Modelling fluid flow using COMSOL Multiphysics

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Course: Meccanobiologia
Date: 01 Dec 2015

Blood flux in a pipe

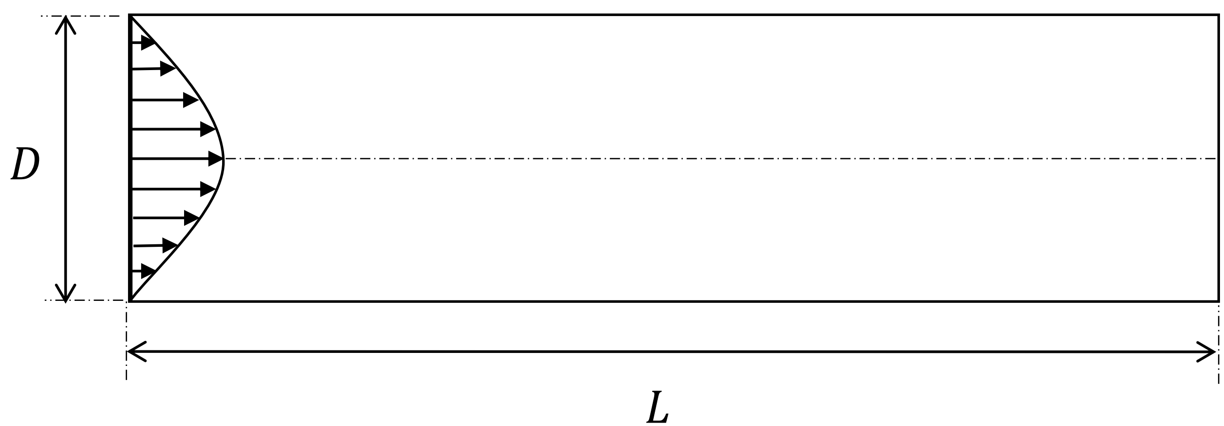
- Steady-state blood flux within a pipe

$$-\eta\nabla^2\boldsymbol{u} + \rho(\boldsymbol{u}\cdot\nabla)\boldsymbol{u} + \nabla p = \mathbf{F}$$

$$\nabla\cdot\boldsymbol{u} = 0$$

Incompressible Navier-Stokes equation for a Newtonian fluid

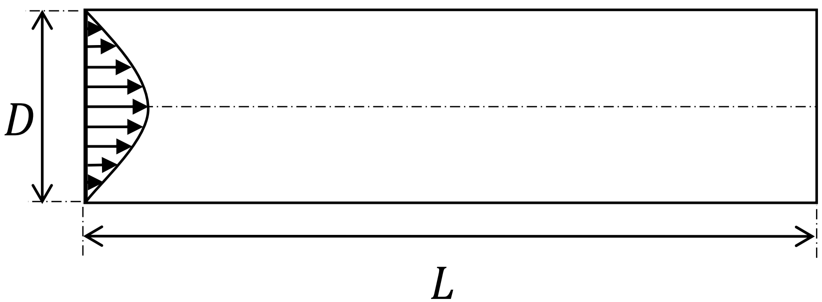
ρ → density = 1060 $kg\cdot m^{-3}$
η → dynamic viscosity = $4\cdot 10^{-3}$ Pa·s
p → pressure (Pa)
F → volume force field such as gravity ($N\cdot m^{-3}$)

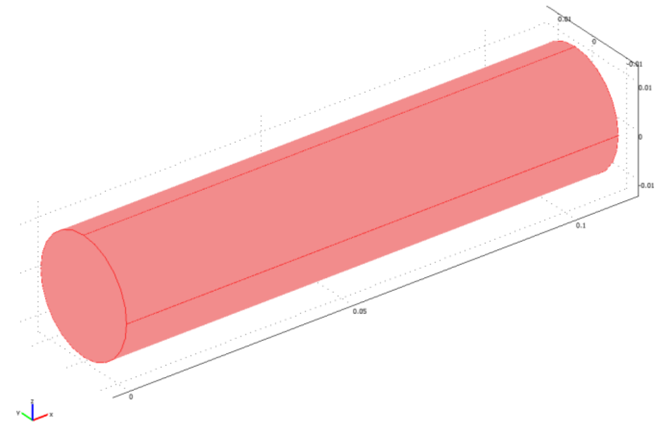


$$D = 25\ mm$$
$$L = 110\ mm$$
$$Q_{in} = 5\ L/min$$

Blood flux in a pipe

- Steady-state blood flux within a pipe

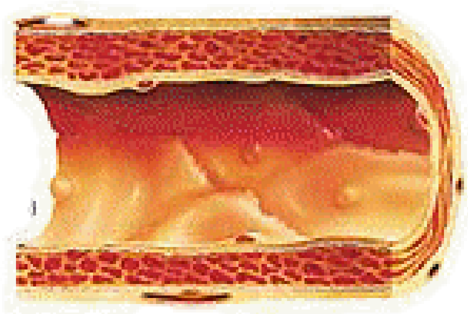




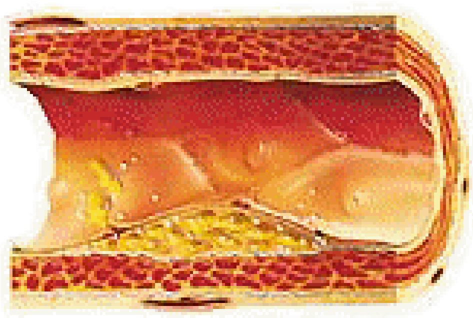
$$D = 25\ mm \qquad L = 110\ mm \qquad Q_{in} = 5\ L/min$$

- Solve the problem considering:
  1. Normal velocity inflow (is the flow profile fully developed?)
  2. Poiseuille inflow profile
- Evaluate wall shear stress

Atherosclerotic artery



Artery with
no deposits

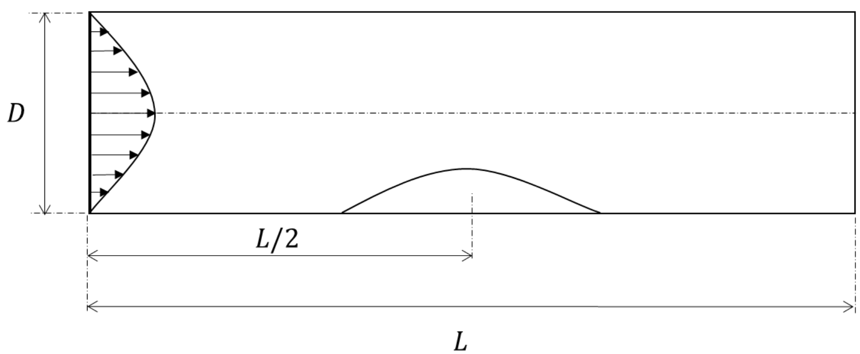


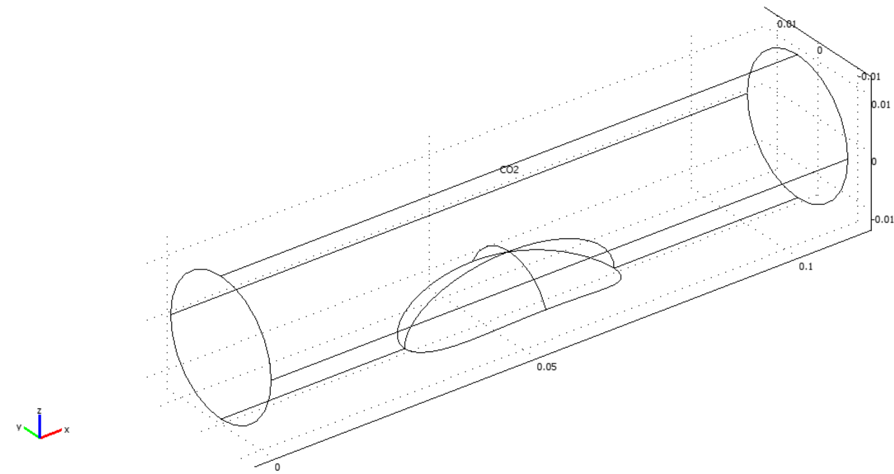
Artery with
atherosclerotic plaque

Stenotic artery with big
atherosclerotic plaques

Blood flux in a stenotic vessel

- Steady-state blood flux within a pipe



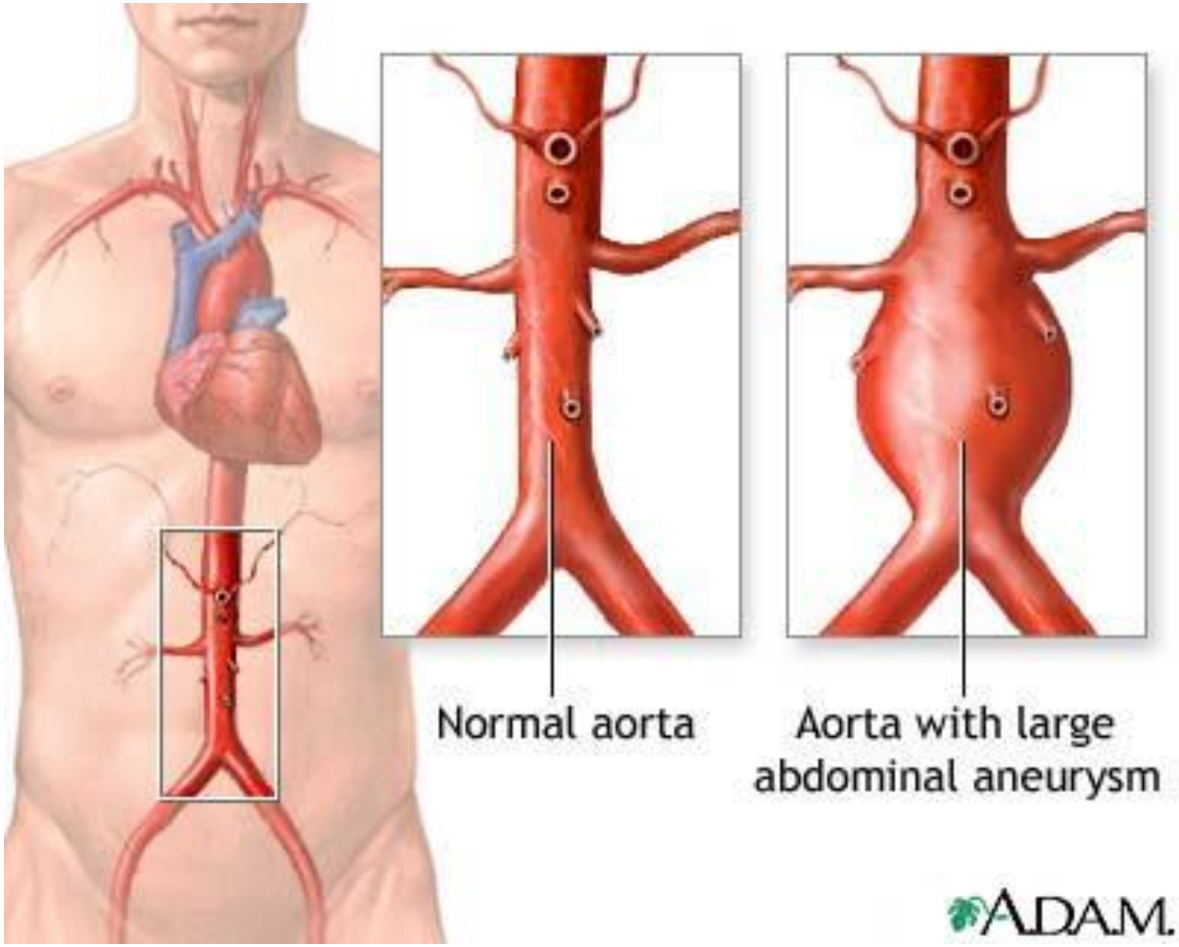


$$D = 25\,mm \qquad L = 110\,mm \qquad Q_{in} = 5\,L/min$$

Atherosclerotic plaque → ellipsoid (semiaxes: x = 20 mm, y = 10 mm, z = 10 mm)

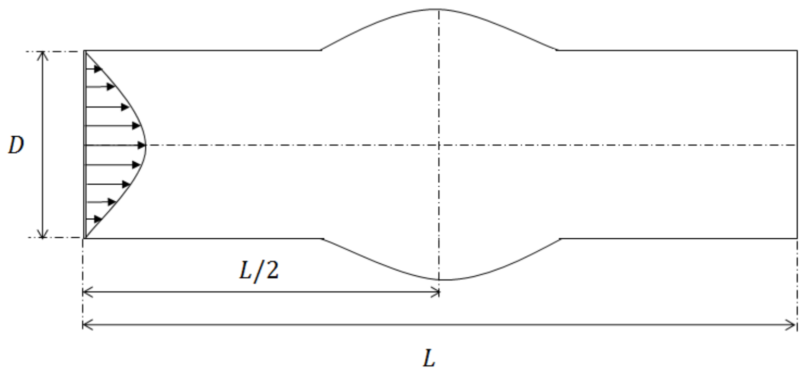
- Solve the problem considering Poiseuille inflow profile
- Evaluate wall shear stress
- Evaluate pressure

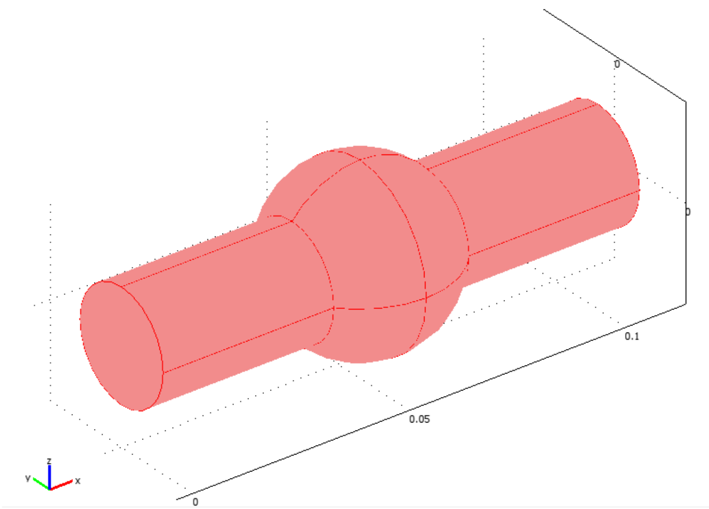
Aneurysm



Blood flux with aneurysm

- Steady-state blood flux within a pipe





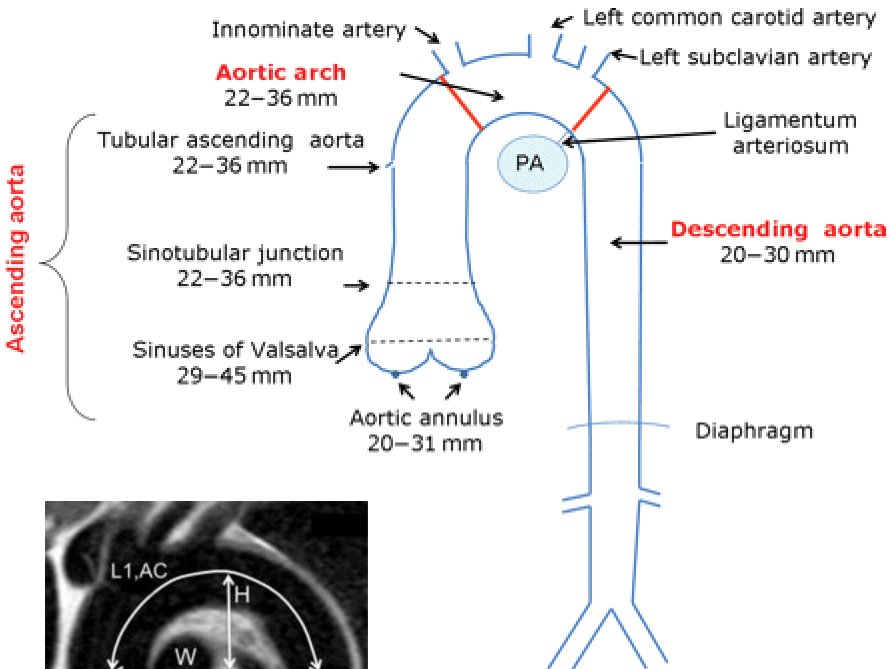
$$D = 25\ mm \qquad L = 110\ mm \qquad Q_{in} = 5\ L/min$$

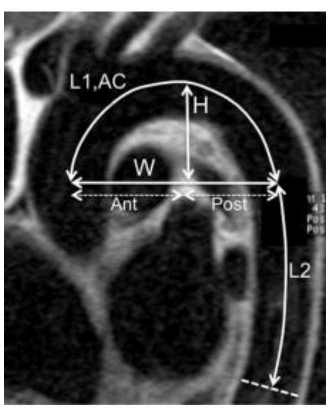
Aneurysm → sphere (radius 20 mm)

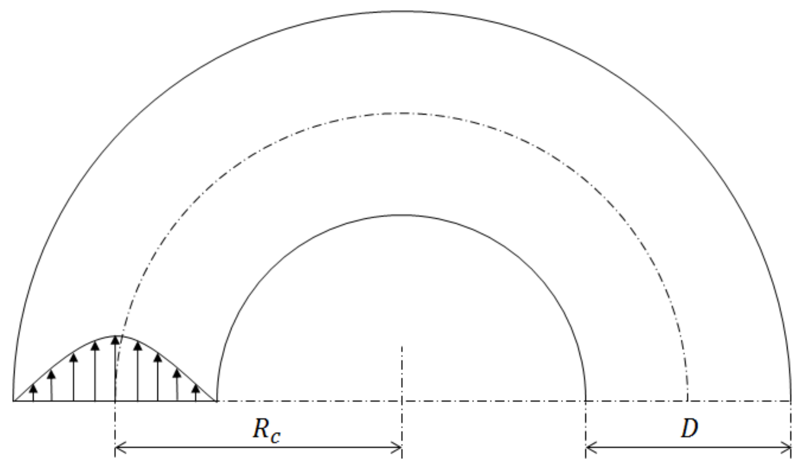
- Solve the problem considering Poiseuille inflow profile
- Evaluate wall shear stress
- Evaluate average pressure on aneurysm wall (what happens in presence of a bigger aneurysm? Increase sphere radius to *30 mm.*

Blood flux in the aortic arch

- Steady-state blood flux within the aortic arch





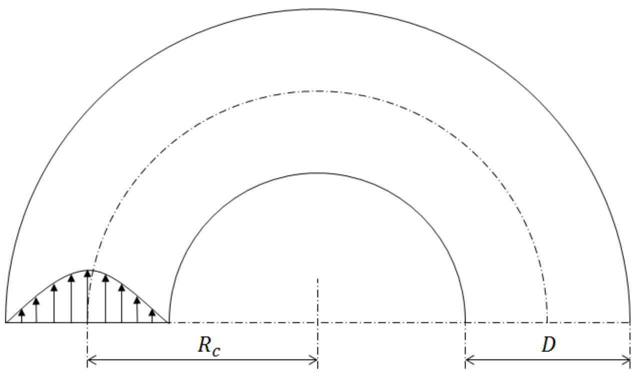


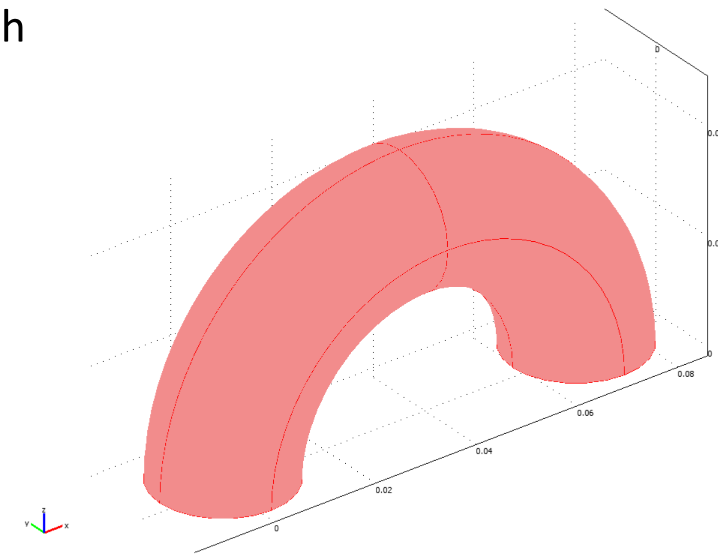
$$R_c = 35\ mm$$
$$D = 25\ mm$$
$$Q_{in} = 5\ L/min$$

J Am Coll Cardiol. 2011;58(12):1262-1270. doi:10.1016/j.jacc.2011.06.012

Blood flux in the aortic arch

- Steady-state blood flux within the aortic arch





$R_c = 35\,mm$ $\qquad D = 25\,mm$ $\qquad Q_{in} = 5\,L/min$

- Solve the problem considering:
    1. Normal velocity inflow
    2. Poiseuille inflow profile