Computational Fluid Dynamics Modelling for Medical Applications

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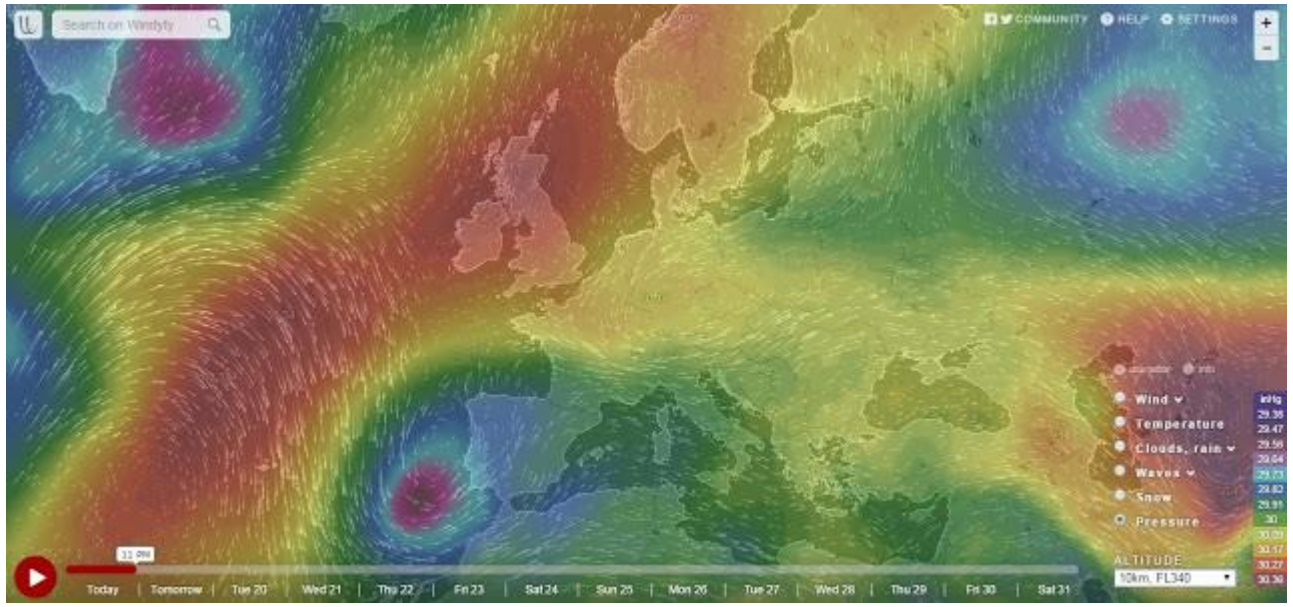
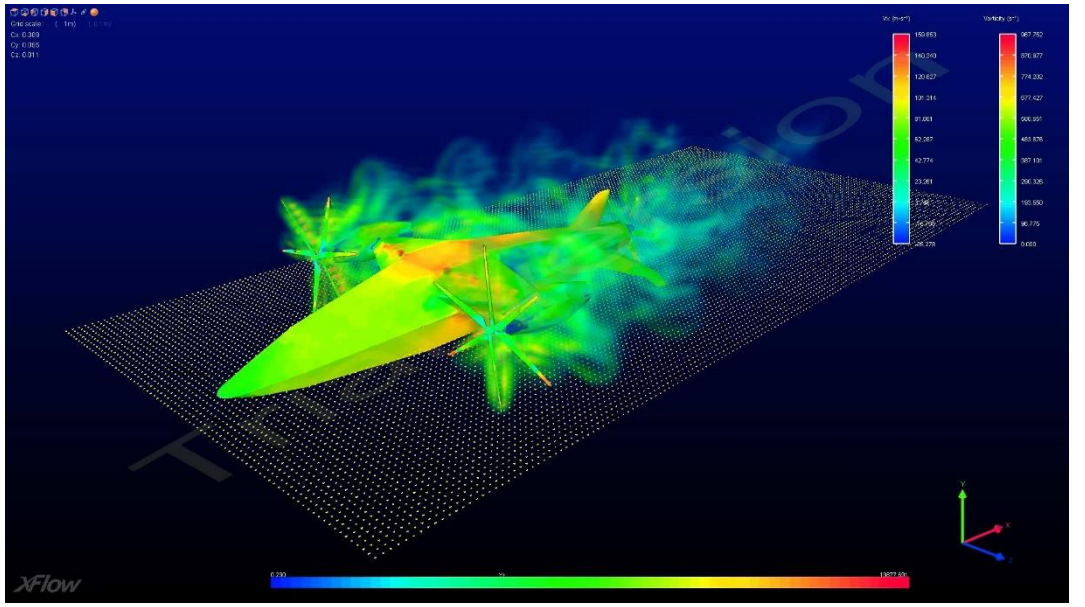
Computational Fluid Dynamics (CFD)





Navier Stokes Equations – Continuity and Momentum Equations

Equations describing flow of all fluids (liquids and gases)

Improved understanding of flows in complex setups

Solved iteratively using computing resources

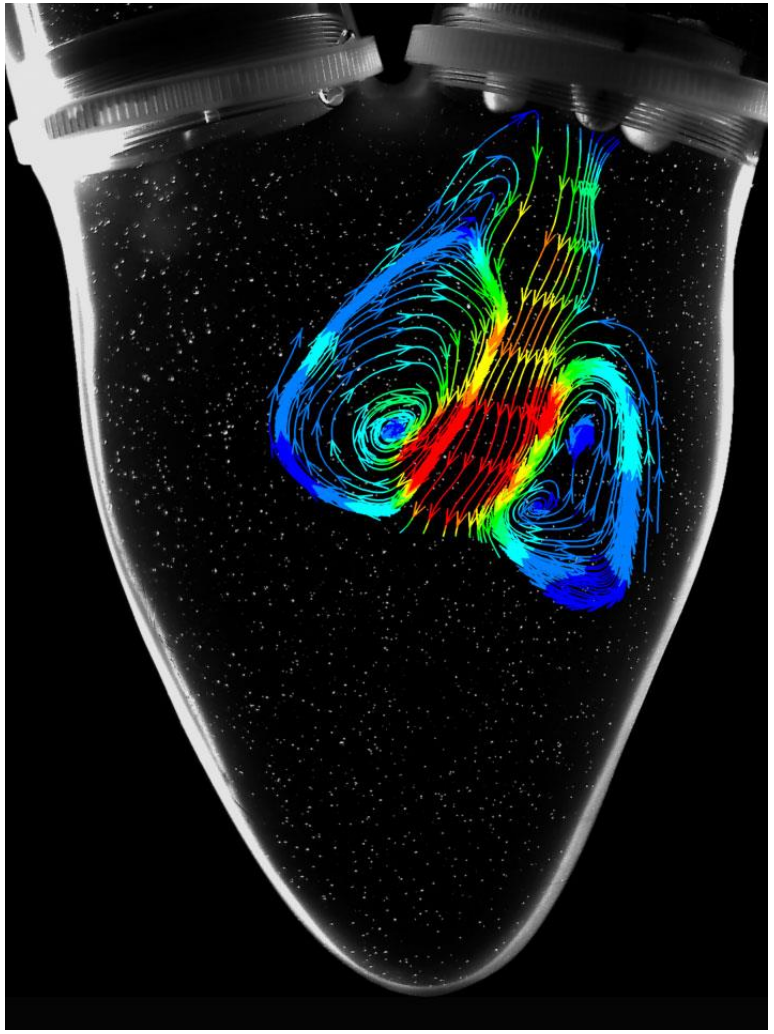
Computational Fluid Dynamics (CFD)

Solution of the equations over a flow field

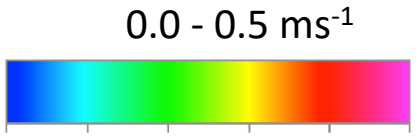
Velocity

Pressure

Balance between accuracy/level of detail and computational cost



Existing Medical Applications of CFD



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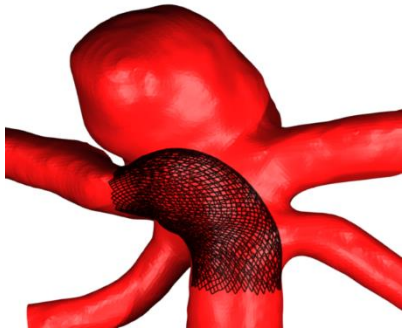
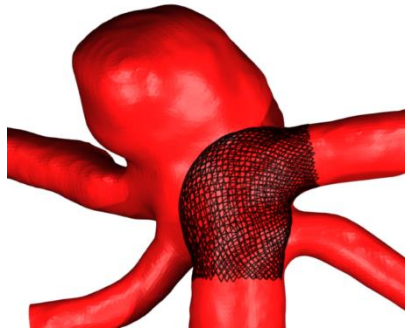
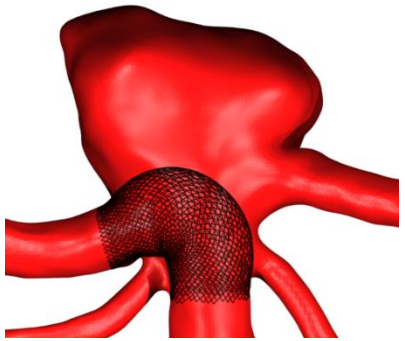
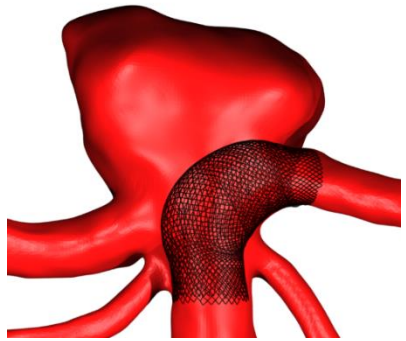
case 1		
case 2		

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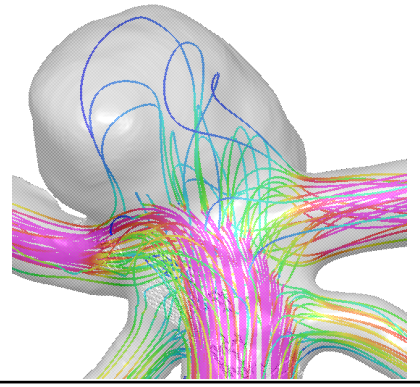
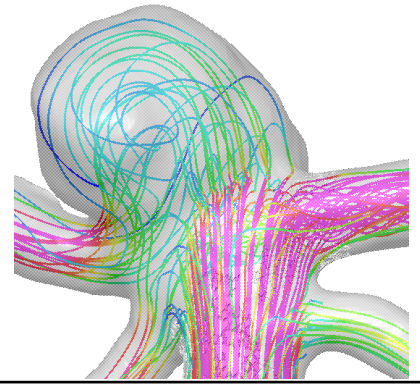
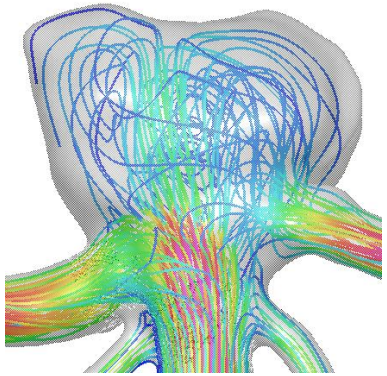
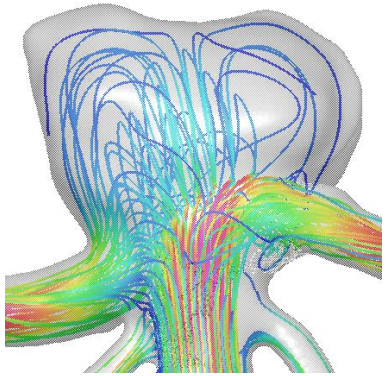
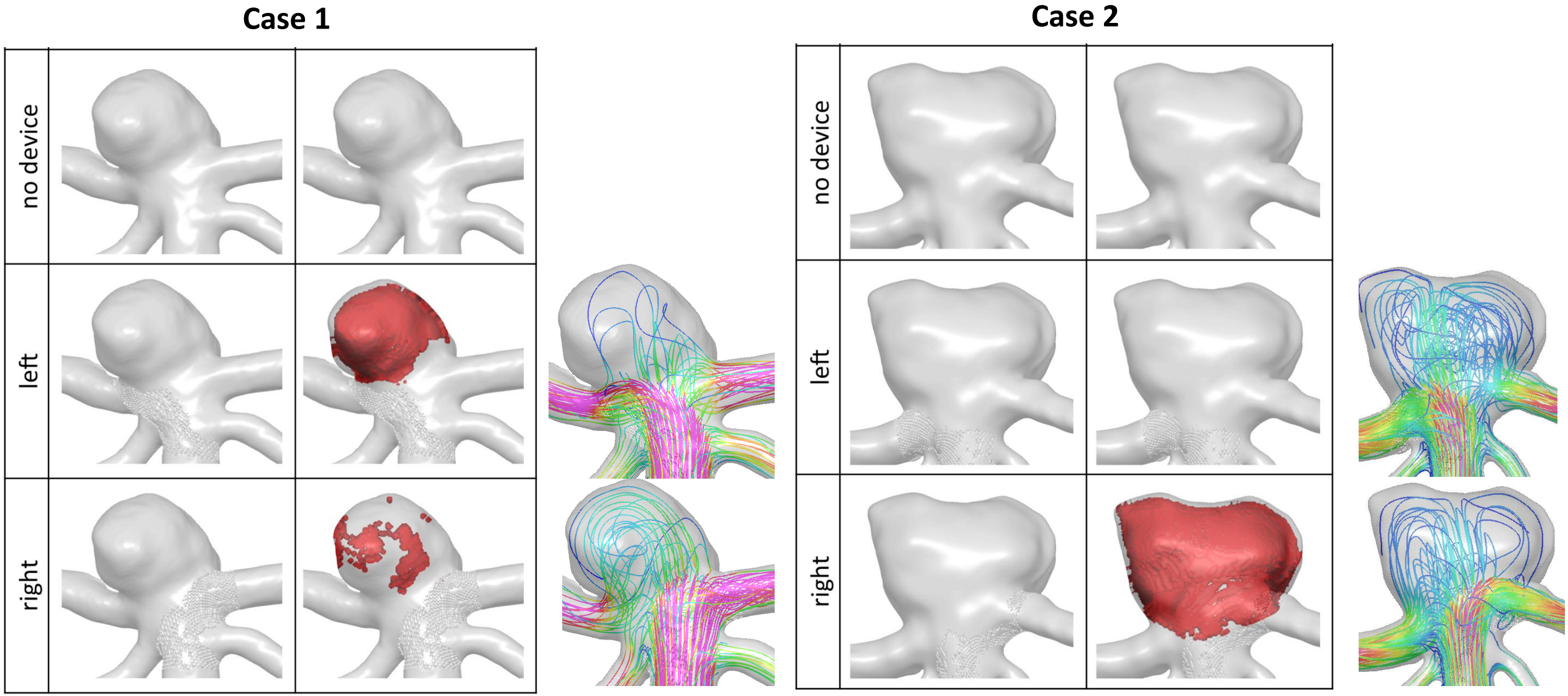
case 1		
case 2		

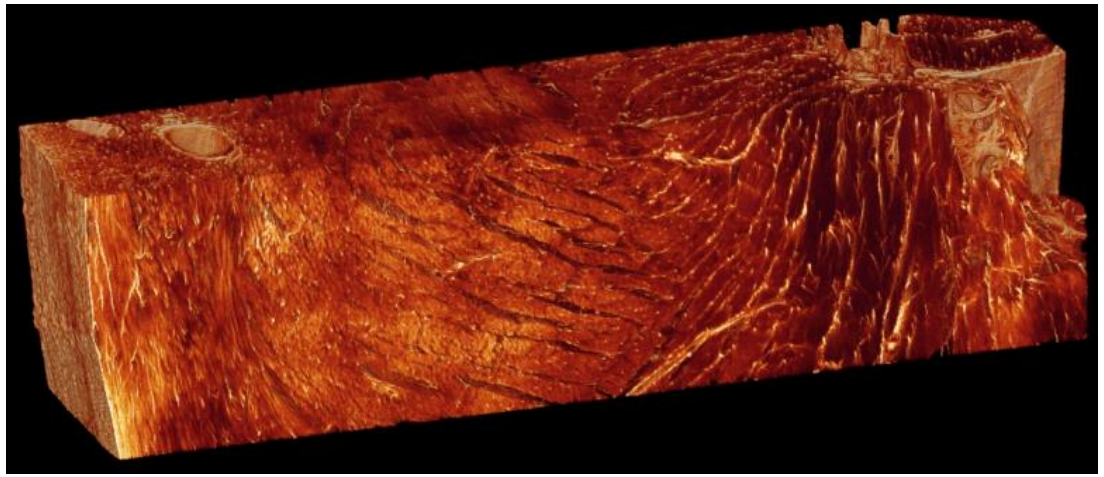
Examining how stent placement affects local haemodynamics in patient-specific aneurysm bifurcations

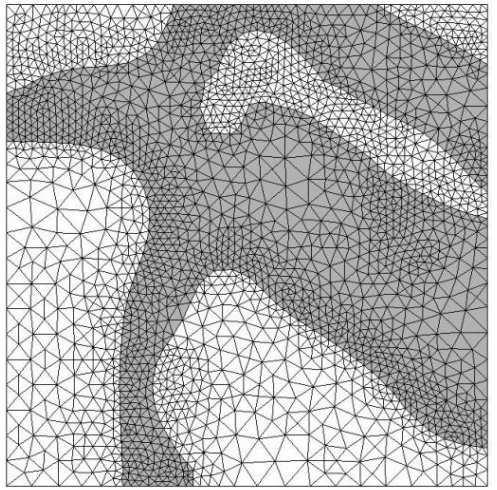
Existing Medical Applications of CFD



Examining how stent placement affects thrombosis in patient-specific aneurysm bifurcations

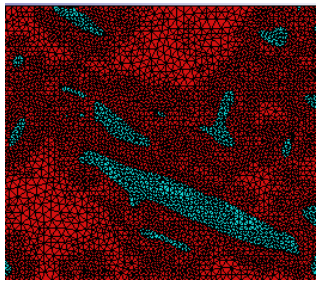
Existing Medical Applications of CFD



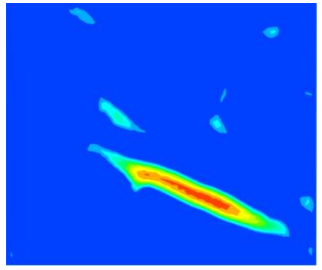


Examining flow of hydrogel in myocardial tissue for the development injectate therapies for myocardial infarction

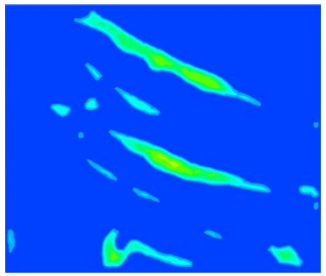
Existing Medical Applications of CFD



Mesh



Block 1 Inlet



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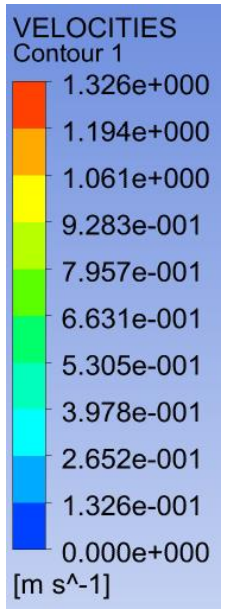

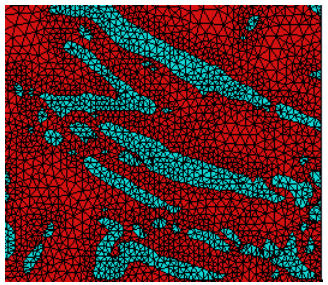

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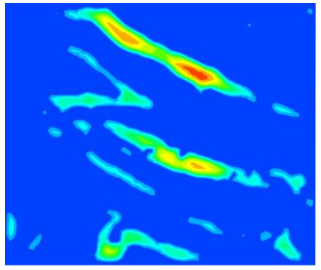

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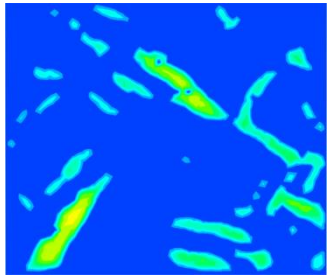

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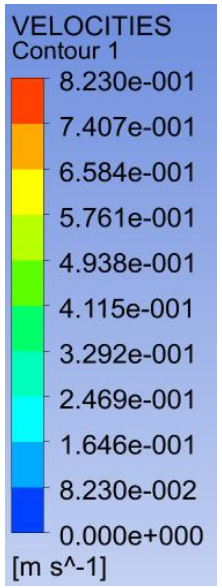

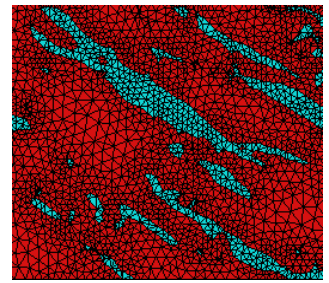

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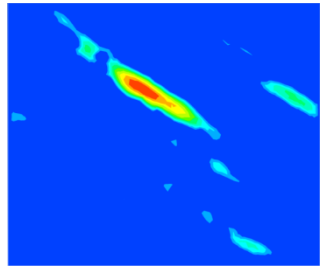
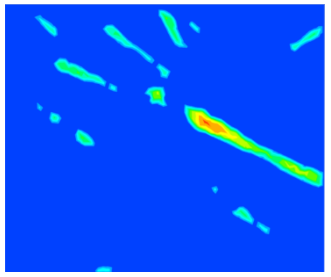
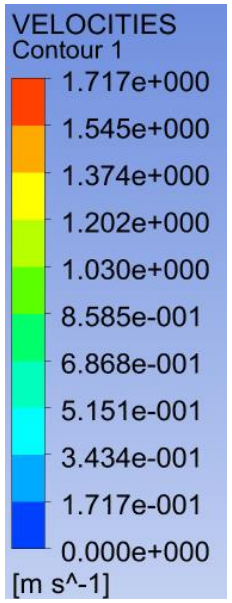


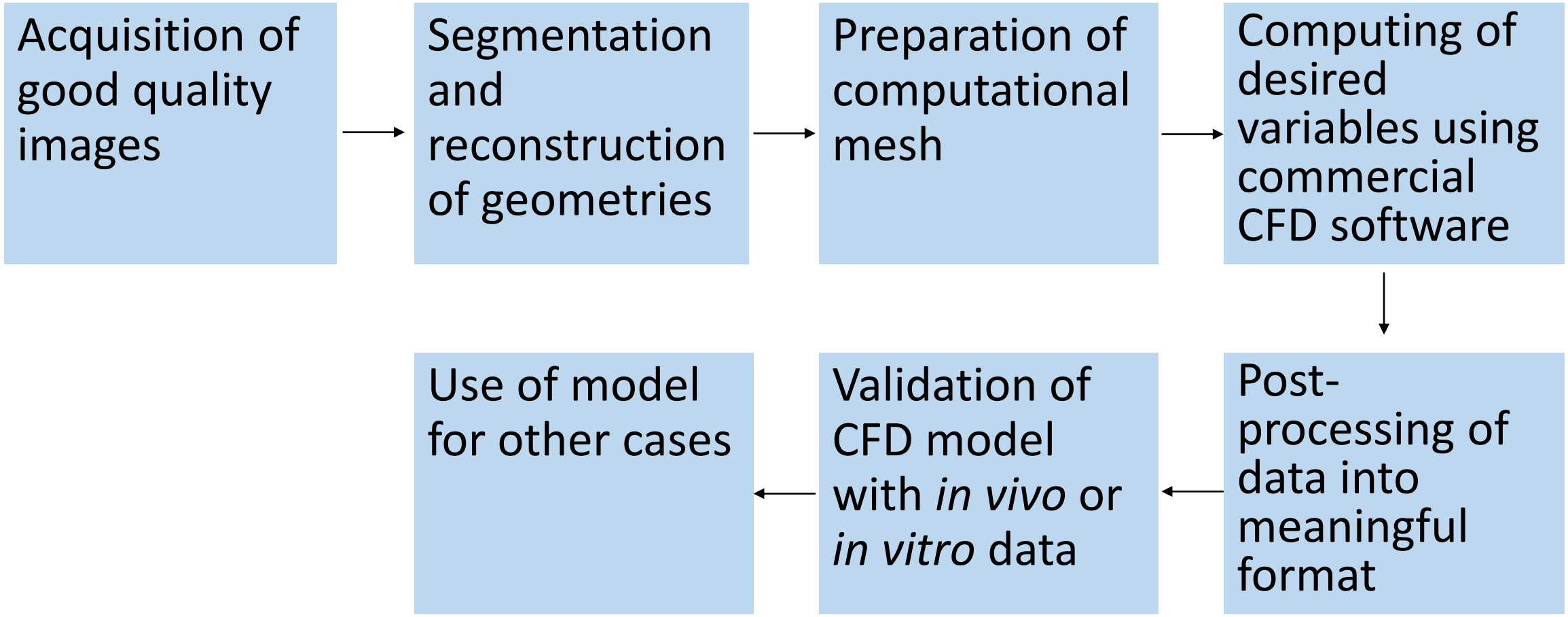
Block 3 Inlet



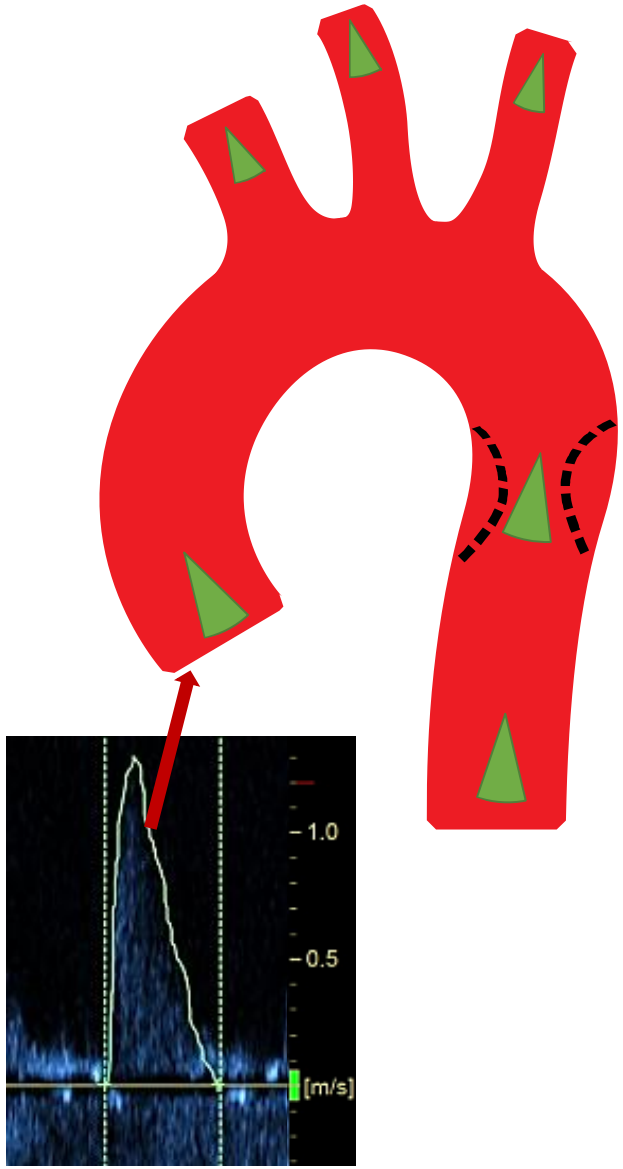
Block 3 Outlet



CFD Model Development



Imaging and data acquisition



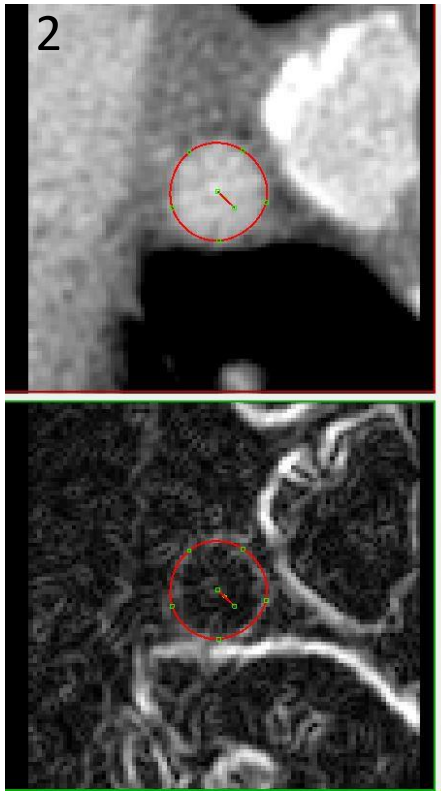
KEY PIECES OF INFORMATION FOR PATIENT-SPECIFIC SIMULATIONS:

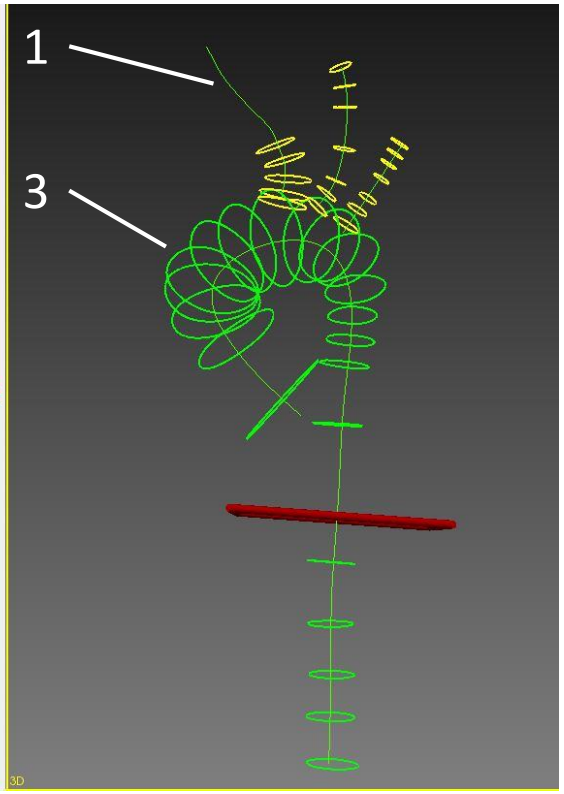
1. **3D Geometry data**
2. **Velocity or Pressure Data**

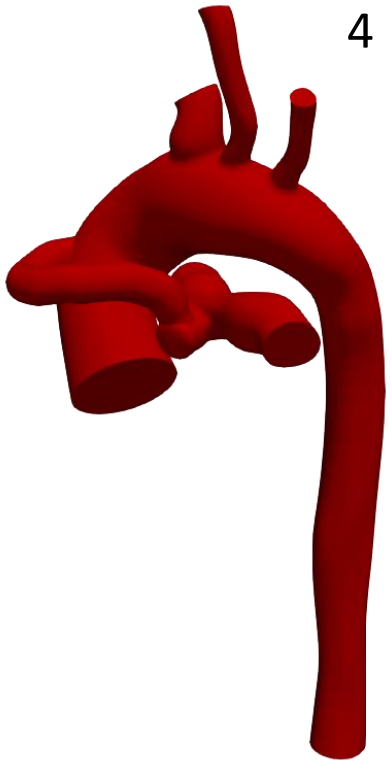
- Geometry data needs to be able to give information in all 3 dimensions
- Velocity data is easier and less invasive to obtain

Segmentation

1. Establish artery path
2. Identify region of interest (ROI) on a slice
3. Apply a segmentation method
4. Generate Geometry

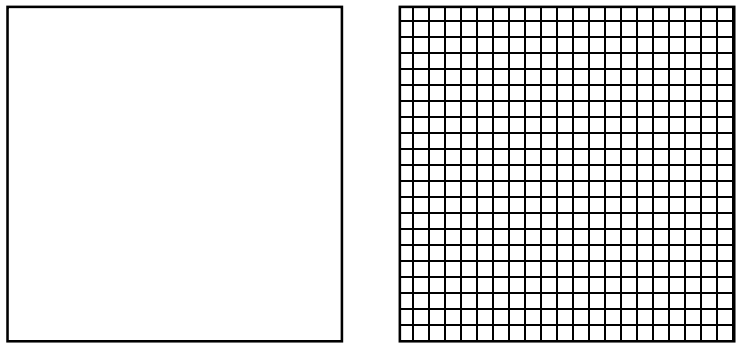






Meshing

- A mesh approximates a shape by discretising it into a number of small **control volumes**
- The accuracy of the answer depends on how fine the mesh is



Schematic of volume meshing

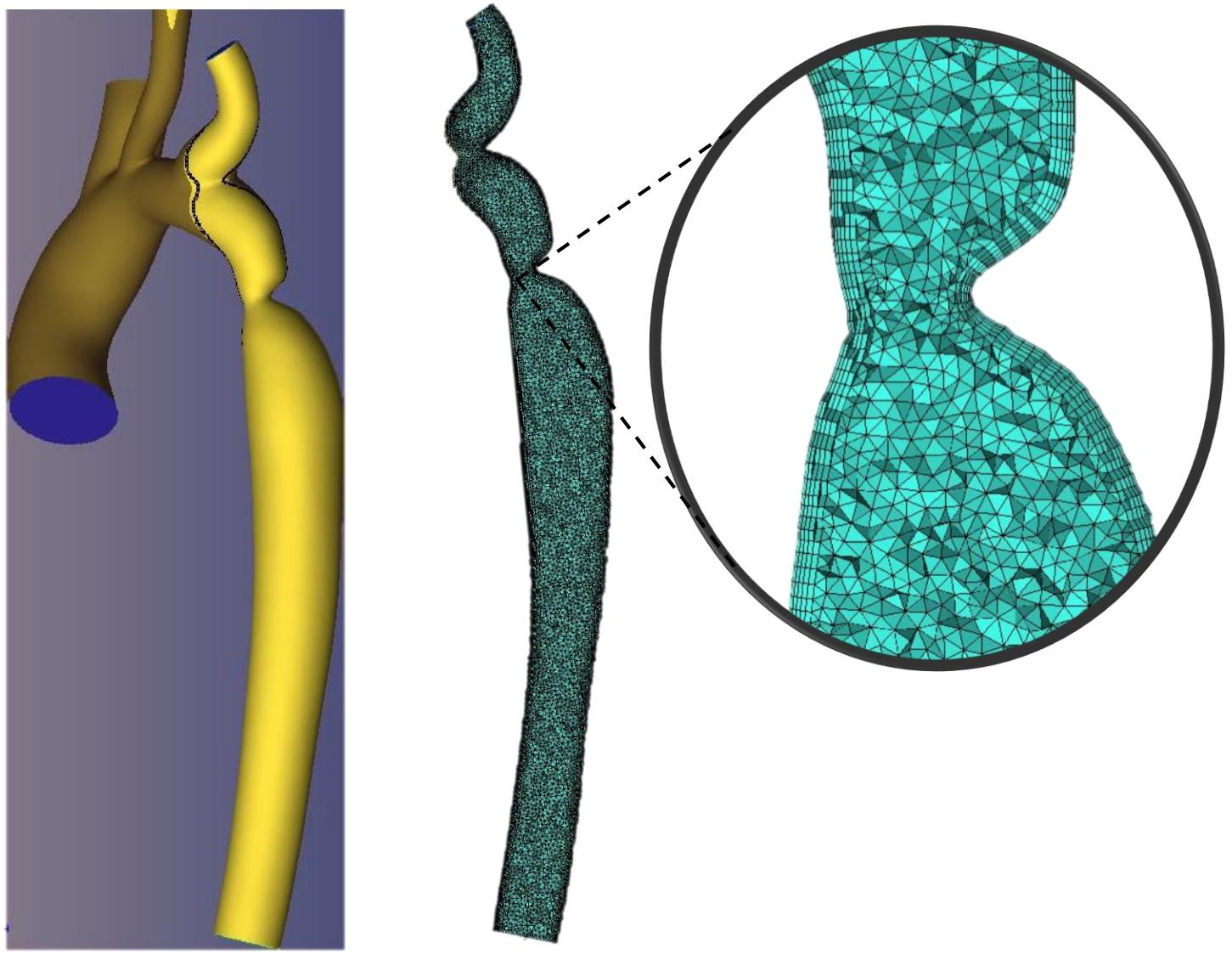
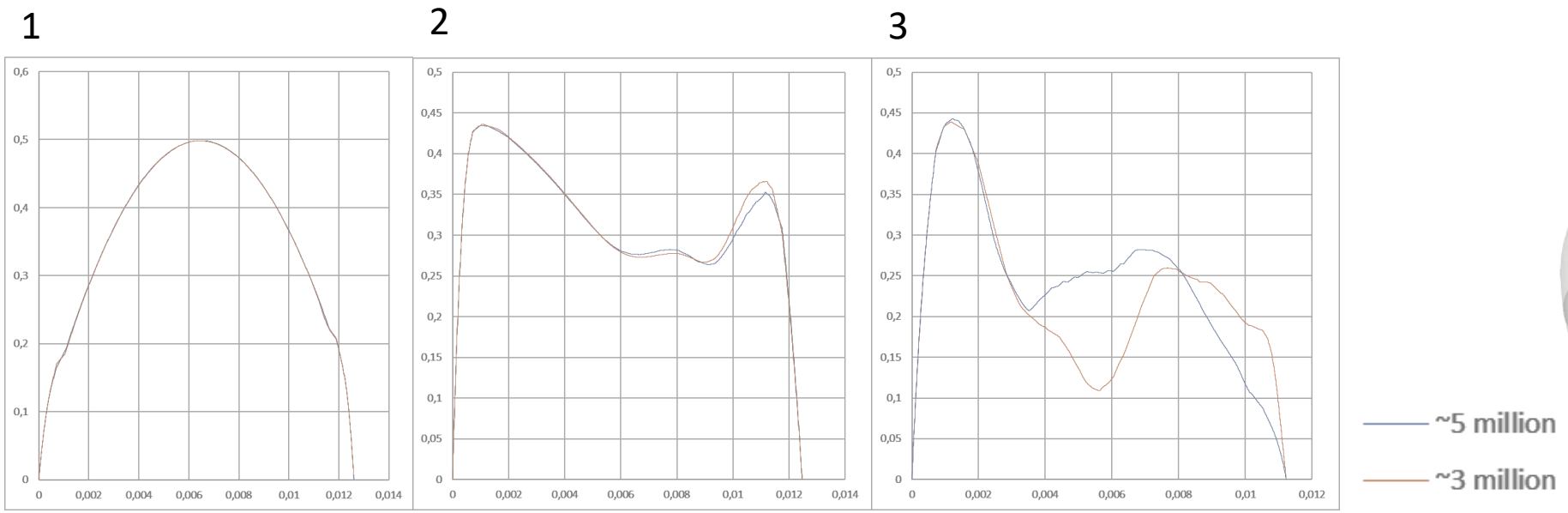
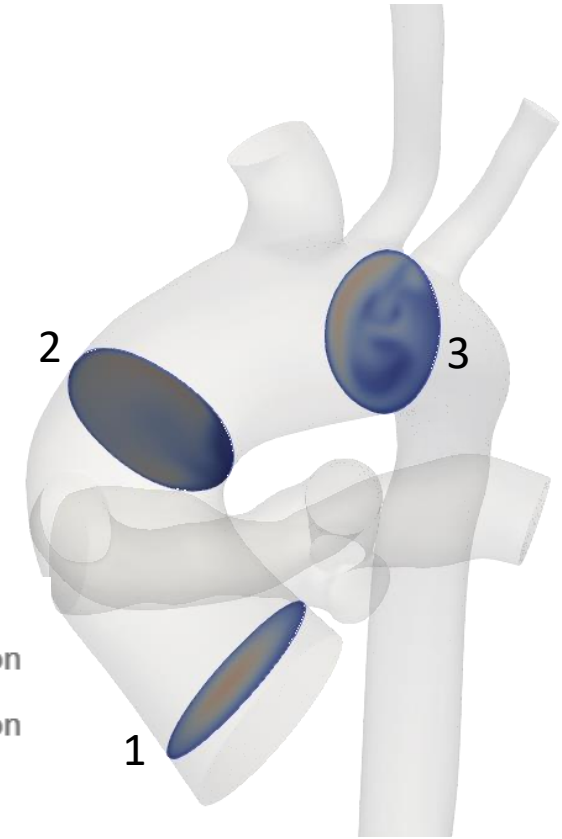


Diagram showing meshing at a point in a coarctation model

Meshing CTD

- A mesh must be fine enough to accurately capture the detail of the fluid flow.





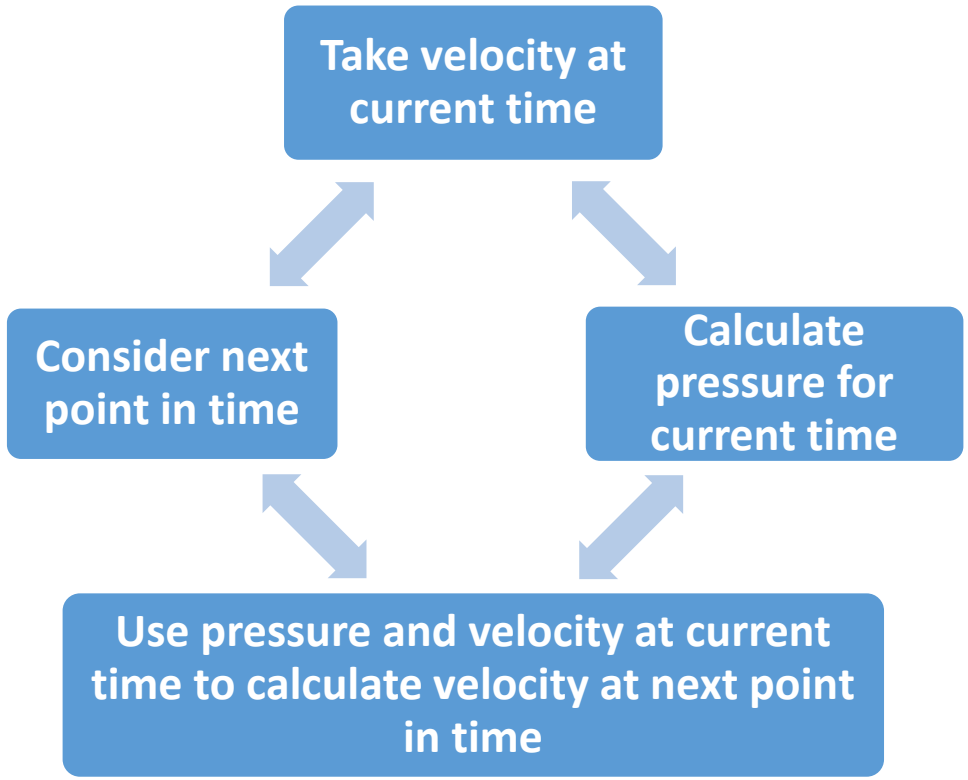
Grid independence studying results and a diagrammatic representation of location

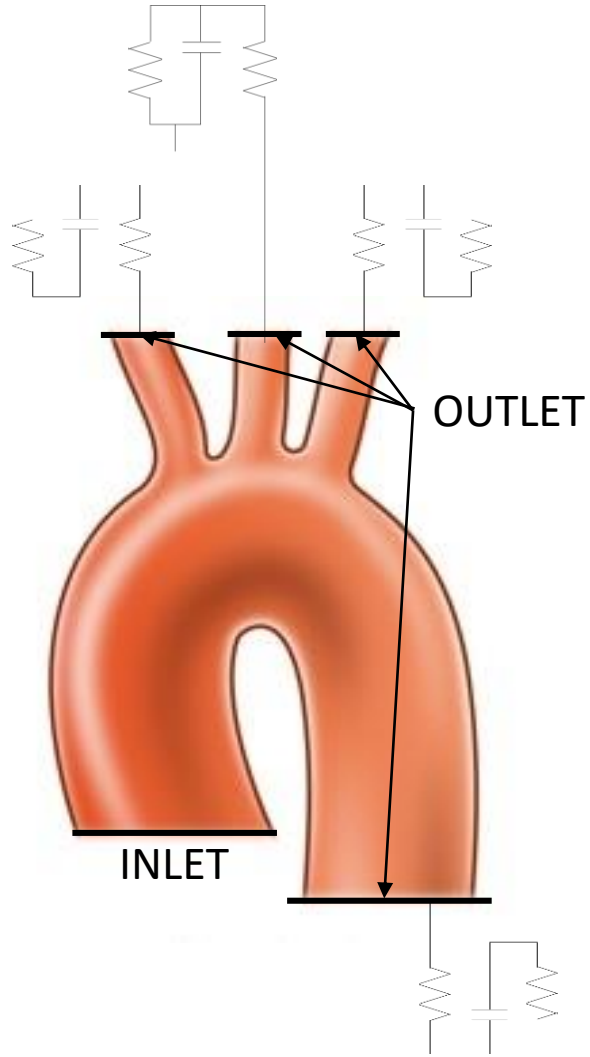
Simulation

- **Apply Boundary conditions**

- Velocity or Pressure and the outlets and inlets

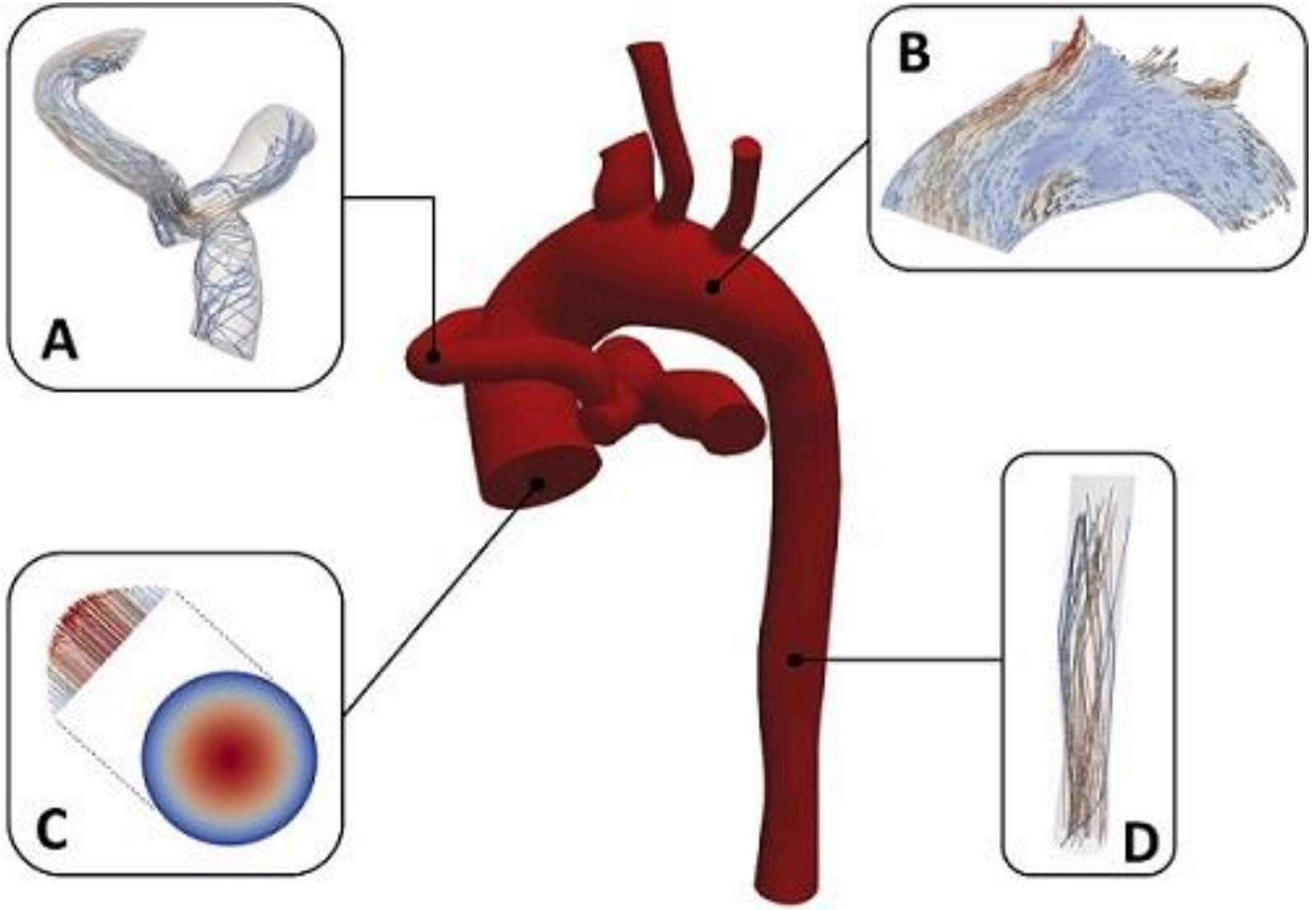
- **Numerically Solve for Velocity and Pressure**



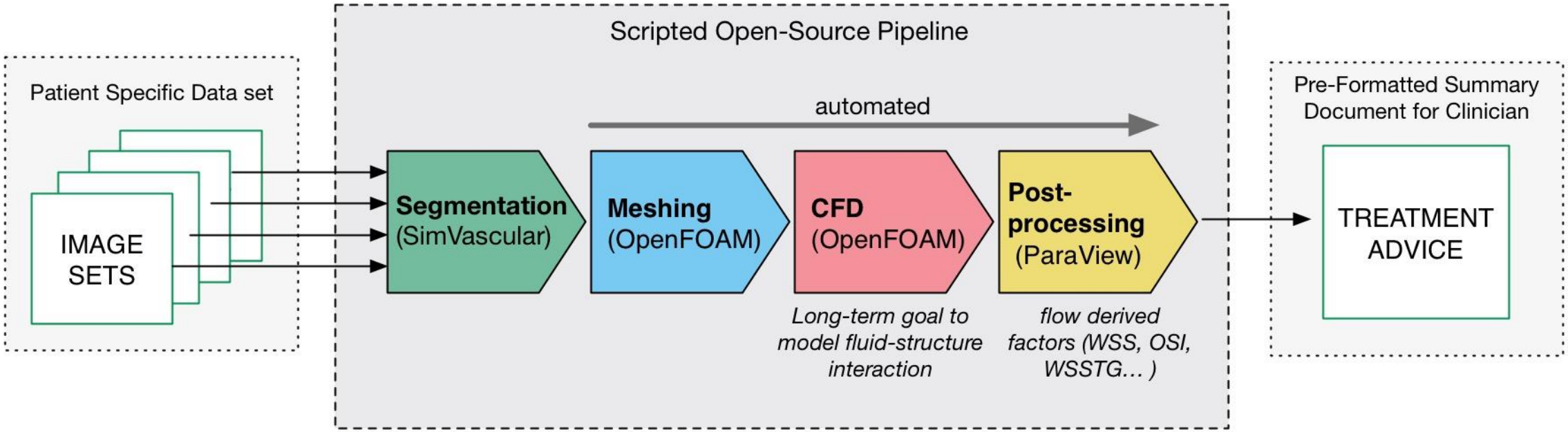


Windkessel model schematic

Results

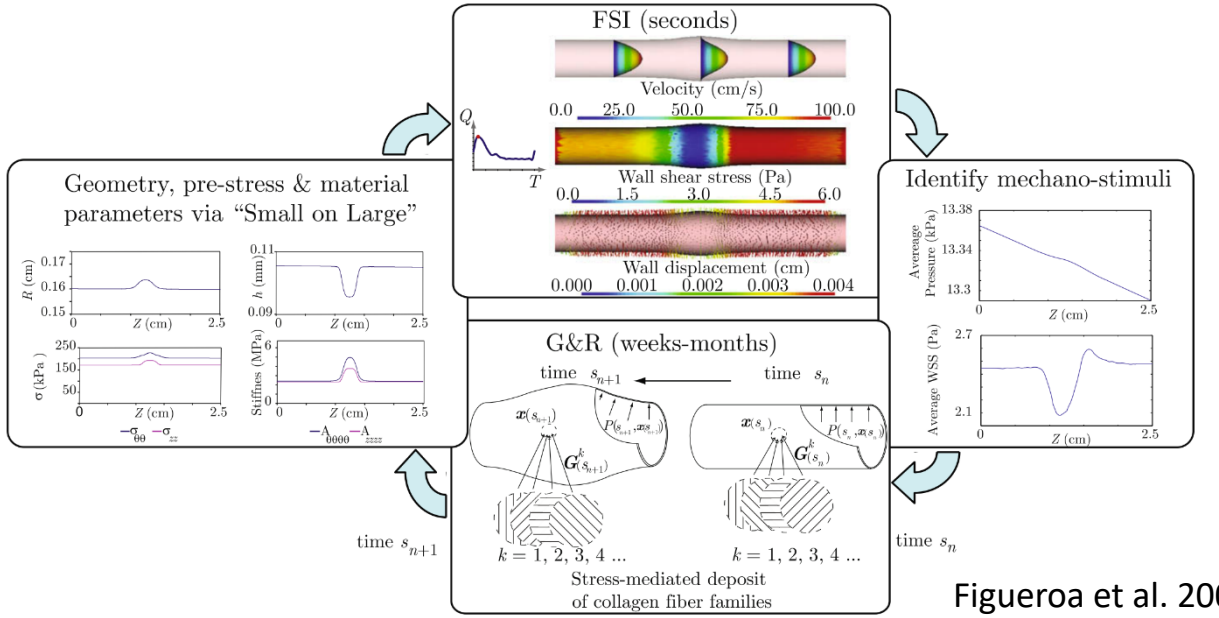


Where does it fit in?



Future Work

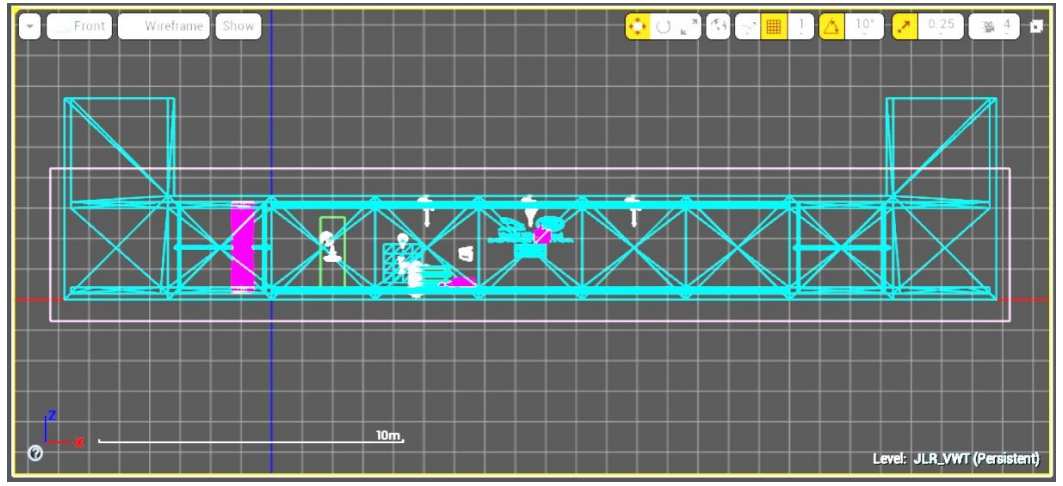
- Include fluid-structure interaction to model deformation of vessel wall and/or influence of valves
- Include growth models to present flow induced remodelling and/or natural growth of a child



Figueroa et al. 2009

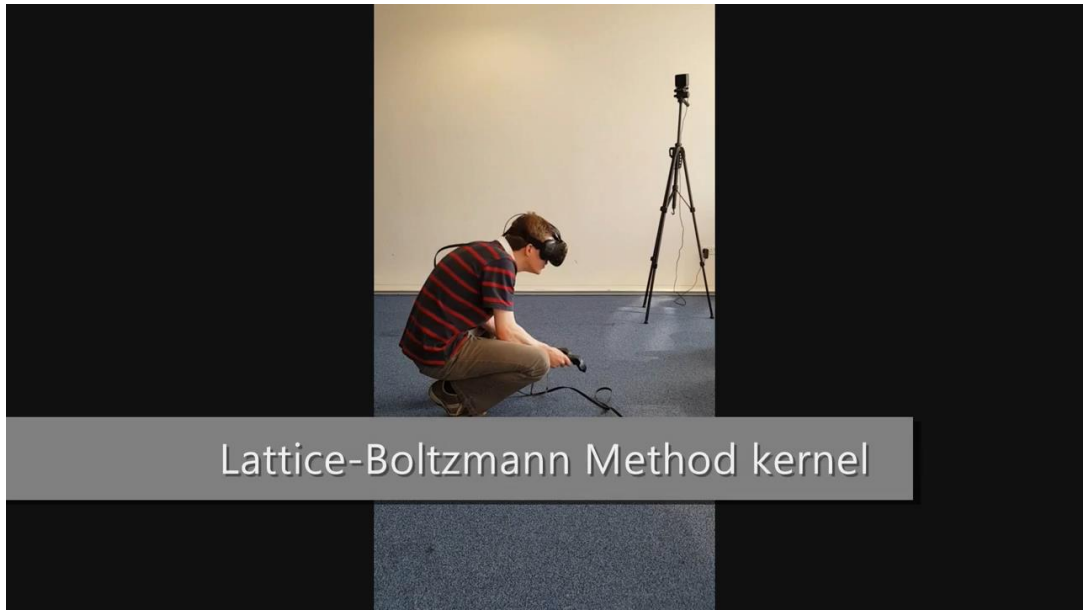
DESIGN-DECISION TIME FOR JAGUAR LAND ROVER

CONCEPT FOR FAST CFD



- Custom-built environment ’Virtual Wind Tunnel’
- Navigation using VR kit or keyboard + mouse

Can easily be adapted for clinical applications, e.g. for bed-side investigation of patient specific haemodynamics



THANK YOU

QUESTIONS?