THROMBUS

A quantitative model of thrombosis in intracranial aneurysms

Cerebral aneurysms are undesired local deformations of the wall of a brain vessel whose rupture can be lethal. The natural repair of an aneurysm is through a thrombosis process. The problem addressed in **THROMBUS** is to propose a multi-scale simulation model to predict how cerebral aneurysms may occlude after the insertion of a stent.

Objectives of the project

Rupture risk of intracranial aneurysms (IA) has been studied at length. However, very little is known about the healing mechanism, namely the formation of a clot (or thrombus) inside the cavity of a cerebral aneurysm. The management of patients with incidentally discovered unruptured cerebral aneurysms (0.01% of the world population) is still a challenge for the community of neuroradiologists and neurosurgeons.

The objective of THROMBUS is the theoretical understanding of the complex thrombosis process in intracranial aneurysms, its cause in terms of the local flow properties and the biology of the wall and of the blood. We will then exploit this knowledge to implement validated multiscale numerical simulations of Thrombosis, and to dedicate those simulations for the characterisation of optimal patient specific stents. From this model we will compute quantitative stent efficiency score by its capability to induce clotting in aneurysms.

The core of the project THROMBUS is to develop and validate a biological model of stent-induced thrombosis in IA

In medical practice the choice of which stent to deploy is left to the medical doctor and remains intuitive to date. It is common to use one or several full-course stents into each other, in order to induce thrombosis formation. Recent pipeline stents will be investigated. The THROMBUS project will study through numerical simulations the effect of stent configuration in patient specific geometry and will help explain why some stents produce good thrombus while others don't.

Project Description

The project will develop a multiscale computational modelling and simulation framework based on the triptych In Vitro – In Vivo – In Silico - rule of three for the thrombosis

THROMBUS will develop ICT (Information and Communication Technologies) -based tools for modelling and simulation of the thrombus formation. The THROMBUS project will provide a fundamental framework which will allow building subject-specific multi-scale model 'from biology and hemodynamic to treatment recommendations'.
Indeed, the THROMBUS framework aims to develop a patient-specific computational modelling and simulation of the effect of a stent on the blood flow inside an aneurysm to assist the neuroradiologist in defining the best stent.

Also, an objective of THROMBUS is to conjugate the need for feasible and reliable patient specific models with the timing of clinical decision making.

The realisation of the objective will lead to:

1. Providing stent manufacturers such as THROMBUS partner EV3 SAS with a reliable, validated numerical model of the intra-aneurismal thrombosis mechanisms based on biological experiments. By using patient-specific medical images (CTA, RMA,…) coupled with recorded parameters, a High Performance Computing (HPC) simulation can be performed to assess the efficiency of a stent as a good flow modulator. The clotted volume induced by a flow modifier is indeed the only appropriate metrics of stent efficiency.

CASE STUDY

Unruptured aneurysms are depicted on Computed Tomography Angiography (CTA) or Magnetic Resonance Angiography (MRA). Digital Subtracted Angiography (DSA) is usually performed prior to therapeutic management. The treatment is a trade-off between the risks associated with the procedure and the probability of SAH (subarachnoid haemorrhages). To date, interventional decisions are based on attempted correlation of static images and clinical presentation with past experience. The three following options are considered during treatment: follow-up of the lesion, surgical clipping and endovascular occlusion. Endovascular treatment consists of inserting coils, stents, flow diverters stents or a combination of the three to occlude the sac

2. Providing clinicians (partners HCL, CHUV) with a virtual tool to help in choosing between different characteristics of stents based on relevant criteria issued from image processing and numerical simulation coupled to an optimisation tool.

3. Providing clinicians and scientists with an interactive end-user tool developed via CREATOOLS (VPH Toolkit) coupled to a medical collaborative video conference tool on the base of the COVALIA SA system.

The biomechanical models will be validated by the biologists and will be used for the numerical simulation. The results provided by the numerical simulation will be validated by the clinicians.

Expected Results & Impacts & Preliminary results

A new 4D aneurysm and thrombosis model developed by the THROMBUS project will have a direct impact on ***more predictive, individualised, effective and safer healthcare.*** It will allow the neuroradiologists and neuro-surgeons to take quicker and more accurate decisions especially concerning the choice of an adequate stent.

The establishment of the 4D Thrombosis model will rely on the serious study of the different biological parameters including the wall motion. ***Development of devices and procedures using in-silico environments,*** in order to synthesise all parameters is a crucial and integral point of the project. The use of the *in-silico* environment, combined with the *in-vivo* and *in-vivo* experiments definitely opens the way to ***accelerate developments of medical knowledge discovery and management.***

THROMBUS project brings together a multidisciplinary consortium which covers the creation of the Thrombosis model form all possible points of view. Potential success of this project lies in the fact that we have at our disposal the experts from all aspects of the issue: from the medical parameters to the dissemination means. Therefore, the foreseen outcomes of the project will lead to ***reinforced leadership of European industry and strengthened multidisciplinary research excellence in supporting innovative medical care.***

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- Université Libre de Bruxelles (Belgium)
- COVALIA Interactive SA (France)
- German Research School for Simulation Sciences GmbH (Germany)
- Universiteit van Amsterdam (Netherlands)
- Ev3 Europe SAS (France)
- Hospices Civils de Lyon (France) & 2 subcontractors:
- Institut National des Sciences Appliquées de Lyon (France)

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Decision support system, Human computer interaction, In silico simulation, Medical Imaging processing and analysis, Virtual Physiological Human