Time-resolved Blood Flow Quantification with Ungated Radial Sampling

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Introduction

Quantitative information on blood flow such as peak forward-velocity and average acceleration in the femoral/popliteal artery can provide clinical information on peripheral arterial disease (PAD) [1]. The most common approach to time-resolved pulsatile blood flow quantification by MRI relies on gated Cartesian scanning [2]. Gated acquisition is susceptible to ghosting flow artifact due to phase and amplitude modulation from pulsatile flow and normal dynamic heart rhythm. The modulations can be reduced in Cartesian scan with smaller flip angle (~5^{o}) at the expense of lower velocity-to-noise ratio. We propose a radial acquisition-based method where external trigger is obviated by a continuous radial scanning where motion manifests as streaking outside the vessel boundary therefore not interfering with velocity quantification.

Methods

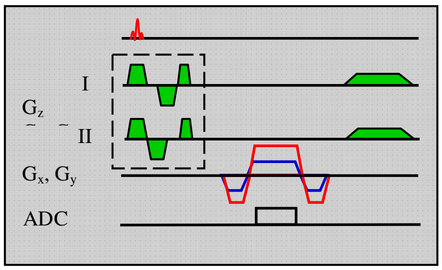
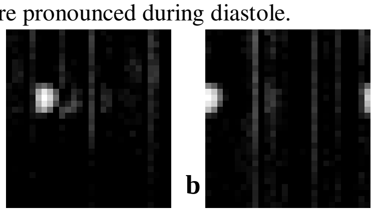


Figure 1 Radial Spoiled-GRE pulse sequence with velocity-encoding, programmed with SequenceTree^{TM} [4].

For each view angle two-step velocity-encoded acquisitions (dashed box in **Figure 1**) are alternated and continued for the duration of about 120% of the average RR-interval before moving onto next view angle and repeated until k-space is covered uniformly via Golden angle scheme [3]. The k-space data along each view are independently time-ordered by taking complex difference (CD) (**Figure 2a**) between successive projections with differential velocity-encoding. Finding the first maximum CD intensity (peak systolic flow) and setting it as the starting point (**Figure 2b**) is an efficient and accurate way to time-order the projections. In short, two stacks of flow encoded images are reconstructed with positive and negative first moment. The phase difference is taken using a sliding-window scheme to achieve an effective temporal resolution equal to TR. Time-resolved femoral artery blood flow velocity was measured in 3 healthy young subjects after obtaining written consent was and the data compared to the standard velocity-encoding product sequence of the Siemens Tim Trio 3T scanner. Axial images were acquired using a phased array eight-channel knee coil (Invivo Inc., Pewaukee, WI) and the following scan parameters: Number of views = 201 giving alias free FOV of 128 x 128 mm^2, thickness = 5 mm, matrix size = 126 x 126, TR = 10 or 20 ms, TE = 4.8 ms, flip angle = 20^{o}, BW = 521 Hz/pix and VENC = 70 cm/s along the slice-select direction.

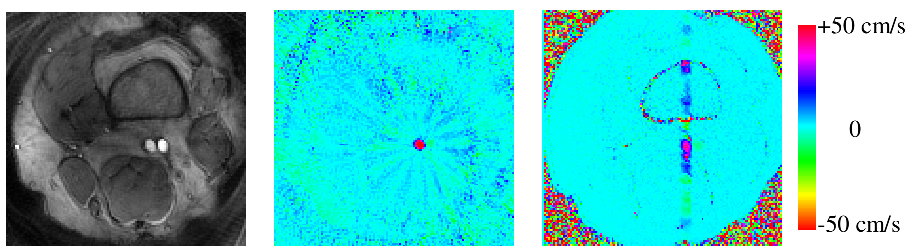
Results and Discussion

Representative magnitude and velocity images are shown in **Figure 3**. During systole the ghosting artifacts are clearly visible on the gated Cartesian velocity image (**Figure 3c**) when the amplitude and phase modulation is most pronounced. On the other hand, streaking is barely visible on the radial velocity image (**Figure 3b**). Time-resolved flow profiles are shown in **Figure 4**. Small discrepancy during the retrograde flow and subsequent forward flow is observed which may be the result of reduced velocity-to-noise ratio and/or the fact that the effect of variation in the heart rhythm is more pronounced during diastole.



a b

Figure 2 a) CD of successive velocity-encoded views at a particular view angle; 28 CDs or time points are shown. b) Reordered view with respect to the peak systole using CD signal intensity.



a b c

Figure 3 a) Radial magnitude image; **b, c**) velocity images constructed from radial (**b**) and Cartesian acquisition (**c**).

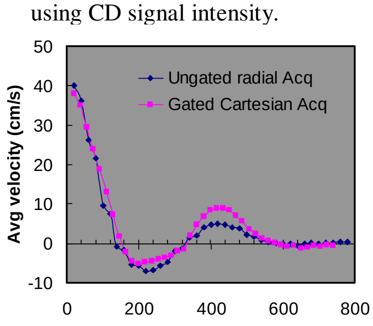


Figure 4 Comparison of the triphasic blood flow profiles derived from Cartesian and radial scan of a volunteer.

Conclusion

We have demonstrated ungated radial acquisition approach to time-resolved triphasic-pulsatile flow in a peripheral artery. The method largely eliminates artifacts caused by amplitude and phase modulation; however, a technique that can quantify flow in a single heartbeat would be preferable since arrhythmia is not always associated with abnormal heartbeat.

References [1]Fronek et al., Circulation 1976; 53:957-960; [2] Nayler et al., J Comput Assist Tomogr 1986;10:715-722; [3] Winkelmann et al., IEEE Trans Med Imag 2007; 26:68-76; **[4]** Magland et al. Seattle, WA. Proc. ISMRM.2006, p 578.

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