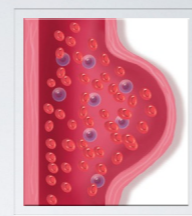# CLUSTER ANALYSIS OF VORTICAL FLOW IN SIMULATIONS OF CEREBRAL ANEURYSM HEMODYNAMICS

Paper by: Steffen Oeltze-Jafra, Juan R. Cebral, Gabor Janiga, and Bernhard Preim

Presentation by: Dennis Park

Risks of treatment:
- Small but non-trivial risk.
- Relatively low risk of rupture.

Risks of non-treatment:
- In the event of rupture, very poor prognosis (near 50% mortality rate)


Hemorrhage

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FACTORS OF ANEURYSM RUPTURE RISK

- Geometric descriptors of the aneurysm.

- Properties of the arterial wall near the aneurysm.

- Genetic predisposition.

- Behavioural factors.

- Hemodynamics within the aneurysm.


PREDICTIVE POWER OF HEMODYNAMIC FACTORS

- **Computational Fluid Dynamics (CFD) simulations** are **used to monitor** the hemodynamics of aneurysms.

- The presence of **vortices** within the aneurysm has been linked to **increased risk of rupture**.

- Previous studies report frequent observation of **embedded vortices** (next slide).
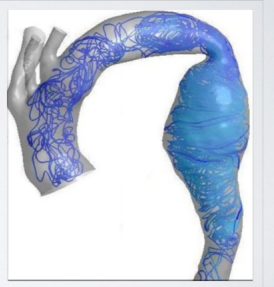

GOAL: SUPPORT THE INVESTIGATION OF EMBEDDED VORTICES AND THEIR RELATION TO ANEURYSM RUPTURE RISK
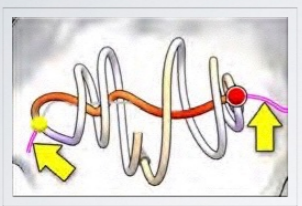
Properties of Embedded Vortices:
- Forms and collapses over the cardiac cycle.
- The formation of an embedded vortex is related to the emergence of a pair of equilibria, where the velocity magnitude is (near-)zero.
- During the course of a cardiac cycle, the two equilibria converge along the vortex core line. Their collision corresponds to the collapse of the embedded vortex.
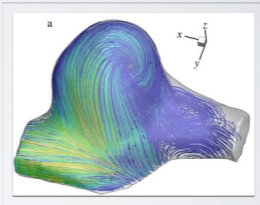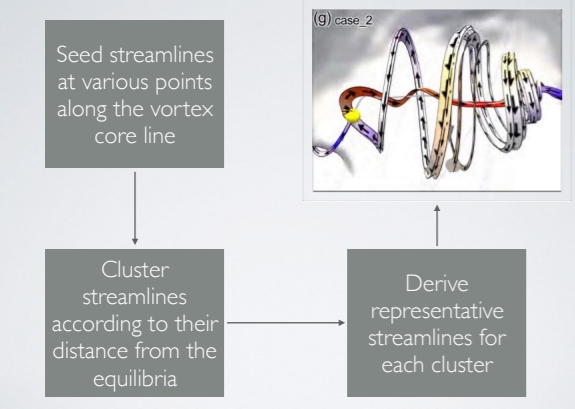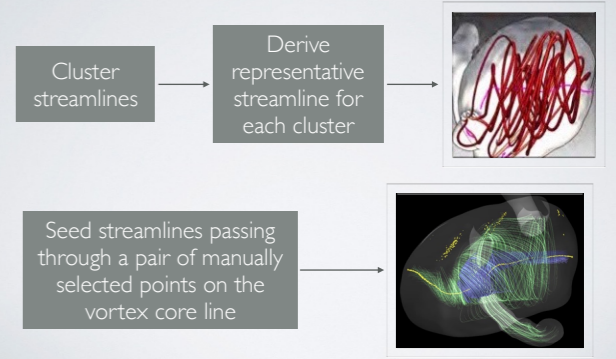
vortex core line
Saddle
Node
Saddle-Node Bifurcation
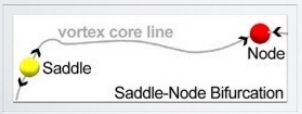
SUPPORTED TASKS
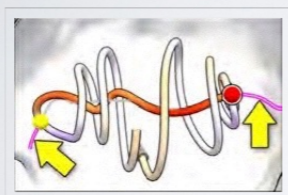
- Discover embedded vortices

- Locate the points of equilibrium

- Characterize flow near the points of equilibrium

DATASET

- Dataset is generated from 3D rotational angiography.

- Can be thought in the abstract as a collection of streamlines

- In the study, only a single point in the cardiac cycle (when the embedded vortex is at full manifestation) was considered.


PREVIOUS SOLUTIONS

Cluster streamlines → Derive representative streamline for each cluster →

Seed streamlines passing through a pair of manually selected points on the vortex core line →

(g) case_2

Seed streamlines at various points along the vortex core line
↓
Cluster streamlines according to their distance from the equilibria
→
Derive representative streamlines for each cluster

THE SOLUTION

- Ribbons to represent streamlines.

- Width of ribbon = # of streamlines in the aggregated cluster.

- Arrowhead glyph along the ribbons to show direction of flow.

- Spherical glyphs to represent equilibria.

- Click on equilibria to highlight nearby streamlines.
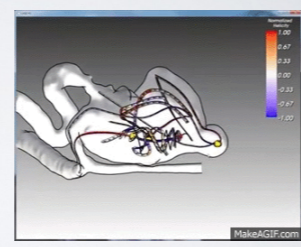
CRITIQUE

Pro:

- Provides easy detection of embedded vortices.

- Very effective reduction of data.

- Overall, effectively supports the tasks it set out to support.

Con:

- Due to the heavy dependence on the equilibria in processing the data, it might be difficult to extend the solution to a simulation where a time-factor is involved.