4D phase contrast imaging for the assessment of morphology and haemodynamics in peripheral arteries: feasibility results from a 3T MR system

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Purpose: Therapeutic decision-making in vascular pathologies such as peripheral arterial occlusive disease (PAOD) and aneurysms is based on both haemodynamic (blood flow) and morphological information. The aim of this feasibility study was to apply time-resolved 3D and 3-directional phase contrast MRI at 3T to iliac and femoral arteries in order to utilize the simultaneously available functional (three-directional blood flow velocities over the entire cardiac cycle) and anatomical information (3D magnitude images) for integration of haemodynamic features into 3D morphological imaging. Advanced data processing permits 3D visualization of the measured haemodynamic information. All results were compared to vascular US. Data from volunteers and a patient with PAOD is displayed ofr demonstration of the potential of this technique for the evaluation of global and local blood flow characteristics as well as the detection of pathologically altered vascular hemodynamics.

Materials and Methods: 5 healthy volunteers (3 male, 2 female, mean age 34 years, range 23-33) and one 63-year-old patient with symptomatic PAOD were included in this feasibility study. Written informed consent was obtained from every person. Studies were performed in agreement with local authorities and ethics committee. MRI was performed applying ECG-triggered 3D phase contrast imaging (3T MR-System, TRIO, Siemens, Germany, 8-element body array coil) in the vessels of interest with the parameters 2.1x1.6x3.0mm resolution, 20 partitions, 12-14 time frames, temporal resolution 49 ms, flip angle α=15°, TE =3.7ms, TR = 6.1ms, FOV = 175x300mm². Scan duration for depiction of the arteries from bifurcation to the proximal superficial femoral artery was heart rate dependent approx. 10-14 minutes. No contrast agent was used for our acquisitions. Postprocessing of data included noise filtering and eddy current correction. Visualization of anatomy and spatially registered blood flow in 3D was performed using a commercially available software package (EnSight, CEI, North Carolina, USA). Various modes included vector graphs, time-resolved 3D particle traces as well as 3D stream-lines. Vascular ultrasound (US) was performed using B-mode US for morphological imaging and color-coded duplex US for flow velocity and pattern analysis on a Siemens Sonoline Elegra with variable arrays. In case of flow acceleration in the patient examination, peak velocity ratios were calcualted by dividing velocities within and before the vascular narrowing. A comparison to visually determined velocity ratios in MRI-investigations was performed.

Results: In all studies, 3D visualization of the MRI data including all visualization options could be successfully completed for all subjects in high spatial and temporal detail. Postprocessing included free manual orientation in the 3D-data package for definition of areas from which vector graphs, 3D streamlines or 3D particles originated. All major vessels including the proximal internal iliac artery were depicted in the volume coverage. In close agreement with color-coded ultrasound no flow disturbances were detectable in the volunteers. A detailed qualitative description of blood flow characteristics such as parabolic flow profiles (Fig. 2) and no substantial acceleration effects was feasible throughout the datasets as illustrated in figures 1 to 3. In the patient peak velocity ratios of 2 were detected in both US and MRI in the external iliac artery. In general, MRI revealed lower velocities than US. Additionally, MRI revealed major complex flow alterations in a moderate dilatation of the diameter of the right common iliac which were not detectable in ultrasound (Fig. 4, open arrows).

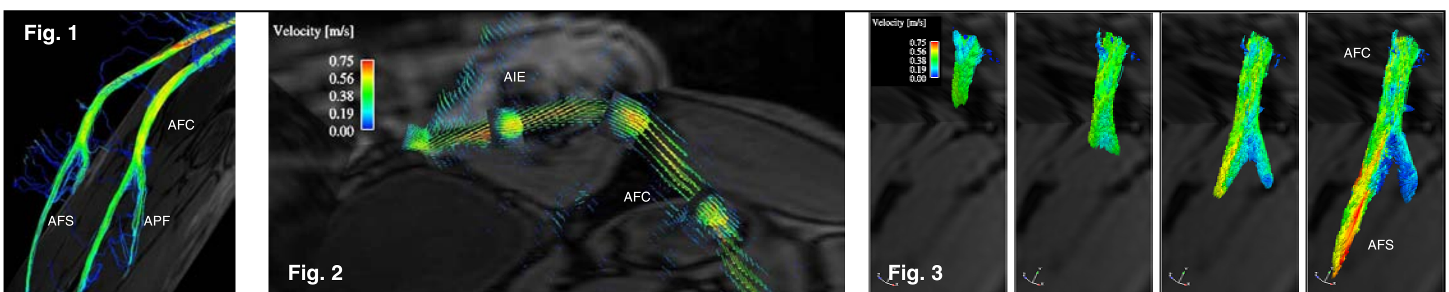
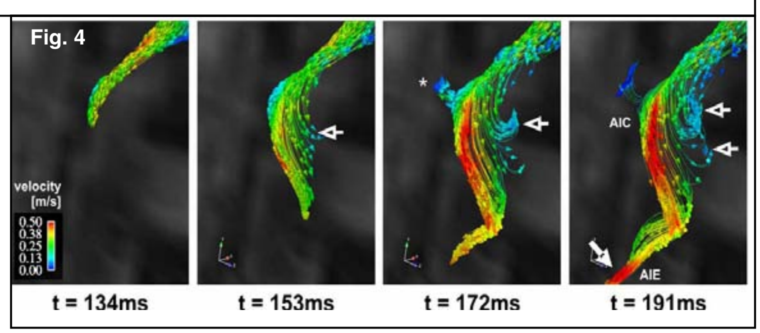


Figure 1: 3D Stream-line visualization of systolic blood flow in the common iliac (AIC), proximal femoral (AFC) and profound femoral (APF) arteries in a normal subject. Blood-flow velocities are color-coded. **Figure 2:** Vector graph depiction of local blood flow characteristics for a healthy volunteer. Planes for visualization and local qualitative assessment can freely be positioned in the 3D volume (arrows). The observer view angle can freely be chosen and altered. Blood-flow velocities are color-coded. **Figure 3a-d:** Time-resolved 3D Particle trace visualization in the femoral bifurcation for investigation of flow evolvement over time in a normal volunteer. Blood flow and distribution over the cardiac cycle in systole are shown at 4 distinct time frames. **Figure 4:** Time-resolved 3D Particle traces in a patient with symptomatic PAOD show considerable complex flow alterations (vortex formation, open arrows) in a poststenotic dilatation of the common iliac artery and flow accelerations in the external iliac artery (solid arrow). Although the latter was also detected in color-coded ultrasound, the complex flow patterns were not assessable in ultrasound.

Conclusion: Simultaneous assessment of morphology and function in peripheral arteries by means of time-resolved 3D phase-contrast MRI at 3T and 3D visualization of flow characteristics was successfully demonstrated. In addition, a patient measurement illustrates the potential to detect blood flow alterations associated with common PAOD. The underestimation of flow velocities in MRI is related to the spatial resolution used here which is subject to further protocol optimization. The significance of the detected flow patterns has to be further evaluated and quantiative parameters such as wall shear stress have to be derived from the data and clinically correlated.



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