A COMPUTATIONAL STUDY TO ASSESS THE IMPACT OF VASCULAR MORPHOLOGY ON THE OUTCOME OF ENDOVASCULAR THROMBECTOMY

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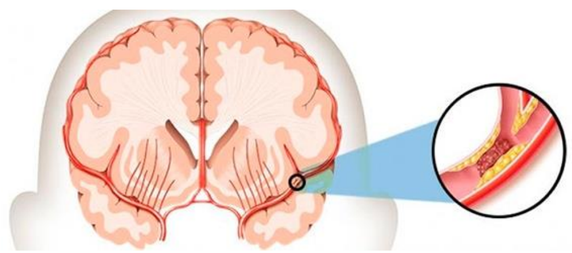
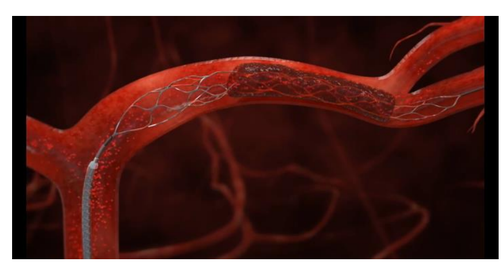
INTRODUCTION

Endovascular thrombectomy (EVT) is the main treatment for **acute ischemic stroke** due to large vessel occlusions (LVO), aiming at mechanically removing the occluding thrombus with a stent-retriever. The **tortuous anatomy** of the cerebral arteries, in particular of the **internal carotid artery (ICA)**, complicates the procedure, reducing the chances of recanalization. **Virtual simulations** of the EVT procedure [1] allow to study the causes of failure, with a detail level hardly possible in the clinical scenario.

This study proposes a methodology for investigating the impact of cerebrovascular morphology on the outcome of virtual simulations of the EVT procedure.



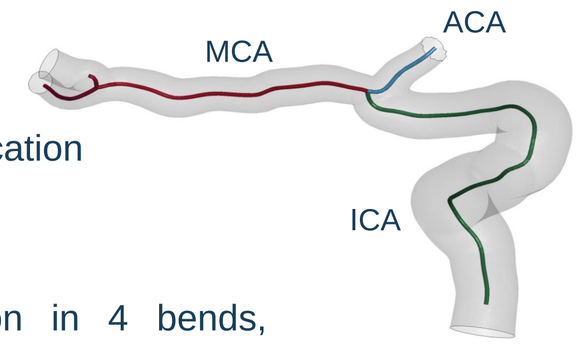


MATERIALS AND METHODS [2]

1. COLLECTION OF PATIENT-SPECIFIC VASCULAR GEOMETRIES

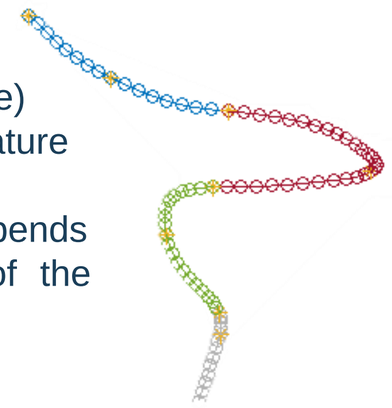
Fourteen patient-specific cerebrovascular segmentations were collected from the MR CLEAN Registry [3]. The centerlines of the vessels mostly affected by LVO were isolated: ICA and its bifurcation into middle cerebral artery (MCA) and anterior cerebral artery (ACA).

2. GEOMETRIC CHARACTERIZATION



Bifurcation parameters:
- 3 angles formed at the bifurcation
- MCA average diameter

ICA parameters:
Division of each ICA siphon in 4 bends, characterized by:
- length
- tortuosity (length over head-tail distance)
- diameter in the point of maximum curvature
- curvature (radius of fitting circle)
- angles between planes containing the bends
- distance between bends (measure of the straight segment between bends)

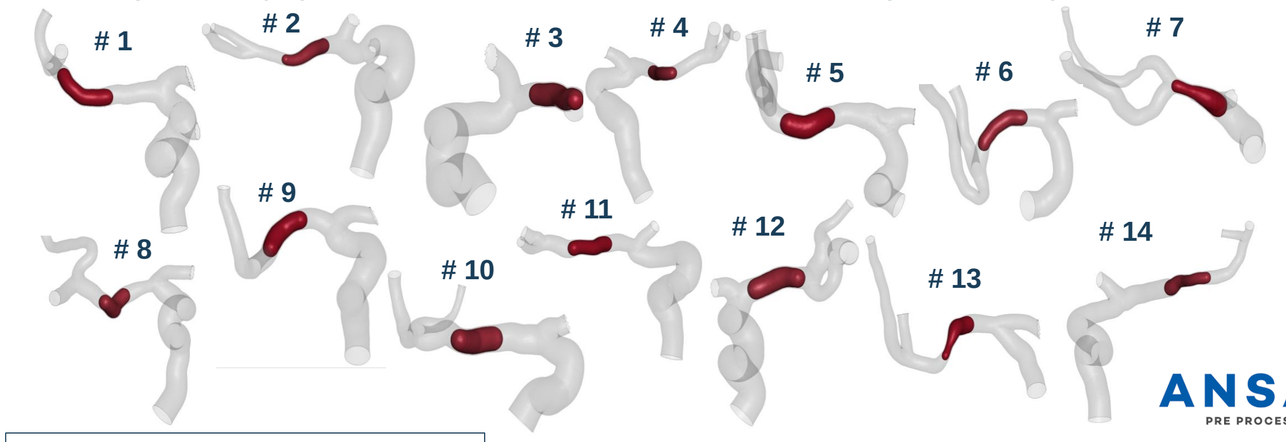


Total of **27 geometric parameters** for each patient-specific vasculature

MATLAB®

3. EVT COMPUTATIONAL SIMULATIONS

Creation of 14 finite-element models [1], where the only changing element is the vessel geometry (same thrombus, stent-retriever and procedure).

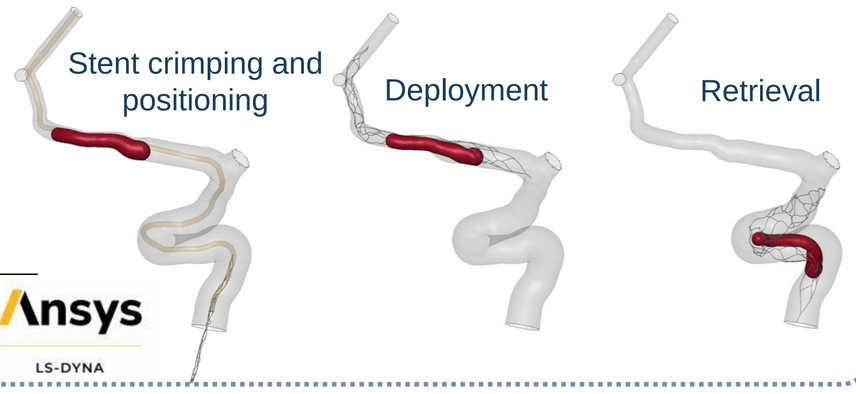


Thrombus:
Location: middle of MCA
Length: 14 mm
Diameter: 90% of MCA diameter
Composition: 65% fibrin
35% red blood cells

Stent: Trevo ProVue (Stryker)

Ansys LS-DYNA

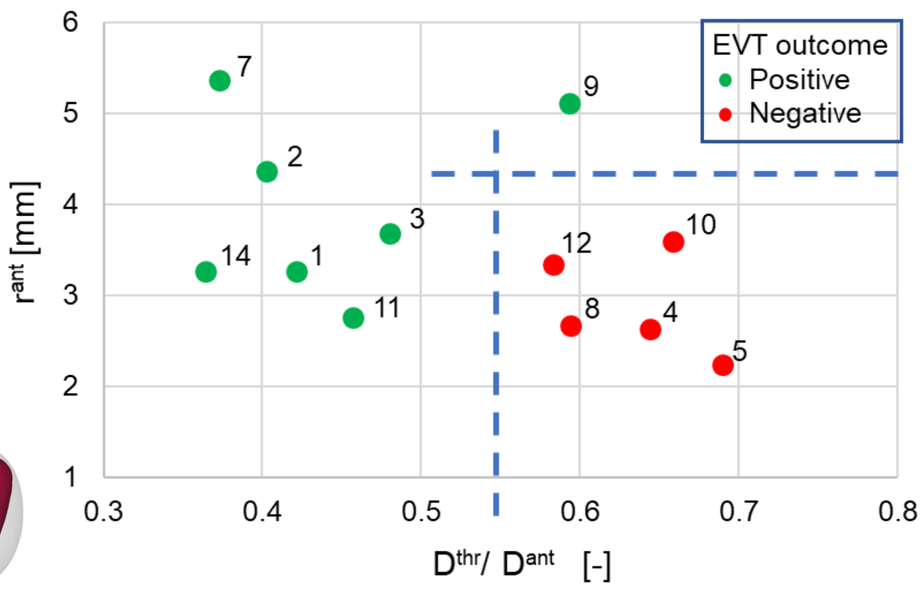
EVT procedure steps



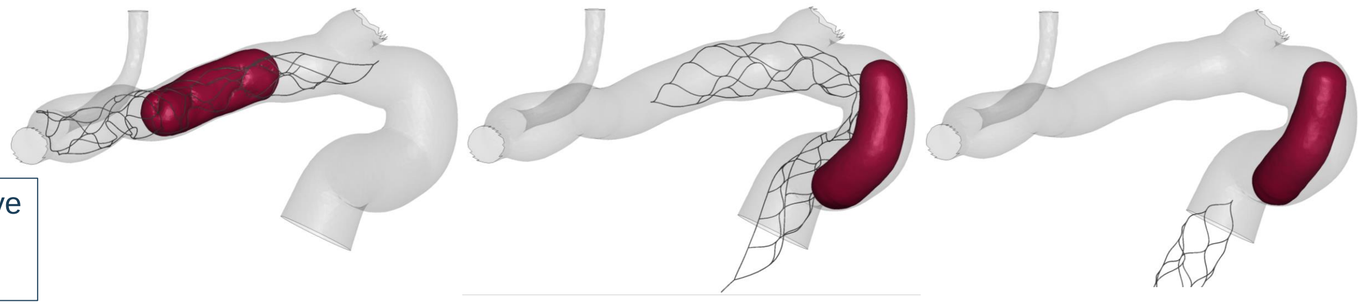
RESULTS

The outcome of virtual EVT procedure is positive if the thrombus is removed from the vessel, negative if it escapes from the stent-retriever. The 14 simulations produced **9 positive** and **5 negative outcomes**, where the thrombus was lost in the anterior bend of the ICA.

The outcomes were analyzed with the associated geometric parameters to find **indicators** able to determine the positive or negative outcome. The best performing indicator is a combination of:
- radius of **curvature of the anterior bend** (r^{ant})
- ratio between **thrombus diameter** (D^{thr} = 90% MCA diameter) and the **diameter of the anterior bend** in the point of maximum curvature (D^{ant})



(patients 6 and 13 did not feature the anterior bend due to a truncated segmentation)



Example of negative EVT outcome (patient 10)

CONCLUSIONS

This study proved the **influence of cerebrovascular anatomy** on the outcome of virtual EVT procedures. Once repeated for more patients, different thrombus properties and with the use of the most common devices, this analysis can be a valuable **support for guiding the interventionist** in choosing the most suitable procedure for the patient.

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References: [1] Luraghi et al., Interface Focus, 2021
[2] Bridio et al., Front. Med. Technol., 2021
[3] Jansen et al., BMJ, 2018

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