# Flow-diverter Treatment Failures: a Patient-specific Computational Flow Dynamics Study on Refractory Aneurysms

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## Introduction

Flow diverting stents shifted the paradigm in endovascular management of intracranial aneurysms, with aneurysm obliteration rate of over 80% by 6 months. However, some aneurysms persist despite successful stent deployment. The risk factors for flow-diverter failures remain unclear. Computational fluid dynamics has been used to study aneurysm hemodynamics and may predict flow-diverting treatment effect. We performed patient-specific fluid dynamics study to identify hemodynamic changes related to flow-diverter treatment outcome.

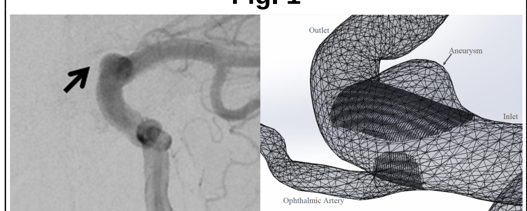
## Methods

Patients with unruptured intracranial aneurysms that failed flow-diverting stent treatment defined as persistent contrast filling of aneurysm on angiogram after 1 year were identified from the hospital database. Successfully treated aneurysms in the same period was taken as control. 3D realistic computational models of the aneurysms were reconstructed from pre-treatment angiograms, with virtual flow-diverting stent structured according to the specifications of Pipeline Embolization Device (eV3, Irvine, California, USA).(Fig.1) Simulation of pulsatile blood flow before and after stent placement was performed, and hemodynamic parameters of treatment success and failure cases were compared. (Fig. 2)

## Results

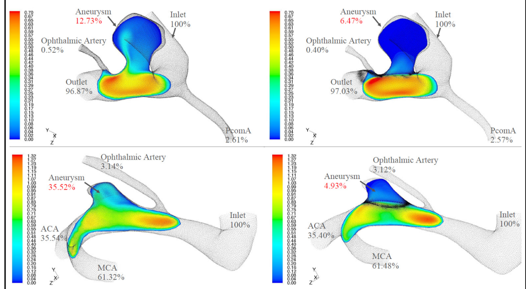
We studied 3 aneurysms that persisted and 4 that was occluded after technically successful flow diverter treatment. All aneurysms demonstrated dramatic reduction in aneurysm flow rate, maximal velocity, and wall shear stress after flow diverter treatment. For aneurysms that failed treatment, the volume flow rate into the aneurysm after stent was 0.005 – 0.252mm3/s, which was 49.2 – 90.2% reduction compared with pre -stent. For the flow diverter success cases, the volume flow rate after stent was 0.014 – 0.31mm3/s, 81.7-92% less than pre-stent. There were no significant difference in the flow diverter success and failure aneurysms in terms of reduction of volume flow rate, maximal velocity or vorticity. (Table 1)

**Fig. 1**



Accurate computational model of the aneurysm in Patient 4, showing virtual flow diverter covering the aneurysm neck

**Fig. 2**



Volume flow rate into the aneurysm before (Left) and after flow diverter (Right). Upper panel: Patient 3 whose aneurysm was refractory to flow diverter treatment. Lower panel: Patient 5 whose aneurysm was successfully occluded with flow diverter.

**Table 1.**

| | Aneurysm location | Size | Outcome | Aneurysm volume flow rate( cm3/s) | | | Maximum velocity (cm/s) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Before PED | After PED | % reduction | Before PED | After PED | % reduction |
| 1 | R PCoA | 8.3 x 4.8mm | failure | 0.051 | 0.005 | 90.2 | - | - | |
| 2 | R PCoA | 5x6x7.6mm | failure | 0.598 | 0.06 | 90 | 24.8 | 1.06 | 95.70 |
| 3 | Left clinoidal ICA | 7x8mm | failure | 0.495 | 0.252 | 49.2 | 51.9 | 18.1 | 65.10 |
| 4 | Left opthalmic ICA | 4.7x2mm | success | 1.72 | 0.31 | 81.7 | 55.5 | 15.1 | 72.80 |
| 5 | Left anterior choroidal a. | 3x3mm | success | 0.553 | 0.077 | 86.1 | 81.6 | 44.5 | 45.30 |
| 6 | Left cavernous ICA | 9x7mm | success | 0.169 | 0.014 | 92 | 12 | 2 | 83.00 |
| 7 | Left clinoidal ICA | 7.6mm | success | 0.202 | 0.03 | 85.1 | 4.55 | 1.14 | 74.90 |

Computational flow dynamics before and after virtual PED in success and failure aneurysms. PCoA; Posterior communicating artery, ICA; Internal carotid artery

## Discussion

Around 20% of aneurysms are refractory to flow diverter treatment. We attempted to investigate the flow dynamic changes effected by flow diverter stent in aneurysm that failed treatment. Although our results confirmed the dramatic reduction of flow into the aneurysm sac after stenting, it failed to differentiate successfully treated aneurysms from those that failed flow diverter treatment. Even for refractory aneurysms, there was up to 90.2% flow reduction after stenting. Further work to include more failed aneurysms is needed to identify specific flow parameters that ccorrelate with treatment outcome. Other factors such as patient's thrombogenicity or endothelial remodelling not measurable by fluid dynamics study may play an important role in the success of flow diverter treatment.

## Conclusions

Computational fluid dynamics can simulate post-treatment flow changes in intracranial aneurysms treated with flow-diverting stents. However, there was no significant flow parameter that predict aneurysm treatment outcome in this preliminary study.

## References

1. Tang AYS et al., J Biomedl Sci Eng 2013 6:8
2. Leung GK et al., Clin Neuroradiol 2012 22:295-303

## Acknowledgements

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