# Predicting Rupture Potential of Cerebral Aneurysms

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## Objective

A key factor governing clinical management of cerebral aneurysms is its rupture potential. In this realm, morphological features of aneurysms, that closely model the underlying hemodynamics of the fluid flow often provide valuable clues to the neurosurgeons to take clinical decisions. This work aims to assess the significance of the morphological factors in predicting the rupture potential of the aneurysms using statistical and machine learning tools.

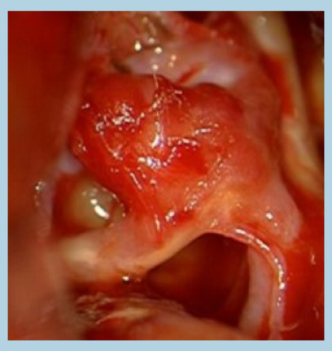


Fig. 1 : Surgical view of an aneurysm (Source : SCTIMST)

## Motivation

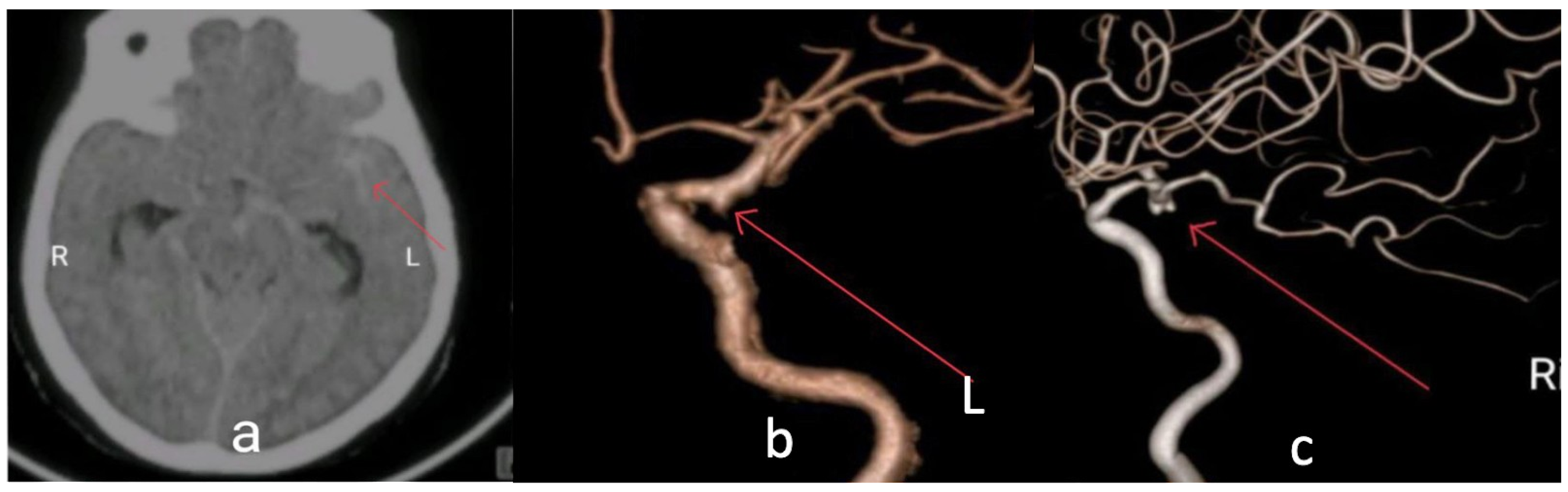



Fig. 2 : A patient with two aneurysms - a large unruptured aneurysm (R) and a much smaller ruptured aneurysm (L), indicating the need to go beyond aneurysm size as the sole determining parameter in predicting aneurysm rupture risk.

- Previous cohort based studies suggest that aneurysms smaller than 10mm represent minimal risk of rupture and possibly do not need to be treated.[1]
- However, it has been discovered that even small aneurysms tend to rupture.[2]
- Although attempts have been made to determine a diagnostic guideline to predict the rupture status, a concrete mechanism is still not well perceived.[3]

## Methodology

The study comprised of 50 patients admitted to the Sree Chithra Tirunal Institute of Medical Science and Technology – with 32 of them having ruptured aneurysms, and the other 18 of them having unruptured aneurysms.

Reconstruct the 3D image from the DICOM images of the CT-Angio scan using 3D-Slicer.

Extract the geometric model of the aneurysm from the entire 3D image using 3D-Slicer.

Isolate the neck plane and extract the morphological parameters using ParaView, ANSYS ICEM CFD & PyRadiomics.

Morphological parameters primarily identified by Raghavan et al.[4] and Dhar et al.[5] In addition, some more derived parameters (neck width to parent vessel width ratio, and the surface area to volume ratio) were added.

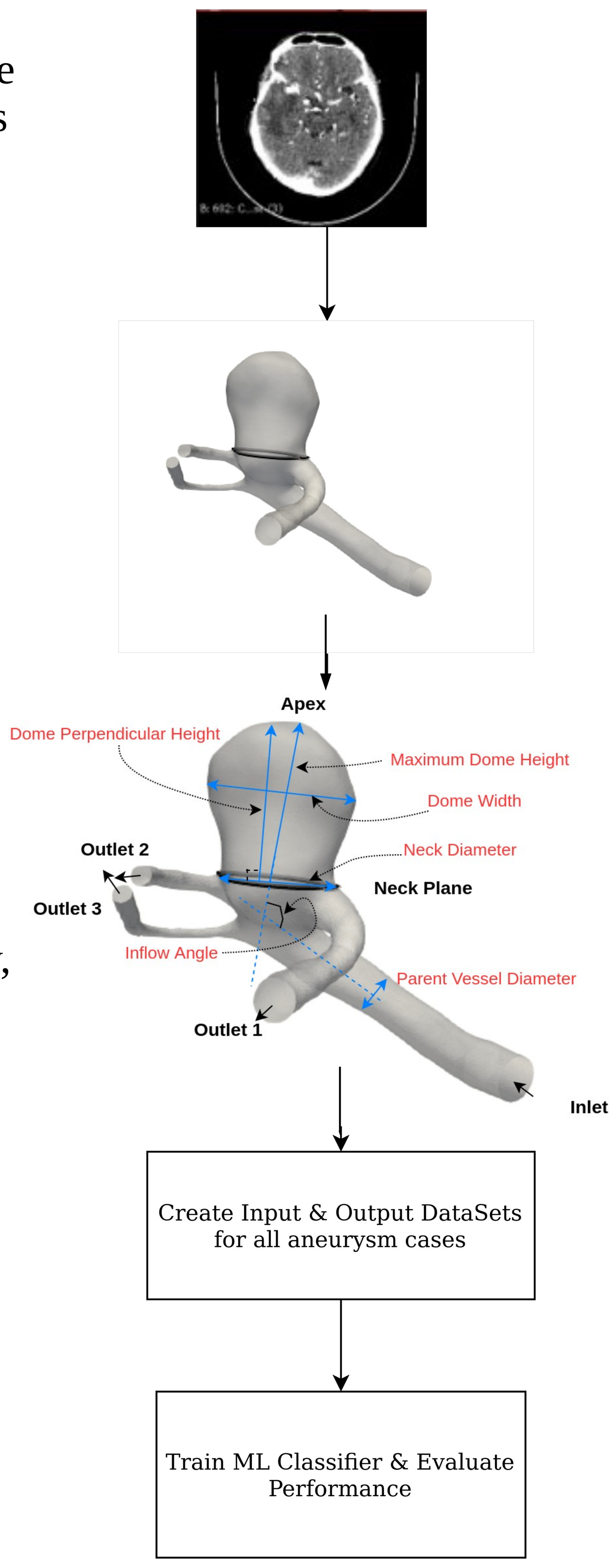



Fig . 3 : Workflow employed for the study – performed on all the cases in the dataset.

## Results

| | Ruptured | Unruptured |
|---|---|---|
| | Mean (Min-Max) | Mean (Min-Max) |
| Age | 49.94 (14-67) | 53.11 (22-74) |
| Dome Height (mm) | 5.98 (0.86-22.33) | 8.00 (1.71-19.63) |
| Dome Perpendicular Height (mm) | 5.21 (0.75 – 16.36) | 7.38 (1.66-18.90) |
| Dome Width (mm) | 7.42 (1.93-28.05) | 9.90 (2.95 – 26.54) |
| Neck Diameter (mm) | 6.03 (1.88-21.78) | 7.39 (2.82 – 15.55) |
| Parent Vessel Diameter (mm) | 3.01 (1.12-10.06) | 3.03 (0.85-4.55) |
| Aspect Ratio | 0.85 (0.29-2.54) | 0.97 (0.50-1.49) |
| Size Ratio | 0.96 (0.30-2.65) | 1.06 (0.55-1.55) |
| Bottle Neck Ratio | 1.19 (1-1.76) | 1.29 (1-1.82) |
| Neck Width to Parent Vessel Width Ratio | 2.01 (0.79-3.63) | 2.31 (1.21-4.55) |
| Inflow Angle (degrees) | 136.72 (79 - 176) | 126.13 (68.40-155) |
| Aneurysm Surface Area (mm2) | 85.41 (6-334) | 218.04 (14-728) |
| Aneurysm Volume (mm3) | 104.49 (1.48-539) | 449.90 (6.81-238) |
| Surface Area to Volume Ratio | 2.06 (0.41-5.12) | 1.10 (0.30-1.92) |
| Undulation Index | 0.06 (0-0.86) | 0.05 (0-0.25) |
| Ellipticity Index | 0.63 (0.36-0.73) | 0.64 (0.51-0.70) |
| Non-Sphericity Index | 0.51 (0.18-0.86) | 0.50 (0.07-0.60) |

Table 1 : Distribution of the morphological parameters extracted for the cases in the study

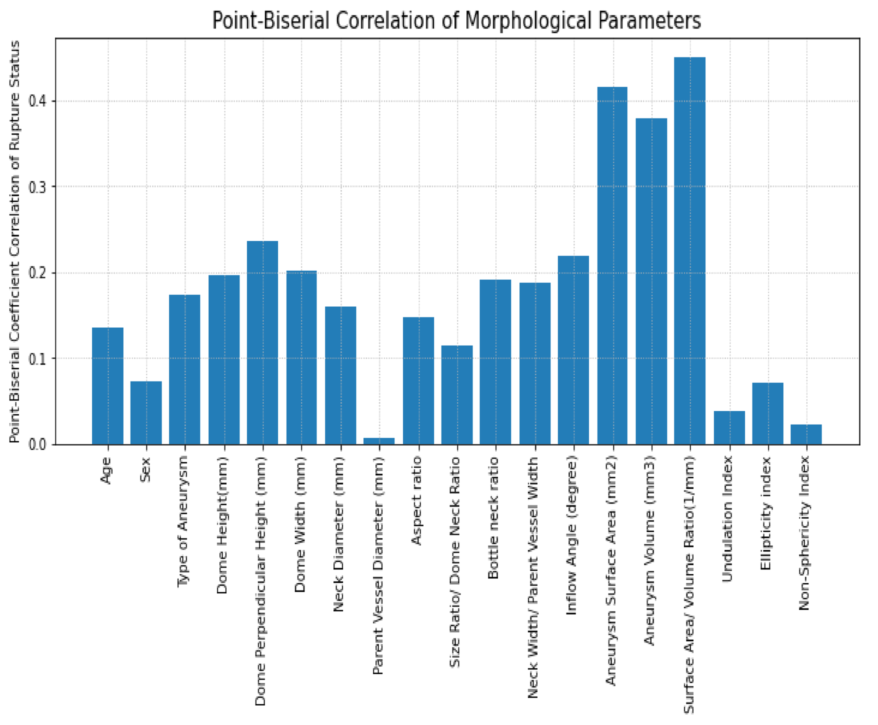
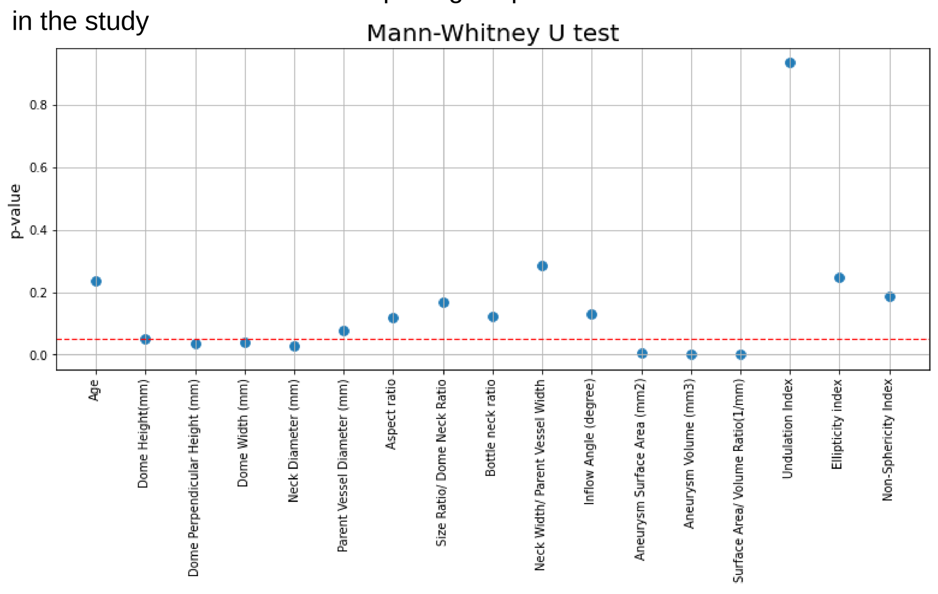



Fig. 4 : Point Biserial Correlation coefficients of the morphological parameters against rupture status



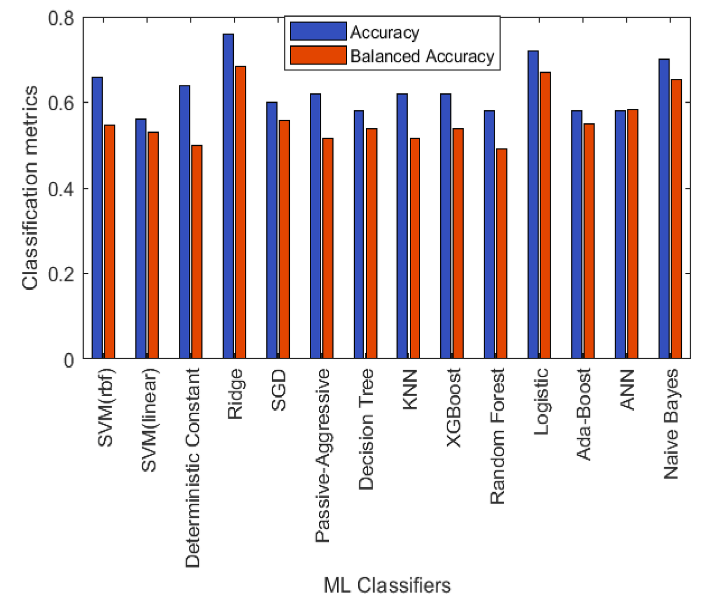




Fig. 5 : Performance of various Machine Learning models on the rupture status prediction

## Conclusions & Limitations of the Study

- Dome height, dome width, dome perpendicular height, neck diameter, aneurysm surface area, aneurysm volume, and surface area/volume ratio of aneurysms were found to be key predictors of aneurysm rupture status, based on statistical studies.
- Ridge & Logistic Classifiers effectively predicted the rupture status of the aneurysms. Such classifiers could be used by neurosurgeons in taking informed decisions on clinical interventions.
- Study was limited to a small dataset - poor for ML model to learn on.
- Dataset heavily biased towards ruptured cases. Further, many of the ruptured cases were significantly distorted from pre-rupture status.

## Future Directions

- Explore Deep Learning and segmentation based techniques for parameter extraction from the 3D geometries – to minimise variations due to operator bias and human errors.
- Once a larger dataset is available, especially with more unruptured cases, further explore one class classifier models trained on the unruptured cases to reduce the impact of distorted ruptured images.

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