The Role of Side Holes in Dual Lumen Catheters:

A Computational Study

Dirk De Wachter, Dimitri Deserranno, Pascal Verdonck

Hydraulics Laboratory,

Ghent University

UNIVERSITEIT GENT

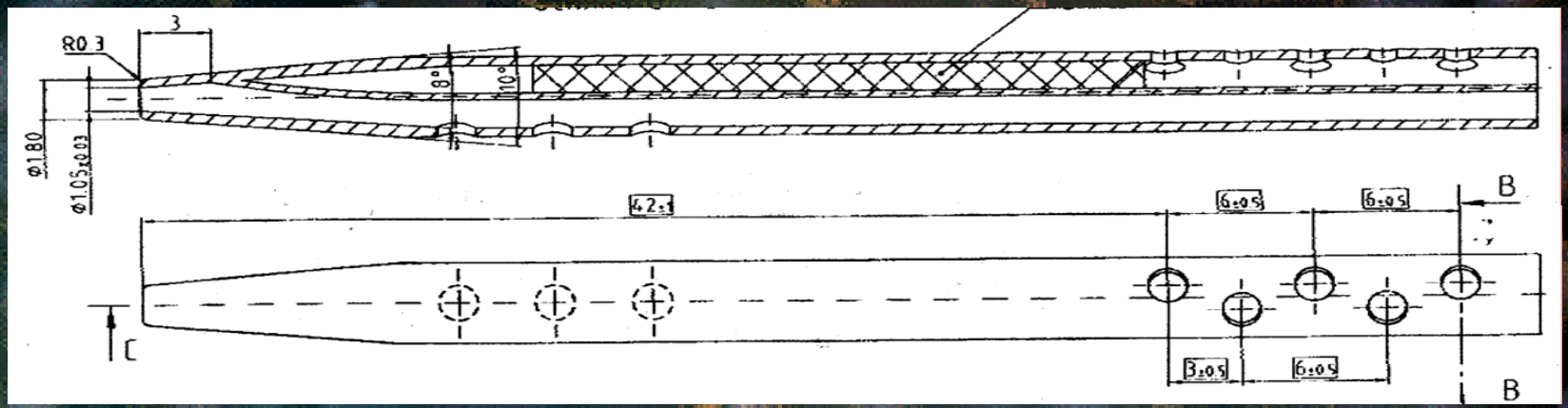
IBITECH GENT

Institute Biomedical Technology

Introduction

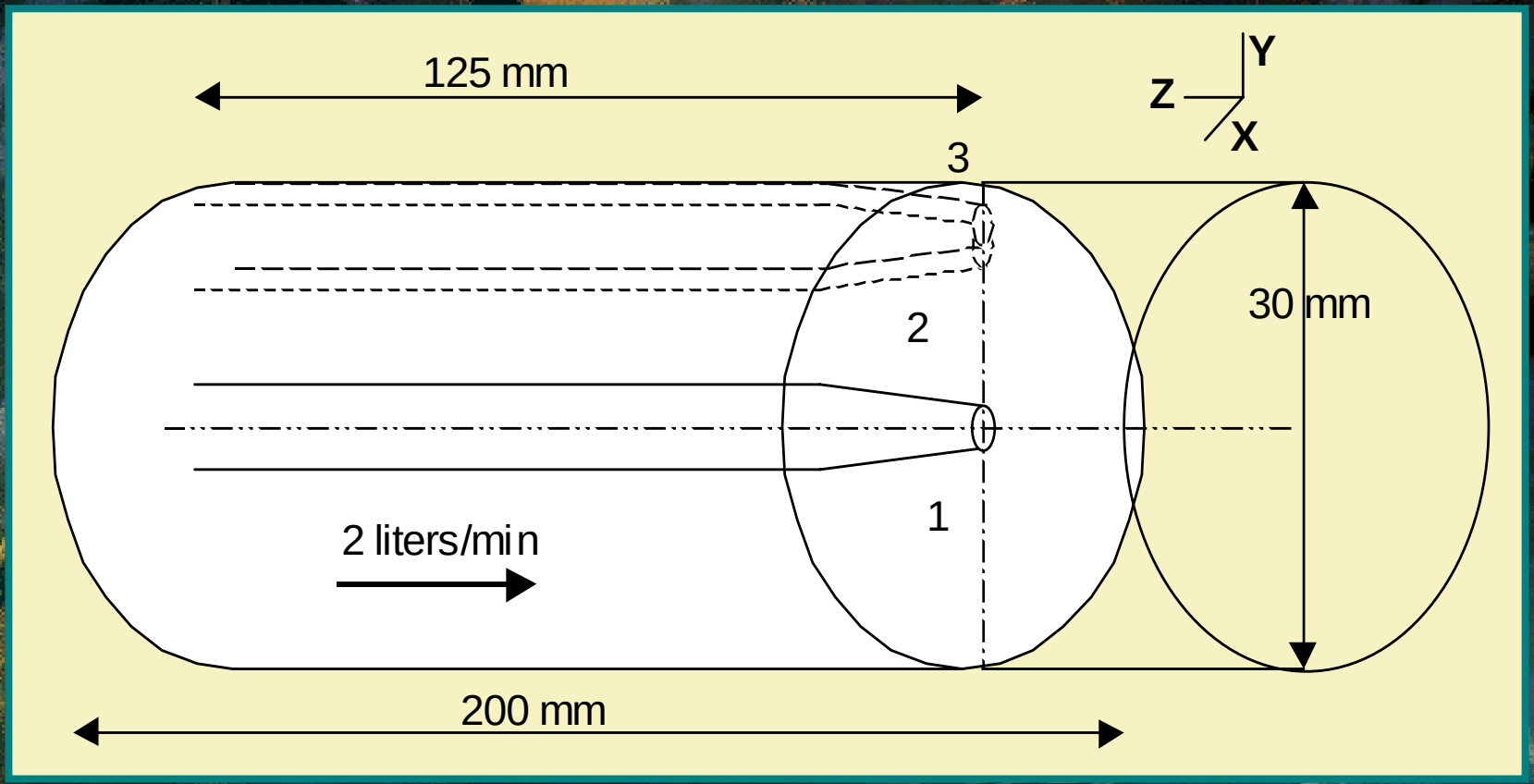
- The geometry of hemodialysis catheters mainly has been designed by trial and error methods
- Common flow problems are:
  - high velocities → high shear rates
  - secondary flows:
    - vortices, dead space
  - recirculation

GambroCath 11Fr Geometry



- Five arterial holes, 20° apart
- Three venous side holes (diameter 1.6 mm)
- One tip hole (internal diameter 1.05 mm)

Computational Model

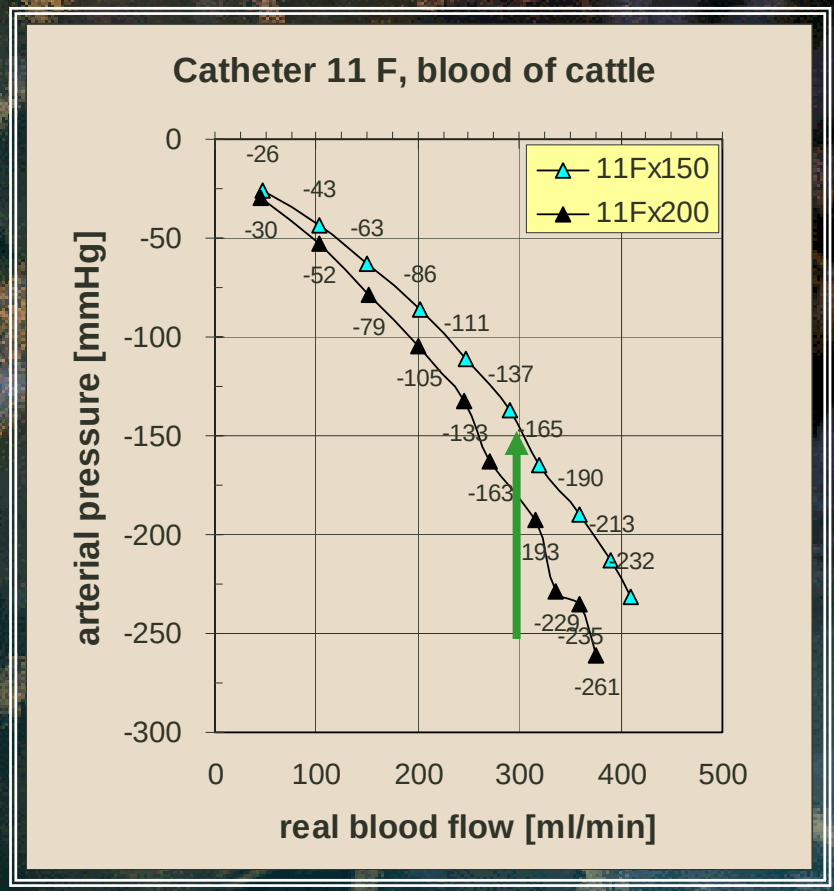


Model Characteristics

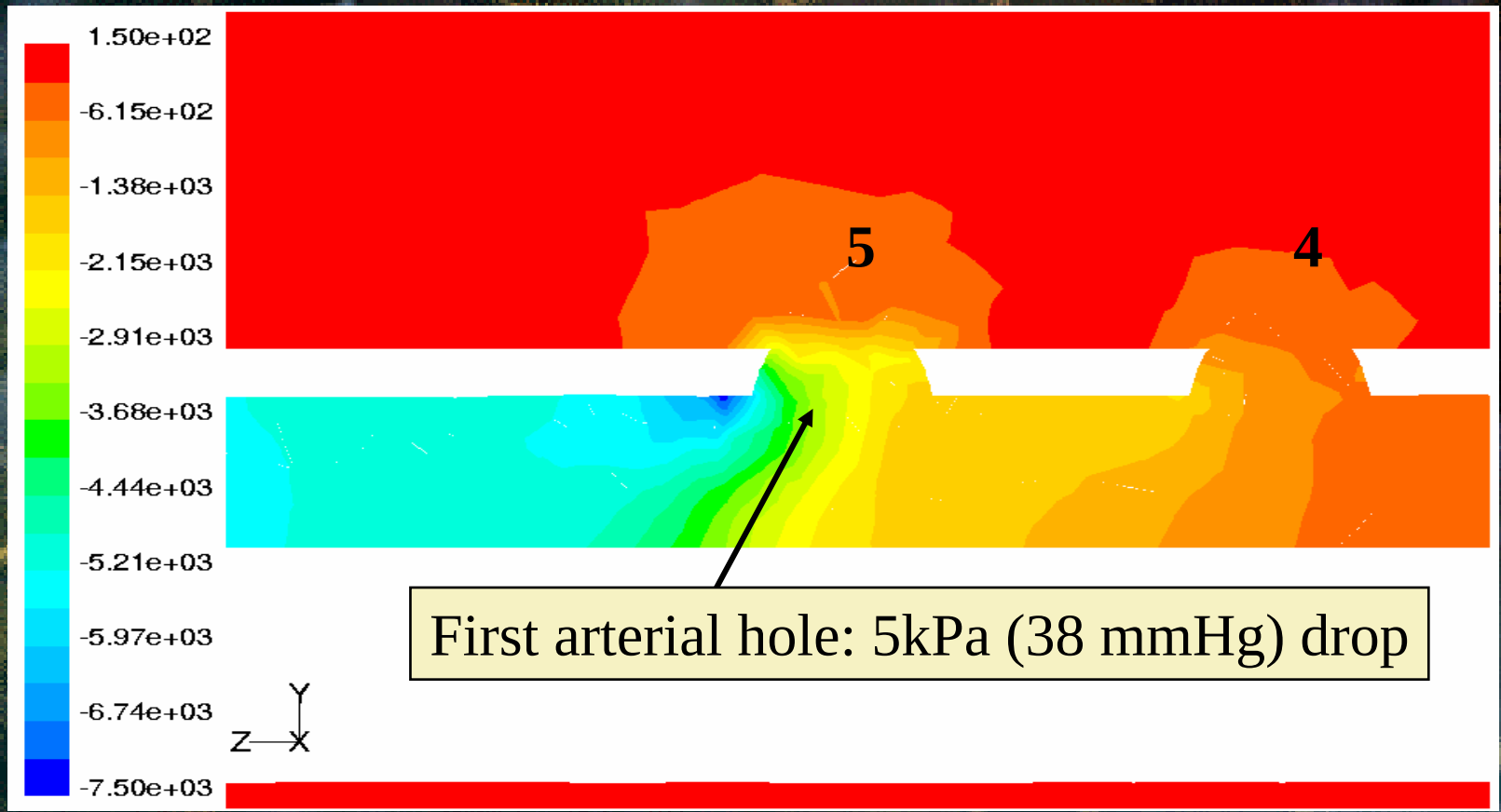
- Three catheter positions
  - coaxial
  - close to the vessel wall (2mm from wall)
  - touching the wall (closing off two holes)
- No simulation of the luer lock (and associated pressure drop)
- stiff vessel wall (no compliance)
- steady flow conditions
- Non-Newtonian blood viscosity

Results: Pressure drop (ΔP)

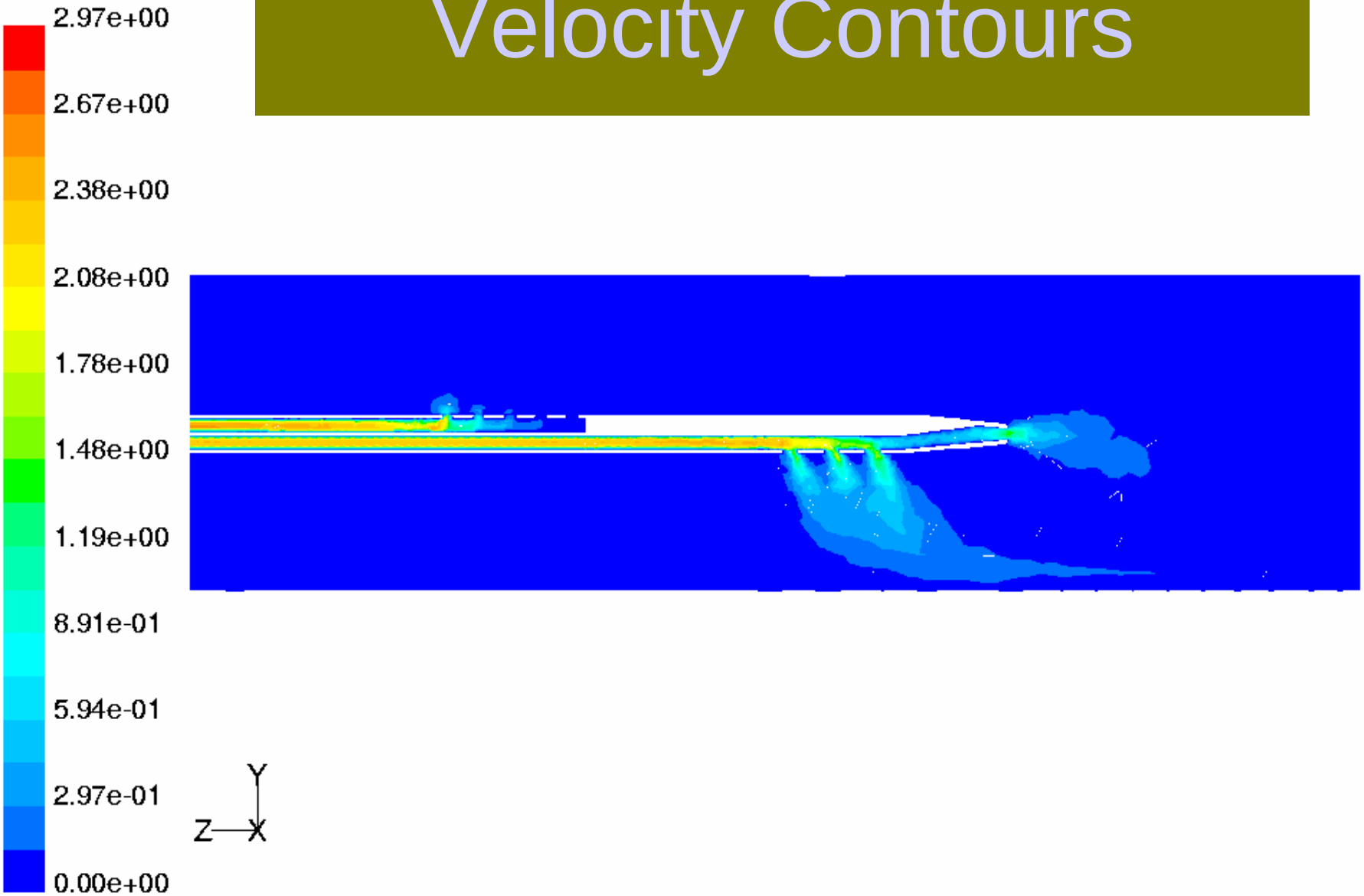
- ΔP at 300 ml/min over the arterial limb
  - 0.532 mmHg/mm
  - 55 mmHg entrance
- L=150: -135mmHg
- Difference:
  - luer lock
  - static pressure
  - viscosity



Detailed profile at the tip

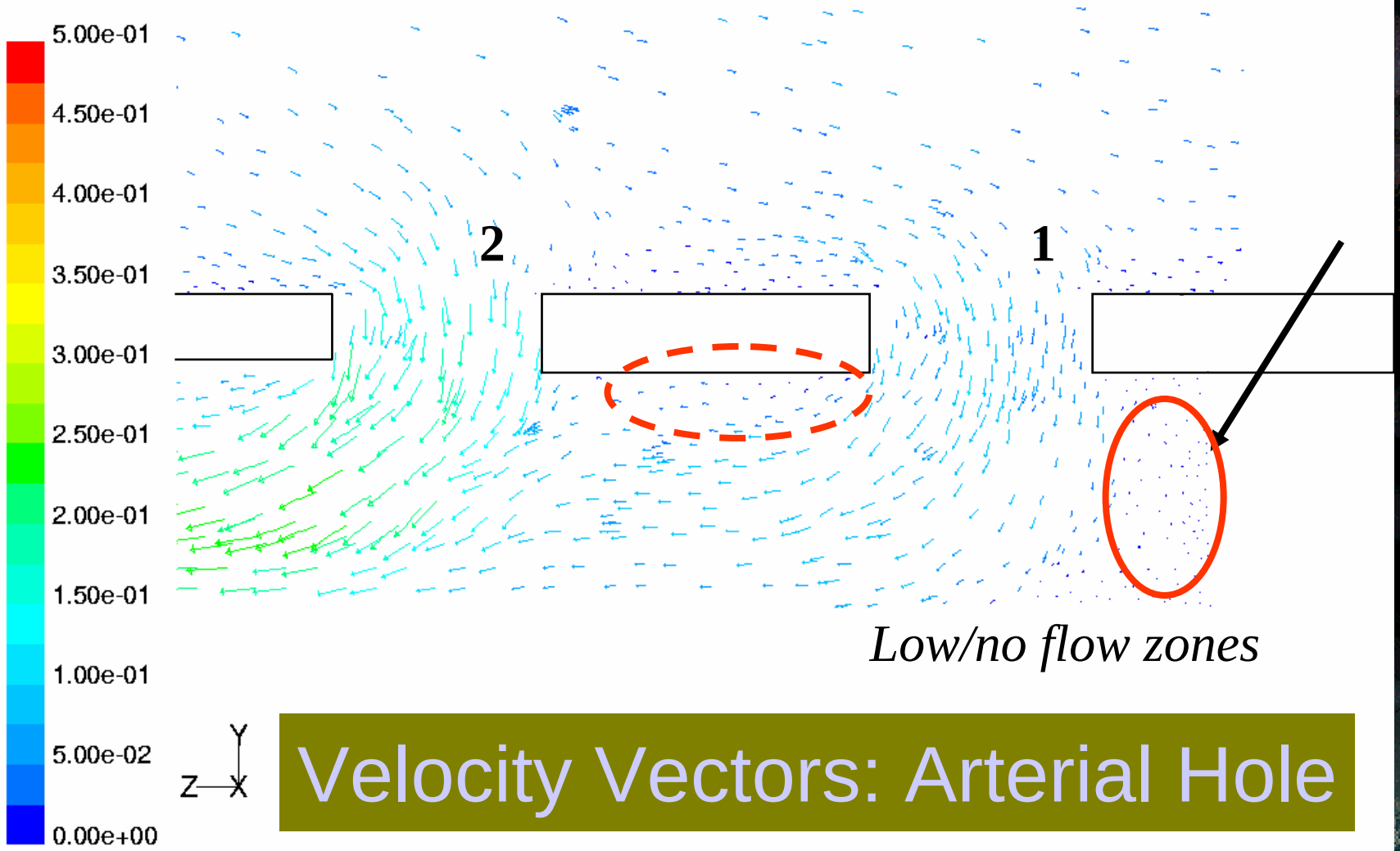


Velocity Contours

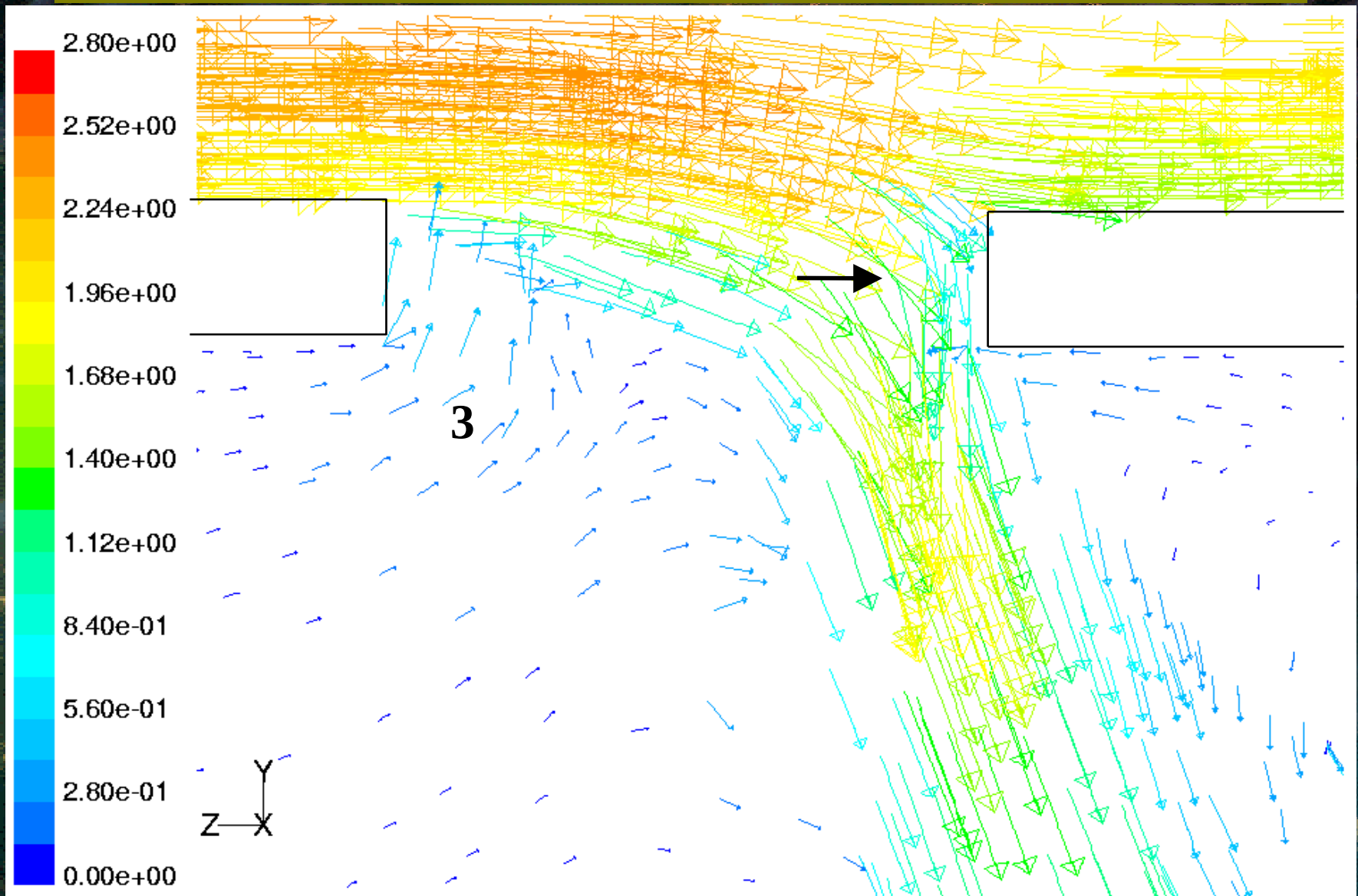


Results: Velocity Contours

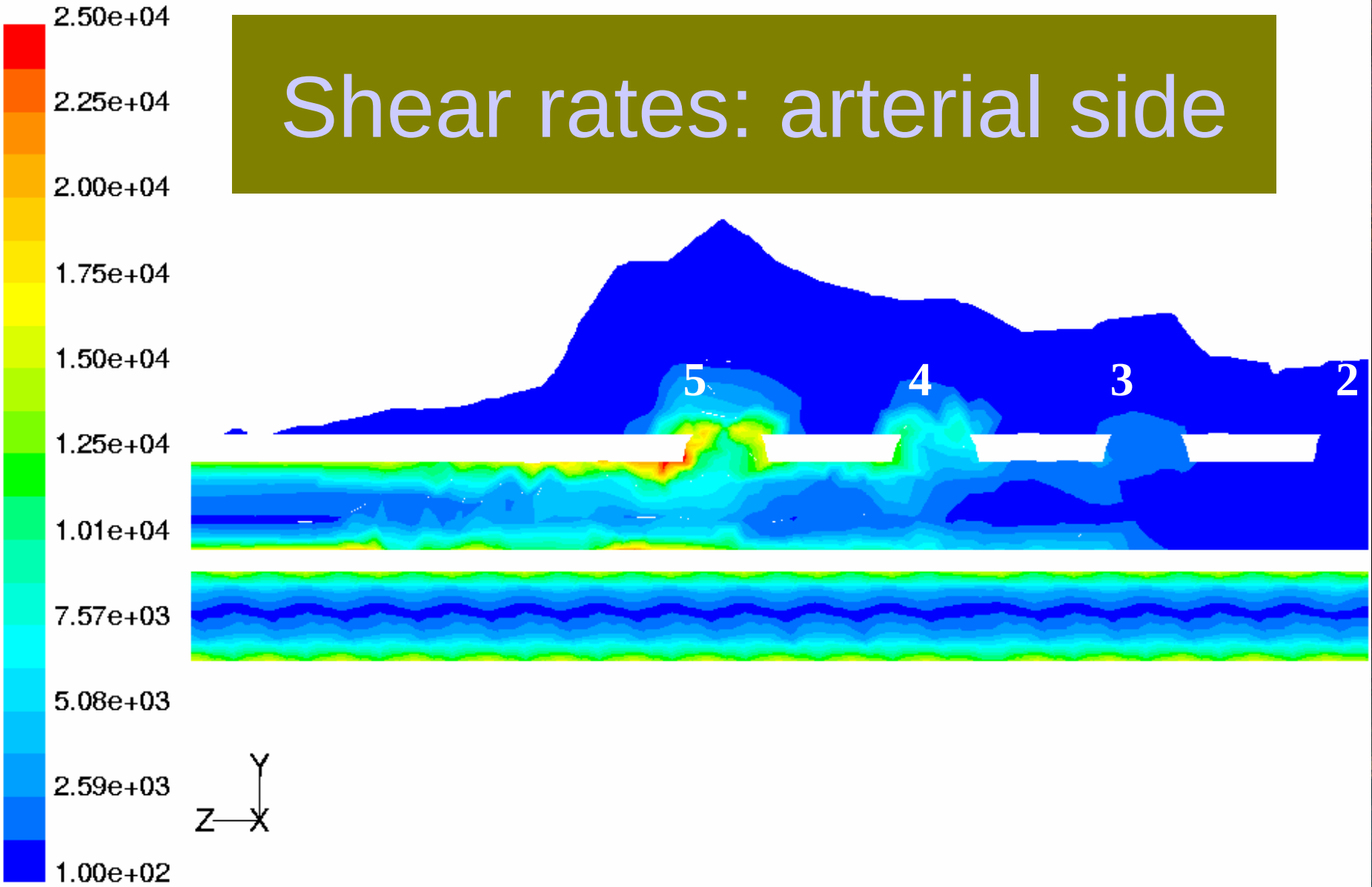
- Maximal velocity of 3 m/s (fire hose)
- Laminar Flow (Re=1100)
- High velocities near the vessel wall
- Only the first arterial hole is fully employed
- 180° flow direction bend is far from ideal
- The first venous hole is underutilized
- The tapered tip increases local velocity


5.00e-01
4.50e-01
4.00e-01
3.50e-01
3.00e-01
2.50e-01
2.00e-01
1.50e-01
1.00e-01
5.00e-02
0.00e+00
2
1
Low/no flow zones
Y
Z
X
Velocity Vectors: Arterial Hole
Velocity Vectors Colored By Velocity Magnitude (m/s)
Apr 13, 2000
FLUENT 5.2 (3d, segregated, lam)

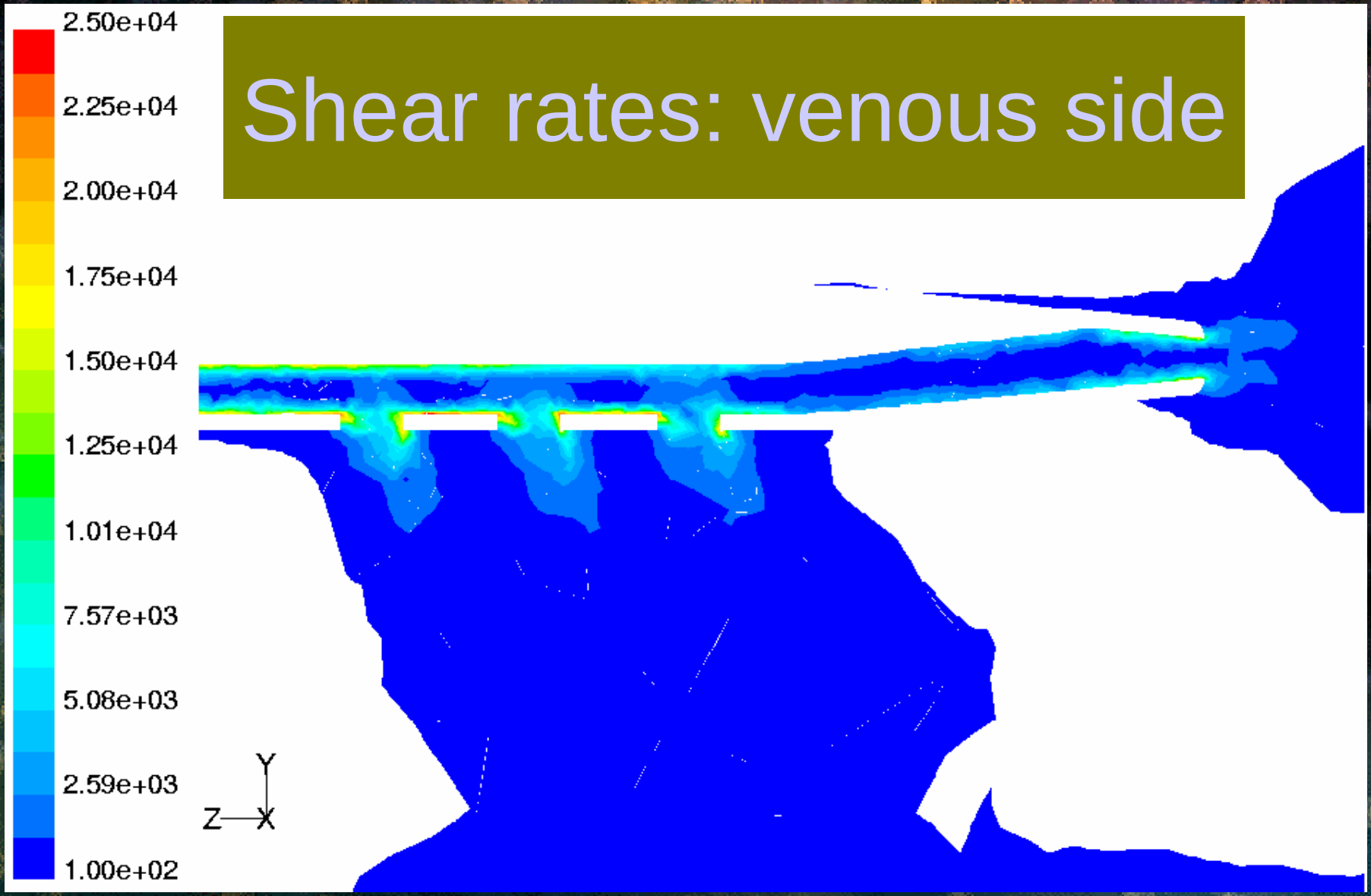
Velocity Vectors: Venous Hole



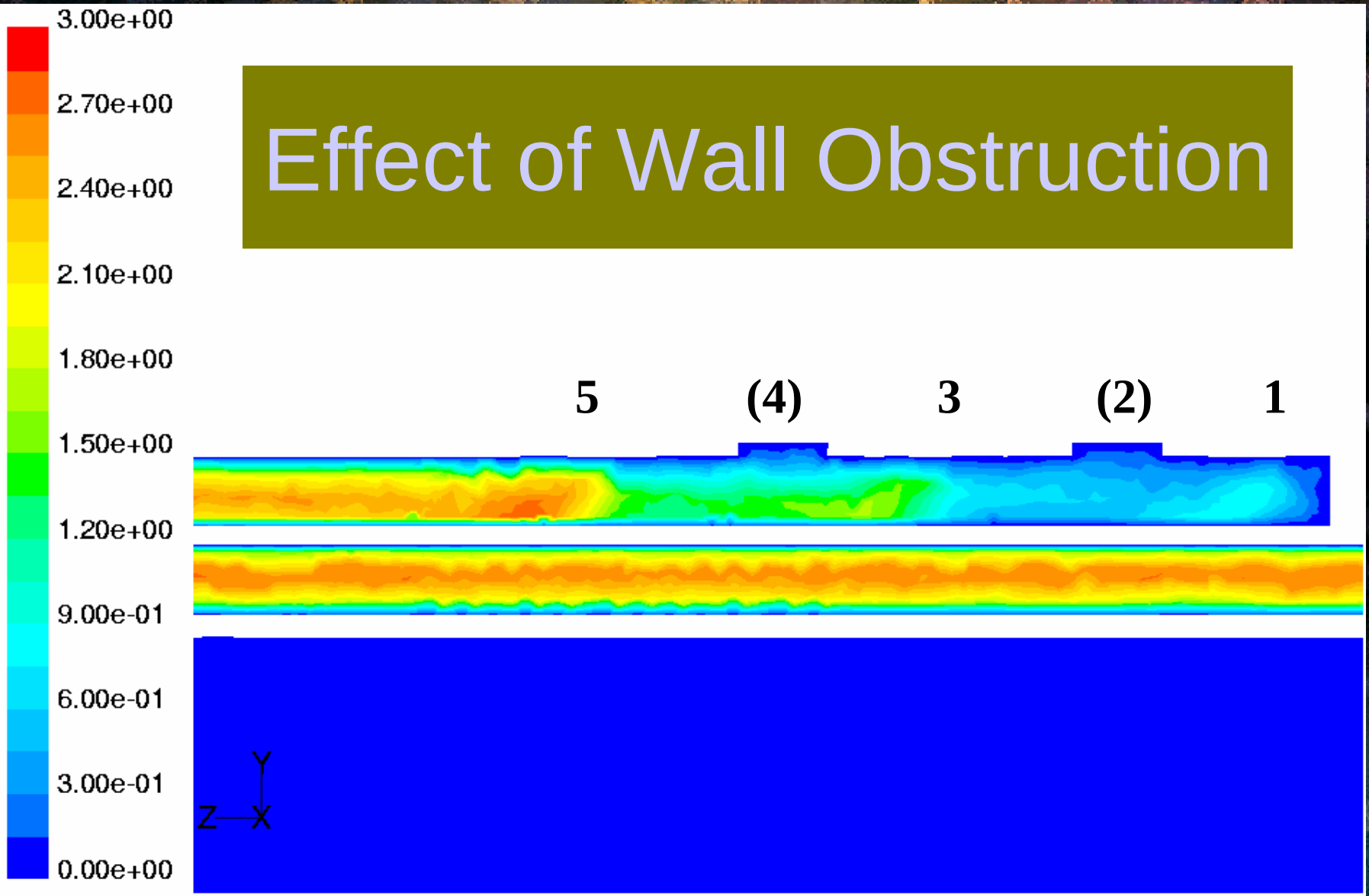
Shear rates: arterial side



Shear rates: venous side

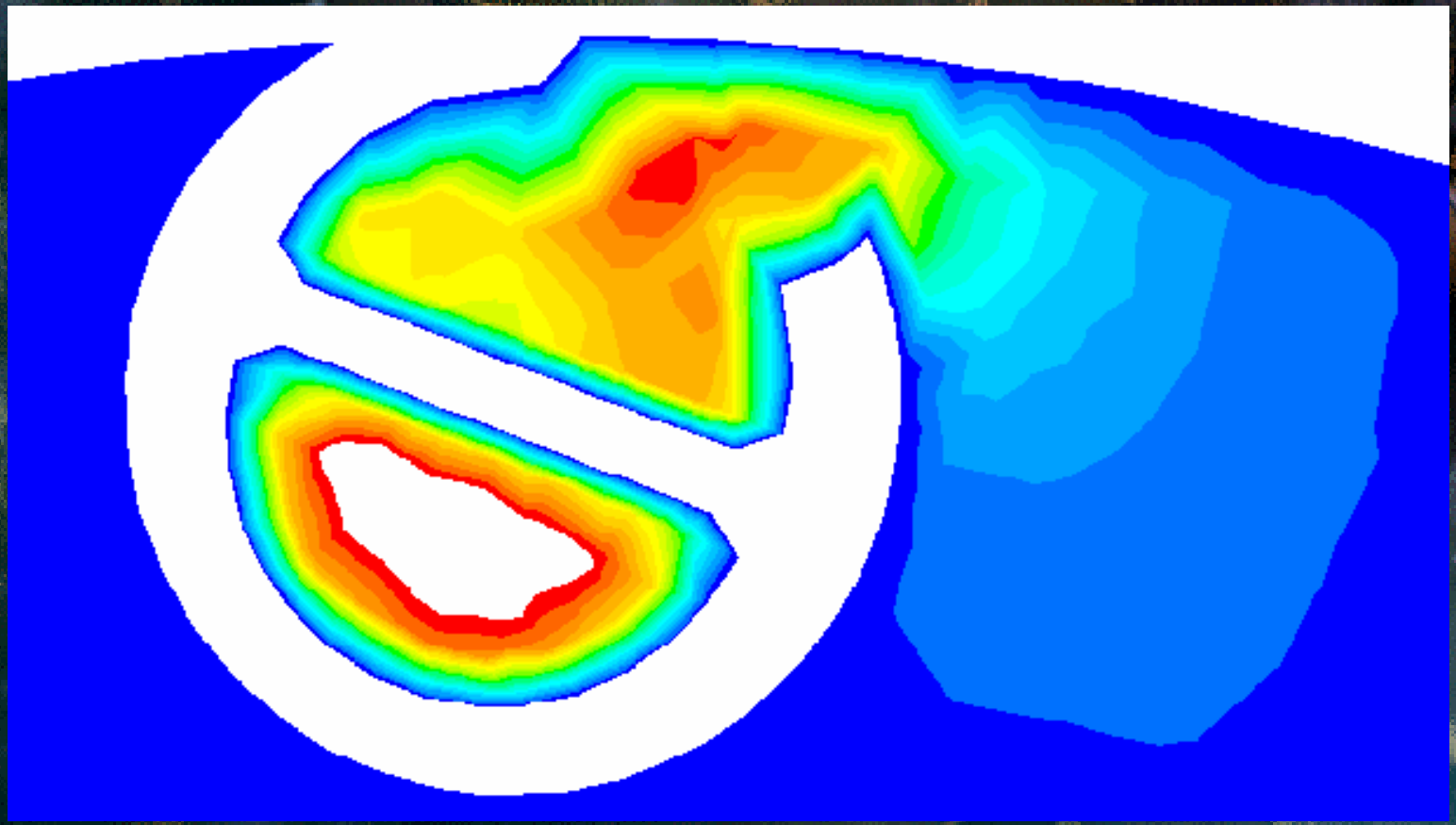


Effect of Wall Obstruction

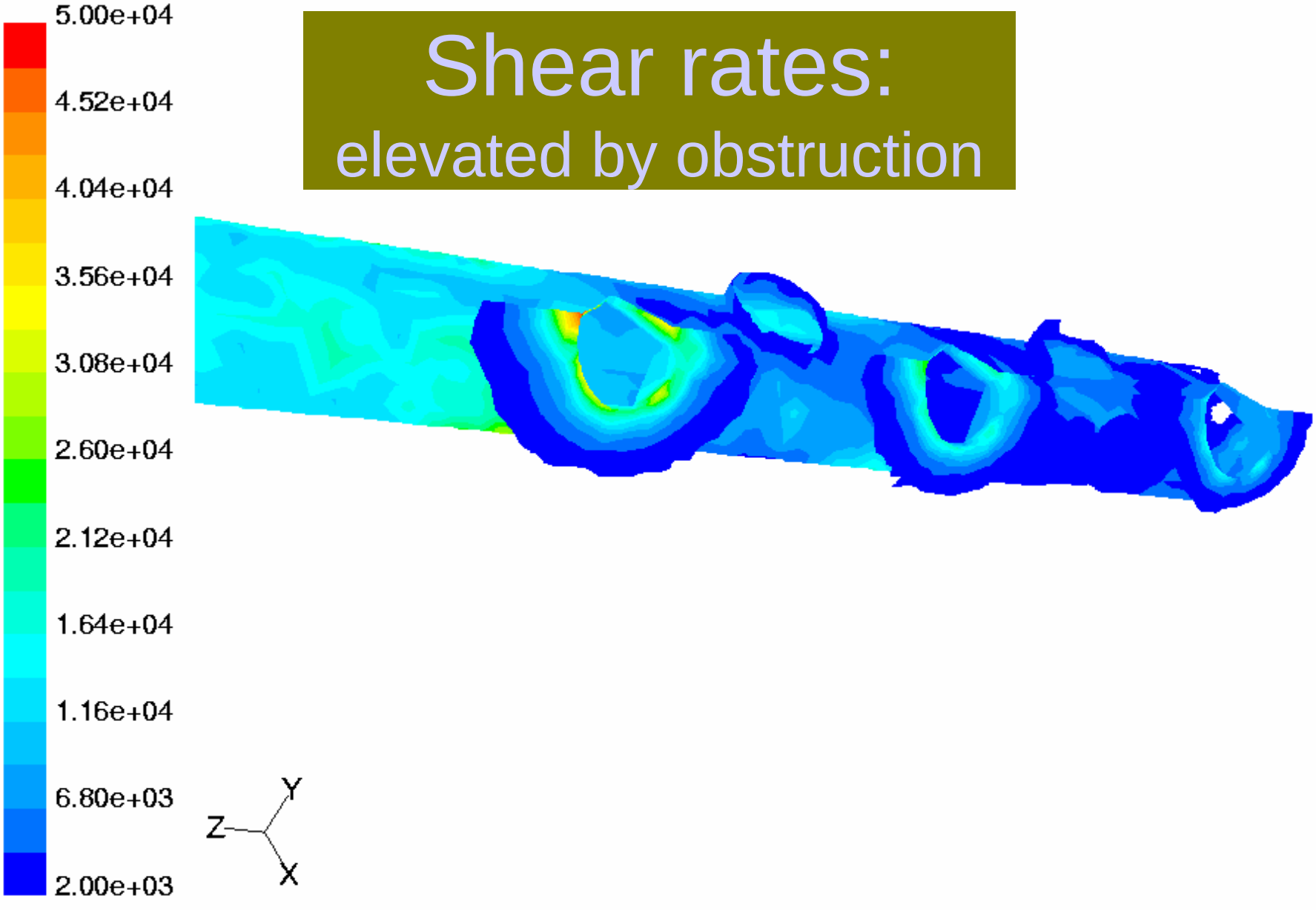


Obstruction of Inflow Area

Velocity magnitude (v < 2.3 m/s)



Shear rates:
elevated by obstruction



Conclusions

- Small dual lumen catheters exhibit:
  - High Velocities
  - High Gradients:
    - velocity
    - pressure
    - shear stress (marginally hemolytic)
- Lateral holes are not adapted to the actual flow patterns
- Limitations: Steady Flow
  No Wall Mechanics

Advisories

» Avoid Multiple Side Holes

» Make the Hole Diameters Large enough

- ¬ use ellipses

» Do not use Tapered Tips

» Use Large Diameters for Great Flows


Thank you
for your kind
attention