Scaled-Up Coronary Flow Measurement using Phase-Contrast MRI

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Aim - To measure coronary flow using dynamically scaled phantom flow with phase-contrast MRI (PC-MRI)

Methods

1) Three left main coronary patient bifurcations with 33°, 72° and 110° bifurcation angle (mean and ±2SD of the first principal mode of variation of 300 asymptomatic patients) were digitalised from CTA

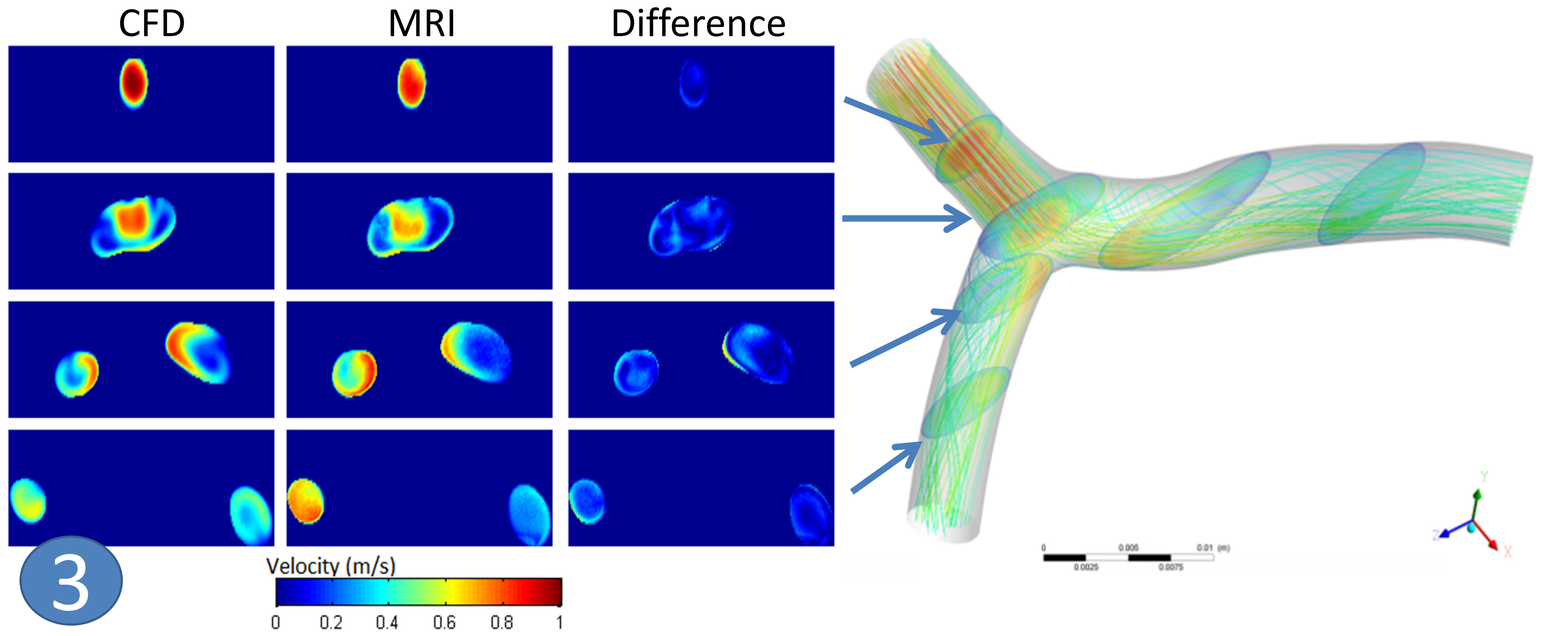
2) These were scaled-up 7x, 3D printed, and their flow was replicated using dynamically scaled blood-liked flow circuit

3) Velocity inlet profiles measured with PC-MRI were scaled and prescribed as boundary condition of identical, but true-scale CFD for comparison

1 - Coronary angiogram cases were segmented (OsiriX, 0.4mm^3), to create digital left main geometries.
2 - These were scaled-up, 3D printed and incorporated into a pump-flow circuit with blood-like fluid, for velocity measurement with PC-MRI.

Results

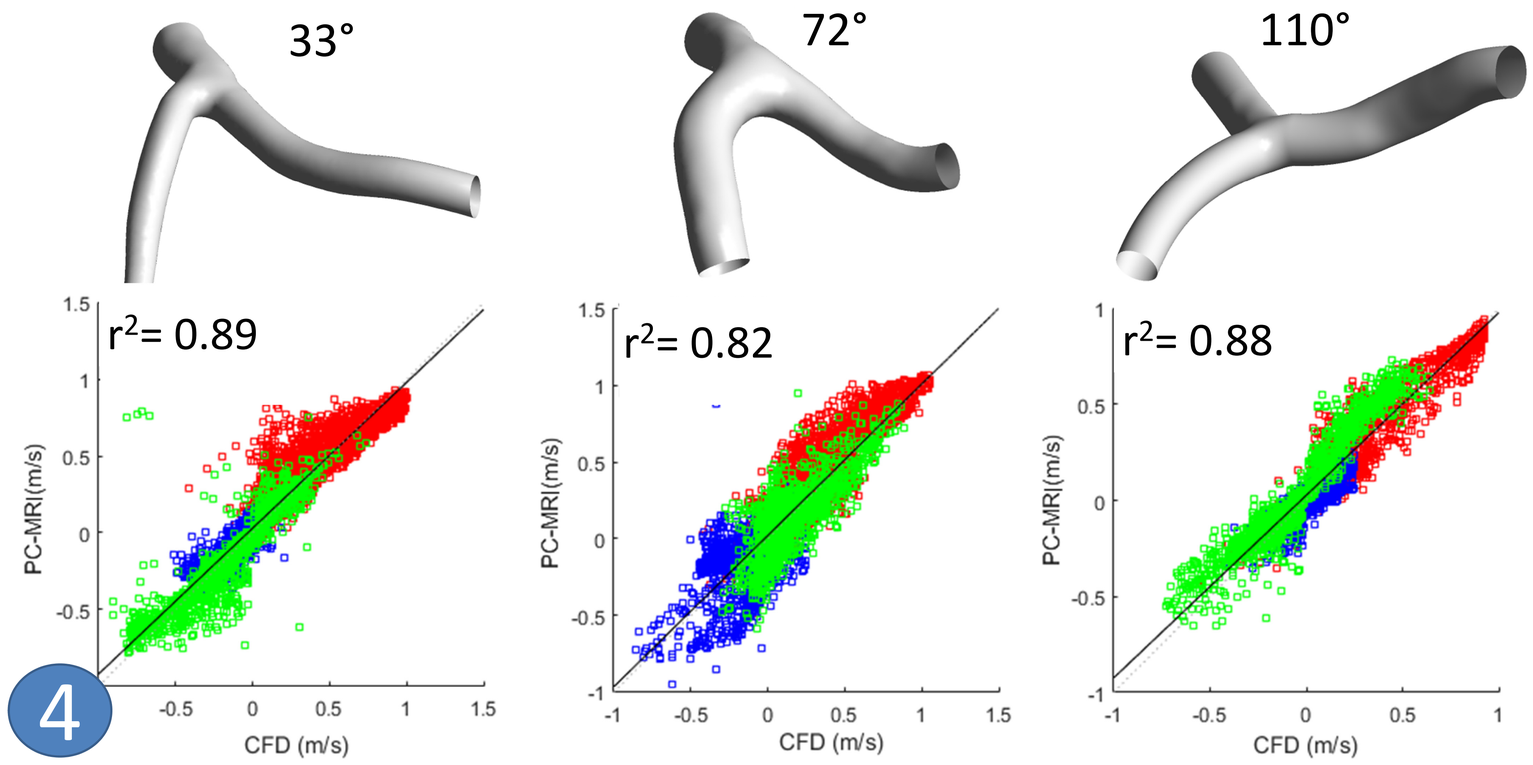
4) Good co-registration covariance σ^2<5e-6 yielded small differences in velocity magnitude (2-12% and ρ≥ 0.72), and a good directional agreement with r^2 between 0.82 and 0.89



3 - (i) 110° Patient bifurcation flow contours from computational fluid dynamics (CFD, left), PC-MRI (middle) and their difference (right) in (ii) four planes of the 3D flow field volume, shown with streamlines.

Discussion

- Agreement was best in regions with high velocities (vessel shape dependent) due to higher signal-to-noise-ratio (SNR)
- Larger discrepancies were found in regions of slow and oscillating flow (lateral walls) and close to the wall (PC-MRI over-estimated wall velocities due to partial voluming)



4 - Patient bifurcation with 33°, 72° and 110° bifurcation angle (left to right, top) and their velocity components directional correlation (green- main flow, blue - anterior-posterior, red- branch direction) with Pearson correlation.

Conclusions

We have developed a new method to quantify coronary haemodynamics by combining scaled-up phantom PC-MRI flow with CFD simulations. With this methodology, PC-MRI measurements can be used validate CFD and inform boundary conditions to ultimate improve the haemodynamic study of stent design, coronary artery risk assessment and clinical practise.

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