Inter-study reproducibility of interleaved spiral phase velocity mapping of renal artery blood flow velocity

Jennifer Keegan[1], Hitesh Patel[1], Robin Simpson[2], Raad Mohiaddin[1,3], and David Firmin[1,3]

[1]*Royal Brompton Hospital, London, United Kingdom,* [2]*University of Freiburg, Freiburg, Germany,* [3]*Imperial College, London, United Kingdom*

Background

Renal resistive index (RI) and pulsatility index (PI) are reliable measures of downstream renal resistance which correlate with the severity of renal disease.[1] To date, breath-hold MR phase velocity mapping studies have lacked the temporal resolution required to accurately determine these pulsatility parameters. Our aim is to develop a high temporal resolution breath-hold spiral phase velocity mapping technique for assessment of the temporal flow patterns in the renal arteries and to determine its inter-study reproducibility.

Methods

An interleaved spiral phase velocity mapping sequence was developed on a 3T Skyra scanner (Siemens) using 1-1 water excitation and with full k-space coverage in 8 spiral interleaves of 12 ms duration. Phase map subtraction of datasets with symmetric bi-polar velocity encoding gradients resulted in velocity maps with a through-plane phase sensitivity of +/- 150cm/s. Retrospectively ECG gated data were acquired in a 17 cardiac cycle breath-hold (includes 1 dummy cycle) with a spatial resolution of 1.4 x 1.4 mm (reconstructed to 0.7 x 0.7 mm) and a repeat time 19 ms. Renal artery velocity maps were acquired in 10 healthy volunteers (10 left and 10 right arteries). Data were acquired in each of two separate scanning sessions with the volunteer leaving the scanner between sessions. For each acquisition (40 in total), RI and PI were calculated by 2 observers as follows:

$$RI = (PSV - MDV) / PSV \qquad\qquad PI = (PSV - MDV) / MV$$

where PSV = peak systolic velocity, MDV = minimum diastolic velocity and MV = mean velocity through the cardiac cycle.

Renal artery blood flow (RABF) per kidney was also calculated. Background phase errors were determined (i) by fitting a background phase map to user defined stationary points in the inter-vertebral disks and (ii) from a large stationary phantom imaged in the same orientation with the same parameters as the corresponding in vivo study. Inter-observer and inter-study reproducibility of RI, PI and RABF were determined as the mean (+/- standard deviation) of the paired differences between observers and between scanning sessions respectively, and by the intraclass correlation coefficient (ICC).

Results

Figure 1 shows example data in the left and right renal arteries. RI, PI and RABF per kidney were 0.71+/- 0.06, 1.47 +/- 0.29 and 413 +/- 122 ml/min respectively. Inter-observer and inter-study reproducibilities are shown in the Bland Alman plots of Figure 2. The inter-study reproducibilities were: RI 0.00 +/- 0.04, PI -0.03 +/- 0.17, and RABF per kidney 17.9 +/- 44.8 ml/min. Inter-study ICCs (observers 1 and 2 respectively) were 0.87 and 0.86 (RI), 0.92 and 0.93 (PI) and 0.96 and 0.95 (RABF). Correction for background phase errors resulted in minimal changes (<2% for each parameter).

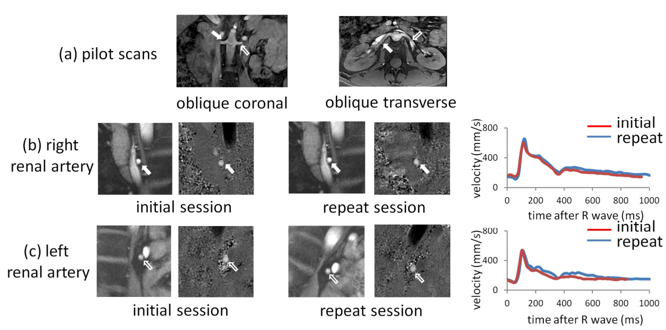

Figure 1: *Example pilot scans (a) showing the proximal renal arteries together with systolic magnitude images and velocity maps in the initial and repeat scanning sessions and the temporal patterns of flow velocity through the cardiac cycle for the proximal right (solid arrows) (b) and left (open arrows) (c) renal arteries respectively.*

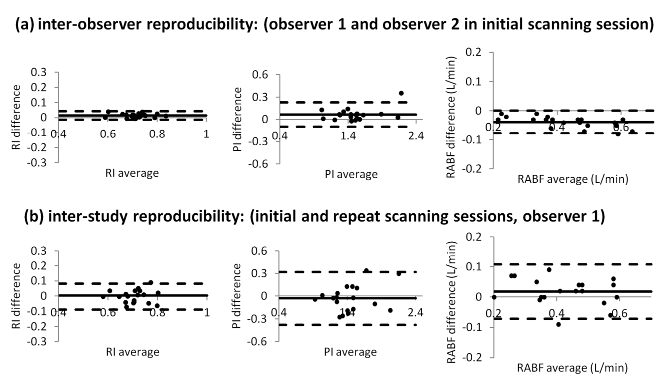

Figure 2: *Inter-observer (a) and inter-study (b) Bland Altman plots of resistive index (RI), pulsatility index (PI) and renal artery blood flow (RABF) per kidney in 10 healthy volunteers. For each plot, the solid horizontal line shows the mean difference and the dotted lines show the 95% limits of agreement (+/- 2SD) between observers (a) and between scanning sessions (b).*

Discussion and Conclusion

High temporal resolution (19 ms) breath-hold spiral phase velocity mapping allows reproducible assessment of renal pulsatility indices and RABF. Background phase errors are minimal and their correction unnecessary. We conclude that this technique is suitable for studying temporal flow velocity patterns in the renal arteries and would be useful to clinical trialists assessing the effects of minimally invasive interventions such as renal denervation and renal artery stenting upon renal perfusion.

References

[1]Tublin ME, Bude RO, Platt JF. AJR 2003; 180: 885 – 892.