Hochschule Karlsruhe
University of
Applied Sciences

Fakultät für
**Maschinenbau und
Mechatronik**

Robotic Intracraneal Aneurysm Treatment

Authors: Artur Habuda & Lucía Montero

Abstract

ActiveStent, a concept for a variable porosity and pore density stent, is developed in order to assess some of the needs in current brain aneurysm treatment methodologies. While the trend of the industry and research community has experienced a shift towards endovascular treatments, surgical operations are still performed in a meaningful portion of cases. This concept aims to further displace surgical operations, to mitigate the negative consequences of intrusive techniques and help to fully concentrate research efforts towards endovascular technology.

Medical Background

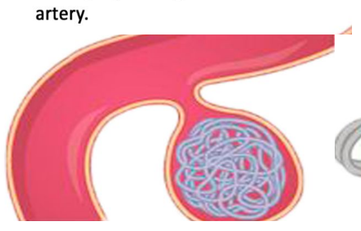
A Brain aneurysm is a bulge or ballononing in a blood vessel witin the brain, the result of a thin artery wall. About 1 in 50 people suffer from unruptured aneurysm.

A ruptured aneurysm causes sudden and severe symptoms and is fatal in about 40% of cases. About 30,000 people in the U.S. suffer brain aneurysm rupture each year

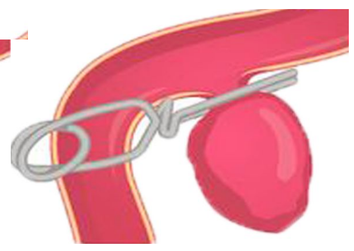
Figure 1. Brain Aneurysm description and statistical data[1].

Unruptured aneurysms are often discovered incidentally during tests for other conditions. Symptoms, when present, may include headaches, eye pain, vision changes, and seizures. Diagnosis is primarily through CT, MRI, and cerebral angiography.
Typical treatments involve:

Endovascular coiling
- Aneurysm is accessed by a catheter, inserted in an artery at the groin and guided to the brain.
- Soft platinum wire is fed through the catheter, coiling up inside the aneurysm .
- Causes blood to clot within the aneurysm, seeling it from the artery.



Surgical clipping
- Aneurysm accessed by removing a portion of the skull.
- Neurosurgeon places a microclip on the opening of the aneurysm.
- Prevents blood from entering aneurysm.



Flow diversion
- Aneurysm accessed by a catheter, inserted in an artery at the groin and guided to the brain.
- Metal mesh tube is placed in the artery, across the aneurysm.
- Blood flow is channeled through the mesh tube, away from the aneurysm.
- Clot forms within the aneurysm.

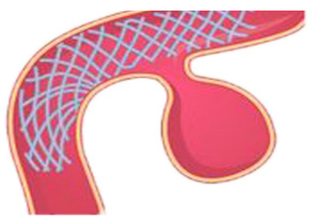


Figure 2. Popular treatments for brain aneurysms[1].

State-of-the-Art

Studies have shown that endovascular treatment produces better clinical and functional outcomes but is associated with an increased need for retreatment. In contrast, surgical treatment is associated with increased durability but potentially worse functional outcomes and longer recuperation times. Over the last decade, a paradigm shift has occurred from open microsurgical clipping towards endovascular coil embolization and particularly flow diverter placement.

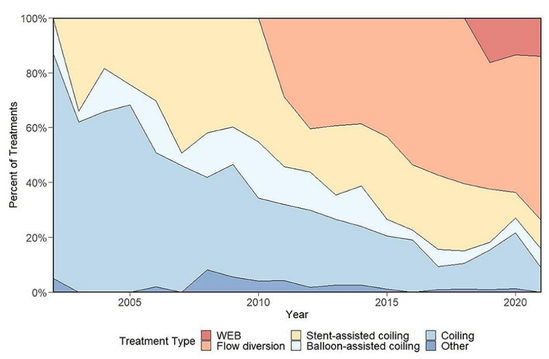


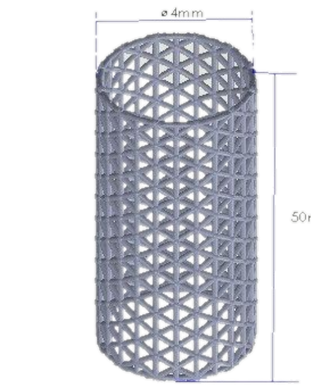
Figure 3.Evolution of endovascular treatment occurance from 2000 to 2020[2].

Contribution

It is clear that the general practice and research community efforts are focusing on endovascular treatment[3]. Although possible thanks to available imaging techniques, manufacturing of individual and custom stents for every patient is very challenging, with some concepts needing up to 10 days for their fabrication[4] and an operation of brain aneurysm occurring each 10 min.(just in the United States) it is clear that preoperative customization is not yet a viable option. A solution is presented that is compatible with mass manufacturing and yet allows to variate the porosity of the stent once inserted in the parent vessel of the aneurysm.

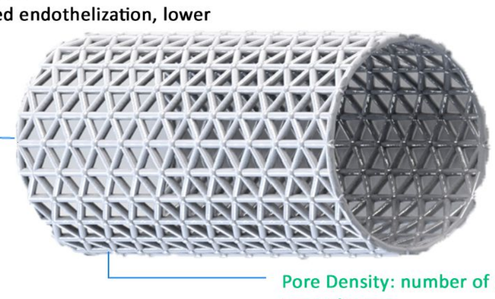
Concept

ActiveStent is formed by a base diamond mesh stent. This base is modified with permanent magnets distributed at each of the nodes of the mesh. To the base mesh, halving vertical magnetized segments will be incorporated. These segments find themselves in equilibrium in the mirroring center between the magnetic fields originated by each permanent magnet pair. An external localized magnetic field can apply a short “push” force to one or a set of halving segments which will be then attracted to its closest permanent magnet, overlapping itself with the base mesh and creating a larger open space

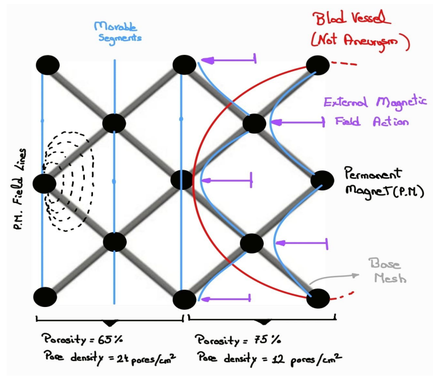


(a)

Porosity: Fraction of open area on the stent
Low = better flow diversion, reduce risk of aneurysm rupture
High = improved endothelization, lower occlusion



(b)



(c)

Pore Density: number of pores (or openings) per unit area
Low = Stronger stent structure
High = Enhanced endothelial cel growth, faster healing

Figure 3. (a)3D View of ActiveStent with explanation of Porosity and Pore density values.(b)Sketch aided description of ActiveStent modulation. (c)Diameter and height of fully expanded ActiveStent[1].

Active Stent Porosity (65-75%) Pore Density(24-12 pores/cm2)	Material/Configuration	Reasoning
Base Mesh	45%Ti 55% Ni Diamond Mesh	Shape-Memory-Alloy(SMA) + Superelasticity, high durability and excellent wear resistance.
Movable Wires	Ti, Ni, Fe + Platinum coating	Iron magnetic particles included for manipulation. Platinum coating for biocompatibility.
Permanent Magnets	samarium–cobalt (**SmCo**)+Platinum coating	Good balance of strength and thermal stability. Highly resistant to corrosion

Table1. Materials selection.

Although a key part of this concept, the magnetic manipulation needs further research. A Magnetic Navigation System(MNS) paired with Fluoroscopy, Magnetic Resonance Imaging or CT angiography, presents interesting features for calibration and navigation[5]. By modulating the movable segments position, pore density and porosity can be effectively modified locally. This way unwanted occlusion of blood vessels connecting to the parent cavity can be avoided. Additionally occlusion of the aneurysm cavity or adjacent vessels can be modified over time according to their evolution. The high versatility of this concept shows promising opportunity for brain aneurysm treatment and opens the door for professionals to avoid intrusive and highly complicated surgical procedures.

References

[1]Infographic: The Hidden Dangers of Brain Aneurysm. Source: MayoClinic.org (accessed in 2023). Available at: https://www.mayoclinic.org/hidden-dangers-brain-aneurysm-infographic/ifg-20404403
[2]Frontiers Editorial Office. A review of technological innovations leading to modern endovascular brain aneurysm treatment. Frontiers. Available at: https://www.frontiersin.org/articles/10.3389/fneur.2020.00006/full
[3]BackTable Vascular & Interventional. (2023). New Technologies for Cerebral Aneurysms. YouTube. Available at: https://www.youtube.com/watch?v=wvaTvN9bR5M&ab_channel=BackTableVascular%26Interventional
[4]Velvaluri, P., Pravdivtseva, M. S., Berg, P., Wodarg, F., Miranda, R. L. d., -B. Hövener, J., Jansen, O., Quandt, E., Thin-Film Patient-Specific Flow Diverter Stents for the Treatment of Intracranial Aneurysms. Adv. Mater. Technol. 2021, 6, 2100384. https://doi.org/10.1002/admt.202100384
[5]Stroke: Vascular and Interventional Neurology Editorial Office. Imaging of Intracranial Saccular Aneurysms. Stroke: Vascular and Interventional Neurology. Available at: https://www.ahajournals.org/journal/svin