

Single Breath-hold Renal Artery Blood Flow Measurements Using Spiral PCMR With r-r Interval Averaging

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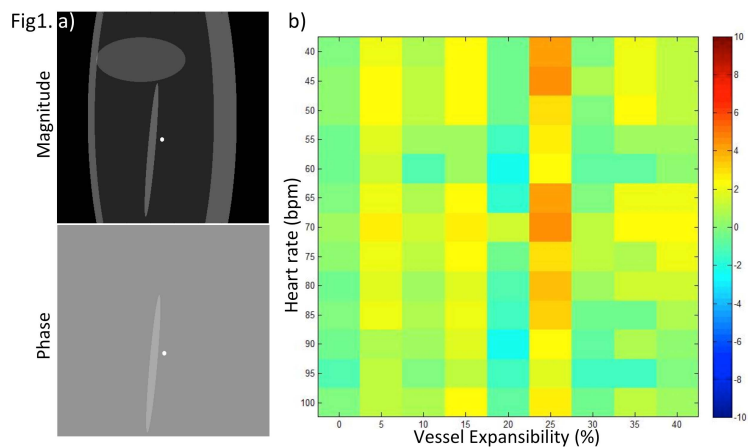
Background: Renal artery blood flow (RABF) provides important information about kidney function. Phase contrast MR (PCMR) can be used to accurately measure RABF, however due to the small size of these vessels, submillimeter spatial resolution is necessary. This results in long scan times, which are exacerbated by the necessity to use respiratory navigators or averaging. However, for most clinical purposes only mean flow is required and as the renal arteries do not translate during the cardiac cycle, this could be measured by averaging data over an integer number of r-r intervals. Such methods could significantly reduce scan times, allowing data to be collected in a single breath-hold. The purpose of this study was to investigate the possibility of using a novel golden-angle spiral PCMR sequence with r-r interval averaging to measure RABF in-vivo, and investigate the limitations of the technique in an in-silico experiment.

Methods: A golden-angle spiral PCMR sequence was developed, to allow optimal filling of k-space. A uniform-density spiral trajectory was used in kx-ky with 90 interleaves required to fill k-space. The other sequence parameters were; TE/TR: 2.0/11.9ms, matrix size: 448x448, FOV: 350x350 mm, venc: 100 cm/s. This resulted in a spatial resolution of 0.78x0.78x6mm. Data was continuously acquired over ~6 seconds (single breath-hold), with vector ECG gating used to retrospectively select data which was within a whole cardiac cycle. These data were then temporally combined and a single PCMR image was reconstructed (using SENSE). The stroke volumes (SV) measured using this technique were compared to a conventional prospectively cardiac triggered, respiratory navigated, Cartesian PCMR sequence (TE/TR: 4.6/11.8 ms, matrix size: 464x348, FOV: 300x225 mm, venc: 100 cm/s, temporal resolution: 23.4 ms, spatial resolution: 0.65x0.65x6 mm acquisition time: 5m12s ± 1m36s). Data was acquired in the left and right renal artery in 15 healthy volunteers (8M:7F, mean age: 32.0±6.8 yrs).

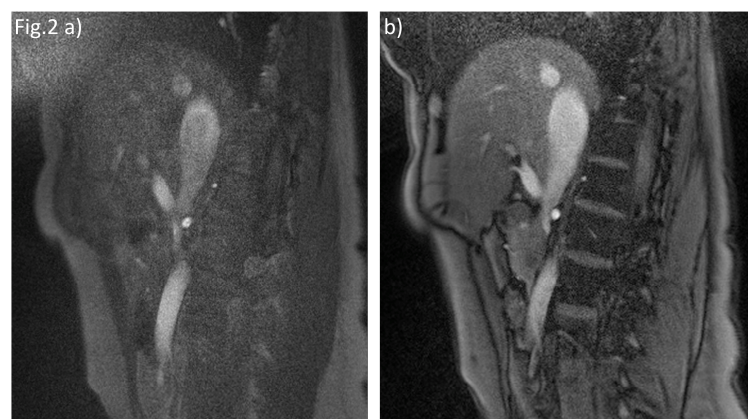
An in-silico model was designed (see fig.1a) to test the limitations of this technique. This allowed us to control the heart rate (40-100 bpm) and the vessel expansibility of the renal vessel (0-40 %) in a controlled manner. The model was sampled using the same golden-angle spiral parameters as described above, and reconstructed as in-vivo. The SV's from the r-r interval averaging spiral PCMR simulation were compared to the true SV's of the model using an automated segmentation.

Results: The results of the in-silico experiment can be seen in fig.1b. For all of the permutations of heart rate and vessel expansibility tested, the SV measured from the r-r interval averaging spiral PCMR simulation were within 6% of the true SV. The r-r interval averaging spiral PCMR method tended to marginally overestimate the SV. Increasing heart rate and vessel expansibility did not have a significant affect on the errors measured. In-vivo data was successfully acquired in 30 renal arteries (left: N=15, right: N=15), see fig.2 for image quality. The heart rate was 64±8 bpm (range:42-106 bpm) and vessel expansibility (assessed by SSFP cine) was 30±8 % (range:13-44 %). The SV measured from the r-r interval averaging spiral PCMR technique correlated well with the reference Cartesian PCMR sequence (7.46±2.25 ml vs. 7.41±2.27 ml, respectively, r=0.9906, P<0.0001, Bland-Altman: bias = -0.05, limits of agreement: -0.66 to +0.56 ml).

Conclusions: It is possible to accurately measure renal artery blood flow using a golden-angle spiral PCMR sequence with integer r-r interval averaging. This allowed sub-millimetre spatial resolution to be achieved within a single short breath-hold of ~6 seconds. This opens up the possibility of not only routine assessment of renal blood flow but also in other abdominal vessels.



In-silico experiment. a) Phantom used, b) SV percentage error comparing r-r interval averaging spiral PCMR to conventional cine PCMR



In-vivo data acquired in one volunteer from; a) conventional cine PCMR, b) r-r interval averaging spiral PCMR