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A CLINICAL AND COMPUTATIONAL STUDY ON HAEMODYNAMICS

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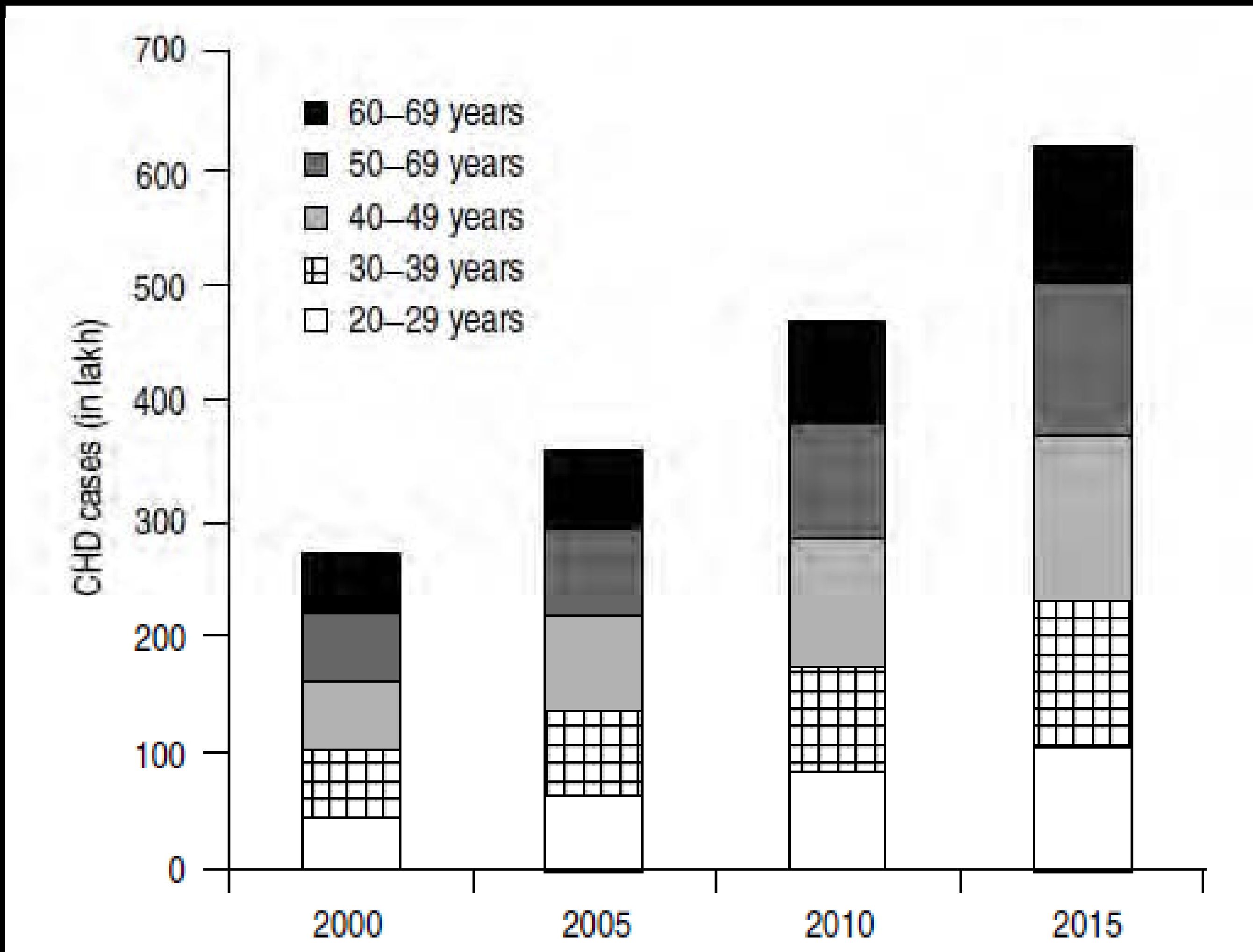
HAEMODYNAMICS AND ITS NEED

Study of the flow of blood through arteries from a fluid mechanics point of view

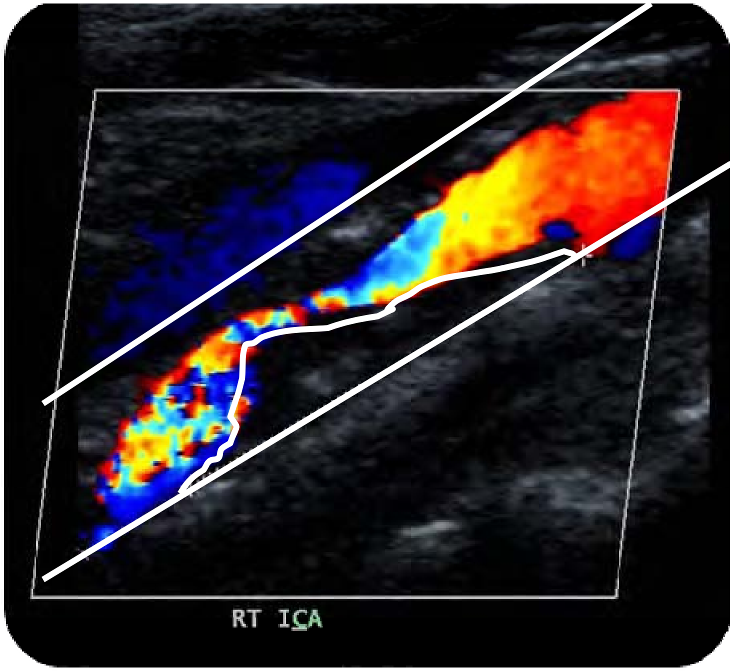
Needed to enrich the knowledge of the blood flow pattern due to recent uprise in cardiac diseases



700
600
500
400
300
200
100
0
CHD cases (in lakh)
60–69 years
50–69 years
40–49 years
30–39 years
20–29 years
2000
2005
2010
2015

STENOSIS

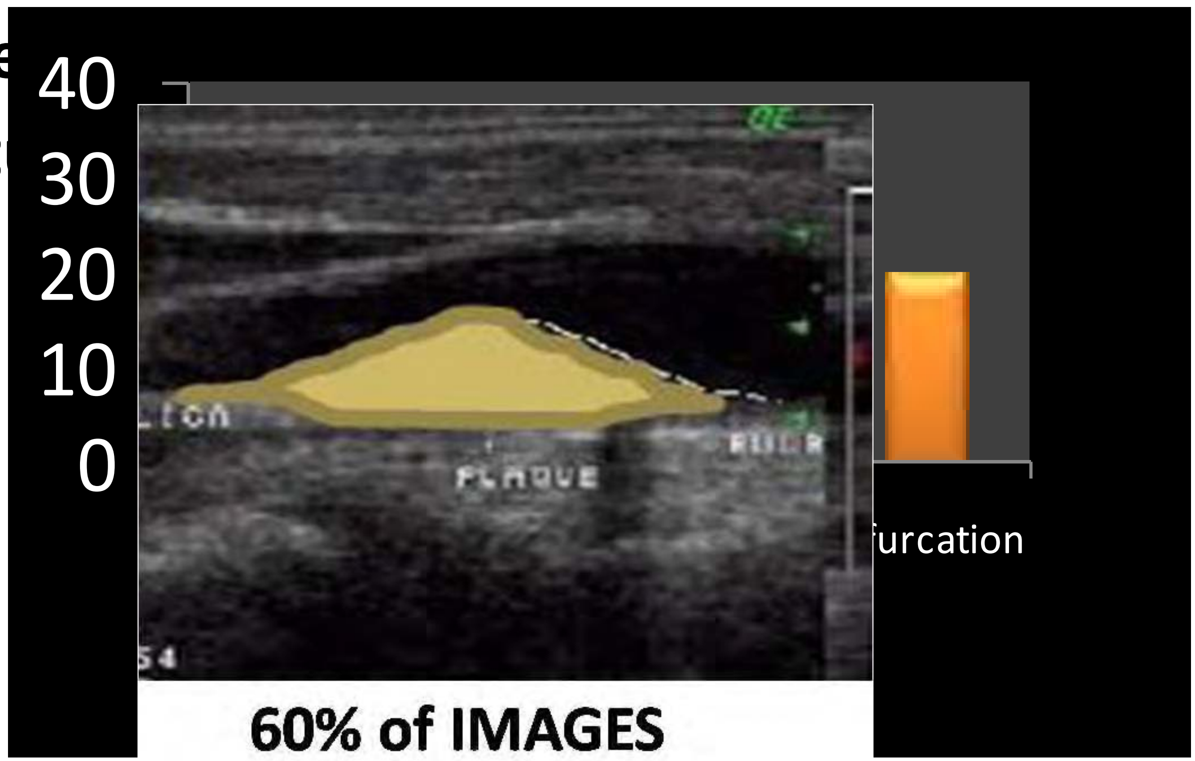
- Abnormal narrowing of blood vessels
- Deposition of cholesterol and other fatty matter



CLINICAL STUDY

Doppler Ultrasound Image of the CAROTID ARTERY of 130 patients of varying age:

- **To determine the location of the stenosis**
- **To de**
- **To st**



BLOOD AS A FLUID

- Newtonian for large arteries, including the common carotid artery
- Non-Newtonian for narrower channels
- Density : 1050 Kg/m^3
- Dynamic viscosity: 0.00345 Pa.s

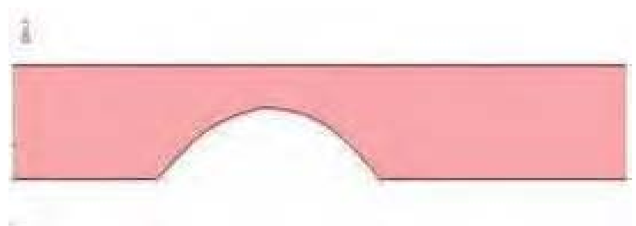
MODELLING USING COMSOL

- VERSION: COMSOL 3.5a
- FLUID MECHANICS MODULE
- INCOMPRESSIBLE NAVIER-STOKES SECTION

MODELLING THE GEOMETRY

(AXIS-SYMMETRIC MODEL)

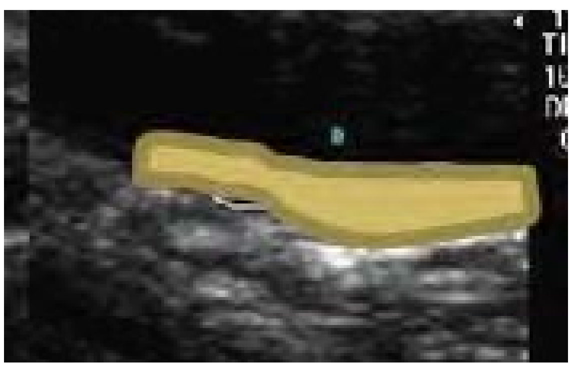
Assumption: The artery is a long straight pipe



CURVED GEOMETRY

DIAMETER(D_0)=0.0057 m

CONSTRICTION= 62% of the radius

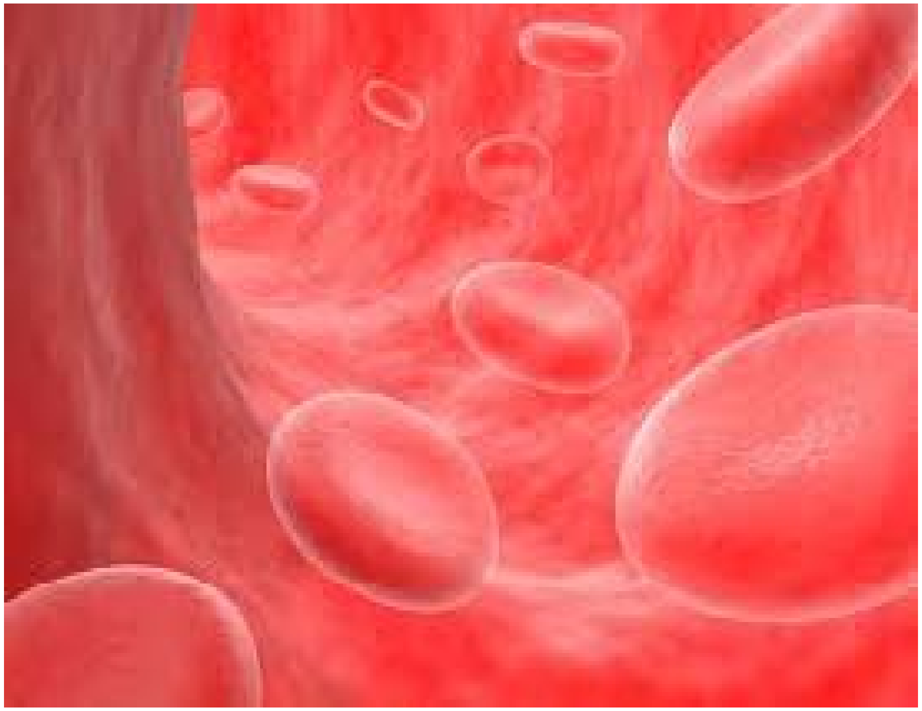


RECTANGULAR GEOMETRY

ASSUMPTIONS

- The artery wall is rigid

- Blood flow is
  - Newtonian
  - Laminar
  - Steady-state
  - Incompressible

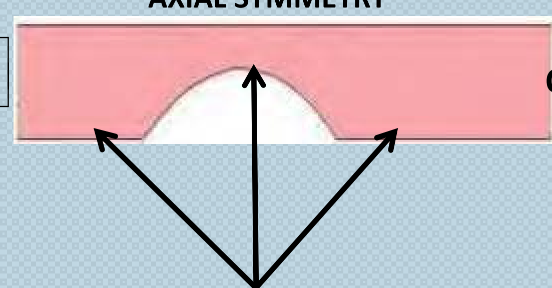


GOVERNING EQUATIONS & BOUNDARY CONDITIONS

Incompressible Navier-Stokes Equation:

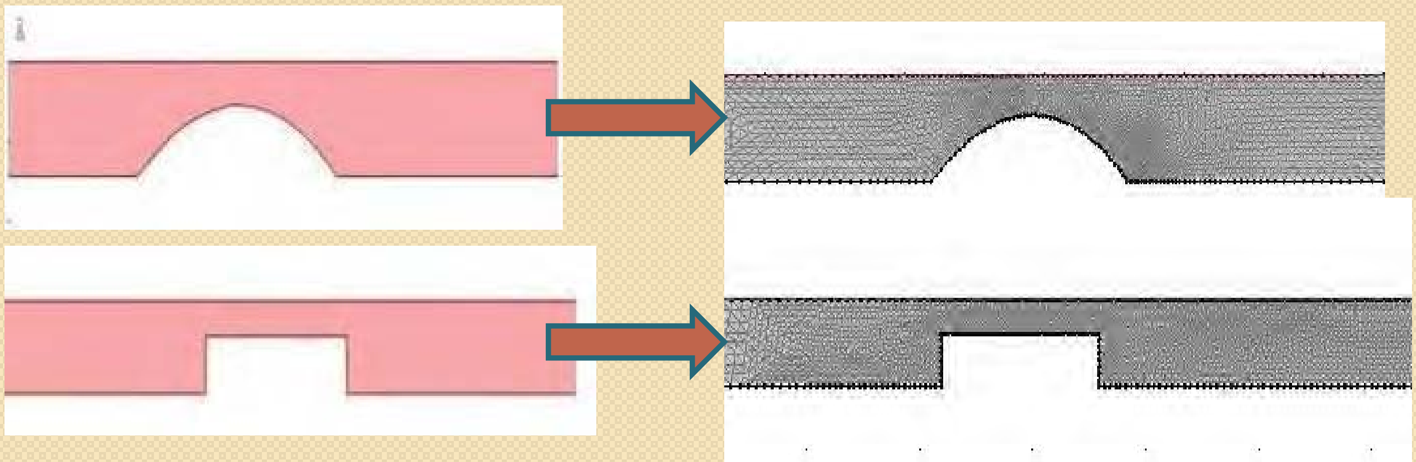
$$\rho(\mathbf{u}.\nabla)\mathbf{u} = \nabla.[-p\mathbf{I} + v(\nabla.\mathbf{u} + (\nabla.\mathbf{u})^T]$$

$$\nabla.\mathbf{u} = \mathbf{0}$$



MESHING IN COMSOL

- **Free mesh using triangular elements**
- **Adaptive refinement near the constriction**



SOLVER USED

- **SOLVER TYPE: STATIONARY**
- **NAME OF SOLVER: DIRECT(PARDISO)**

SUMMARY OF VALUES USED

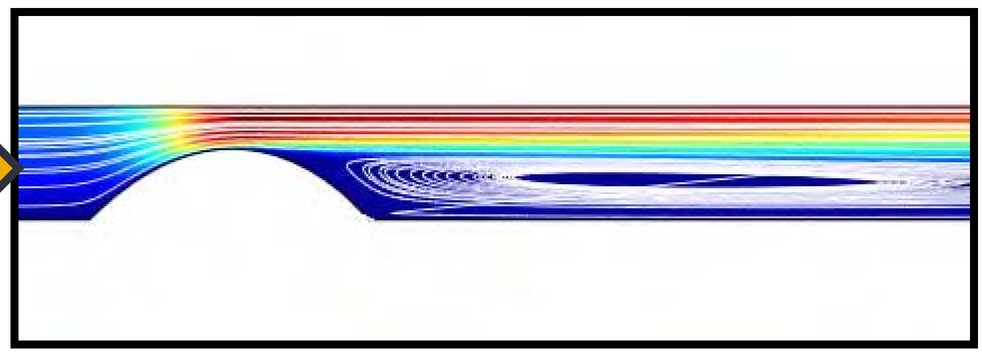
FLUID PROPERTIES	VALUES
DENSITY	1050 kg/m^3
DYNAMIC VISCOSITY	0.00345 Pa.s.

GEOMETRICAL PROPERTIES	VALUES
DIAMETER OF ARTERY	5.7 mm.
MAXIMUM CONSTRICTION	62%

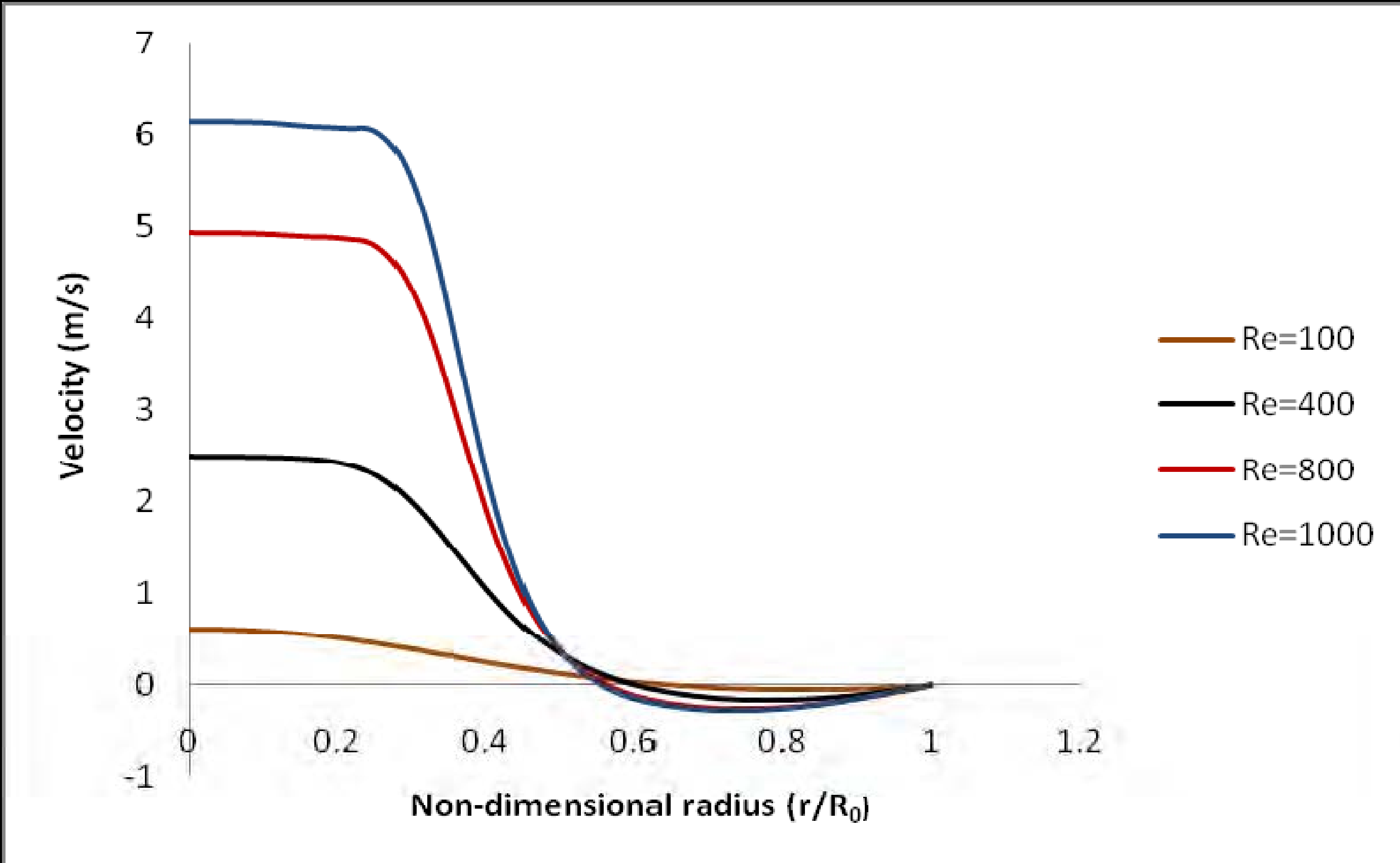
FLOW PARAMETERS	VALUES
REYNOLDS NUMBER	100, 400, 800, 1000

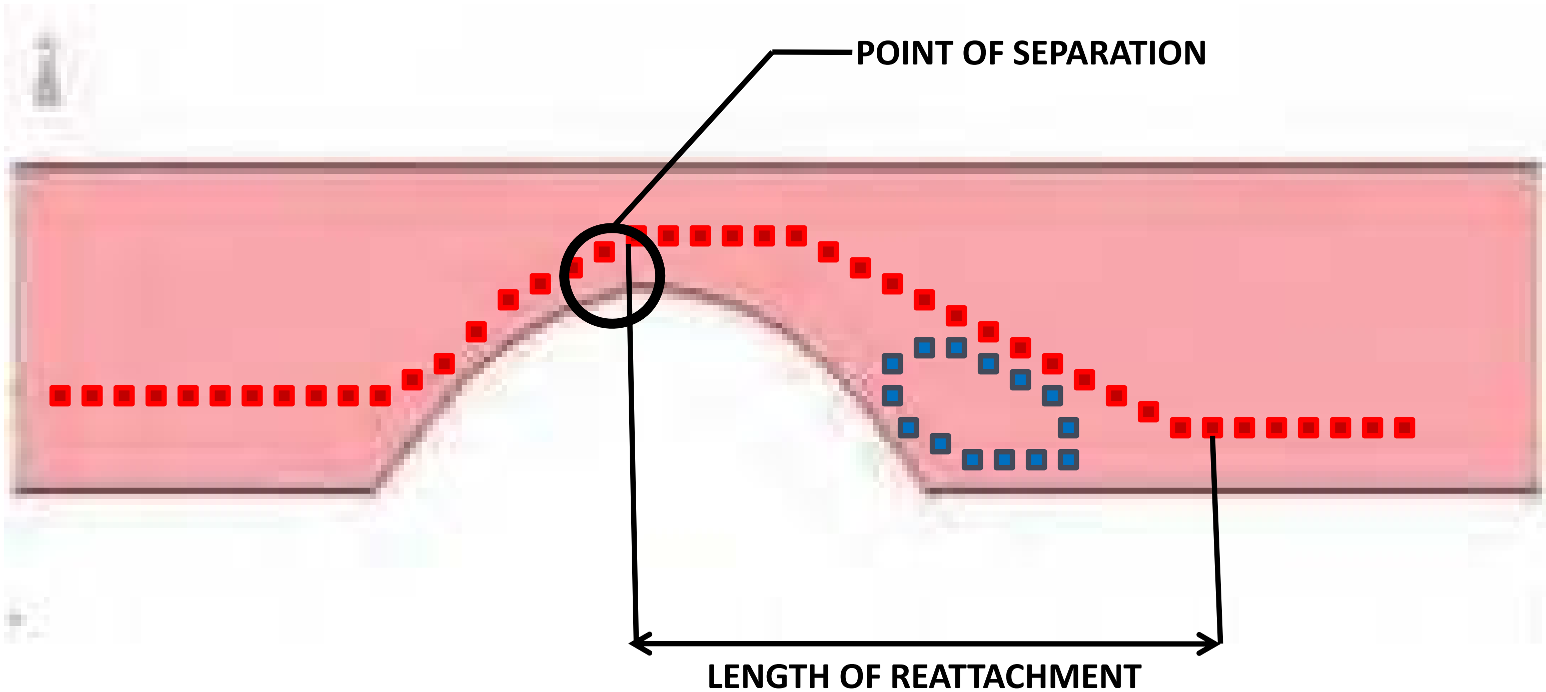
RESULTS

Close similarities between clinical and computational results

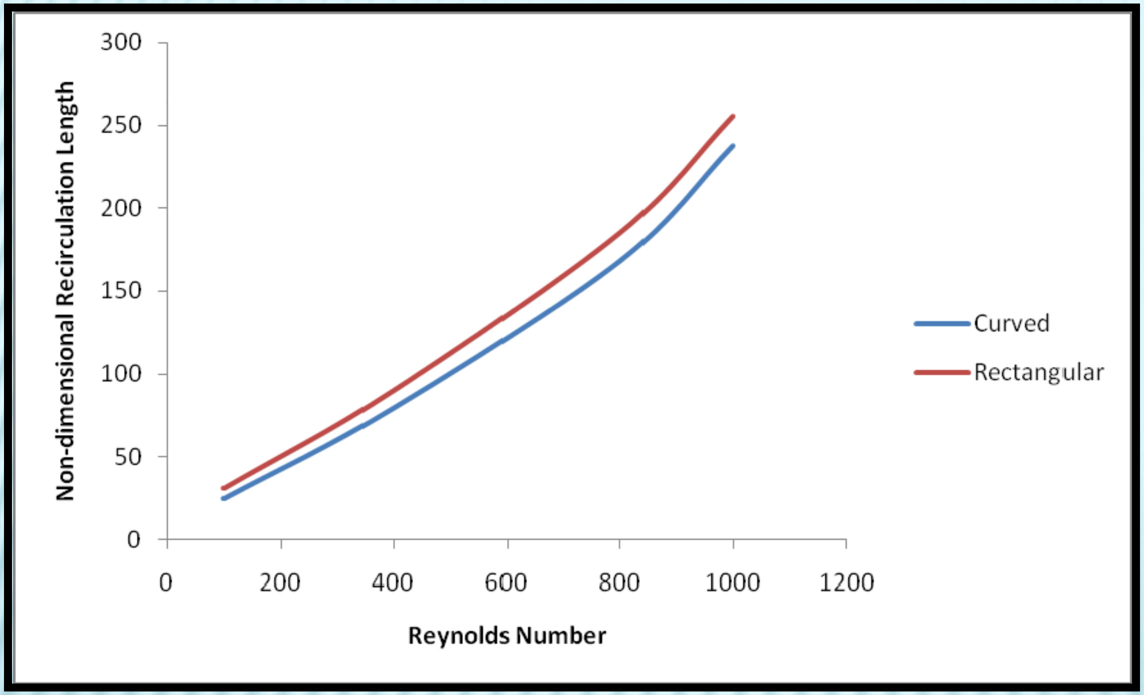


RADIAL VELOCITY PLOT




POINT OF SEPARATION
LENGTH OF REATTACHMENT

REATTACHMENT LENGTH VS. REYNOLDS NUMBER

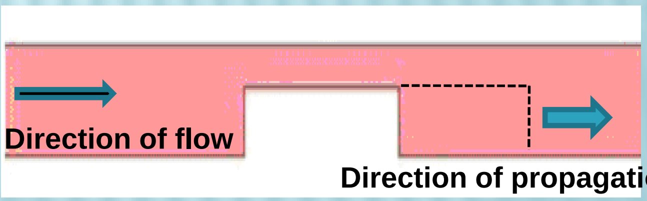


- The reattachment length increases with increase in *Re*

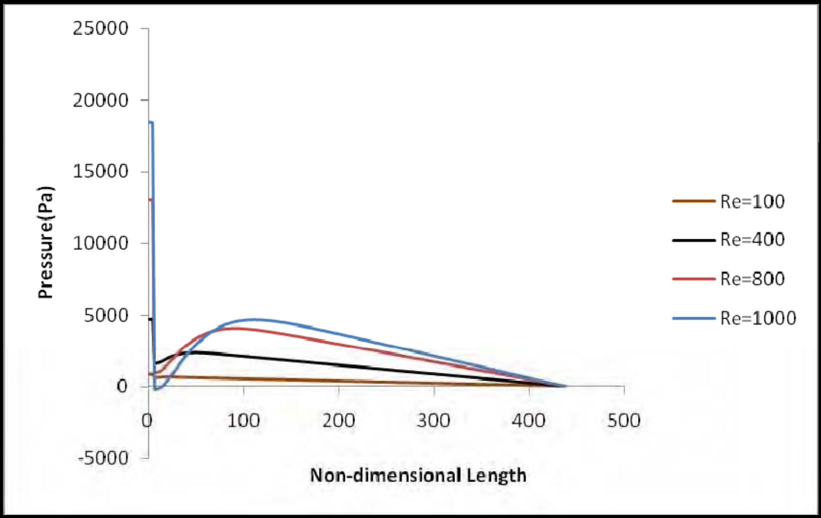
- The length of reattachment is 10% higher for the rectangular stenosis than the curved one

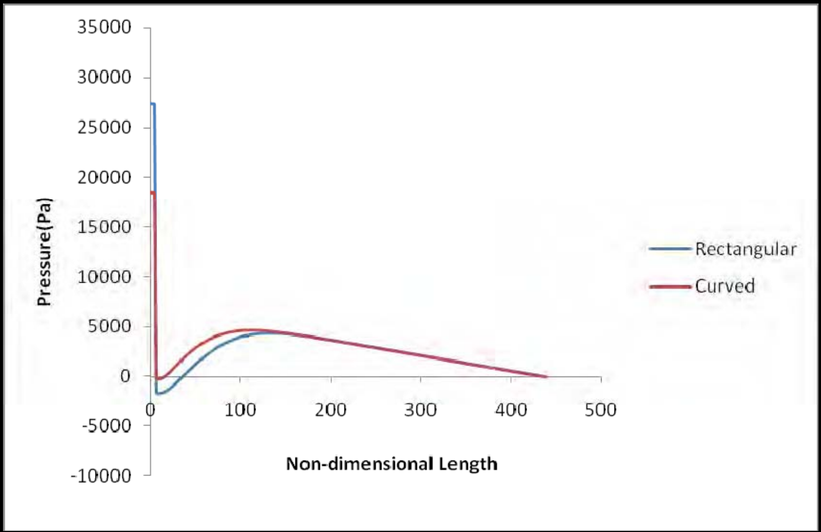
HIGHER REATTACHMENT LENGTH

HIGHER RATE OF PROPAGATION OF STENOSIS



CENTERLINE PRESSURE PLOTS





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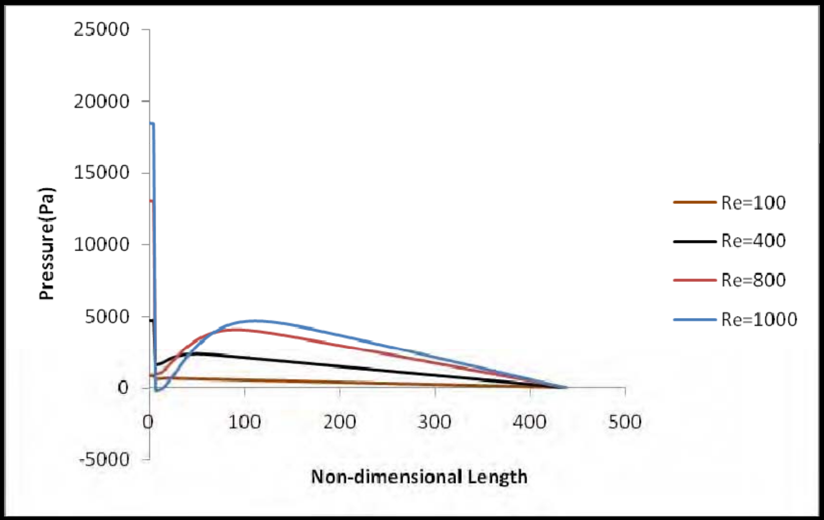
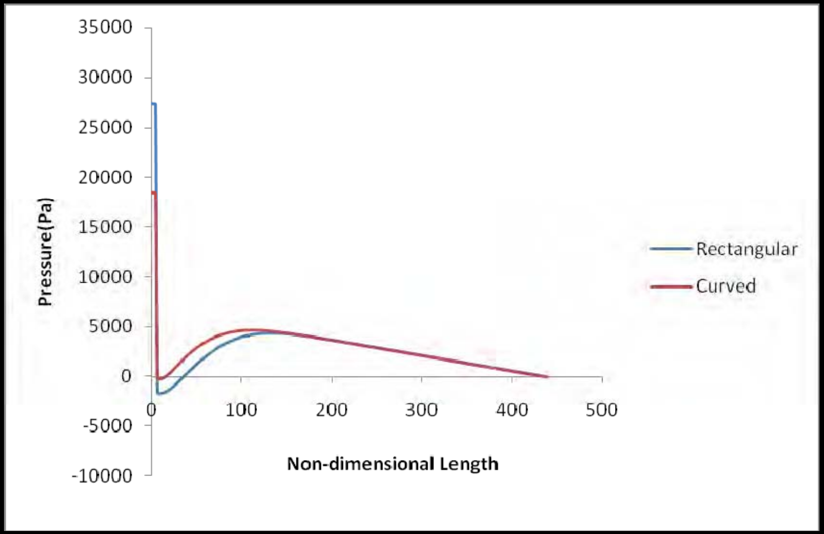
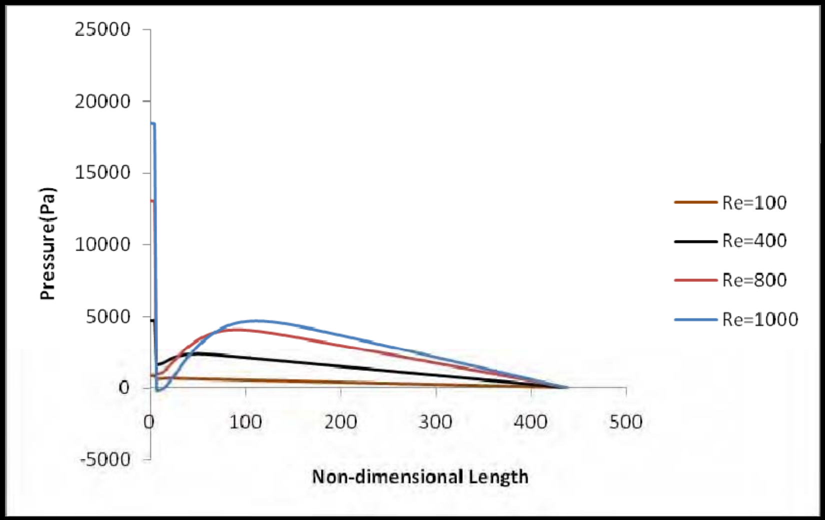
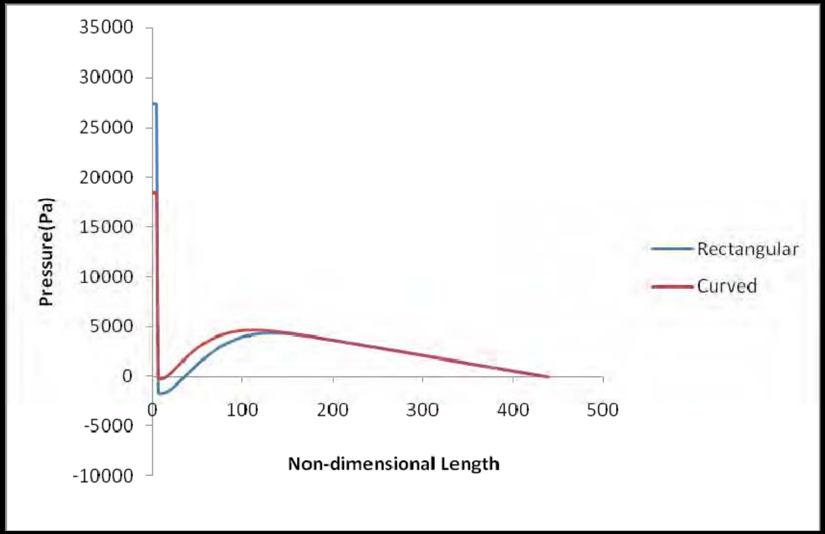




- Shows that irreversible pressure rise increases with increase in *Re*

CENTERLINE PRESSURE PLOTS





- Shows that irreversible pressure rise increases with increase in *Re*

- Shows that the pressure rise is higher for the rectangular stenosis by 23%.

HIGHER LOAD ON HEART

CONCLUSIONS

- Severity increases with increase in Reynolds number i.e. increase in blood velocity.

- The length of the stenosis gradually increases.

- A rectangular constriction is more severe than a curved one.

- A curved geometry gradually approaches a rectangular shape

THE CONDITION ESSENTIALLY WORSENS WITH TIME

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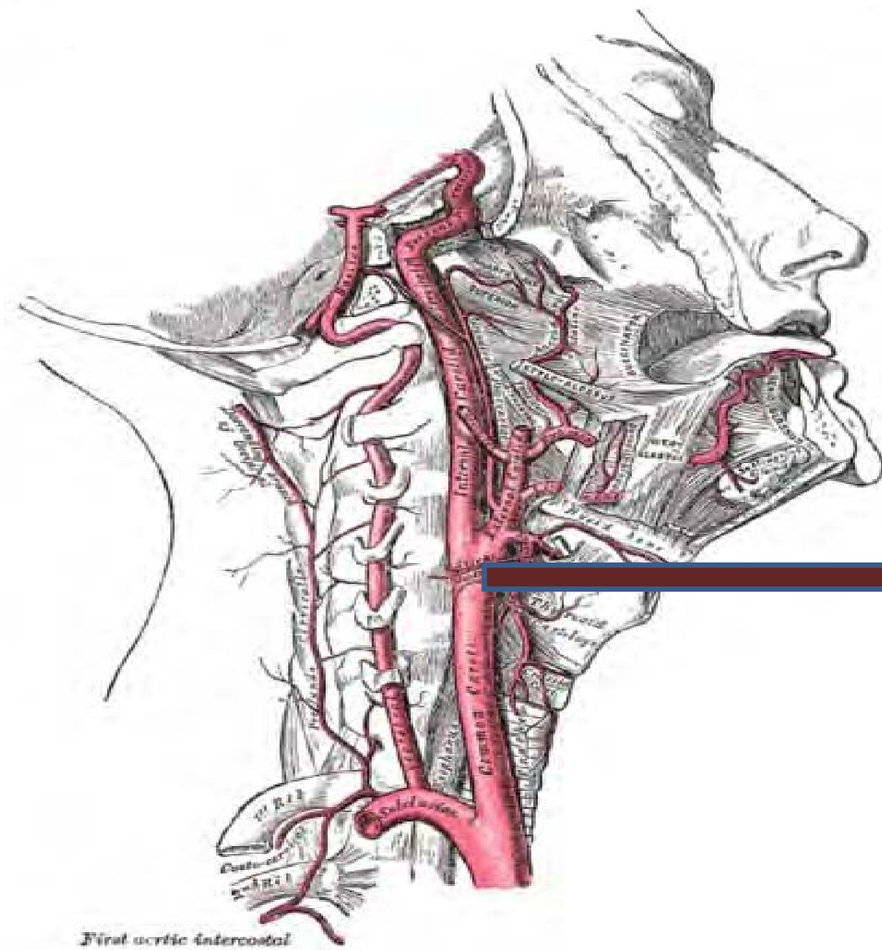
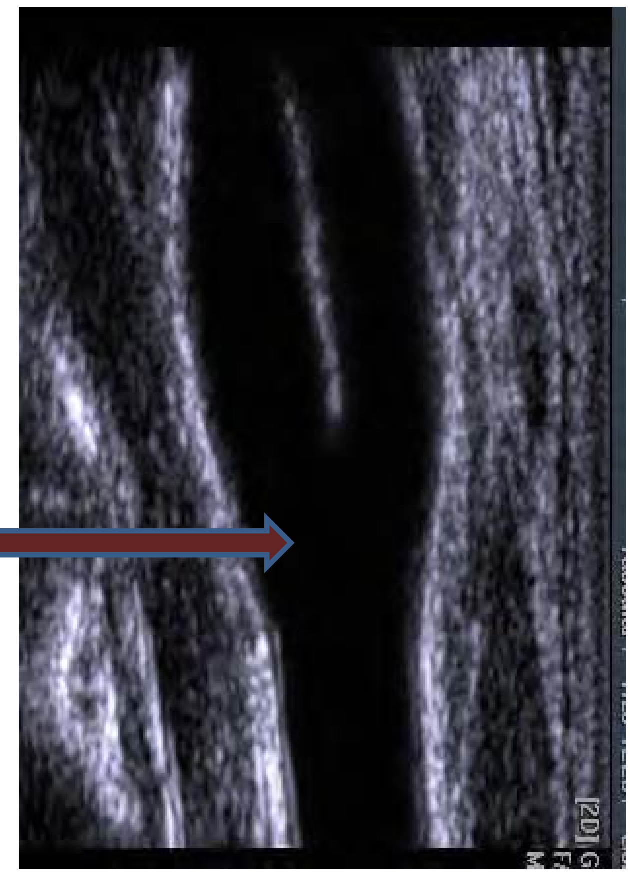
THANK YOU

CAROTID ARTERY





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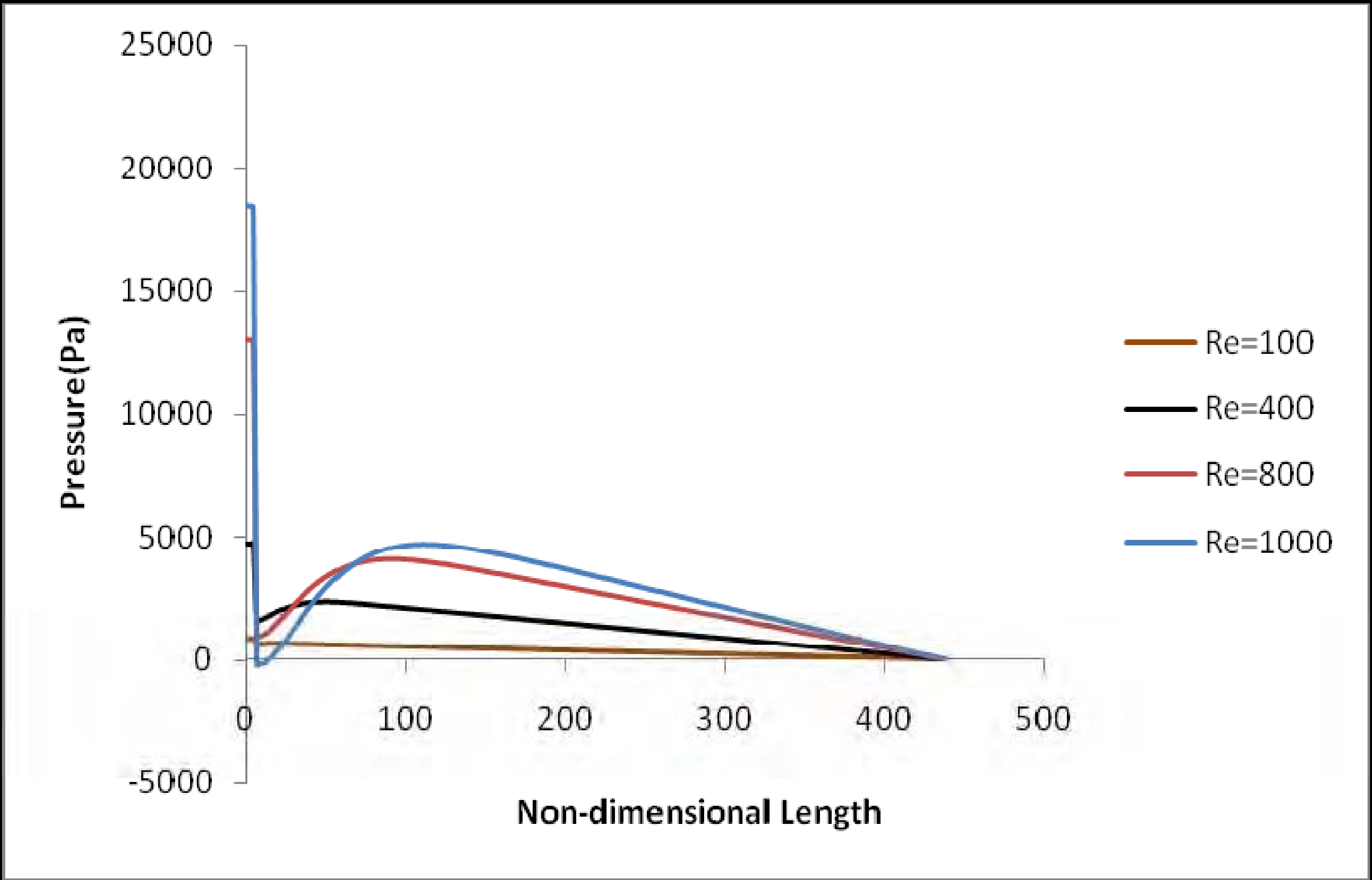

CENTERLINE PRESSURE PLOTS