Ultra-High Resolution Peripheral MRA With k-Space Segmentation Featuring a Blood-Pool Contrast Agent and Venous Suppression

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Introduction: Contrast-enhanced (CE) 3D MR angiography (MRA) permits comprehensive assessment of the arterial system of the lower extremities. The method combines intravenous bolus application of a non-nephrotoxic, paramagnetic contrast agent with the acquisition of a fast 3D data set. Contrast-enhanced 3D MRA is being employed in clinical routine throughout the world for the evaluation of various arterial pathologies. Timing of contrast application plays a major role to achieve the highest arterial signal in the arteries while avoiding venous signal overlay. Recently, intravascular "bloodpool" contrast agents have been introduced to the market [1]. They remain for a longer time in the intravascular space and thus potentially allow for extended data acquisition times. Ultra-high resolution peripheral CE-MRA was evaluated in 5 patients with known peripheral arterial vascular disease. Venous overlay was suppressed by k-space segmentation such that the central part of k-space was acquired during the first-pass and the peripheral part was acquired during the steady-state of the blood pool contrast kinetics [2].

Materials and Methods: Segmentation of k-space for separated data acquisiton of the central and the peripheral part of k-space [2] with elliptical centric view ordering was implemented in the Siemens system architecture. The method features parallel imaging and partial Fourier acquisition in phase and slice direction. Multi-station bolus-chase peripheral CE-MRA was performed acquiring in the first run (head-to-feet) only the central part of k-space during the first-pass of the contrast medium. Subsequently, for each station in reverse order (feet-to-head), the peripheral part of k-space was acquired during the steady-state of the blood pool contrast medium. Central and peripheral k-space data were combined to reconstruct images of the peripheral vasculature with ultra-high resolution and with venous suppression. Additionally, low resolution first-pass data were reconstructed including zero interpolation (ZIP) to the high-resolution matrix. All experiments were performed on a 1.5-T Magnetom Avanto (Siemens, Erlangen, Germany) equipped with a full matrix of surface coils (Tim technology, Siemens) and with high performance gradients. Five patients (2 men, 3 women, mean age: 56 years) with known PAOD Fontaine grade IIB underwent a three-station peripheral CE-MRA with Vasovist (Schering AG, Berlin, Germany). The first-pass data set of the central k-space (TA = 63s; acquired voxels: 0.8 x 2.0 x 2.0 mm, 0.8 x 2.0 x 2.0 mm, 0.7 x 1.8 x 1.8 mm), and the steady-state data set of the complete k-space with increased resolution (TA = 63s + 282s; acquired voxels: 0.8 x 0.8 x 1.0 mm, 0.8 x 0.8 x 1.0 mm, 0.7 x 0.7 x 0.9 mm) were acquired. Both data sets featured GRAPPA with acceleration factor 2. Prior to contrast administration, both, the first-pass and the steady-state data acquisition run, were acquired to achieve native data sets for subsequent mask-subtraction of background signal. Vessel sharpness was compared by two blinded radiologists on source images according to a 3 point scale (1 = blurred, 2 = moderately sharp-edged, 3 = sharp-edged) for all three stations. Furthermore minimal vessel size and ability to track the vessels for certain lengths were compared. Venous overlay or overlays of the venous vessel wall were also considered.

Results: Comparison of vessel sharpness (VS) revealed statistically significant differences for the first-pass data sets and the steady-state data sets in all three stations: VS fist-pass (pelvis_mean) = 1.7 versus. VS steady-state (pelvis_mean) = 2.9; VS fist-pass (thigh_mean) = 1.8 versus VS steady-state (thigh_mean) = 2.8; VS fist-pass (calf_mean) = 1.8 versus VS steady-state (calf_mean) = 2.9. Due to the high spatial resolution, partial volume effects were reduced resulting in overall sharp delineation of small arteries. In all five patients smaller arteries of the calves running more peripheral could be detected in the steady-state data sets. One female patient presented with a small, one millimetre diameter artery of the calf which could be depicted for over 15 cm and could not be seen in the first-pass data sets. Veins, however, were almost completely suppressed by k-space segmentation in both data sets.

Discussion and Conclusion: Peripheral CE-MRA with first-pass and steady-state k-space segmentation using a blood pool contrast agent proved feasible and provides ultra-high resolution data with sharp delineation of the arterial vessel tree while suppressing venous overlay. The technique is restricted in breathing-dependent body parts like the abdomen and chest because of changes in the location of the small vessels over time. Breathing motion in these body parts additionally limits the ability for background signal suppression with mask-subtraction of native data sets. While in the non-breathing dependent body parts like the thighs and calves smaller vessels could be depicted over longer length, images of the abdomen did not show superiority in displaying smaller branches. Vessel sharpness, however, was superior in the steady-state data sets of all three stations. Another point of discussion is that inherent to the method zero interpolation has been used for display for first-pass images while no interpolation has been used for steady-state imaging. This virtually enhances image resolution for the first-pass data sets beyond the acquired resolution. Consequently, by using ZIP also for the steady-state data sets, the displayed resolution potentially could have been increased even further. Because of the increasing amount of high-resolution image data and associated prolonged image reconstruction times, ZIP has been omitted in this case. In summary, our study shows that first-pass and steady-state imaging with k-space segmentation provides high-resolution MRA data sets with detailed arterial display while suppressing venous signal and thus deserves further evaluation on patients. Further developments aim towards combining this technique with data acquisition during continuous table movement.

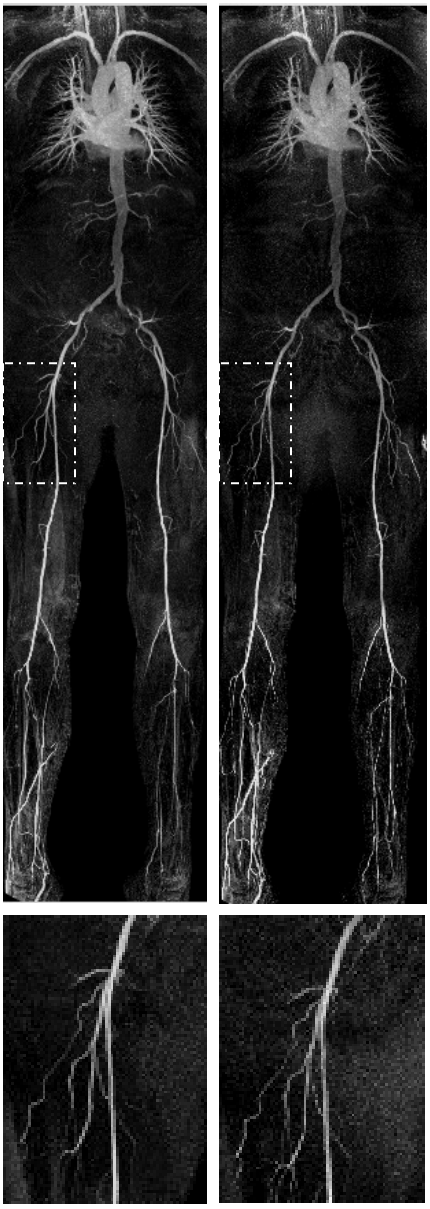

Fig.1: MR angiography of the calves and image magnification: left: first-pass data sets (central k-space acquired); right steady-state data sets. Note the higher signal intensity of the small arteries, the sharp edge of the vessels in the steady state data and the smaller arteries displayed.

References

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2. Foo-TK et al. Radiology. 2001 Jun;219(3):835