for the distal veins. Moreover, total scan time for the 1-step method was decreased due to the interleaved acquisition pattern requiring only a reduced number of RF pulses for signal saturation of inflowing blood. Compared to CE MRA no temporal constraint for TOF acquisitions exists, whereas in case of CE measurements contrast bolus injection, table speed and data acquisition have to be synchronized. This temporal flexibility also constitutes an advantage of TOF acquisitions over ECG-gated 3D partial-Fourier TSE methods [2] which strongly depend on exact timing of the triggered acquisitions. The diagnostic potential of the SuMo TOF methods has to be evaluated in future studies.
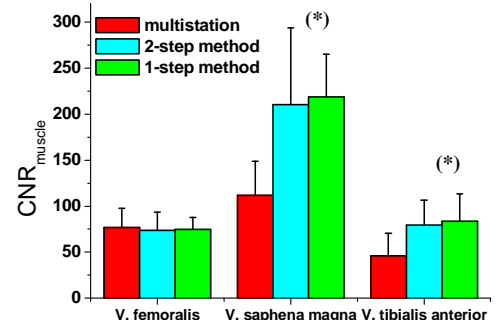
References: [1] Huff S et al. *Proceedings ISMRM*, 2008. [2] Miyazaki M et al. *Radiology 2008*;248:20-43.

Fig.3: Results of the CNR_{muscle} analysis for three representative veins obtained with a multistation and the two SuMo TOF approaches. (*) indicates vessels with significantly superior results for both CMT TOF methods.