Project update: Simulation results from first 20 patient data.

David Tranter

University of Exeter

21/05/2013

Since the last meeting:

Since the last meeting

20 of the 35 dicom images processed

Investigation of simple time independent simulations versus complicated time dependent simulations

Attempt made at trying to model a pressure sensor inside the coronary artery for study

Discussion of time dependent simulations

Time dependent simulations

For our time dependent simulations we would need to run two simulations, rest and hyperaemia, in order to obtain an FFR reading.

Comparing two different simulations means that we need to have physically accurate numerical data to describe the inflow/outflow of our model.

Discussion of time dependent simulations

Time dependent simulations

However, data for velocity/pressure is patient specific.

A wide range of feasible velocity/pressure values exist in the coronary network.

During hyperaemia the coronary arteries dilate which affect the flowrate/pressure distributions in the model. The amount of dilation that occurs in the network under the effects of adenosine also varies widely amongst different people.

With such sensitivity to the boundary conditions, our time dependent simulations are thus unreliable.

Discussion of time dependent simulations

Time dependent simulations

At HeartFlow the approach is to represent all outflow regions as an electrical circuit in series, with each vessel having its own resistance value.

These resistance values were found empirically and are the same for each simulation, resulting in a 'one size fits all' physiological model. The values of resistance during hyperaemia are the same for each patient even though the behaviour of the vessel radius under the effects of adenosine can vary widely.

"reductions in resistance due to adenosine-mediated hyperemia will vary amongst patients." [4]

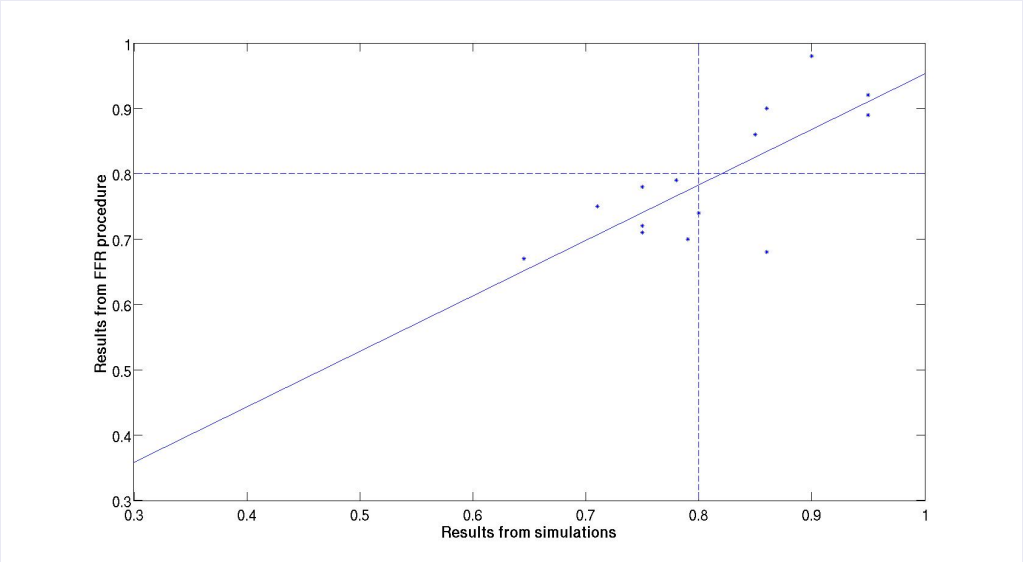
Discussion of time independent simulations

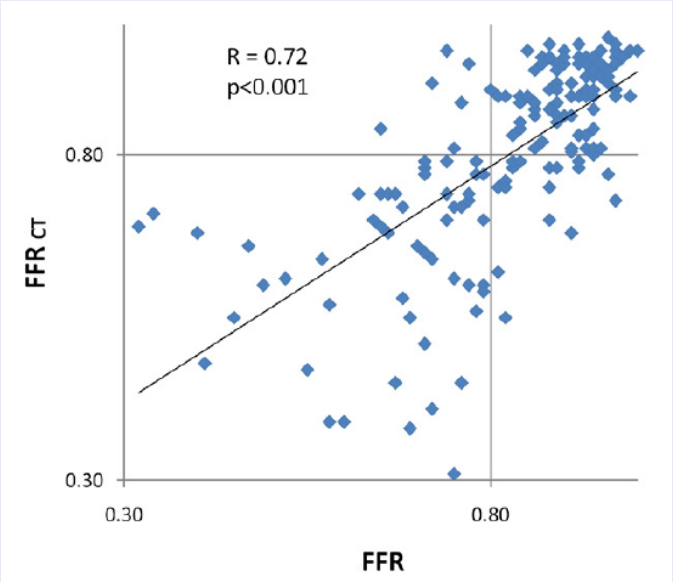
Time independent simulations

We are simply measuring the severity of the stenosis by seeing the local pressure drop attributed by the geometry of the stenosis which can be accurately represented by ScanIP i.e we are not taking physiological or transient effects into account.

However the agreement between the two is encouragingly good.

Discussion of time independent simulations





The left figure shows the initial results from our simple simulations and on the right is the DISCOVER-FLOW study sponsored by HeartFlow. The results from our simple simulations are in good agreement with the procedural results. Furthermore the accuracy seems to be just as good as the DISCOVER-FLOW/De-FACTO study. However, we currently have a much smaller data set.

Discussion of time independent simulations

Time independent simulations

In our simple calculations we have a good true positive/negative agreement. The simulations will tend to underestimate the FFR value however, this makes sense since we are not including physiological effects. I have chosen not to include 6 data because the scans are of a difficult quality. This means it is impossible to isolate the artery and to represent the stenosis with confidence.

Discussion of time independent simulations

Time independent simulations

The HeartFlow sponsored study apply a linear fit to their results and get an R value of 0.72. Doing the same on our current data gets an R value of 0.75.

If we obtain an R value against a curve of y=x, which seems more appropriate, we get an R value of 0.72. This suggests that our simple calculations might be just as good as the HeartFlow calculations. However, we still have some more data to process.

Discussion of time independent simulations

Table 3. No. of Patients With FFR_{CT} and FFR Above and Below the 0.80 Threshold in the Intention-to-Diagnose Sample

	Per-Vessel Performance		Per-Patient Performance	
	$FFR_{CT} \leq 0.80$	$FFR_{CT} > 0.80$	$FFR_{CT} \leq 0.80$	$FFR_{CT} > 0.80$
FFR ≤0.80	121	30	116	13
FFR >0.80	96	160	56	67

Abbreviations: FFR, fractional flow reserve; FFR_{CT}, fractional flow reserve calculated from computed tomography.

Diagnostical accuracy from latest HeartFlow trial.

Conclusion

- Sensitivity to the boundary conditions, along with the high variability of coronary velocity/pressure, make time dependent simulations not feasible.
- Time independent simulations seem to be just as accurate and with dramatically reduced computational cost.
- The rest of the data available needs to be processed to see if the trend continues.

Future developments

- Persevere with CAD implant of pressure sensor.
- Process last batch of data and write up results.
- Begin work on semi-automated workflow in ScanIP to OpenFOAM.

References

Hozumi, Takeshi, et al

"Noninvasive assessment of significant left anterior descending coronary artery stenosis by coronary flow velocity reserve with transthoracic color Doppler echocardiography."

Circulation 97.16 (1998): 1557-1562.

Koo, Bon-Kwon, et al

"Diagnosis of ischemia-causing coronary stenoses by noninvasive fractional flow reserve computed from coronary computed tomographic angiograms Results from the prospective multicenter DISCOVER-FLOW."

Journal of the American College of Cardiology 58.19 (2011): 1989-1997

Kim, H. J., et al.

"Patient-specific modeling of blood flow and pressure in human coronary arteries"

Annals of biomedical engineering 38.10 (2010): 3195-3209.

Taylor, C.A., Fonte, T.A., Min, J.K

"Computational Fluid Dynamics Applied to Cardiac CT for Noninvasive Quantification of Fractional Flow"

Journal of the American College of Cardiology (2013), doi: 10.1016/j.jacc.2012.11.083.