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Aortic 4D flow: quantifying the effects of contrast and field strength at 1.5 T, 3T and 7T

Aaron T Hess*, Malenka M Bissell, Andrew Lewis, Ntobeko A Ntusi, Jane M Francis, Saul G Myerson, Stefan Neubauer, Matthew D Robson

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Background

4D flow is a promising new method for assessment of aortic pathology, but is limited by signal-to-noise ratio (SNR) leading to long acquisition times. Higher field strength may prove a solution. SNR in aortic 4D flow increases at 3T versus 1.5T (Strecker et al, JMRI 2012) and further by adding a contrast agent (Bock et al, MRM 2010). This work extends this comparison to human 7 Tesla and quantifies the field strength dependent effects of contrast agents.

Methods

Four healthy male volunteers were scanned six times: both with and without contrast (MultiHance, Braco, Milano, Italy) at each field 1.5 T, 3 T, and 7 T. All scans were acquired within four weeks and on Siemens scanners. Identical protocols were used, TR/TE 4.33/2.5 ms, temporal resolution 52 ms, bandwidth 1502 Hz/pixel, matrix 192 × 124 × 24, field of view 384 × 310 × 60 mm^3, resolution 2.0 × 2.5 × 2.5 mm^3, flip angle 7°, segmentation 3, GRAPPA 2, VENC 150 cm/s. At 7 T no RF spoiling was employed and a flip angle post B1 shimming ranging from 5° to 7° through the aorta. 7 T scans employed dynamic B1 shimming alternating between navigator and aorta specific shim. SNR was calculated by taking the difference of two symmetrically flow-encoded in one direction magnitude images (enc1 and enc3). SNR($\mathbf{r}$) = mean(enc1($\mathbf{r}$, t) + enc3($\mathbf{r}$, t))/√2 (std (enc1($\mathbf{r}$, t) - enc3($\mathbf{r}$, t))), $\mathbf{r}$ is the spatial coordinate and t are the temporal frames during diastole. SNR was assessed in the descending aorta over a 40 × 7.5 mm^2 × aorta diameter ROI centered 60 mm below the midpoint of the aortic arch.

Results

SNR for each of the six scans for each subject are plotted and a set of stream lines seeded in the LV (7 T data) are shown. The mean ± SD increase in SNR due to contrast agent is 1.8 ± 0.2, 1.8 ± 0.5 and 1.4 ± 0.2 for 1.5 T, 3 T and 7 T respectively. The mean ± SD increase in SNR due to field strength without and with the contrast agent is 1.8 ± 0.4 and 1.7 ± 0.1 for 1.5 T to 3 T and 2.1 ± 0.7 and 1.7 ± 0.4 for 3 T to 7 T. The average difference in peak net flow rate at the same location in descending aorta at 7 T compared to 3 T was 7 ± 7 ml/s. Of interest is that increases in SNR by stepping up in field strength are comparable to the increase from contrast.

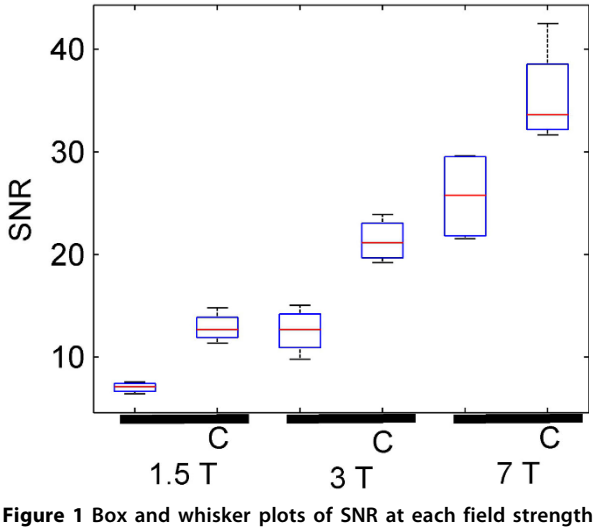

Figure 1 Box and whisker plots of SNR at each field strength in the descending aorta at 1.5 T, 3 T, and 7 T both without and with a contrast agent (C).

University of Oxford Centre for Clinical Magnetic Resonance Research, Oxford, UK

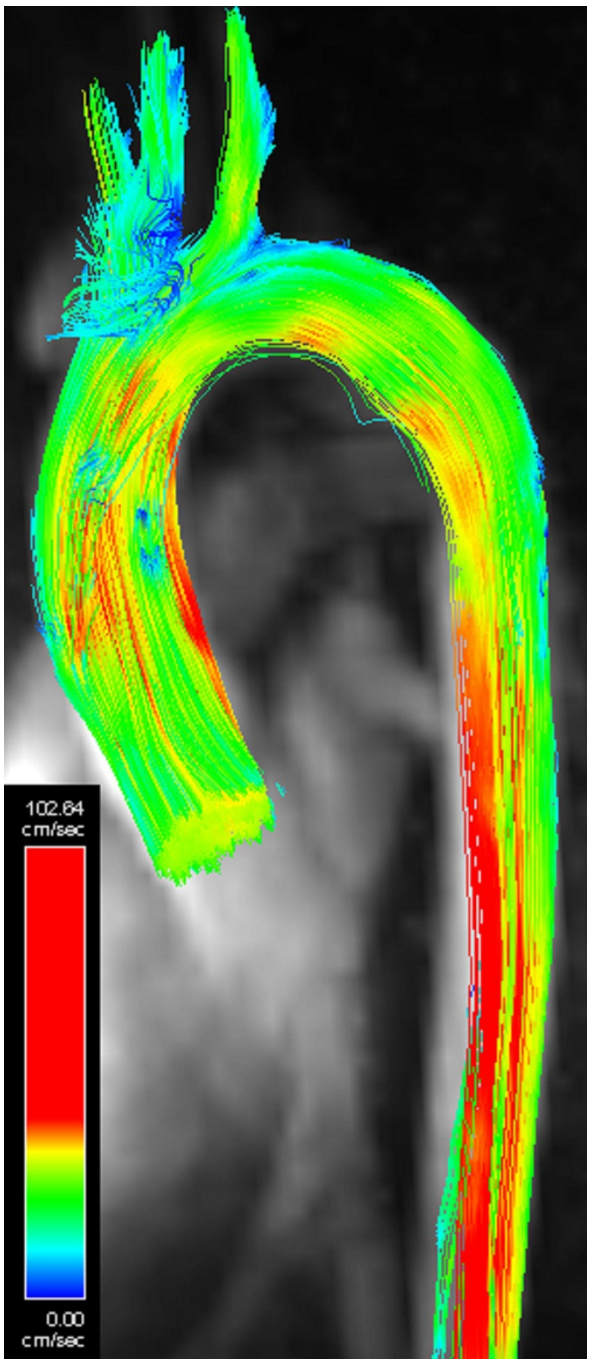

Figure 2 Streamlines generated from a 7 T scan with contrast using software from Siemens and by seeding the streamlines in the left ventricle at 155 ms after the ECG R wave.

Conclusions

4D aortic flow is feasible at 7 Tesla and yields substantial SNR improvements over lower field strengths. Future work will exploit this higher SNR to explore improved spatial and/or temporal resolution.

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