Prof. R Krishna Kumar
Perry L Blackshear Chair Professor

Discussion Meeting with Dr. Praskash Keshaviah

October 05th, 2020

Research Work in Biomedical Engineering in the past three years

- Surgical Planning for Cerebral Aneurysm
- Wave Propagation in arteries – Effect of continuous and pulsatile flow LVADs on cerebral blood flow
- Development of Percutaneous LVAD
- Brain Shift in Neurosurgery
- Virtual Reality planning of surgical interventions
- Fetal Ultrasound – Project with Univ. Sydney
  - Thalamus extraction
  - Quality control
  - Super resolution
- Portal Pressure using Ultrasound
- Mentoring a company on neuro navigation system – "Cartosense"

Surgical Planning for Cerebral Aneurysm

Blood Flow Analysis

Image processing

- Different filters for processing MRA
- Summary on 3D reconstruction
- 3D models used

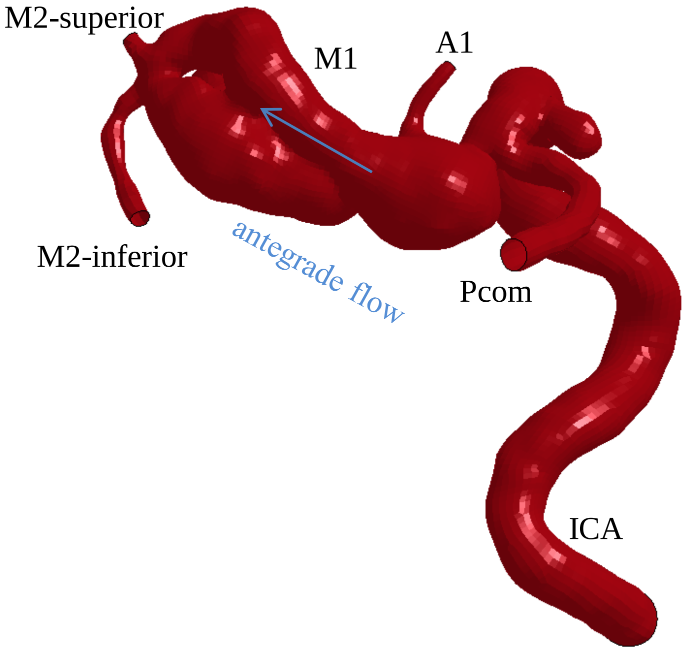
Electrical – 0d model

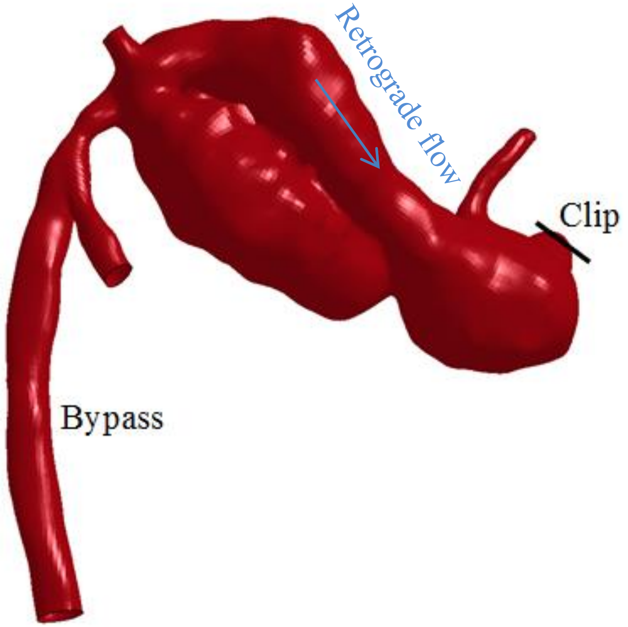
- Multi compartment model
- Boundary conditions

Fluid Structure Interaction

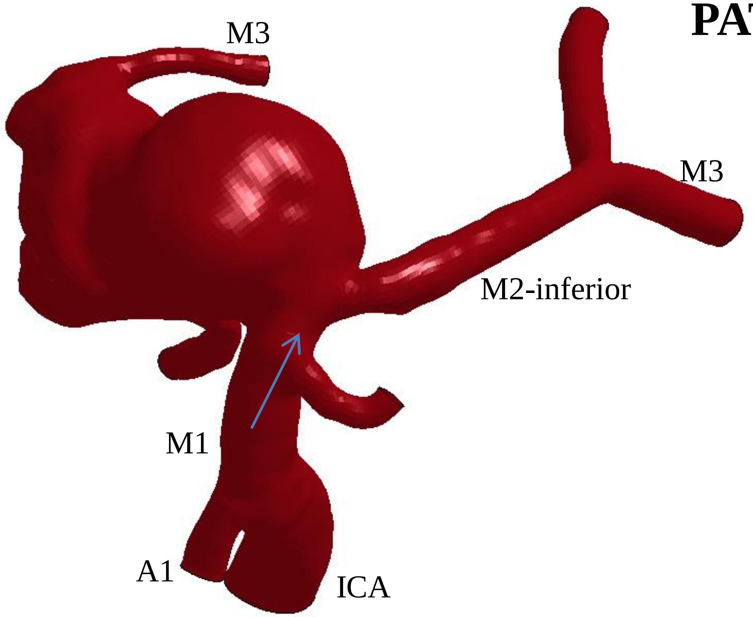
- Material models
- Cerebral results & discussion
- LVAD results & discussion

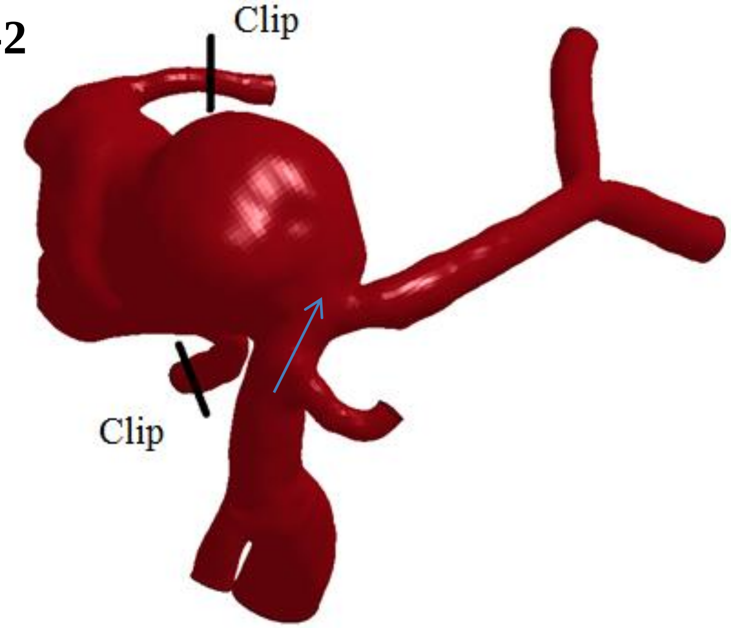
PATIENT-1





PATIENT-2





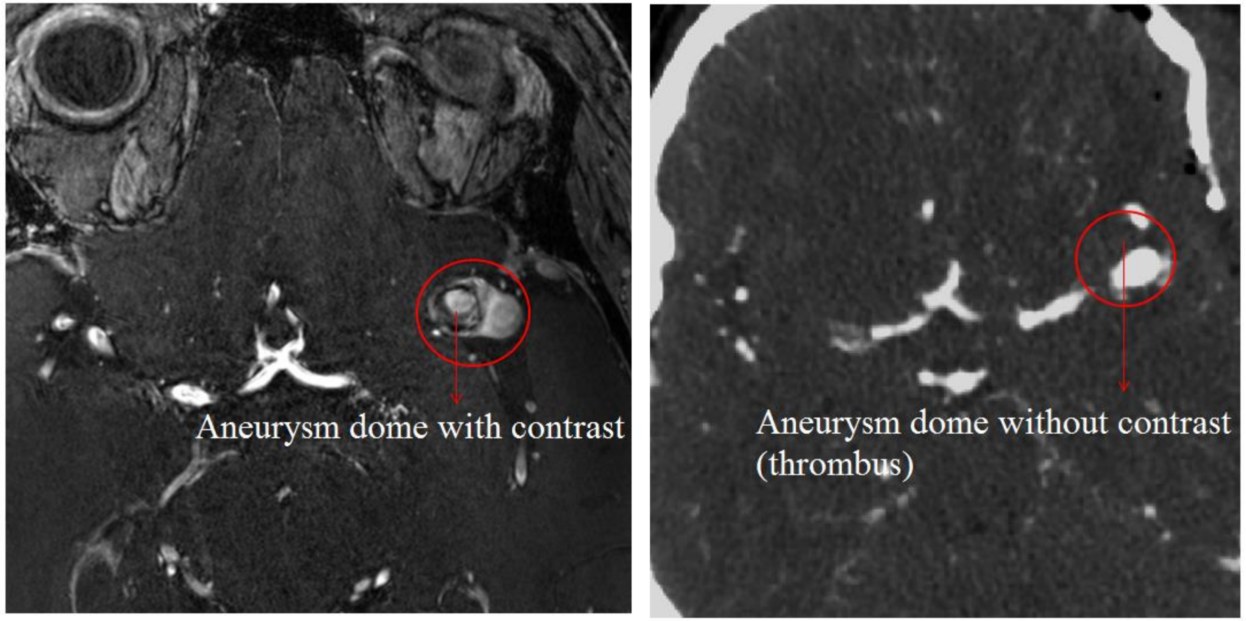


Figure: Comparison of pre-surgery (LHS) and post-surgery (RHS) scans

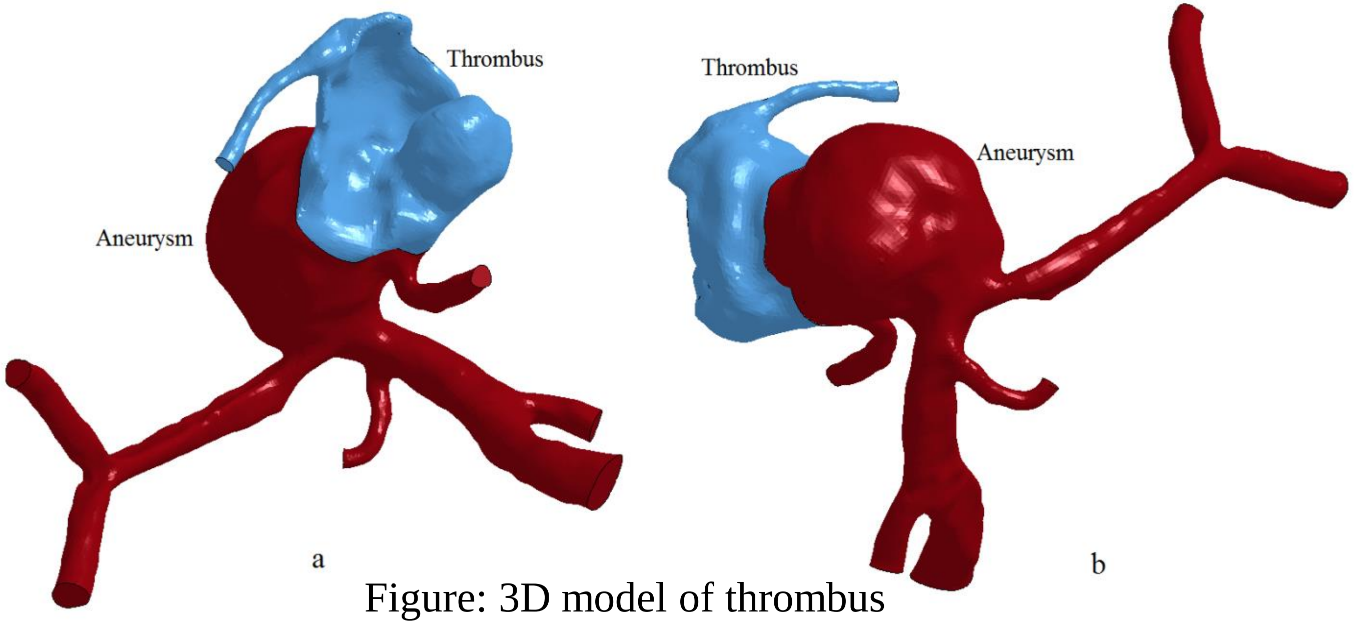


Figure: 3D model of thrombus

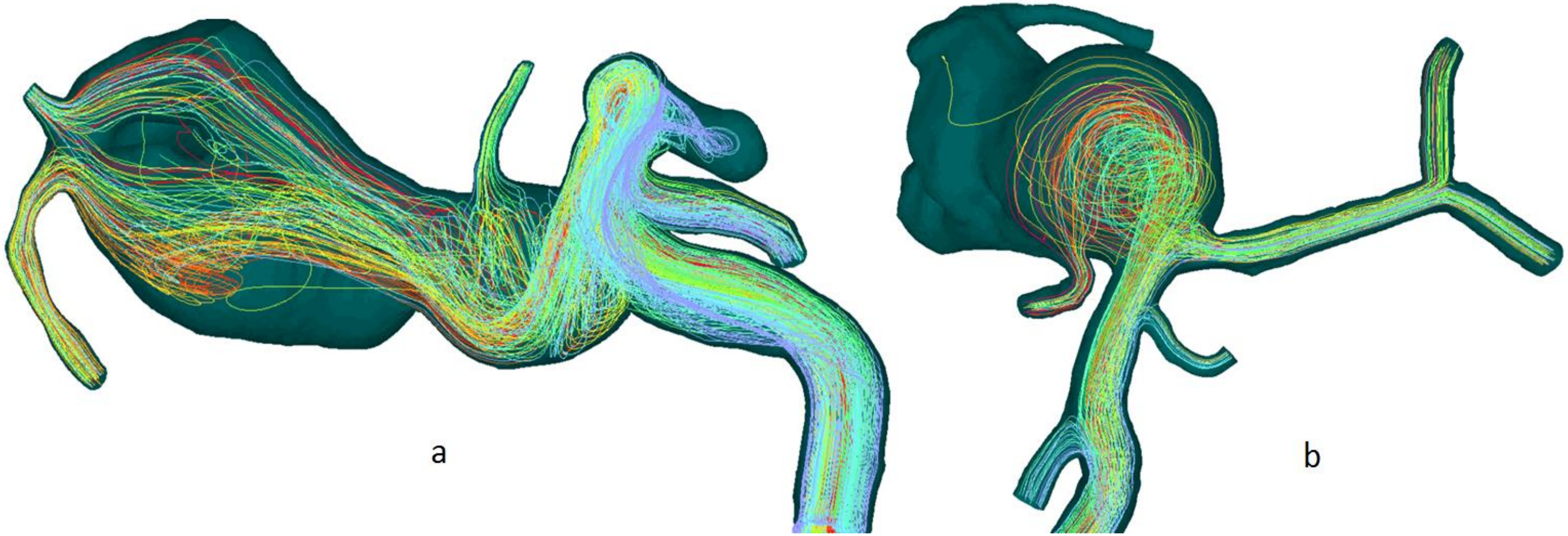
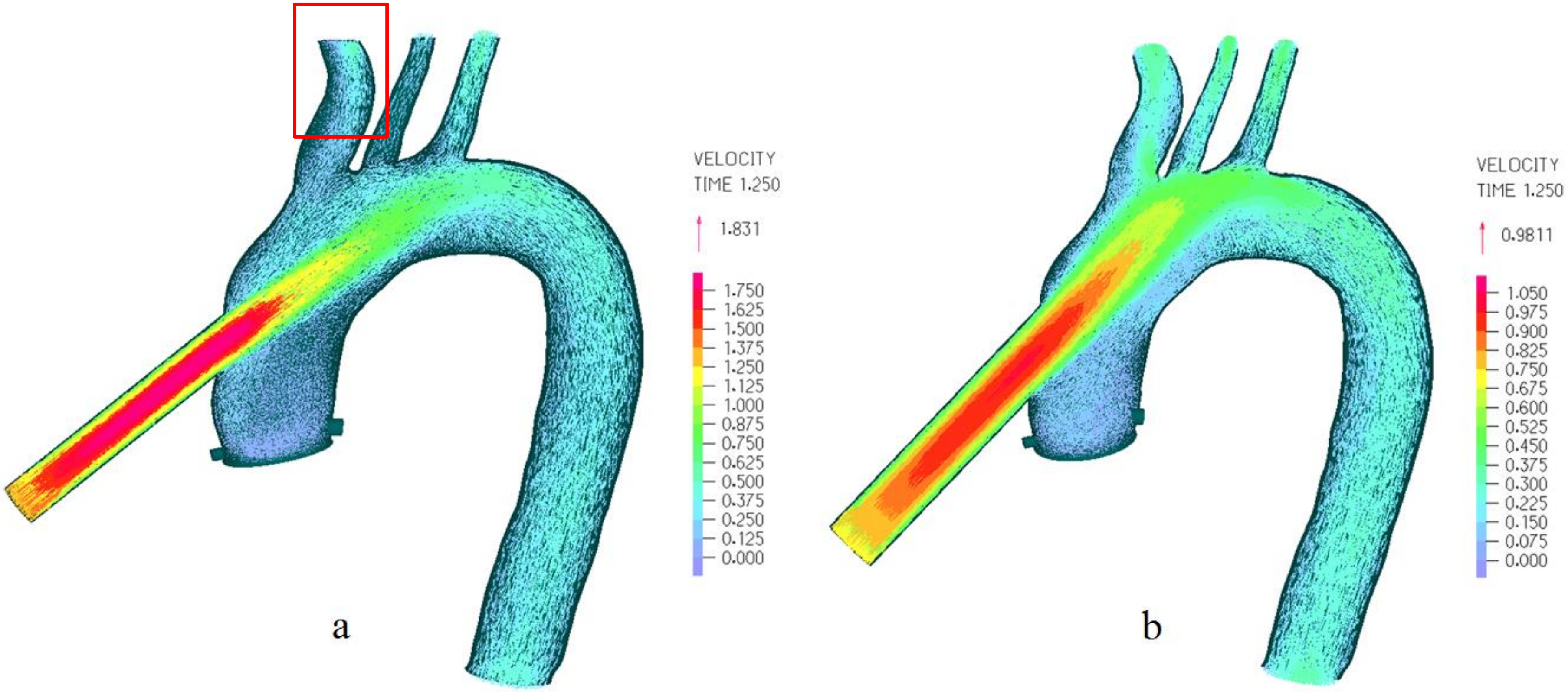


Figure: Helical flow pattern in the aneurysm before bypass surgery: a.Patient-1   b.Patient-2

- Helical flow inside aneurysm
- Helical flow reduces LDL deposition and thrombosis
- Saccular aneurysm : No helix at the dome region

Reduced cerebral circulation – jet effect - LVAD



Aim

To develop a computer aided next generation operation theatres which is capable of

Accurately predicting the biomechanical behaviours (movements, deformations, etc.,) during surgical interventions

↓

Updating the preoperative images to the intraoperative situations by accounting the intraoperative deformations

↓

Using Virtual Reality and Augmented Reality to improve the surgical outcomes

↓

Next Generation Operation Theatres

Questions

- What if the **brain shifts** after the craniotomy and the **preoperative image data becomes invalid**?

- What if the **brain deforms during intervention** and the image overlay which is registered onto it is not deforming ?

- So how to provide a better, accurate and realistic neuro-navigation?

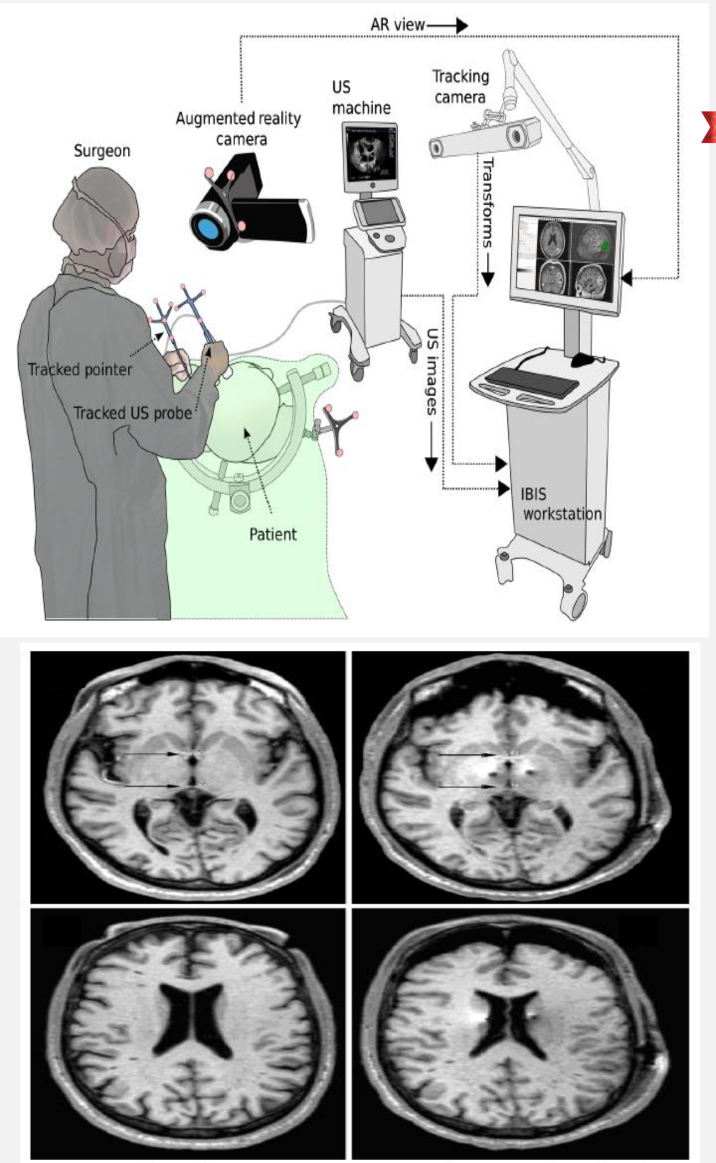


Fig.4. Neuro-navigation & Brain tissue deformation after Craniotomy (Elias et al)

Causes of brain shift

- **Fluid loss** (cerebrospinal-fluid drainage),
- **Gravity** (tissue sagging due to its own body weight),
- Tissue loss (Tumor removal),
- Surgical equipment - Retractors (forces from interventions),
- Neuronavigation-hardware movement
- Patient positioning,
- Drug usage (Mannitol) and
- Tumour type.

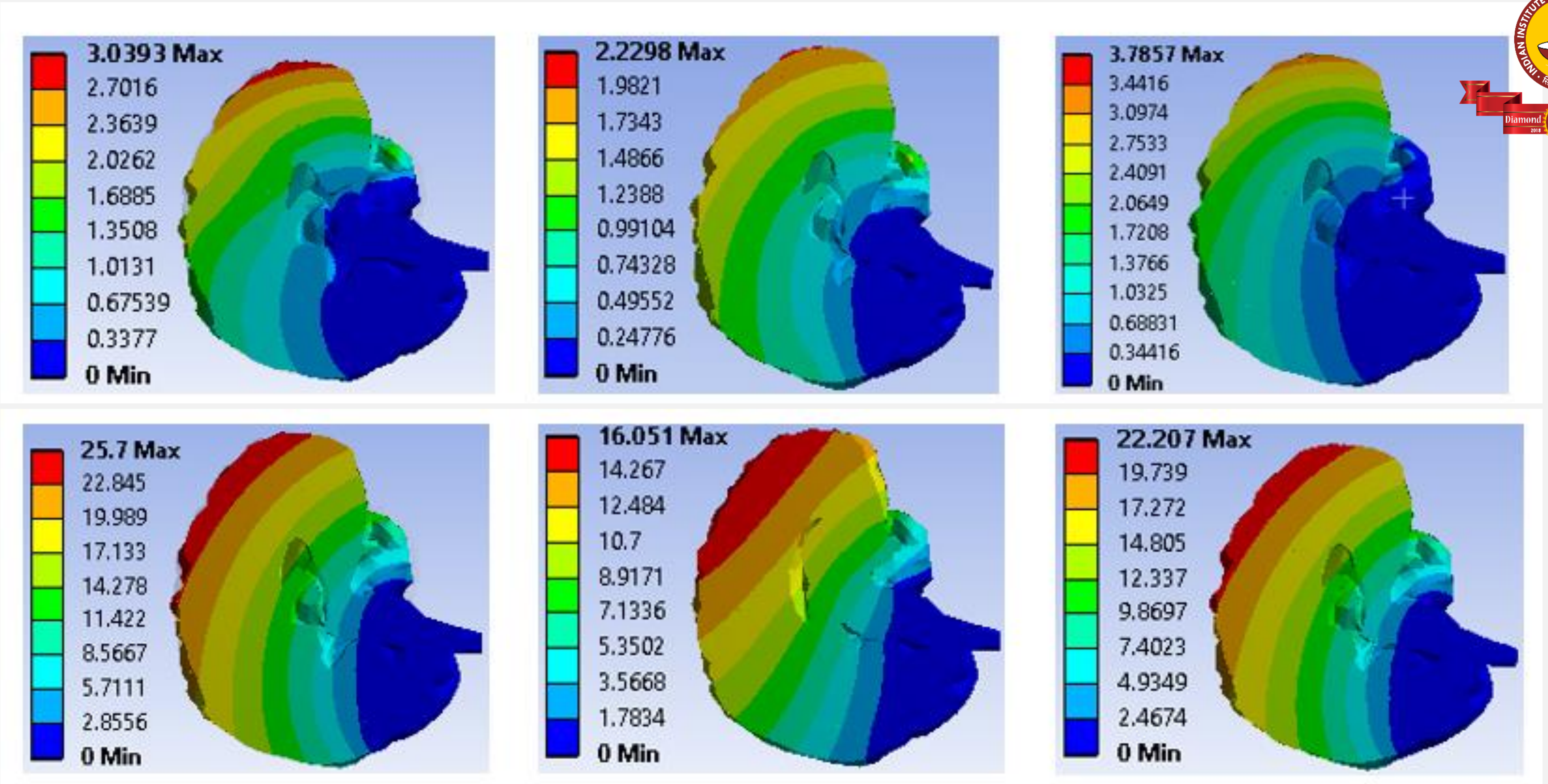


Figure.7. Cerebrospinal fluid leak induced deformations (when ICP is 15mmHg) and Gravity-induced deformations for Parietal, Temporal and occipital craniotomy procedures (from left to right). All dimensions are in mm.

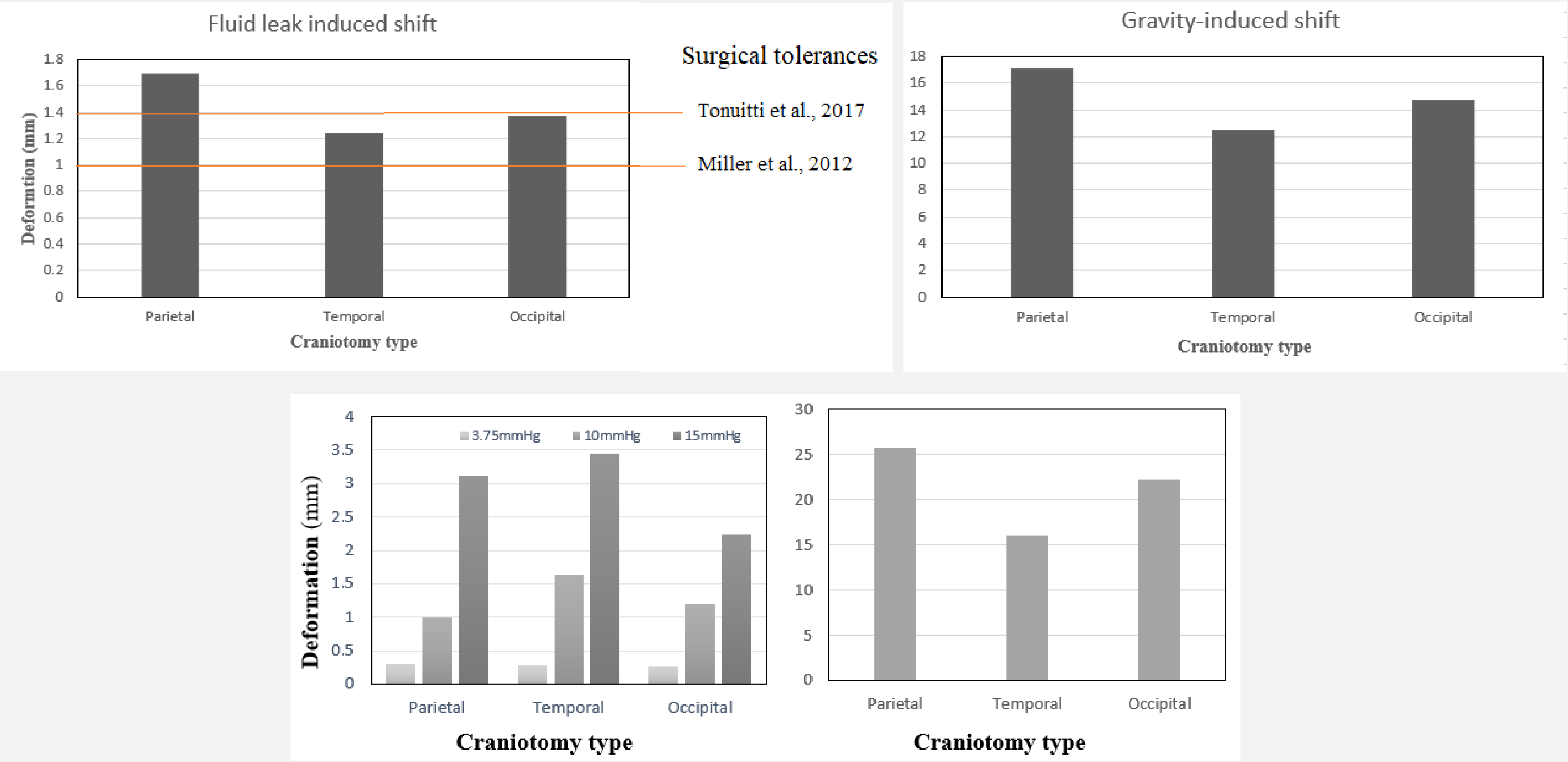


Figure.8. Maximum deformations in the ventricles (top) and maximum over all brain shift (bottom)

Patient-2 (Eleven Year Old Child from Egypt)

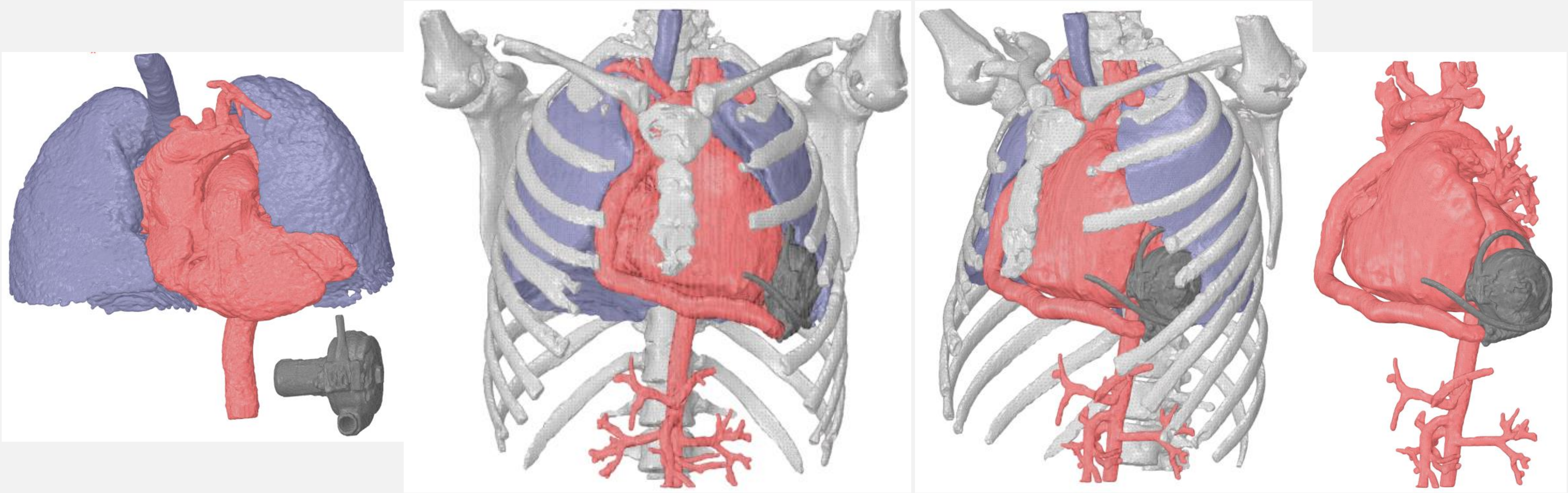
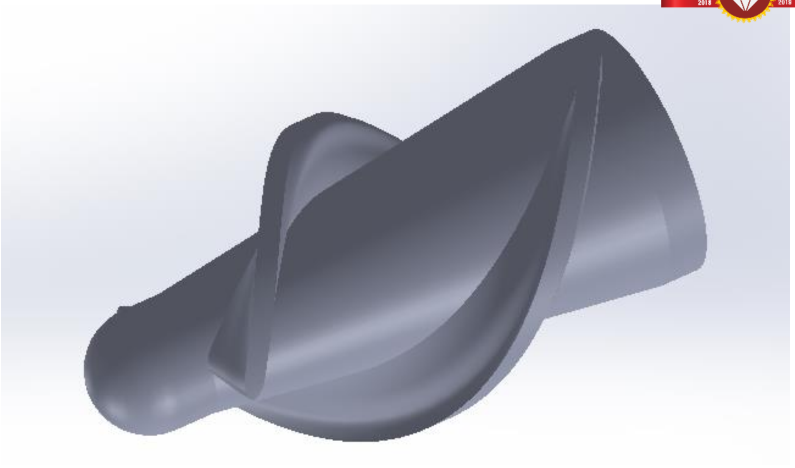


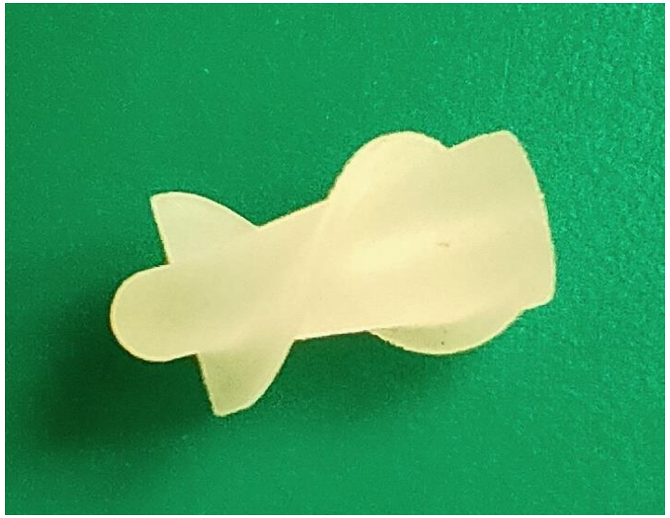
Fig.11. Before surgery (during virtual surgery) and post surgery comparison.

OBJECTIVE

A. Solid modelling of a Percutaneous Left Ventricular Assist Device (PVAD).

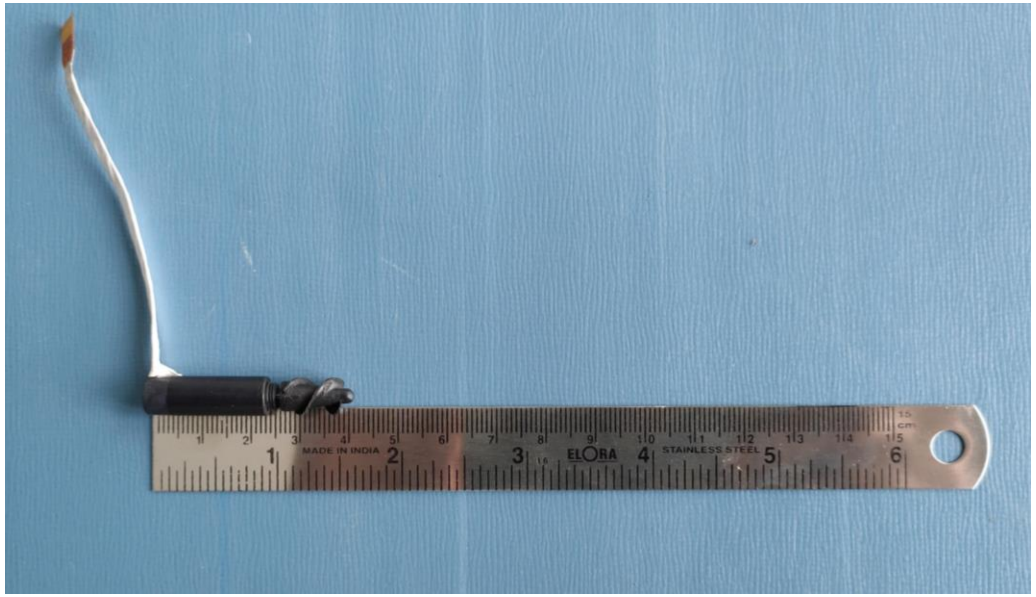


B. Prototyping of the designed PVAD



ASSEMBLY

Impeller was tight fit in the motor without the use of any coupling



EXPERIMENTAL SETUP

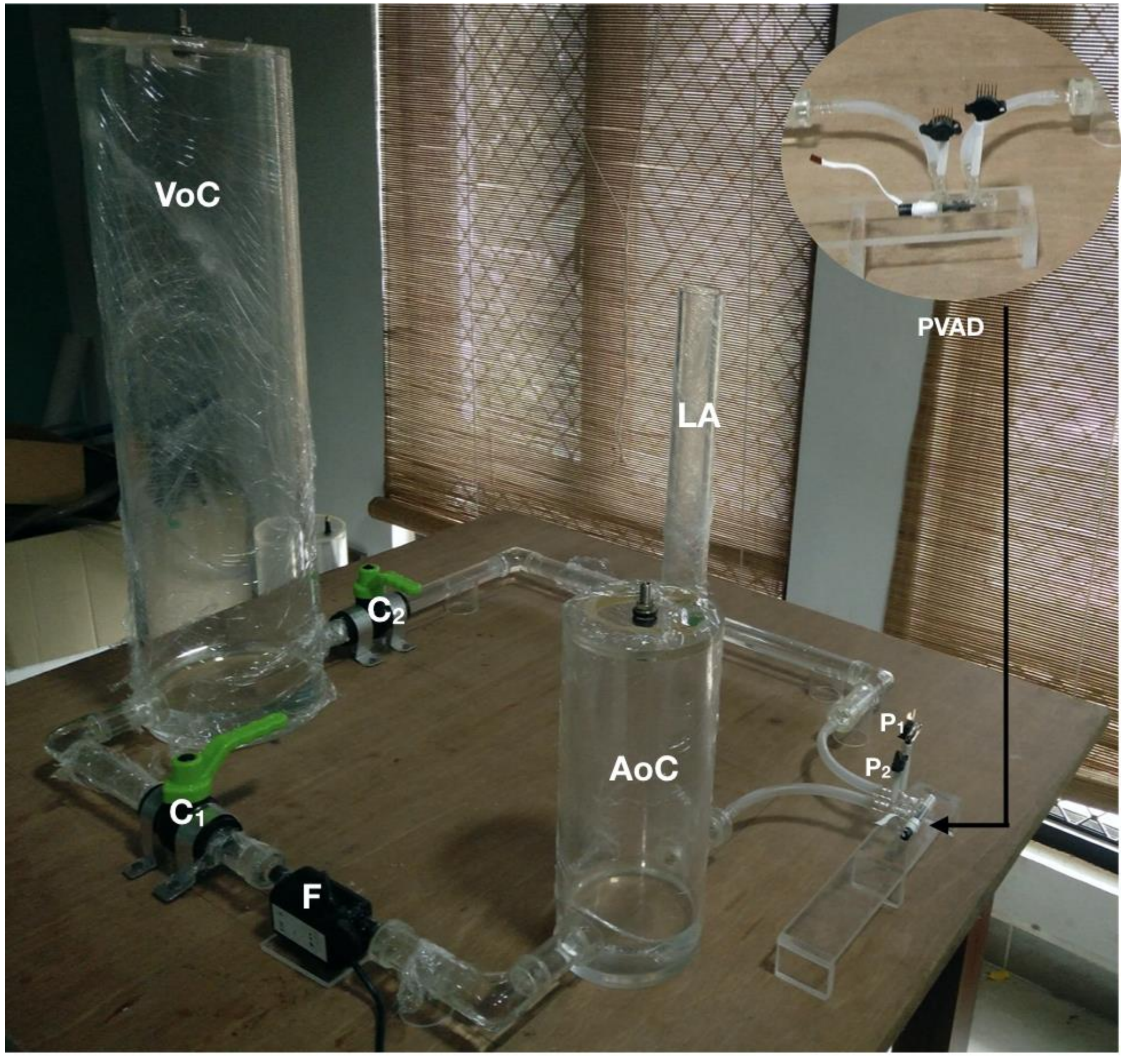


Figure 19: Systemic Mock Circulation Loop (SMCL)

Acrylic tubes of diameter 150mm, 100 mm and 40 mm, were used to fabricate the venous compliance chamber, arterial compliance chamber and left atrium respectively.

The connecting tubes were made from 20 mm acrylic tubes.

A non-invasive ultrasonic flow sensor is used.

Two free scale absolute, MPX-5100 AP pressure sensors is used.

COMPARISON OF CFD AND PIV RESULTS

The maximum velocity is near the shroud and it decreases towards the centre. The difference between the CFD and the experimental results is less than 10%

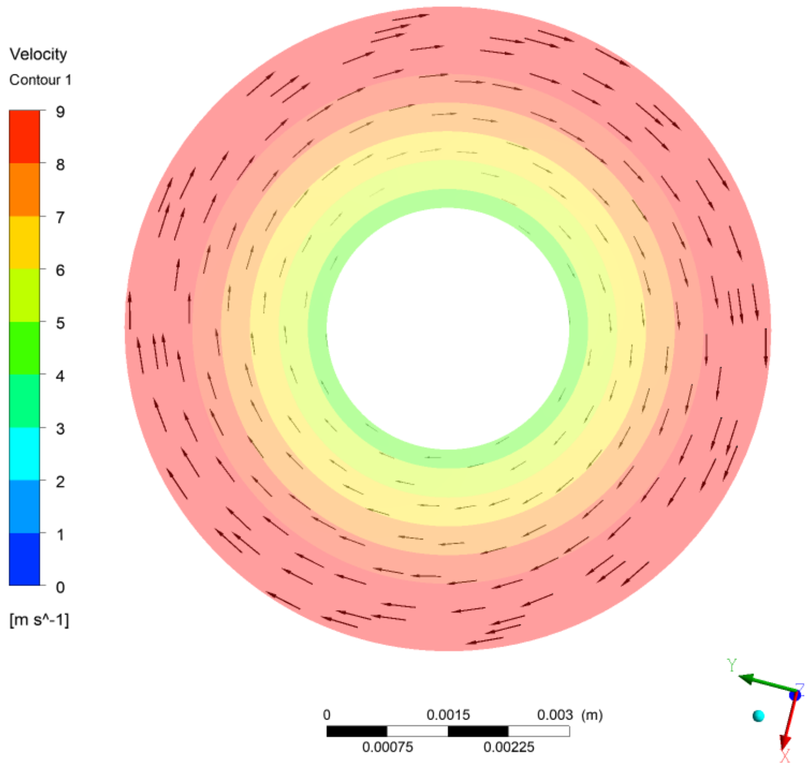


Figure 31: CFD results at inlet

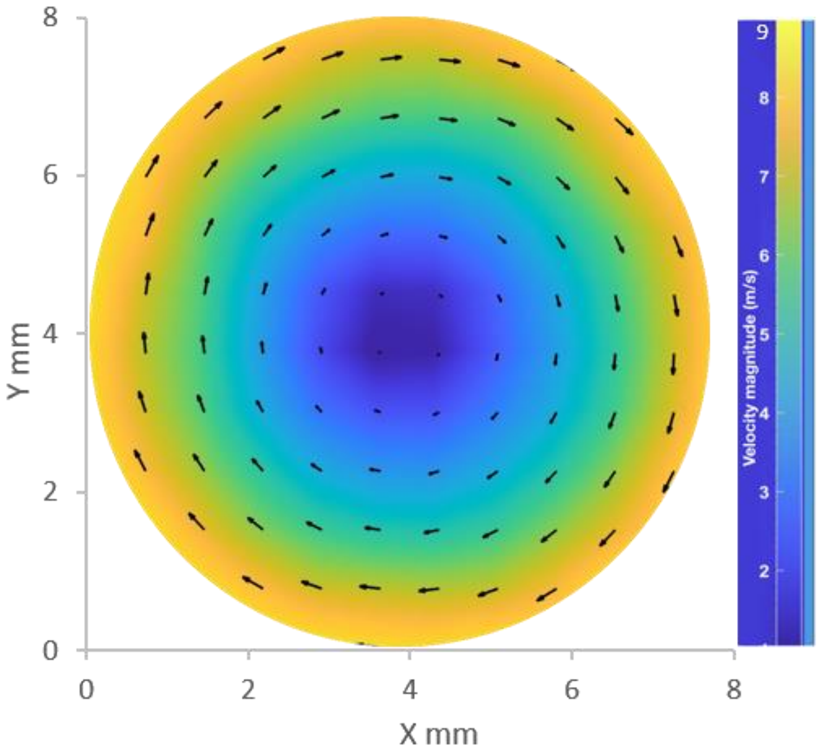


Figure 32: PIV results at inlet

HEMOLYSIS INDEX

Hemolysis index is a measure of amount of haemoglobin released in the plasma due to rupture of red blood cells to the net haemoglobin content. In order to calculate the amount of free haemoglobin in blood stream with respect to total haemoglobin, a power law model given by Giersiepen et. al. (1990) was used.

$$\frac{\Delta\, Hb}{Hb} = HI = A.\, t^{\alpha}.\, \tau^{\beta} \qquad (7)$$

The formula describes the amount of haemoglobin $\Delta\, Hb$ in relation to the total haemoglobin Hb. The Hemolysis Index (HI) depends on the exposure time and the shear stress acting on the RBC'c. A, α, β corresponds to the constants that were obtained by regressing experimental data by Giersiepen et. al. The values of these constant are A= 3.62×10^{-5}, $\alpha = 0.785$, and $\beta = 2.416$.

The residence time (t) as a measure for exposure time for each computational cell was approximated using the mean velocity magnitude u and the cell size defined as the cube root of the cell volume (V).

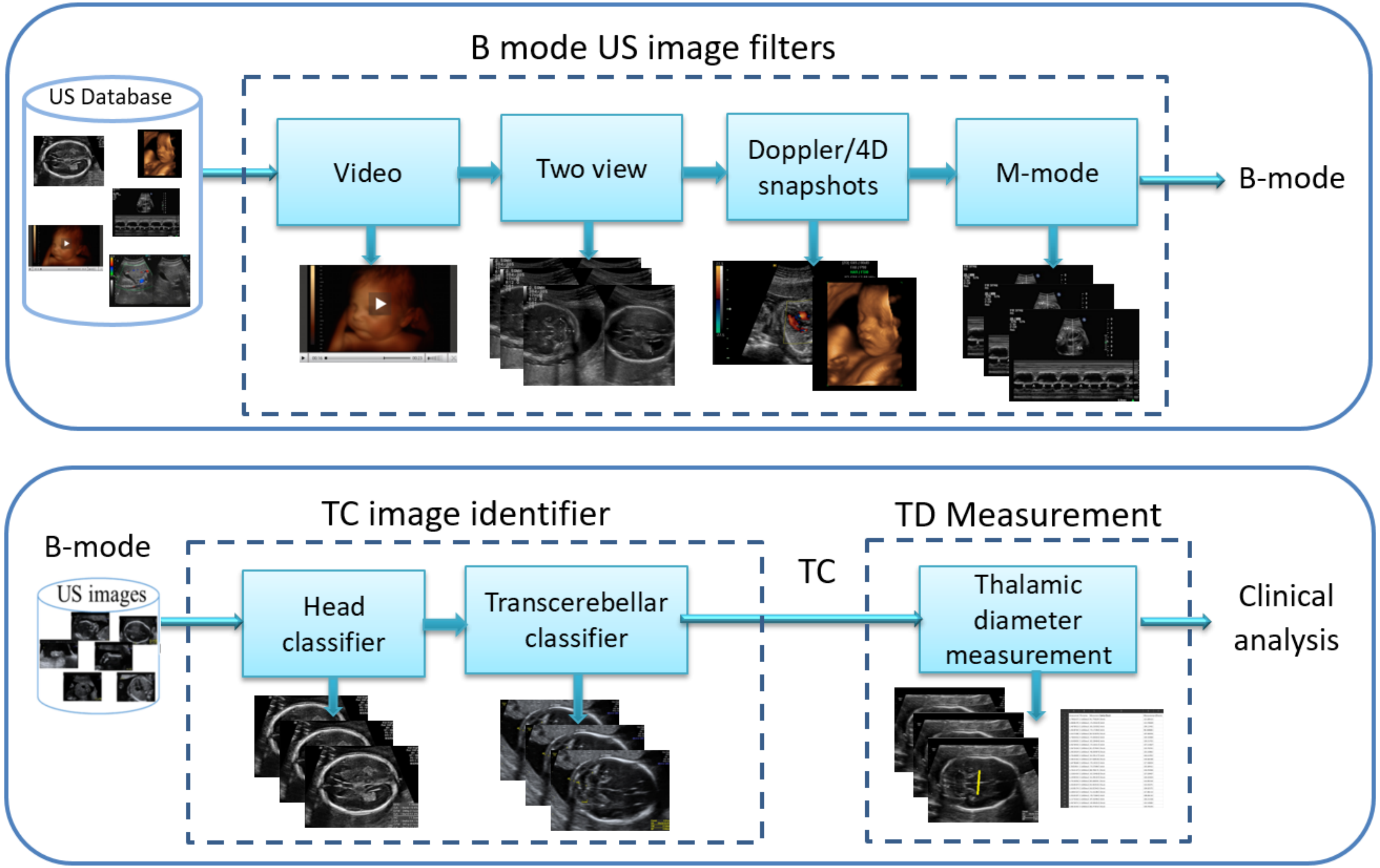
$$t = \frac{\sqrt[3]{V}}{u} \qquad (8)$$

In our study the cell volume is $6.73 \times 10^{-16}\, m^3$ and the mean velocity u is 0.96 m/sec, hence the exposure time t is $9.12\mu s$.

The hemolysis index in designed PVAD is 1.26×10^{-5}. The studies done by Bente et. al. (2015), where Hemolysis index for HVAD is 3.75×10^{-5} and for HM II is 3.85×10^{-5}, shows that the designed PVAD is in good agreement with the state of the art devices commercially available.

Automated Framework for Fetal Biometry

- PhD Thesis of Dr. Pradeeba Sridar

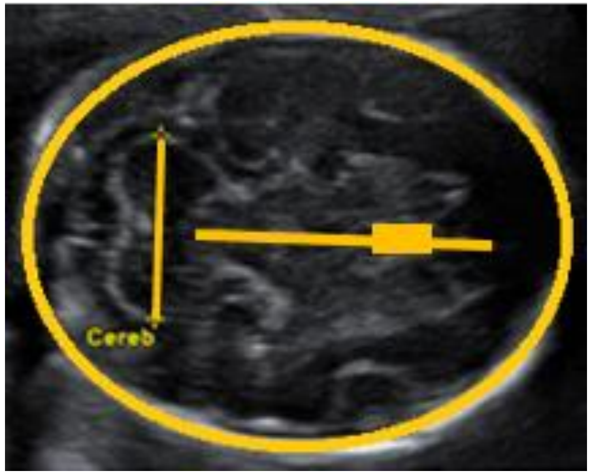


Super Resolution in Fetal Ultrasound

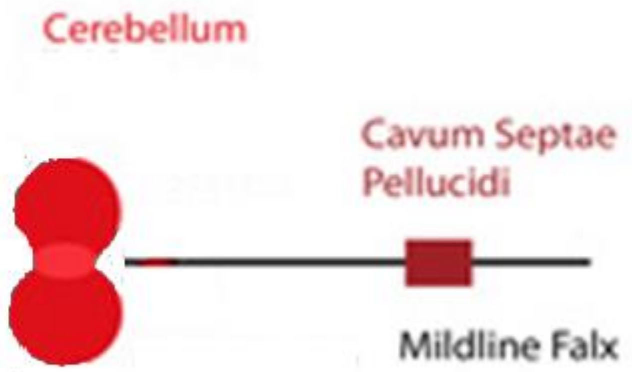
2. Automatic Quality Assessment of Fetal-head Ultrasound Images

Landmarks and their qualitative features

- Skull: Elliptical shape
- Cerebellum: Peanut-shaped
- Midline Falx: Major axis of the elliptical skull
- Cavum Septum Pellucidum: boxed-shaped, lies on the falx



Localization → Segmentation → Quantification



Part 2- Motivation – automatically remove outliers of TC images

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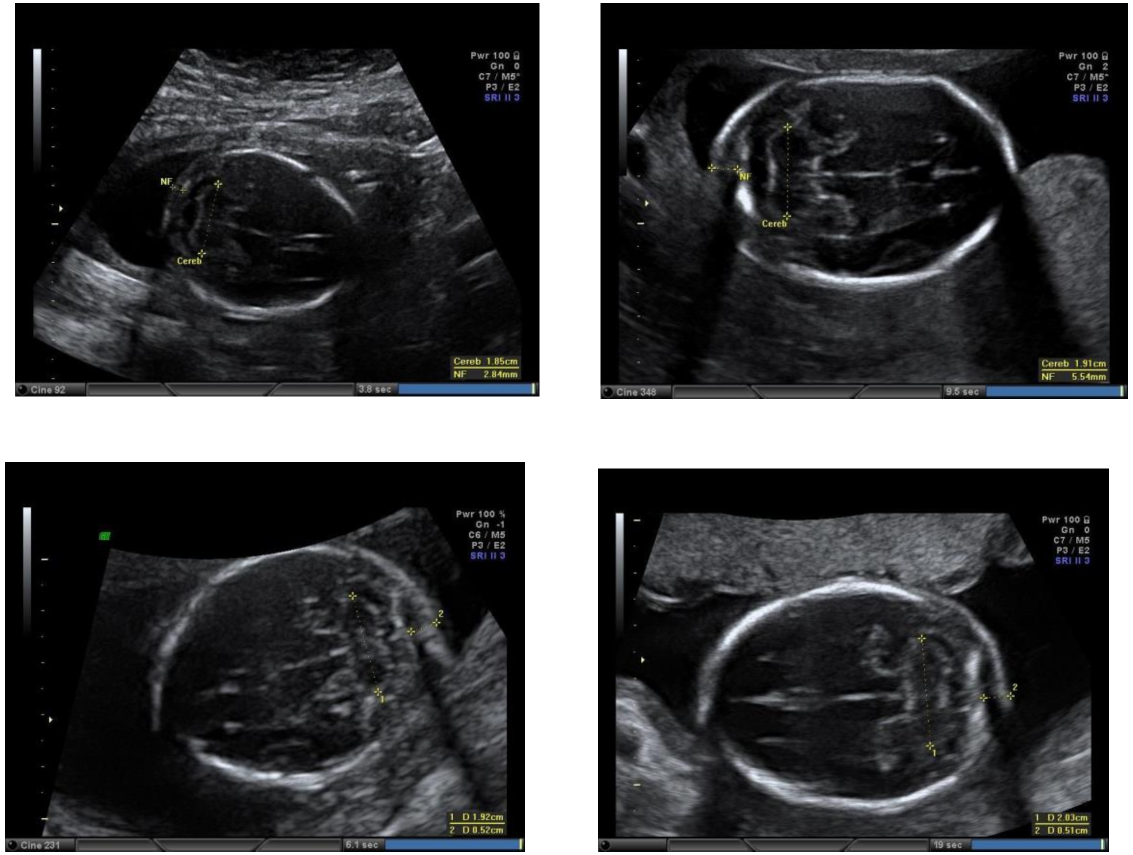
High quality



Low quality