THROMBUS

PROJECT FINAL REPORT

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Project title: A Quantitative Model of Thrombosis in Intracranial Aneurysms

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http://www.thrombus-vph.eu

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Executive summary

The challenge of THROMBUS is the theoretical understanding of the complex thrombosis phenomena in intracranial aneurysms (IA). Considering the importance of this healing mechanism, namely the formation of a clot inside the IA, this investigation is focused in the effect of the flow diverter (FD) stent in the thrombosis process. In medical practice the choice of which stent to deploy is left to the medical doctor experience remaining intuitive and subjective. It is common to use one or several full-course stents to induce thrombosis formation. Recent FD stents allowing simple or multiple devices constructs have been investigated. Thrombus project goal was to predict through medical imaging, image processing (ICT), *in vitro* experiments and numerical simulation, the effect of a custom stent configuration in the blood-flow and the probability of appearance and growing of the thrombus according to the patient-specific condition.

In consequence, the applied strategy consisted in acquiring and processing patient-specific data to make a posterior validation of the multi-scale numerical simulations of thrombosis. The associated technological aim of the project has been to deliver software with an interactive end-user interface, providing a virtual modelling of the FD deployment, as well as blood-flow and thrombosis simulations in IA.

The main objectives achieved by Thrombus are:

1. Providing clinicians and stent manufacturers with a reliable numerical model of thrombosis mechanisms based on patient-specific medical and biological data.

2. Providing clinicians and scientists with an interactive end-user interface coupled to a Pipeline of Applications (PIPE) and a Collaborative Online System (COS).

Additionally, the most important results are 1) the design of a new model of thrombosis taking into account medical, biological and hemodynamic parameters, 2) the virtual deployment of FD stent based on a new mathematical model allowing to design, create and use customized configurations one or more FD stents in patient-specific vessels, 3) a patented *in vitro* biological test-bench, and 4) two software prototypes, the PIPE and the COS.

The results of Thrombus are likely to be of great interest to the clinicians and researchers involved in the treatment of intracranial aneurysms, since new insights for the understanding of aneurysmal pathology are given, especially after treatment by the flow diversion technique. They improve the understanding of the efficacy of FD in specific cases. Also, these results may help to understand and to anticipate some complications that occur with these devices, which potentially could be applied in the clinic practice. This can also help to improve of the patient diagnosis, the selection of the best stent design and deployment, and/or the antiplatelet regimen.

Furthermore, the outcomes of THROMBUS strengthened multidisciplinary research excellence in supporting innovative practices and medical care, and lead to reinforce the leadership of European SME such as COVALIA, OVIZIO, and FLOWKIT.

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Summary description of project context and objectives

A quantitative model of thrombosis in intracranial aneurysms

Call FP7-ICT-2009-6 (STREP) - Objective ICT-2009.5.3: VPH GA N°269966

THROMBUS - http://www.thrombus-vph.eu - PI: Guy Courbebaisse

Context

The use of the flow diversion technique is an emerging endovascular treatment for large and complex aneurysms considered otherwise difficult to treat by conventional technique, such as coiling or clipping. Flow Diverter Stents allow the morphological reconstruction of the diseased arterial segment and act on its hemodynamic in order to induce the intra-aneurysmal thrombosis. Their deployment has shown great promise in therapeutic success and outcomes. Several studies have demonstrated acceptable rates of aneurysm occlusion, morbidity and mortality for patients treated by this technique. Therefore, these devices are gradually being deployed in greater number of patients with more locations of deployment and even with smaller size aneurysms. With increasing experience and number of patients treated, some of the limitations and unexpected complications of flow diverter stents appeared. The variability in outcomes and especially the non-occlusion of the aneurysm, in up to 24% of cases at 9 months of follow-up, has been highlighted. Non negligible rates of intraparenchymal (3%) and subarachnoid hemorrhage (3%), as well as ischemic stroke (6%), have also been reported.

Most of the studies dedicated to the understanding of the flow diversion technique are based on computational flow dynamic (CFD) simulations and focus only on the hemodynamic effects of the flow diverter stents. Little is known about the biological processes that take place on the deployment site, and especially within the aneurysmal sac, induced by the interaction between the device and both the blood and the vessel wall. Since, the effect of the flow diverter stents cannot be reduced to the interaction between the device and the blood flow, investigations including patient-specific biological parameters, hemodynamic conditions, as well as the aneurysmal geometry, and the stent design and its mechanical properties are mandatory in order to understand these innovative new generation devices.

The Thrombus project was a collaborative project aiming to develop and validate a biological model of intra-aneurysmal thrombosis (either spontaneous or stent induced). Its originality relies on a multiscale and multidisciplinary approach investigating through numerical simulations the effect of deploying flow diverter stents in patient specific geometry, but taking also into account the patient specific hemodynamic boundary conditions and biological profiles.

Objective

The objective of THROMBUS (Figure 1) 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. This knowledge has been exploited to implement validated multiscale numerical simulations of thrombosis. Numerical simulations have also been developed to characterize optimal patient specific stents.

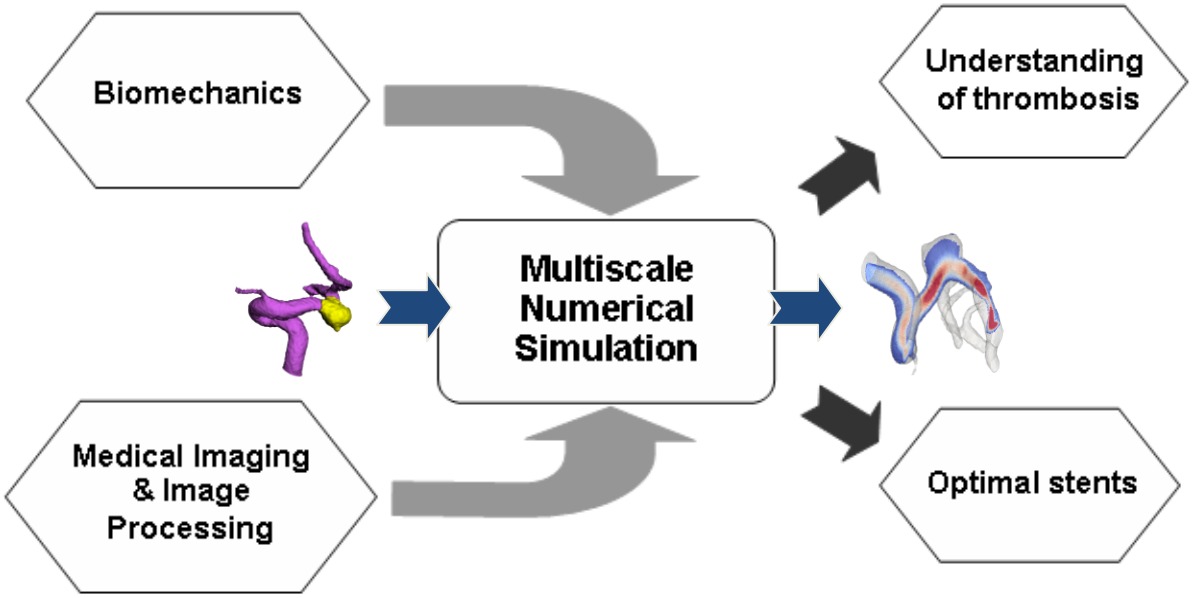


Figure 1. Synoptic of the THROMBUS project

As illustrated in Figure 1, research and technology developments are based on several components linked through the numerical simulations. In more detail these components are:

1. Biomechanics

In a previous work, the UNIGE partner has proposed a preliminary model to describe the intra-aneurysm thrombosis. For the first time a numerical model could explain several clinical observations, in particular the fact that the occurrence of thrombosis in giant aneurysms depends on an aspect ratio threshold. These results suggested that the aneurysm morphology and its size could change the hemodynamic and the behavior of the platelets and other coagulation factors leading to the thrombogenesis.

The main objectives of the Biomechanics components were as follow:

1- To measure *in vivo* values of flow velocities in human-aneurysms,
2- To measure the relationship between the shear rate and the platelet adhesion or aggregation on whole blood (on several coatings: collagen, fibrin, laminin …),
3- To show the possible role of Red Blood Cells on the platelets adhesion and aggregation,
4- To study platelet aggregation (Figure 2) in a setup that mimics the aneurysm shape and size in a flow chamber.

In summary, the Biomechanics goal was to provide new biological data and insights to improve the numerical models of thrombosis.

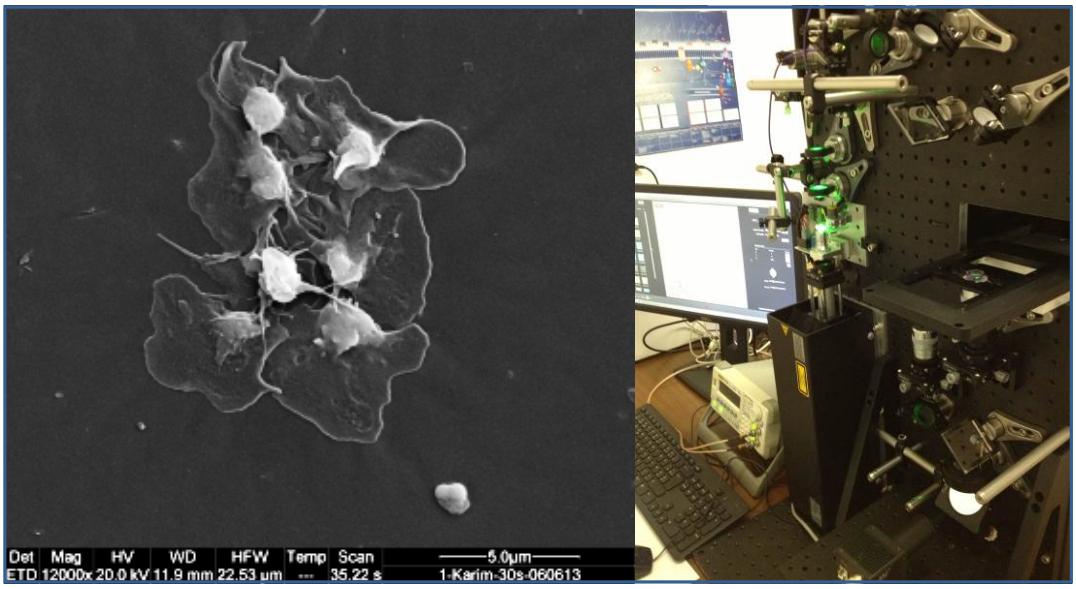


Figure 2. Platelets and holographic microscope

2. Image Processing

Using recent advances in this field, the goal of image processing work package was to generate the following results:

-Very precise and fast segmentation (Geometric active Functions) of the aneurysm sac and the parent vessel from 3D images (CTA, MRA) in order to extract patient-specific geometries of the aneurysm and of the adjacent vessel structures. This data was then used to virtually and interactively deploy a custom flow diverter and to use them as an input in 3D computational simulations (Figure 3).

-Segmentation of the thrombus edges,

-Stent modelling and virtual stent deployment,

-Tracking of the aneurysm wall motion in 4D image datasets.

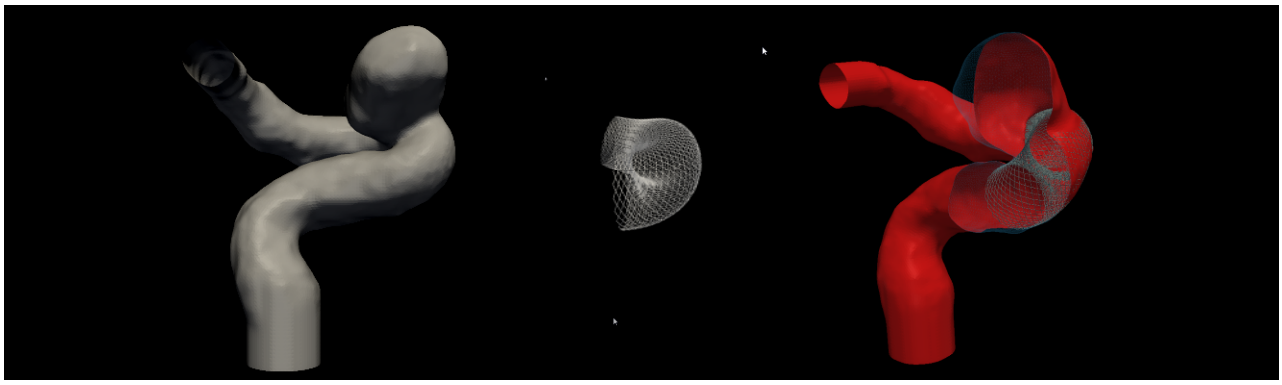


Figure 3. Virtual stent deployment

3. Multiscale Numerical simulation

Numerical simulations were the key element of this proposal (Figure 4) as they provided the link between the biological observations and the medical, patient specific observations. The numerical models integrate the mesoscopic mechanisms that lead to thrombosis in the presence of blood flow

and implement the fully resolved movement of red blood cells (RBC) and platelets. The underlying numerical framework is the Lattice Boltzmann (LB) method which is recognized as a powerful alternative to more traditional CFD tools. This method was well mastered by several Thrombus partners who had been using and developing it for many years. Another methodological element of this project was the CxA (Complex Automata) framework for developing multiscale applications.

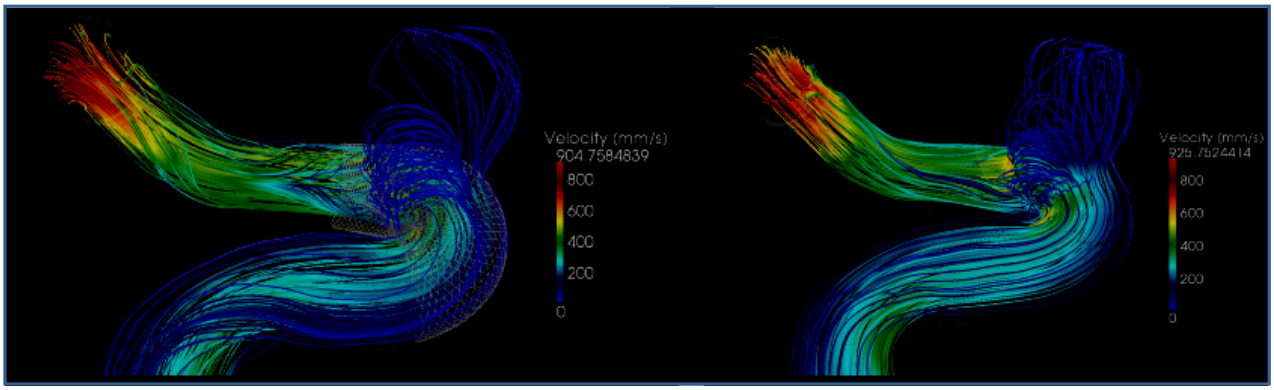


Figure 4. Blood flow simulations

The THROMBUS project aimed at developing ICT-based tools for the modelling and simulation of thrombus formation. A fundamental framework must be provided which should allow the building of a patient-specific multiscale model 'from biology and hemodynamics to the treatment recommendations'.

Indeed, THROMBUS offers a framework for patient-specific computational modelling and simulation of the effect of a stent on the blood flow inside an aneurysm. It assists the neuroradiologist in defining the best stent configuration and deployment location. An objective of THROMBUS was also to conjugate the need for feasible and reliable patient specific models with the timing of clinical decision making.

The table below gives the list of objectives accomplished and the measurable criteria.

Objectives	Measurable criteria
Understanding of the intra-aneurysmal thrombosis mechanisms	Reliable validated model of thrombosis based on biological data
Providing clinicians and scientists with an interactive end-user interface	Software integrating image processing and multiscale numerical simulation and end-user interface
Providing clinicians a virtual tool to find the optimal stent for a patient specific	Expert system functionalities integrated in the above mentioned software.
Providing clinicians and scientists with a medical collaborative tool	COVOTEM -Thrombus software based on telemedicine concept

Description of the main S&T results/foregrounds

The THROMBUS project developed ICT-based tools for the modelling and simulation of thrombus formation. Its direct application consisted in the preparation of a personalized stent adapted to a patient-specific intracranial aneurysm. But these scientific and medical works gave rise to the development of algorithms, experimental systems, new models and new concepts.

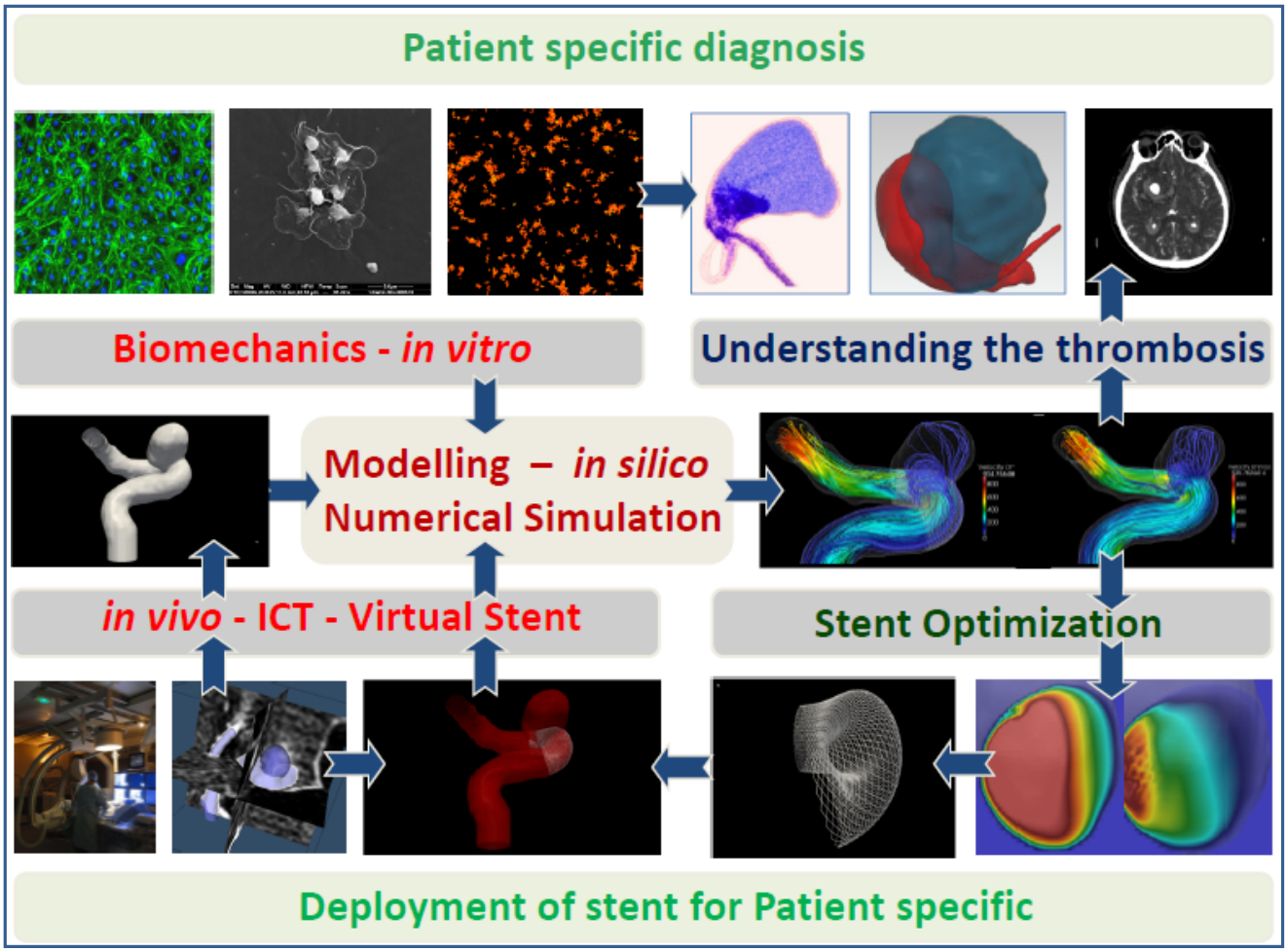


Figure 1. Diagram of THROMBUS

As illustrated in Figure 1, research and technology developments will be based on several components linked through the numerical simulations. In more detail these components are:

-1- Biomechanics and biology - Modelling of the aggregation of platelets and the thrombosis by the mean of *in vitro* experiments providing precise values of parameters, allowing the selection of the relevant parameters useful to understand the thrombus formation and mechanisms which initiate the phenomena - The biomechanical models have been validated by the biologists and used for the numerical simulation.

-2- Medical imaging and image processing - Fast algorithms based on Hybrid level set and lattice Boltzmann methods for the 3D segmentation of the vessel, and thrombus of intracranial aneurysms - The quantification of wall movements has been performed with an innovative 4D lattice Boltzmann method using 4D geometries (3D + time) recorded via medical imaging modalities and *in vitro* test

bench system. All the results have been validated by the clinicians and the resulting geometries of IA have been used for the numerical simulation.

-3- Numerical simulation - Multiscale numerical simulations of the blood flow and the thrombosis are performed with the code implemented in PALABOS, taking in consideration the boundary conditions associated to the patient-specific data.

In addition, a Human Machine Interface (HMI) has been created allowing to the medical Doctor the access at all the data generated by the Pipeline of Applications (PIPE) comprising the Image Processing software (CreaTools-THROMBUS) and the Numerical Simulation software (PALABOS-THROMBUS), and managed by the Collaborative Online System (COS) which works in the framework of COVOTEM-Thrombus.

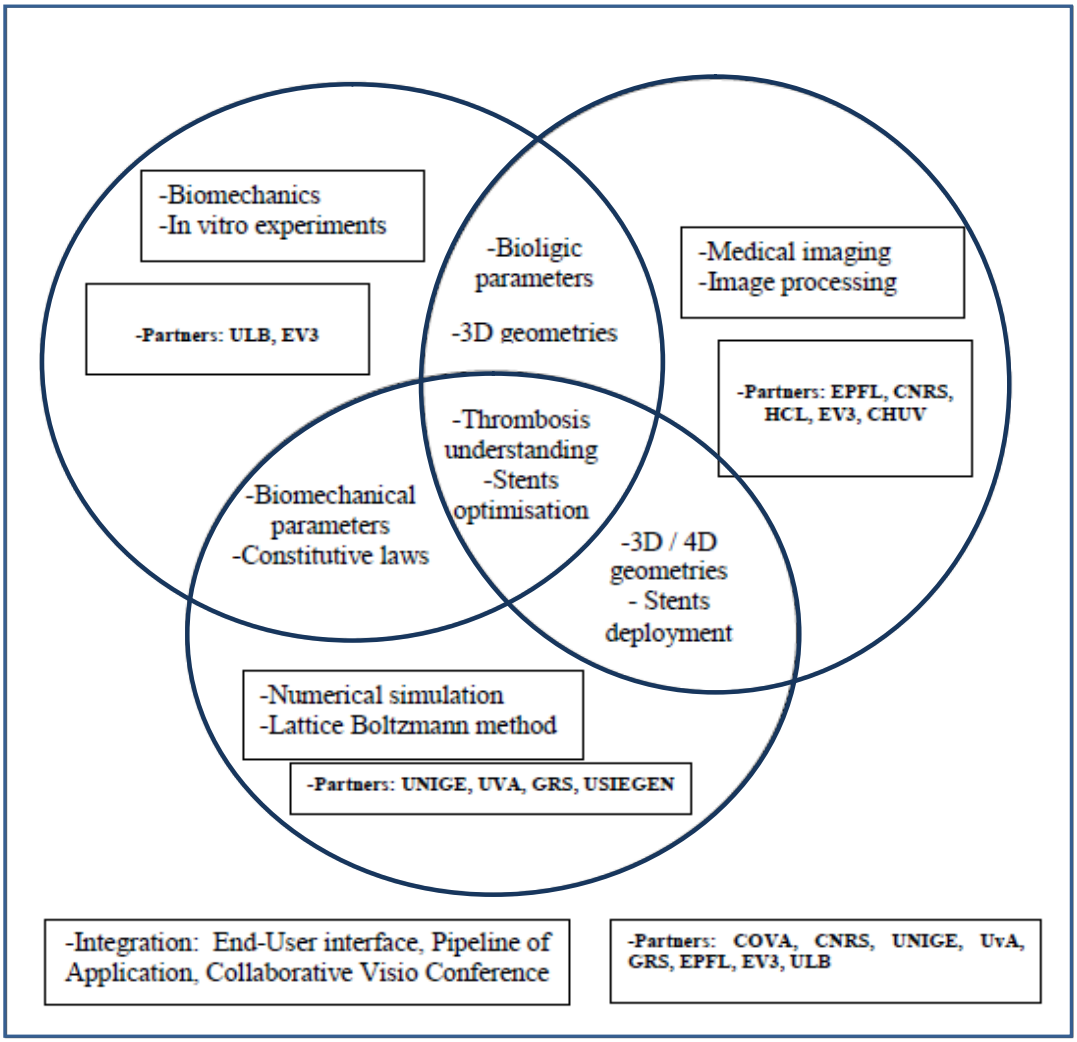


Figure 2. Structure of THROMBUS

S&T result by Work package

Work package 1 (WP1)

Work package 1 (WP1) is dedicated to the Management of the Project and Partners, to the Scientific Coordination. Figure 2 illustrates the different nesting levels of the work packages. Additionally

these tasks include project communication, Website updates, dissemination, Ethic, management of the risk and conflict, industrial transfer, intellectual property rights (IPR), organization of the final conference.

Work package 2 (WP2)

Work package 2 (WP2) is the work package which has brought the innovation with a remarkable amount of work in biology and biomechanics. A patent has been presented concerning an in vitro test bench (or testbeb).

The main goals of WP-2 (biomechanics) were to validate the existence of a hemodynamic threshold below which thrombosis initiates, and by *in-vitro* experiments and *in-vivo* measurements, to furnish quantitative data on the adhesion and aggregation of platelets in several biological relevant conditions so a mathematical model for the formation of thrombosis inside intracranial aneurysms could be created by the other partners from the project. The experimental work carried out by this group can be divided in 5 main objectives:

First, to study how specific hemodynamic conditions can modulate platelets adhesion and aggregation properties and follow up, in 3D, the evolution of platelet aggregates formation. To fulfill this task, we used a platelet function analyzer capable of applying particular shear rate forces to anti-coagulated whole blood samples coupled to other analysis technics and we used also a new technology developed and patented by ULB, the digital holography microscope.

Secondly, using an innovative assemble of techniques, we studied how specific components found in suspension in the blood stream (albumin, fibrinogen), or components present on the vessels wall (laminin, fibronectin, collagen), or even the shape of red blood cells (known to be altered by the action of certain enzymes over-expressed in specific illnesses related with alterations in the coagulation process) can decisively modulate platelets response to the thrombogenic stimuli. Still part of this task was to study (with other laboratories) how endothelial cells and the factors that they express and release under normal-stress conditions can interfere in the thrombosis process.

The third task was to the development of a non-invasive technique capable of determining real pressures and the velocities inside patients' aneurysm. The initial plane was to use an intravascular wire system capable of providing, simultaneously, both pressure and flow rate and digital storage, the Doppler flow and pressure wire, Combo Wire®. The implementation of this technique had to be abandoned because, according to the ethical committee, it could endanger the patients. So an alternative technique was presented and accepted, the pc-MRI method. Using this new technique, we were able to accurately measure patients' flow velocities profiles in intracranial affected vessels.

In the fourth task, equipped with these precise measurements we were able to reproduce them on silicone replicas on the *in-vitro* testbed for aneurysms, developed by our group. This device, recently patented, enabled us to help validating and improving numerical models for blood flow inside patient-specific aneurysms models. Equipped with patients specific flow velocity profiles and the *in-vitro* testbed for aneurysms we were able to study specific hemodynamic conditions effect on the behavior of the blood inside the intracranial aneurysm, before and after treatment by the deployment

of a flow diverter and finally to confront our experimental results with numerical models used nowadays to simulate blood flow inside intracranial aneurysms (Figure3).

Figure 3. CT scanner results obtained for the replica of a patient intracranial aneurysm. Different times steps. Up: full CT scanner and down: processing to binary algorithm. On the left: geometry without flow diverter. On the right: geometry after the deployment of the flow diverter.

Finally, we developed a score, based in the analysis of the frequency variation of the flow inside intracranial aneurysms, capable of predicting if aneurysms will thrombosis, spontaneously or by the deployment of a flow diverter.

All these data was then assembled to create a new and more complex theoretical model for the formation of thrombosis intra-aneurysm, and successfully integrated in new computational models also developed inside the thrombus framework. The expertise and experimental data gathered by the WP-2 (bio-mechanics) during the Thrombus project brought, a big improvement on the existent models for the understanding of the role of platelets, red blood cells, endothelium and the hemodynamic forces involved in the process of thrombosis inside aneurysms.

The synthetized results are the following:

Platelet aggregates formation and evolution

Using the Impact-R platelet function analyzer we determined the range of shear rates where the probability of interaction with the internal cavity of the aneurysm is higher. We discovered also that the number of platelet aggregates formed is defined in the first seconds after blood contact with the damaged endothelium (adhesion), and then, the formed aggregates, can just grow in size (aggregation). The combination of Digital Holographic Microscopy and Scanning Electron Microscopy enabled us to measure with precision the amount of platelet aggregates formed and their 3D expansion through time.

Mechanisms of thrombus formation

Pre-activated platelets and their role in platelet aggregates formation

The combination of the Impact-R results and the analysis of the concentration of platelets, quiescent and pre-activated, by flow cytometry, revealed that they are the pre-activated platelets which will start the thrombus, reinforcing the pro-coagulant profile of the region by the release of coagulation factors that will activate quiescent platelets in the surroundings.

Red blood cells shape impact on platelet adhesion

According with the results gathered here, we hypothesize that, in patients suffering from specific diseases associated with increased levels of neuraminidase, RBCs and platelets membrane glycoproteins will be significantly affected, altering their electronegative charges, decreasing, this way, the natural repulsion of blood cells. This will ultimately promote an increase in platelet reactivity and favor thrombosis.

Pro / Anti thrombotic molecules found in suspension on the blood stream

Our studies also revealed that the albumin, present in blood, helps creating an anti-adhesion profile inside the blood vessels. This profile can be switched when the concentration of pro-coagulant factors, like tissue factor (TF) released by damaged or under stress endothelial cells, or the fibrinogen, a precursor of fibrin linked to the coagulation cascade is initiated, increases. Exposure of whole blood to coatings with different combinations of albumin and fibrinogen resulted in the formation of more platelet aggregates when fibrinogen concentration increases and less aggregates when albumin increases, meaning that these molecules have a direct impact on platelet adhesion properties. The presence of TF created bigger aggregates of platelets, thus, affecting platelets aggregation properties.

Impact of the shear rate on the expression of pro/anti thrombic molecules by the endothelium

The hemodynamic changes in the blood flow provoked by the entrance in the aneurysm cavity potentate the endothelial cells covering the vessel wall to express more tissue factor (a pro-coagulant factor) and less thrombomudulin (an anti-coagulant factor) in the regions where the flow is more altered. The same hemodynamic changes also provoke changes in the hematocrit increasing the probability of platelets to interact with the wall, pre-activated platelets will adhere to the wall and release more coagulation factors that will activate even more platelets and result in the formation of more platelet aggregates and the growth of the ones already settled.

Influence of different proteins coatings on platelet adhesion - aggregation properties

By decreasing the shear rate to which platelets are exposed, we observed a loop like curve in the number of platelets aggregates, increasing rapidly from 0 s^{-1} to the peak between 25 and 100 s^{-1}, with a slightly shift of this peak and the number of observations according to the adhesion protein used to coat the Impact-R well, followed by a gradual decrease to the other extremity of the curve, at 400 s^{-1}. This means that for platelets to exercise their role conveniently, they need at least a small flow so they can attach and roll throw the wall and this way get activated and establish strong and stable connection to the wall and to other platelets. The number of aggregates is significantly affected by the surface to which platelets interact. According with these findings, we can hypothesize that in a saccular aneurysm, where the pattern velocities could be small enough to theoretically initiate

thrombus formation, the weight of the interface composition in interaction with platelets is a key point for the adhesion and aggregation of platelets.

In-vitro testbed for the study of intracranial aneurysms

Validation of the in vitro testbed in patient-specific aneurysm model.

The in-vitro test bed for the study of aneurysms has proven to be a powerful and very flexible device capable of reproducing with high accuracy complex flow signals measured in patients.

Test with Computed Tomography (CT) scanner

This device was successfully coupled to a CT scanner and the data resulting on the study of wall motion and flow behavior were crucial from the studies being developed inside Thrombus project.

The gravity effect on the red blood cells – An experimental study

Using this device, we demonstrated also that, gravity, normally excluded from the numerical models for blood flow simulation as a relevant variable, has a very significant impact on the flow behavior inside intracranial aneurysms, especially after FD deployment.

Embolization score

The frequency variation analysis provides what seems to be a very important tool for the understanding and assessment of the mechanisms behind thrombosis inside intracranial. Nevertheless, to better tune the thrombotic score (Figure 4), to associate it to the percentage of thrombosed volume expected and to study the impact of the use of flow diverters with different materials and different configurations, a more extensive study needs to be carried out.

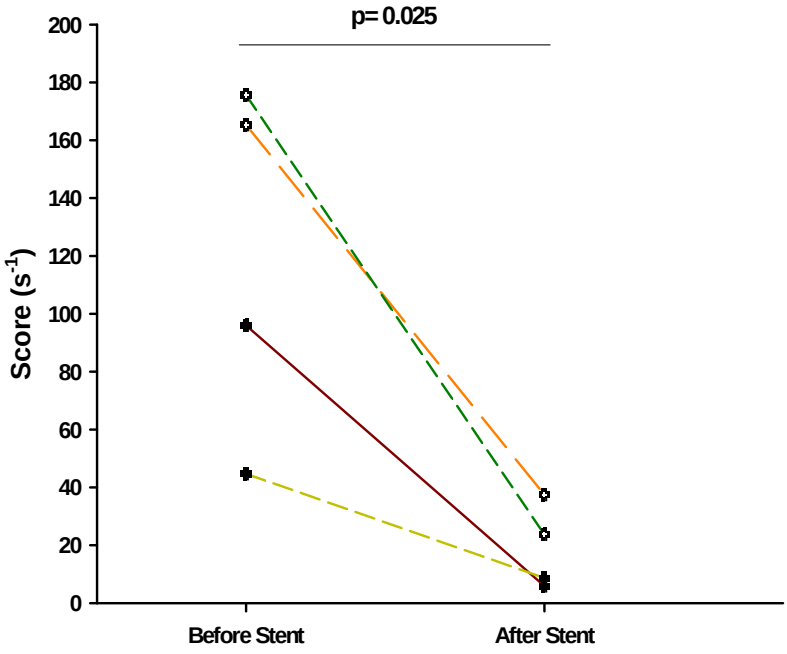


Figure 4. The impact of the deployment of the generic flow diverter on the Thrombotic Score

Work package 3 (WP3) focused on the ICT producing signal processing and image processing tools, and notably some mathematical models applied to the virtual deployment of stent. In addition, advanced processing concepts have been conceived for the segmentation of the thrombus of aneurysms (Figure 5) and for the estimation of movement of the wall of aneurysms.

WP3 is dedicated to the development of advanced image processing tools producing data as input for the numerical simulation of the blood flow and thrombosis performed in the WP4.

More precisely, in this WP we have developed, implemented and validated the image processing techniques necessary for:

- Fast, robust and accurate 3D image segmentation to extract the 3D geometry of aneurysms and adjacent vessels in CTA and MRA datasets,
- Tissue segmentation and classification techniques to segment the thrombus of an aneurysm,
- Motion tracking of the aneurysm walls in 4D (3D + time) dynamic CTA datasets,
- Virtual stent deployment.

Indeed, as a contribution to the overall objectives of the project, WP3 developed and contribute to the key technologies needed to allow the other work packages to develop the Thrombus biological model of aneurysm (WP2) and its numerical simulation (WP4).

In this context, we have implemented a complete series of image processing and associated tools. They allow obtaining the key information on real cerebral aneurysm for a better understanding of its evolution and thrombosis process under the action of stents.

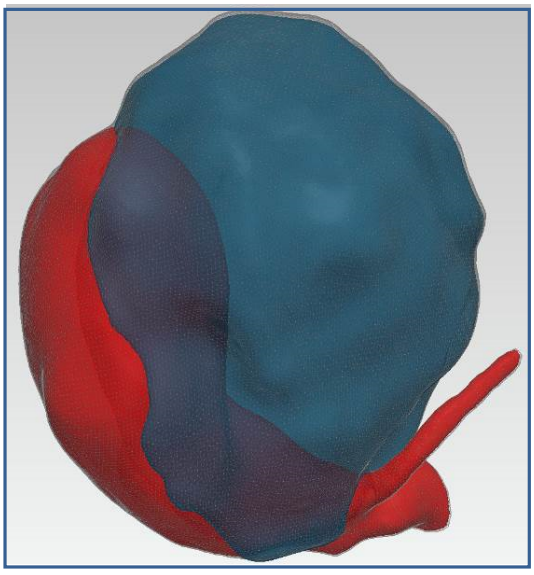
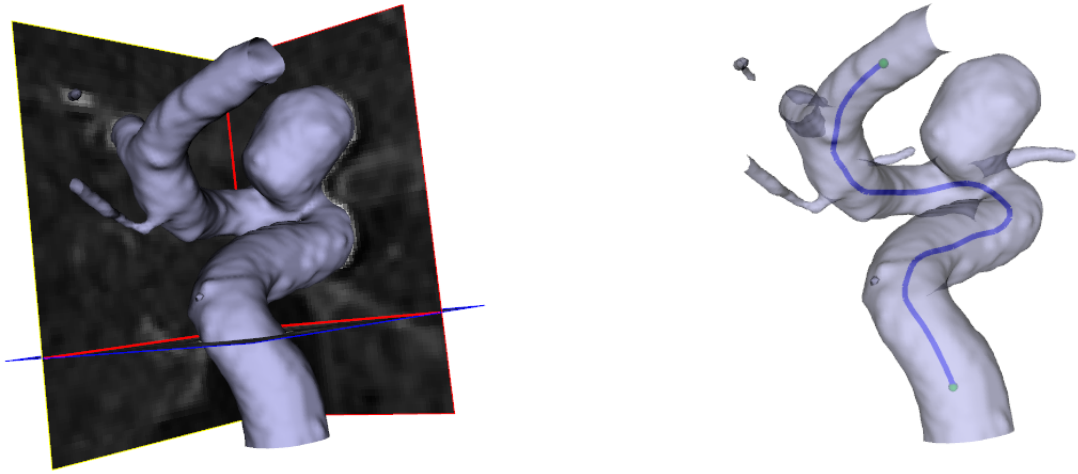
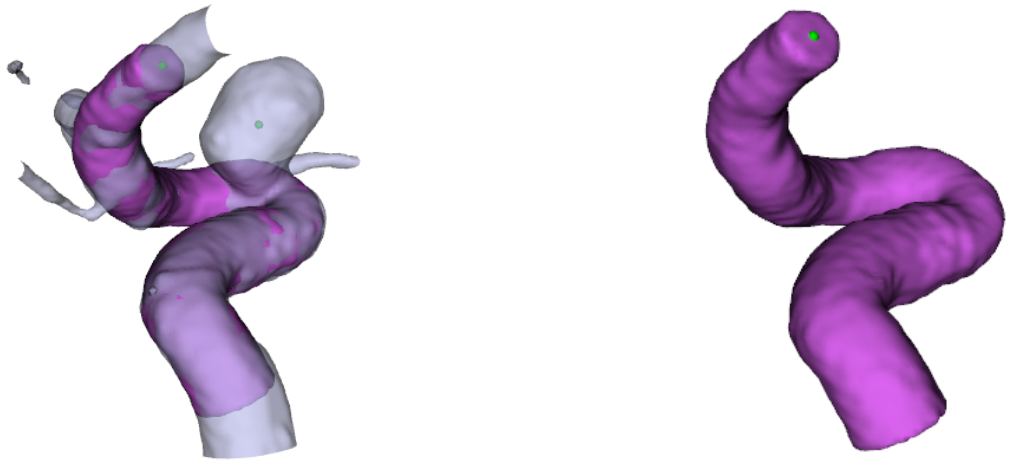


Figure 5. Segmentation of a Thrombus (blue) and the lumen of an IA

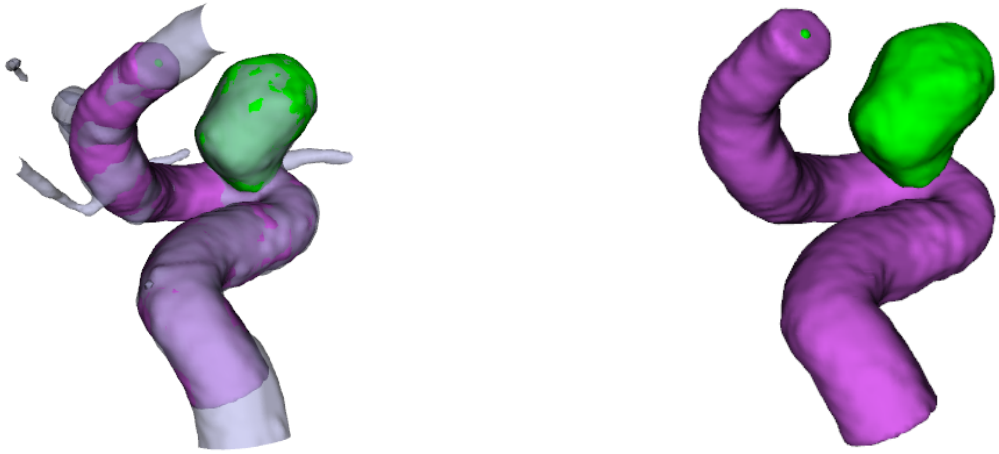
In this context Image segmentation techniques have been developed to extract, with very high accuracy, the aneurysm sac geometry as well as the geometry of the neighbouring vessels (Figure 6). We gave high importance both to the accuracy of the segmentation as well as its fast execution, allowing real



(a) First step: axes extraction. 110ms are needed in average



(b) Second step: vessel segmentation. 163ms are needed in average



(c) Third step: Aneurysm segmentation. 149ms are needed in average

Figure 6. Illustration of the global strategy used to extract the different geometries of IA

time interactive segmentation of the structures of interest. These works led to the publication of several conference and journal papers, including several methodological papers published e.g. in the IEEE transactions on Image Processing.

In parallel, a segmentation method to extract the thrombus volume in cerebral aneurysms has been developed. A very original and efficient framework has been proposed, fusing variational methods and Lattice Boltzmann numerical scheme. This has been published e.g. in the Medical Image Analysis journal.

To close the loop, a virtual stent deployment tool has been developed. It allows obtaining a numerical model of the stent deployed in real vessel/aneurysm geometry (Figure 7), appropriate to be used in the numerical simulation of blood flow and thrombosis process.

Those three key tools allowed us to constitute a database of imaging data of real patients, with their 3D segmented geometry, the thrombosis volume and stent deployment information that has been transferred and used for the numerical simulation.

Finally, aneurysm wall motion detection has been studied with the double objective of providing motion information in order to investigate the effect of the wall motion on the thrombosis process.
In this WP, we have developed all the image processing tools needed to perform numerical simulations on real patient data, taking into account their real aneurysm and vessel geometries, the presence and evolution of the thrombosis inside the aneurysm sac, as well as the presence of a stent deployed in the vessel. A reference database has been created and processed, that has been used by the other WPs. Finally, additional work on wall motion estimation has been performed, both for questioning the influence of the wall motion on the thrombosis process as well as for paving the way for future researches on the importance of the wall motion as predictor of aneurysm rupture risk.

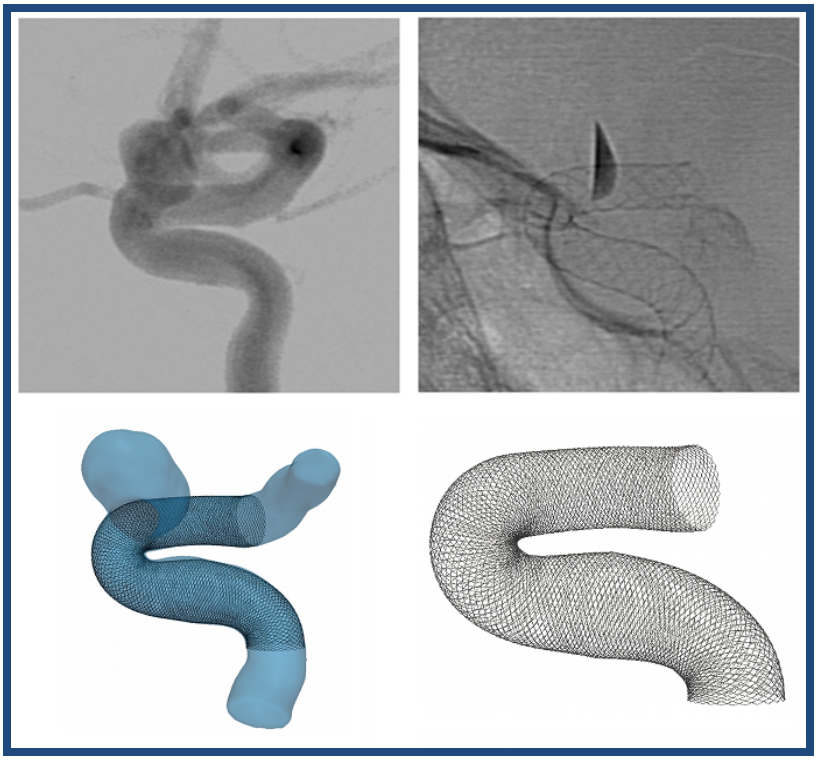


Figure7. Virtual FD stent deployment and validation with medical imaging sequences

Work package 4 (WP4) is crucial in the project as it had to integrate the medical data, the biological data the geometry of vessels, aneurysms and stent, and the models issued from the results of the other work packages. From this work package two mains innovations driven with the WP2 and the WP3 led to new models of thrombosis and aggregation of platelets.

In terms of thrombosis modelling, the THROMBUS project was based on the pioneering 2D model developed at UNIGE. This model was able to explain the partial and full clotting of cerebral aneurysms. In short, this model assumes that, for a low shear rate on the aneurysm wall (low WSR), the thrombus can grow. While doing so, it fills the cavity and changes the flow pattern, until the WSR reach a value above a given threshold. At this stage, the thrombus stops. Of course, this model is very qualitative and the goal of THROMBUS was to go beyond this simple scenario.

From the biological point of view (WP2), the low shear hypothesis was first tested with the Impact-R device, in order to study the adhesion and aggregation of platelets as a function of the shear rate. It was observed that the adhesion is more pronounced at shear rates between 25 and 100 s^{-1}.

The value of the wall shear rate (WSR) in patient-specific geometries was then measured with the numerical simulations. Typically the WSR ranges between 10 and 400 s^{-1}. This can also be tested in the case of simple synthetic side-wall geometry, for various aspect ratios (AR). AR is the ratio of the depth of the aneurysm to its diameter of the neck. The WSR decreases as the aspect ratio increases. In our hypothesis low shear rate favours thrombosis. Thus, this observation explains why giant aneurysms are more likely to spontaneously grow a thrombus than smaller ones. More quantitatively, clinical data collected during THROMBUS show the relation between the volume of the thrombus and the AR.

Adding a flow diverter reduces the WSR significantly in many points in the aneurysm cavity. The Figures 8 and 9 give the value of the velocity and wall shear stress (WSS) in simulations done on patient1 from the THROMBUS database. Note that for blood, the WSR can be obtained by multiplying the WSS by 250, provided one is using the MKS system of units.

The WSR obtained in the simulation at several selected points in the aneurysm (anterior, top, and posterior points in the dome) have been used in WP2 to conduct an in-vitro experiment aimed at determining the proteins expressed by endothelial cells submitted to such a WSR. The main result is that there is an increase of the production of tissue factor (TF) when the WSS decreases. This effect is maximum at the anterior point of the aneurysm cavity, from where the clot is often observed in clinical cases. This suggests that the so-called extrinsic clotting pathway can be the main reason of the thrombus growth.

For this reason we have developed a new thrombosis model, based on the production of TF at the wall of the aneurysms, provided that the WSR is locally low enough. When this is the case, thrombin is produced. It can react with the fibrinogen brought by fresh blood and transform it in fibrin. This is what makes the clot. The process can however be slowed down or stopped by the presence of anti-thrombin transported by fresh blood.

There is therefore a competition between the two mechanisms, whose result depends on the value in space and time of the density of the various species. In practice, the growth stops when all the

thrombin has been annihilated. Note that platelets also play a role in this model. They compact the fibrin strands and make the clot less and less porous to thrombin. Platelets, if numerous enough, can also recover the surface of the fibrin. This enables the re-endothelialisation of the clot, and the formation of layers, as reported in the literature (onion-like structures).

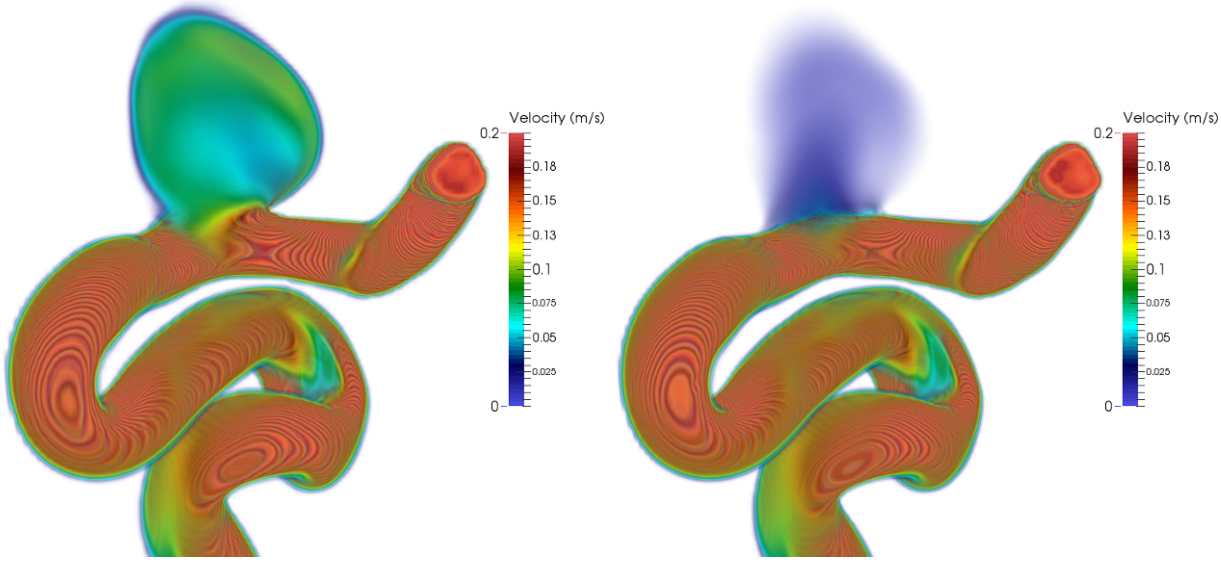


Figure 8. Comparison of velocity distribution between no stent (left) and full stent (right) cases

In Figure 8, blood flow analysis reveals that velocities within the aneurysm are substantially reduced after stent deployment.

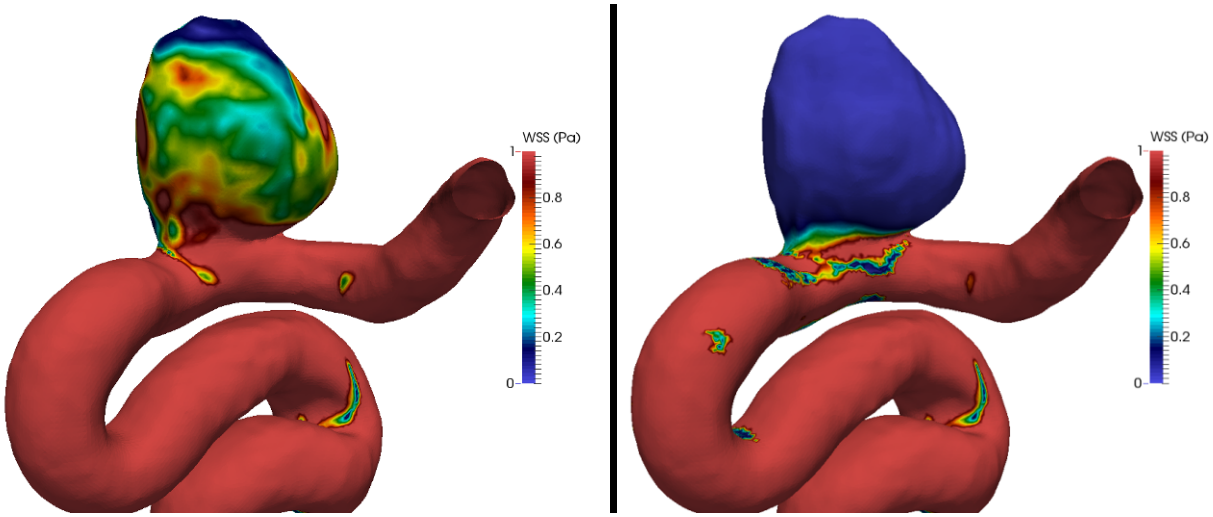


Figure 9. Comparison of WSS between before and after stent

This thrombosis model has been implemented in the PALABOS Lattice Boltzmann solver. Here we simply show the comparison between simulations and the case of two patients with a giant aneurysm that has partially clotted. The Figure 10 shows the result of the numerical model (in red), superimposed with the actual geometry (in blue) segmented by WP3. Note that for these two cases the inlet and outlet flow properties where unknown and we used standard pulsatile data. We can observe anyway a very satisfactory agreement between reality and simulation, showing a robustness of the process to some variations of the parameters.

Figure 10. Comparison of the actual (blue) and predicted (red) thrombus formation in two patient-specific geometries. The lumen after thrombosis is highlighted in plain color

In conclusion our numerical model, built on the findings of WP2 and the image processing done in WP3, provides the first thrombosis model for cerebral aneurysm based on first principle mechanisms and taking into account the spatio-temporal nature of the process. A very interesting result is that the start and stop of the thrombus growth is an emergent property of the interaction between the blood particles, the geometry of the aneurysm, and the flow properties.

Work package 5 (WP5)

Work package 5 (WP5) performed the global integration of all the components of the projects leading to the achievement of the objectives described in the Description of Works (DoW).

Data integration and connecting multiple heterogeneous software components are two of the principal goals of Work Package 5 (WP5). The first one seeks to guarantee a clean, secure and reliable management of the patient's data. Proper data storage, usage, and transfer will be required to trigger the medical image processing (WP3), biomechanical studies (WP2), and numerical simulations (WP4). On the other hand, software integration gives a solution to: 1) the incorporation of algorithms designed and developed by Thrombus researchers to solve specific requirements during the patient's data processing into a full workflow (pipeline of applications), and 2) the connection of these components with external applications, as well as its rapid and easy execution to assure the treatment of multiple cases.

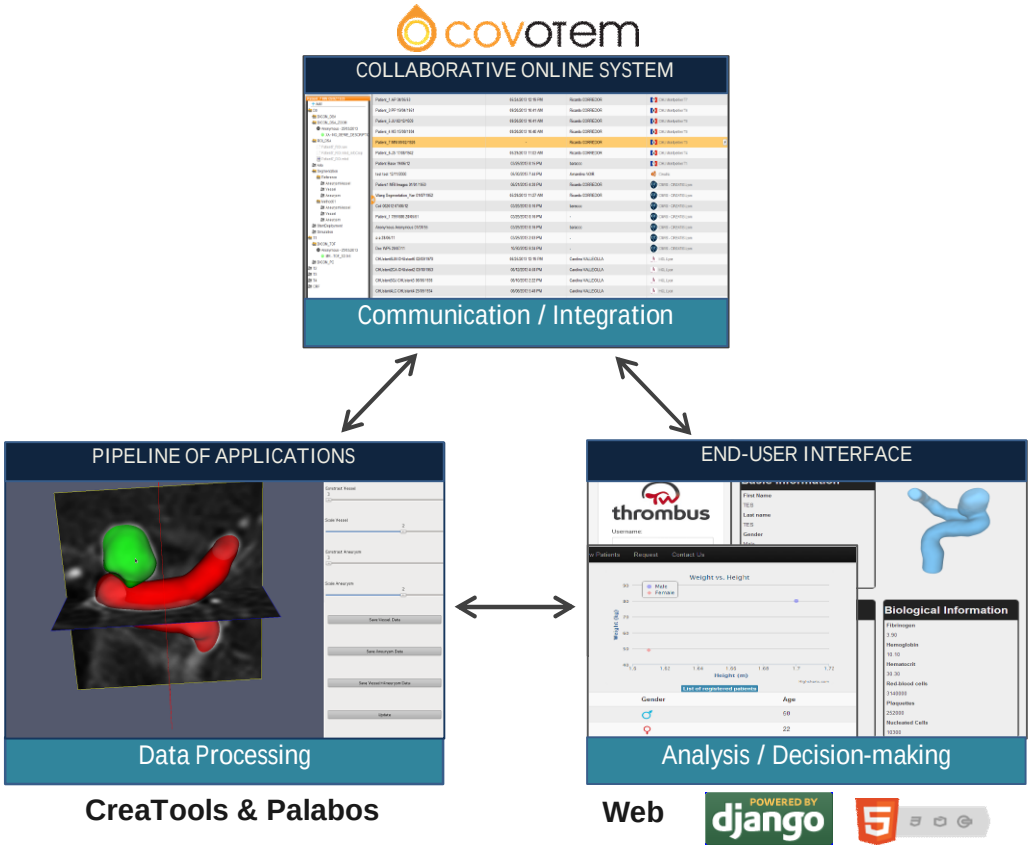


Figure 11. Thrombus software platforms

Thrombus software solutions are mainly based in four platforms as it was explained in previous deliverables. CreaTools, COVOTEM ™, Palabos, support the Pipeline of Applications (Figure 11). The fourth platform corresponds to a custom software solution that supports medical analysis and decision-making process.

CreaTools is an open-source software suite that makes part of the VPH NoE Toolkit. It is composed by ready-to-use applications and C++ class libraries that help the development process of scientific algorithms and their integration in medical image processing work-flows. This platform can be used by several users (software programmers, students, scientists, and medical practitioners) to create rapid prototypes or stand-alone applications by making high-level connections among heterogeneous modules for input/output (I/O) data management, image/mesh processing, graphical user interfaces, 2D/3D visualization, and user interaction.

The pipeline of applications (Figure 12) consists of a sequence of tools that allows using real patient's data (medical images) in numerical simulations, as well as producing geometries that can be 3D printed to create models to be used in *in-vitro* experiments. Multiple prototypes have been designed and implemented on two main software platforms (CreaTools and Palabos Web). These tools can be sequentially launched from the collaborative online system, COVOTEM (Figure 13): extract a region of interest, extract vessel centerline, vessel and aneurysm segmentation, flow diverter configuration, virtual flow diverter deployment, and launch a remote blood-flow simulation.

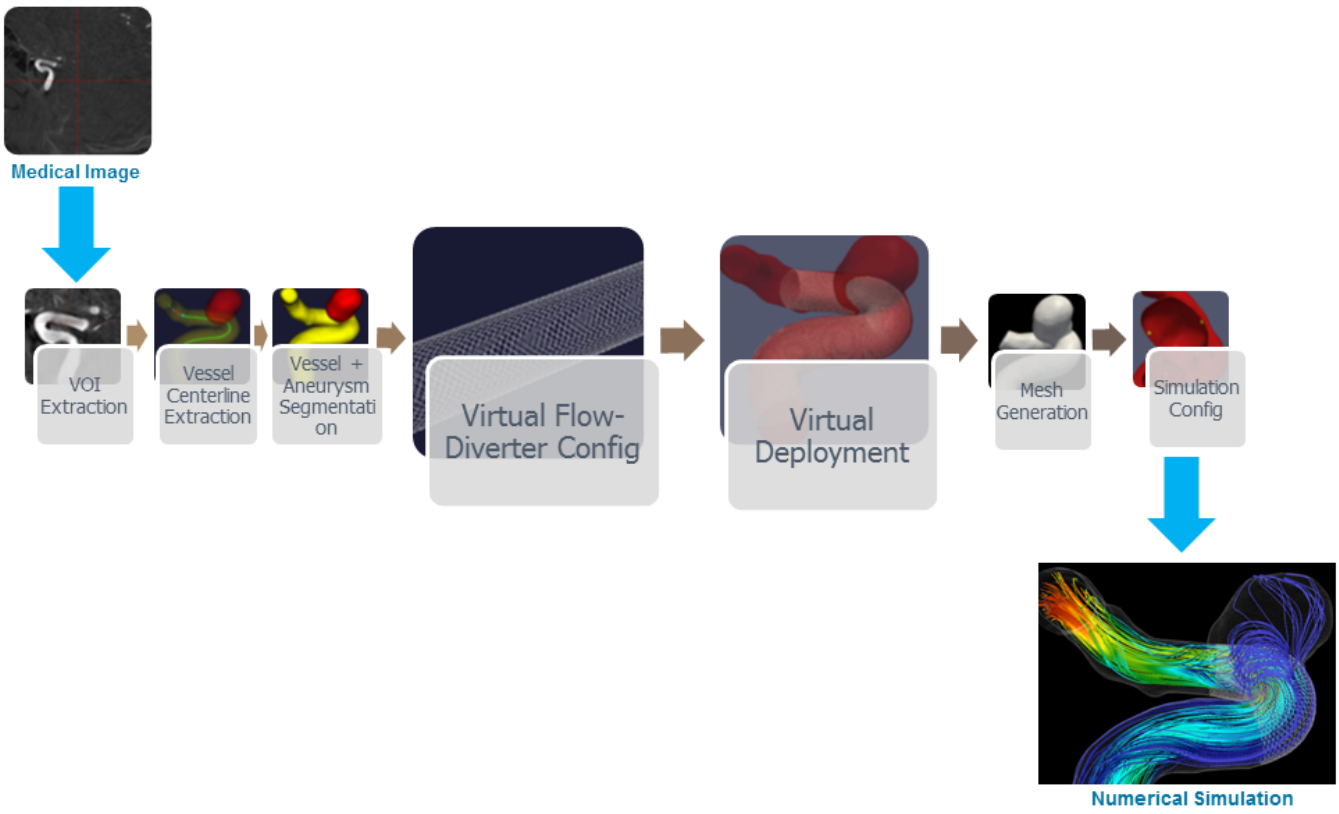


Figure 12. Pipeline of Applications

Thrombus Tools are a collection of solutions to resolve two main goals of Thrombus:
-Data and applications integration.
-Providing prototypes that allow medical doctors and scientists to use patient-specific data in numerical studies.

Some important constraints were evaluated to design tools that allow scientists and medical doctors to use real patient data during *in-silico* and *in-vitro* studies:
- Managing heterogeneous data (medical images, 3D meshes, velocity profiles, biologic data, patient history …).
- Running and integrating advanced scientific algorithms and/or software frameworks (medical image processing, blood flow simulations …).
- Repeating the same procedure for multiple cases.
- Implementing intuitive and user-friendly interfaces.

In order to solve these requirements, multiple software platforms were developed to provide a complete environment that helps researchers and physicians during their medical decision-making process.

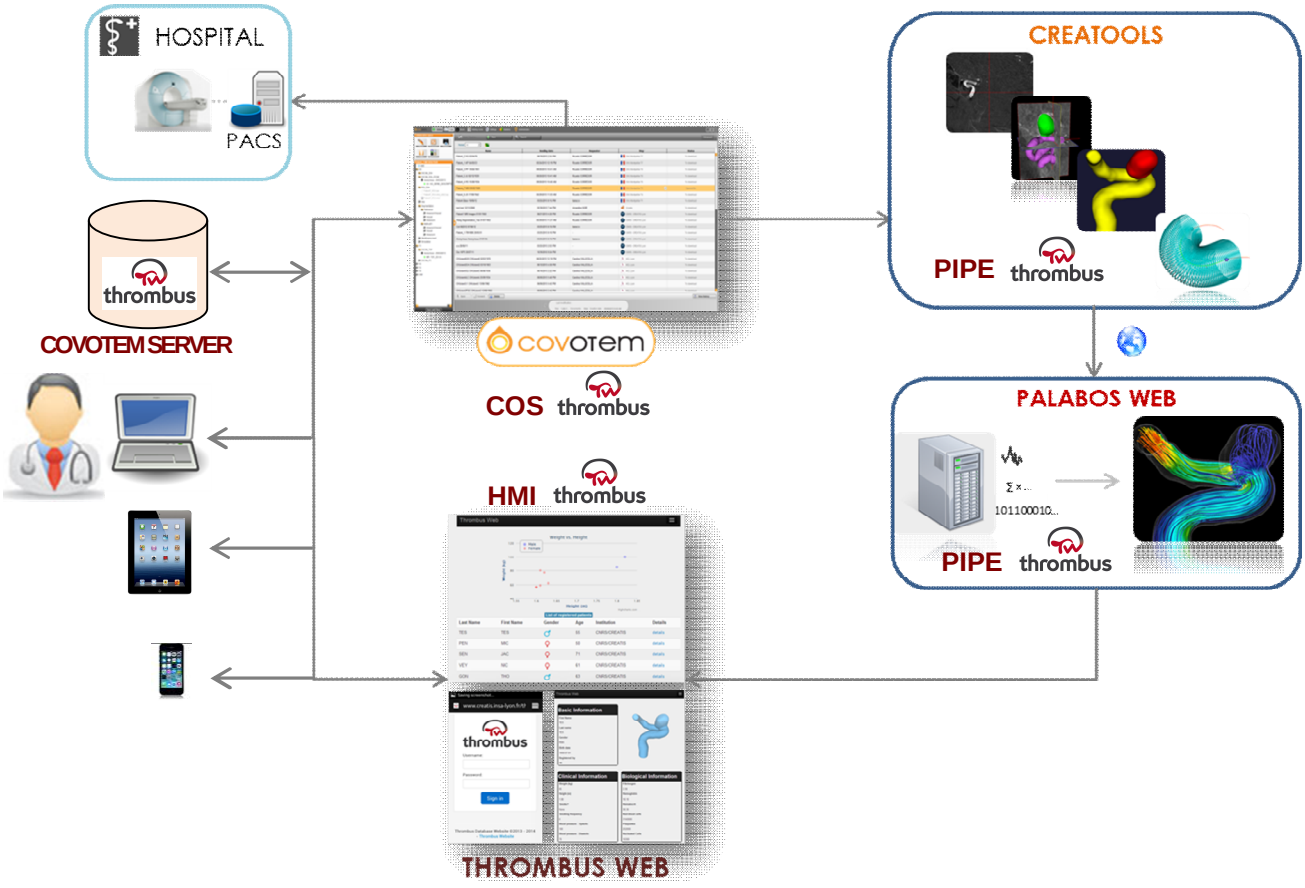


Figure 13. Pipeline of Applications - Collaborative Online System - Human Machine Interface

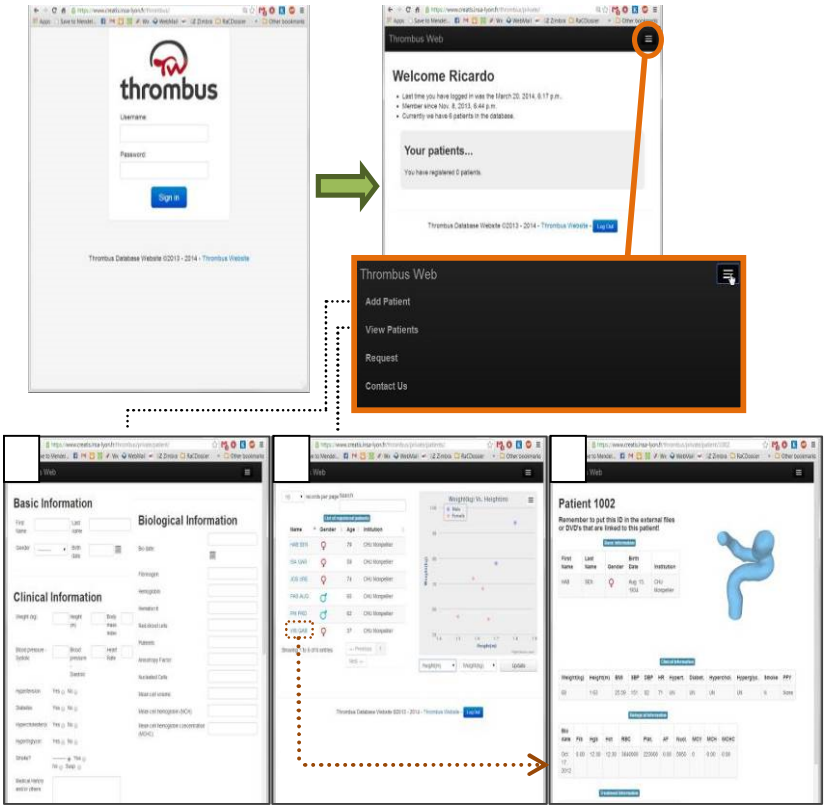


Figure 14. Web system for medical decision-support

A new web system (Figure 14) was developed to summarize all the available information of the patient that can help the medical decision-making process. Gathering clinical parameters (age, blood pressure, heart rate, medical history …), biological parameters (hematocrit, number of platelets, mean cell volume …), geometrical patient-specific measurements, and results from the numerical simulations, this tool provides a workspace that helps experts (medical and the scientific community) to accomplish a proper and objective analysis through statistics and interactive techniques (charts, 3D surfaces, interactive tables). The current version of the tool allows including new patients into the database, displaying a general overview of all the patients in the database, and consulting the details of a patient (including the 3D geometry, the patient specific velocity profile used in the simulation, and others). This tool is available online (https://www.creatis.insa-lyon.fr/thrombus) after a basic authentication using a valid username and password.

Final results after 39 months

New biologic knowledge

A new understanding of the thrombosis has been established based on biologic experiments. Several biologic mechanisms have been revealed, mimicking the growth of a thrombus within the cavity of an intracranial aneurysm.

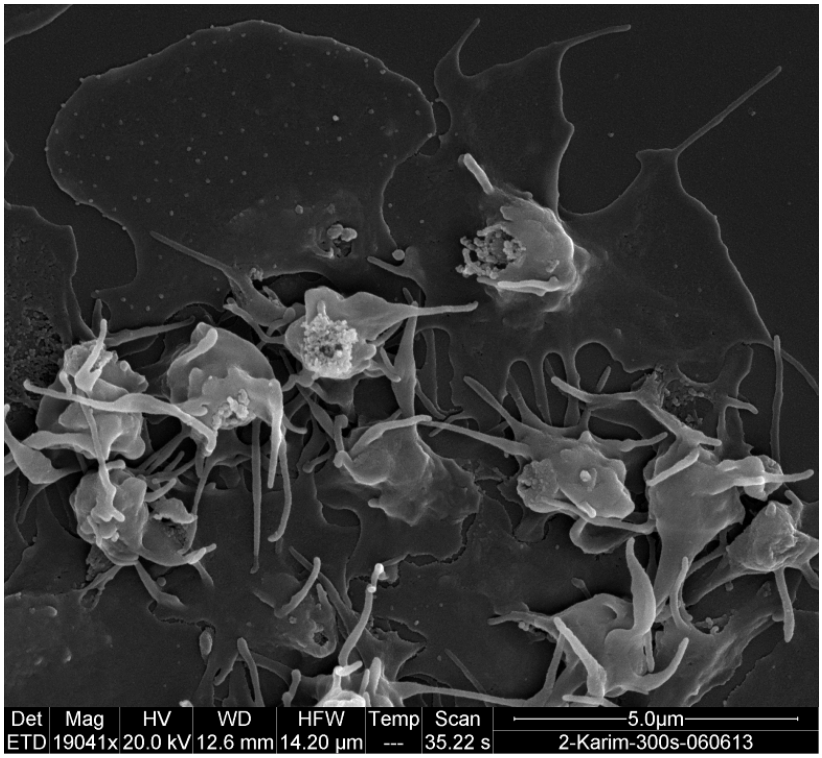


Figure 15. Platelets aggregation

To illustrate this work, we highlight the study of the behaviour of the platelets (Figure 15) and the discovering of the proteins which influence the capacity of aggregation of platelets of a considered patient. Also this study of platelets has been the opportunity to use a holographic microscope contributing in part to the validation of the results.

Scientific and medical research led to the development of software prototypes:

-1- PALABOS implementation (http://www.palabos.org/) dedicated to the modelling of thrombus and platelet aggregation.

-2- CreaTools implementation (http://www.creatis.insa-lyon.fr/site/en/thrombus-tools) for:

a) The modelling and optimization of flow diverters and their virtual deployment

b) The realization of a Pipeline of Applications coupled to the collaborative online system.

-3- COVOTEM-Thrombus implementation is a custom release version of COVOTEM allowing the construction of the Collaborative online system of Thrombus (http://www.covalia.com).

-4- A web interface including biological, clinical, geometrical, and all numerical data of the patients with the objective to optimize the expert system to assist diagnosis and treatment (https://www.creatis.insa-lyon.fr/thrombus).

The project generated several concrete achievements:

-1- Patent on the 'In vitro' test bench (N° EP13158858.4 – March 2013)

It concerns a test bench (Figure 16) allowing, amongst other things, to reproduce the complex pulsed flow within silicone aneurysms designed from three-dimensional medical images of patients' aneurysms and to perform observations by the mean of a scanner.

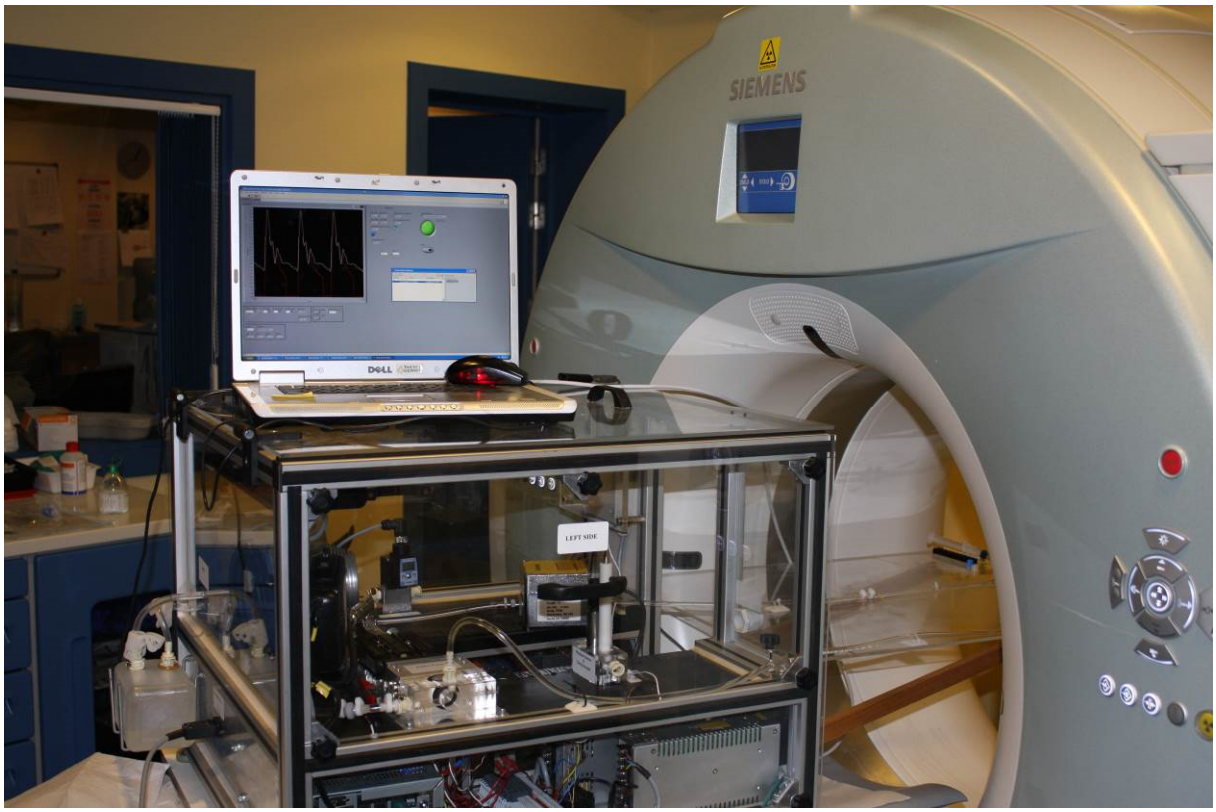


Figure 16. In vitro test bench

-2- Transfer agreement 'COVALIA-CNRS' for COVOTEM-Thrombus (N° CNRS 6624)

It concerns the evolution of the COVOTEM product providing a new version of this Telemedicine software able to associate advanced image processing tools applied to medical imaging sequences and to the follow up of patients.

-3- Pipeline of Application (Figure 17) available at http://www.creatis.insa-lyon.fr/site/en/thrombus-tools.

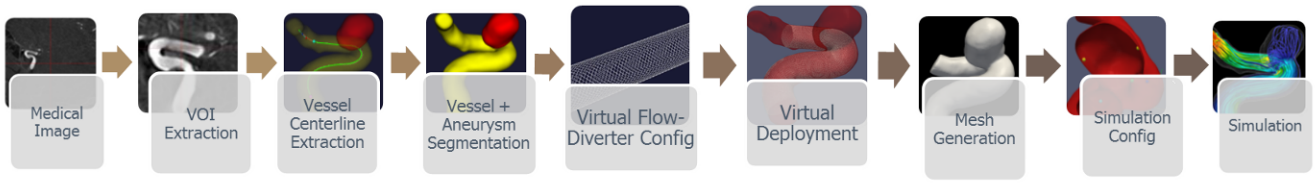


Figure 17. Pipeline of Applications fonctionalities

-4- Proceedings and scientific publications (see deliverable 'Final Dissemination') and the co-organisation of two events, the SFNR 2014 congress (http://www.sfnrcongres.net/) in Paris and the ICS 2014 congress (http://www.ics14.org/) in Zurich.

Final International conference

From the beginning of Thrombus, it was planned that a final international conference will be organised at the end of the project in order to capitalise and disseminate gathered knowledge. It was decided the co-organisation with some major events in the domain covered by Thrombus.

Two events have been selected as THROMBUS Final Conference:

- The 1rst event was organised jointly with the SFNR 2014 meeting http://www.sfnrcongres.net/ in Paris (3-5 April 2014) in which a Thrombus session has been programmed on Thursday 3rd. The programme can be seen here http://www.sfnrcongres.net/programme-2014/synoptique-et-pdf and Thrombus is concerned because:
    - 4 researchers of Thrombus were invited speakers and were members of the Academic Staff of the SFNR 2014. Also Guy Courbebaisse (CNRS) and Benjamin Gory (HCL) were respectively the chairman and co-chairman of the session.
    - A Thrombus business workshop dedicated to neuroradiologists and stent designers has been organised.
    - Alain Bonafé, (neuroradiologist of CHU Montpellier subcontractor of CNRS) as president of SFNR participated to the organisation of the congress
    - Francis Turjmans (HCL - Partner 9) has been invited as neuroradiologist to present a lecture on "Thrombectomie : 'vite fait, bien fait' ?"

During this event, medical, academic and industrial recognized players in the field of aneurysms have been invited. SFNR 2014 allowed the medical doctors, researchers and external participants to have a complete view of the Thrombus project outcomes and to make personal contacts which may result in the continuation of the project's work. These events are of great importance for Medical

Doctors, Stent Manufacturers and scientific researchers. The large audience of these events can be estimated to several hundred participants (450 persons cf. organiser of the congress).

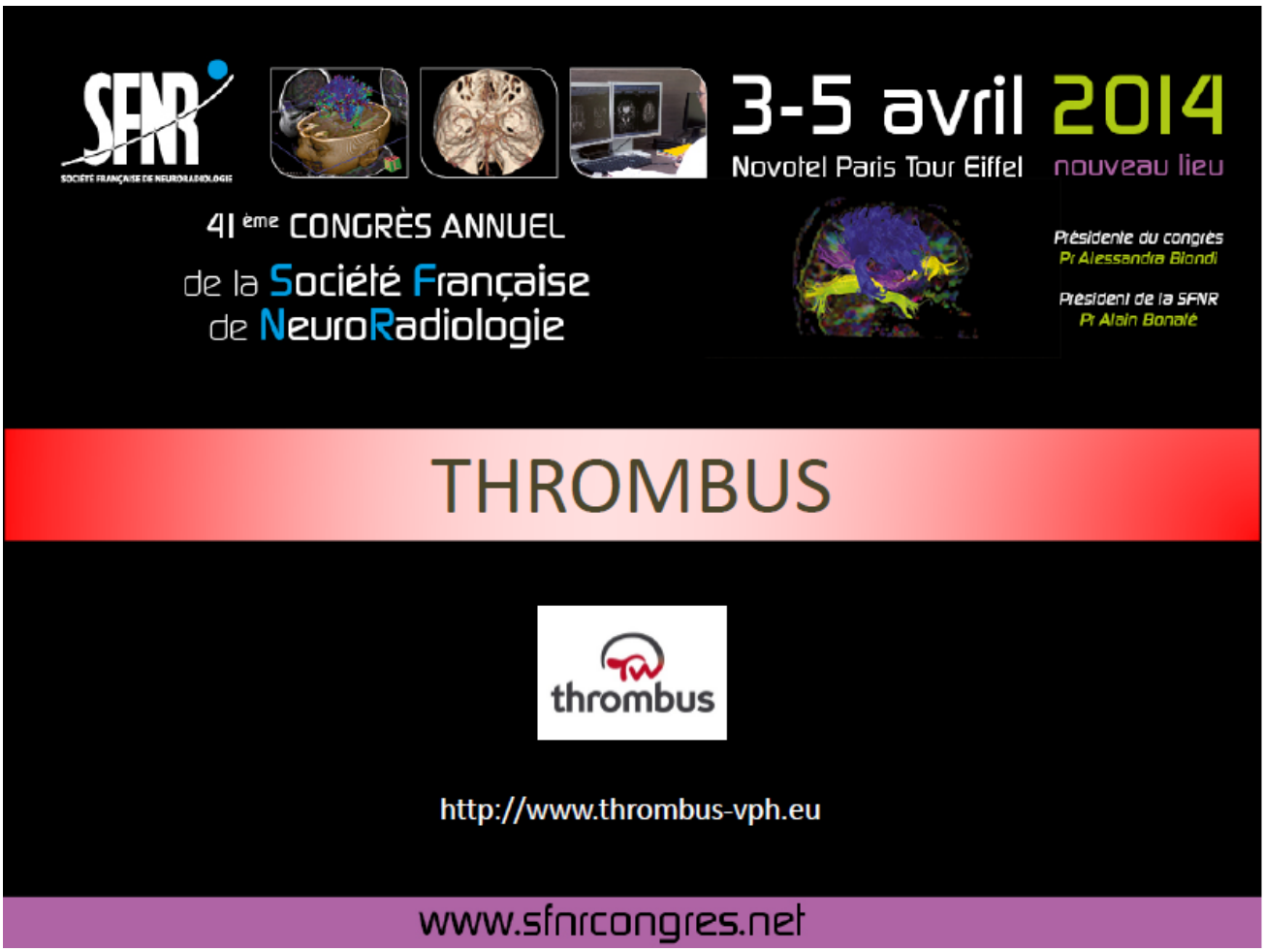


Figure 18: THROMBUS at the SFNR 2014 congress

- The second event has been organised jointly with the ICS 2014 meeting in Zürich programmed on the 2^{d} to the 4th of June 2014 (http://www.ics14.org/), for which four researchers of Thrombus are invited speakers.

During those events, world recognized players in the field of aneurysms has been invited. It allowed the project researchers and external participants to have a complete view of the project outcomes and to make personal contacts which may result in the continuation of the project's work. These events are of great importance for Medical Doctors, Stent Manufacturers and Scientific Researchers. The large audience of these events can be estimated to several hundred participants.

Potential impact and the main dissemination activities and exploitation of results

The goals that THROMBUS Consortium had decided to achieve during the life of this project clearly underpin all the expected impacts listed in the objective ICT-2009.5.3.Virtual Physiological Human. Clearly, THROMBUS main objective was the development of a multiscale model and simulation of organs/systems (cerebral aneurysm and its occlusion) targeting specific clinical needs (giving recommendations for best treatment). This project provided a better understanding of the functioning of the organs and their pathologies aiming at prediction/early diagnosis. Indeed, no final understanding of how a thrombus forms in cerebral aneurysms was known, especially when taken into account the blood flow. The proposed model is based on the tuning and integration of existing model, involving clinical validation and biological research.

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

The establishment of the mentioned 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 synthesize all parameters is a crucial and integral point of the project. The use of the *in-silico* environment, combined with the *in-vitro* and *in-vivo* experiments definitely opens the way to accelerated developments of medical knowledge discovery and management.

The outcomes of the WP5 Integration, which include the communication platform, will allow improved interoperability of biomedical information and knowledge. This tool will enable medical operators to exchange observations, medical images, comments and all necessary data in a real time, and within a completely secure environment encoding all possible personal data. The real time accessibility from tablet, iPhone to the data of the patient will allow the optimization of the treatment.

Our consortium includes medical practitioners and high-tech companies who will play a major role in the validation of obtained models and assessing at an early stage the socio-economic implications of new technological solutions. By that our project will contribute directly to the increased acceptance and use of realistic and validated models that allow researchers from different disciplines to exploit, share resources and develop new knowledge.

THROMBUS project brings together a multidisciplinary consortium which covers the creation of the Thrombosis model from 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 ineluctably lead to reinforced leadership of European industry and strengthened multidisciplinary research excellence in supporting innovative medical care.

Industrial network:

- BALT extrusion Company: Linda Nicolini / Director of market Development
  Subject: modelling of stent or telescopic systems.
- EV3 – COVIDIEN Europe: Christian Outrilla / Sale Territory Manager -Neurovascular Division
  Subject: Stents dedicated to in vitro experiments.
- Oxford Wave Research Ltd: Dr Anil Alexander / Research Director
  Subject: End User interface for the pipeline of THROMBUS from IPAD system
- ANSYS France Company: Michel Rochette / Director of Research
  Subject: Numerical simulation of Flow diverters
- ITGI Medical Ltd: Matthew Lewis / VP - Medical Affairs
  Subject: High quality heterologous tissue covered stents for Neurovascular interventions
- Medical Embedded Systems 'mes': Hans Peter Einzer
  Subject: Mobile DICOM viewer
- Flowkit CFD Solution which is a company located in Geneva (http://www.flowkit.com/)

International network:

1. European medical network: SFNR (http://www.sfnr.net/), ESMINT (http://www.esmint.eu/), ICS (http://www.ics-meeting.net/), CHU Charleroi (http://www.chu-charleroi.be).
2. International scientific network with USA (Guillermo Cardenas Lab (http://garcia-cardena.bwh.harvard.edu/) and Japan (ELyT http://www.elyt-lab.com/) partners.
3. Member of the VPH-Institute (http://www.vph-institute.org/) and linked to the VPH Network of Excellence (http://vph-portal.eu/thrombus).

Dissemination

A dedicated interactive website with two levels of access

The World Wide Web became a major information channel and it is now indispensable for producers of information – particularly in the scientific and technical domains – to publish on the web. Since the first days of the consortium a website has been started. In order to develop an efficient communicating tool, the services of a professional web interface designer have been used. The creation of the website has been entrusted to the local company Kinesphere and the address of THROMBUS website is: http://www.thrombus-vph.eu/, since the 17th of May 2011.

An e-mail address contact@thrombus-vph.eu has also been set up to enable visitors to contact THROMBUS the coordinator of Thrombus.

The website (Figure 19) has been a key tool to provide information about the project and news of its activities and results. But the website has been also a working tool with a private area allowing THROMBUS members to share confidential data in order to improve communication between consortium Partners.

In consequence, it includes a private area, accessible to the Project Partners only and a public area:

(a) Public accessible level: the public area allows broad dissemination of the Project outcomes in form of common scientific publication database and information on events related to THROMBUS project. This contains information about the management structure, contact points and activities of the Projects including conferences, workshops, symposia …

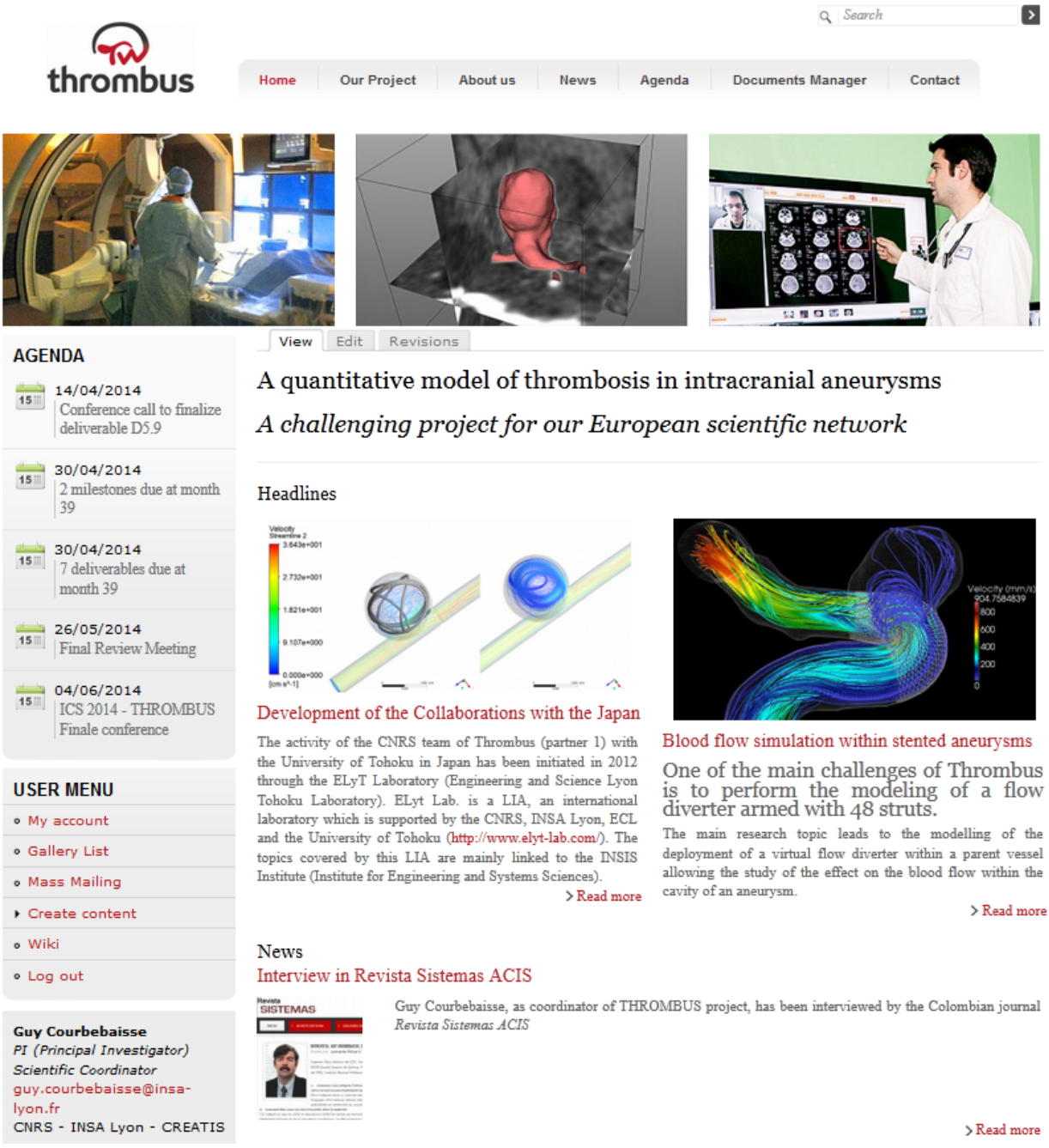


Figure 19. Website of the European project Thrombus

(b) Password-protected level: this access-level allows private information exchange about available facilities and work in progress for members in Work Groups only. It contains information about the Governing Board meetings, and general meetings with all Partners, scientific reports, non-technical interim and annual reports, financial reports, working papers, guidelines and manuals. Dissemination actions and meetings organized within the project are published on the website. Information on progress was updated throughout the project.

The website continues to be maintained in order to ensure the sustainability of the project and to enable researchers continuing their work on the subject with an interactive communication tool. We expect that this project will open the door to a new collaborative community.

Logo

In order to develop a corporate identity as well as to provide en efficient communication tool to support dissemination action, an identifiable logo has been created. A competition to produce the best proposal logo (Figure 20) was launched with partners Thrombus project and a professional designer author of the website of Thrombus, the Kinesphere Company.

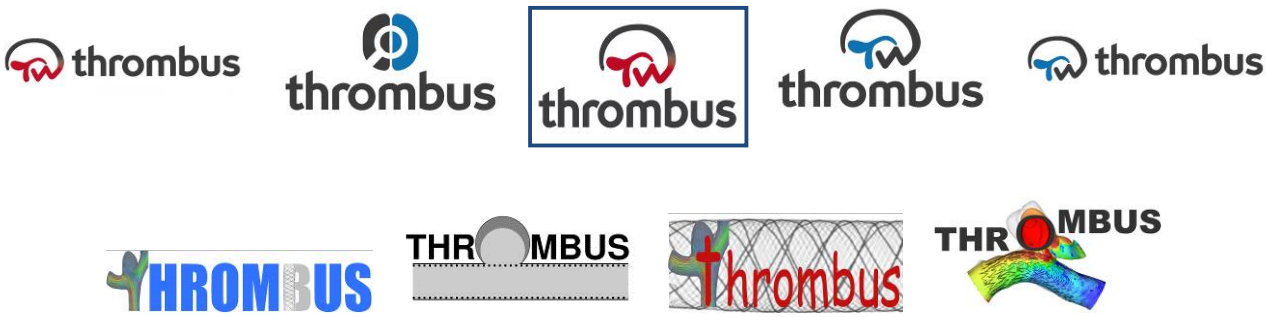


Figure 20. Proposed logos

Promotional material

In order to advertise THROMBUS project, ballpoint pens and USB keys has been ordered with the logo and the address of the website printed on the object.

Figure 21. Vectors of communication

Dissemination mailing list

A dissemination mailing list has been established gathering those who have expressed interest in the project (website visitors subscribing to the newsletters, regular collaborators, colleagues, supporting researchers and institutions and legal representatives) but also private and public institutions such as:

- Balt, Covidien and other stent manufacturers
- Hirslanden Private Hospital (Zurich), University hospital of Geneva, CHUV Lausanne (Switzerland), Clínica Sagrada Familia in Buenos Aires (Argentina), Hospital of the Fondation Rothschild in Paris, la Pitié Salpêtrière in Paris, La Croix Rousse in Lyon, CHU Charleroi, CHU Montpellier, HCL Lyon (France)…
- Medical doctors members of ESMINT (European Society for Minimally Invasive Neurological Therapies), EANS (European Association of Neurosurgical Societies), SFNR (French Society of Neuroradiologists), ICS (Interdisciplinary Cerebrovascular Symposium).

The dissemination mailing list was an open list, updated regularly.

YouTube 'Thrombus'

Thrombus is present on You Tube in order to introduce the project to a wide public,

http://www.youtube.com/user/thrombusVPH/

Several videos are presenting the project and scientific results obtained within THROMBUS such as:

- A presentation of THROMBUS members: http://www.youtube.com/watch?v=PWIhF4JKdBg&list=UUpyerbp9NV2S1gNw2hQvB8Q
- The in-vitro testbed to study cardiovascular diseases: http://www.youtube.com/watch?v=KsyR_LHfVsc&list=UUpyerbp9NV2S1gNw2hQvB8Q
- Blood flow simulation in intracranial aneurysm: http://www.youtube.com/watch?v=_tPlBQYYrc0&list=UUpyerbp9NV2S1gNw2hQvB8Q
- Pipeline of applications - From the medical image acquisition to the blood flow simulation: http://www.youtube.com/watch?v=6DOb5xrq9X8&list=UUpyerbp9NV2S1gNw2hQvB8Q
- Detailed stent deployment: http://www.youtube.com/watch?v=izQjYKRo5wk&list=UUpyerbp9NV2S1gNw2hQvB8Q
- Rapid stent deployment on intra-cranial aneurysm: http://www.youtube.com/watch?v=_hufTLe5IVE&list=UUpyerbp9NV2S1gNw2hQvB8Q

Communication to the scientific community

- Participation to conferences, workshops or scientific meetings

Lectures are an important and useful method to spread the THROMBUS activities to research and medical community. There are several ways to give a lecture: either during an event organized by

THROMBUS consortium or at conferences, workshops or seminars initiated by other organizers (for details see Appendix 1).

- Scientific articles, reviews and other publications

Publishing was one of the most important actions related to research activity within THROMBUS project. It allowed the consortium not only to disseminate the results, but also to get a fast and competent feed-back from the targeted community. Publishing and presenting the results of the project in the most well-known conferences and relevant journals gave THROMBUS Partners the opportunity to reach the other researchers focusing on the same or similar problems.

- THROMBUS project - member of the Biomed Town Portal

Biomed Town https://www.biomedtown.org/ is the home of different entities with an interest in biomedical research. By this way, THOMBUS was involved in the biomedical community.
Thrombus building is available at https://www.biomedtown.org/biomed_town/thrombus

- THROMBUS project on ePractice

THROMBUS project has been presented on ePractice.eu and was one of the 'Editors choice 2013' in the eHealth domain: http://epractice.eu/en/cases/thrombus
In addition, Guy Courbebaisse - as THROMBUS coordinator - has been invited to attend the conference 'eHealth and the Brain - ICT for Neuropsychiatric Health' where he presented a lecture on the main results of Thrombus (http://www.epractice.eu/en/events/brain2013).

International collaborations

- Collaboration has been achieved with the Department of Materials Science and Engineering, Harvard Medical School-MIT - Biomedical Engineering Center, Edelman Laboratory / Garcia-Cardena Laboratory.
- Fruitful collaboration have been achieved and continue today with Leonardo Flores, Pontificia Universidad Javeriana, Bogota, Colombia.
- Intense exchanges between Joerg Bernsdorf (GRS - Partner 6) and Marc Garbey, University Houston Texas on aneurysm-related simulations (joint PhD)..
- Collaboration between Alfons Hoekstra and Eric Lorenz (UvA - Partner 7) and Frans van de Vosse and Jens Harting (TU Eindhoven)
- Alfons Hoekstra and Eric Lorenz (UvA - Partner 7) initiated a collaboration with Ed van Bavel (Amsterdam Medical Center)
- Regular monthly meetings between Alfons Hoekstra and Eric Lorenz (UvA - Partner 7) with Daniel Bonn on the physics of dense suspension, in University of Amsterdam
- Bastien Chopard (UNIGE – Partner 2) has been collaborating with Prof Hans Herrmann, ETHZ, Switzerland
- Bastien Chopard (UNIGE – Partner 2) has been collaborating with Professor Niels Kuster, ETH Zurich, ITET Department

- Guy Courbebaisse (CNRS-CREATIS) is collaborating with Professor Makoto Ohta (University of Tohoku – IFS) within the framework of ELyT Lab (http://www.elyt-lab.com/) This collaboration has given the opportunity to attend the congresses ICFD 2012 and 2013.
- Guy Courbebaisse, as coordinator of THROMBUS project, has been invited by Julius Dengler, M.D. (Dept. of Neurosurgery, Charité – Berlin) to participate to the 1st Study Group 'Giant Aneurysm Registry' Group in the Framework of a EU Project,2012 Berlin.
- Guy Courbebaisse supported the collaboration of Karim Zouaoui (ULB – CHU Charleroi) with the University of Mons. The Professor Gregory Coussement who has been the PhD supervisor of Kamil Chodzinski, has invited Guy Courbebaisse and Jean-Philippe Thiran to be member of the jury of the thesis "Study and development of an in vitro technology for testing vascular tissues submitted to physiological pulsatile flow conditions", private defense on 14/11/2013 and public thesis defense on 13/12/2013.

Links with others FP7 projects or actions, projects with proximity and/or complementarily objectives

Networking is necessary and efficient to promote a project. Thus, collaborations with other projects with proximity and/or complementarily objectives have been initiated; this was fruitful for both projects.

- MAPPER project (http://www.mapper-project.eu) dedicated to a multiscale modelling methodology, Partner 2 - UNIGE and Partner 7 – UvA: Continuous communication with the MAPPER project on multiscale simulations, HPC and multiscale simulation environments.
- RT3S project (http://www.rt3s.eu) dedicated to real time simulation for safer vascular stenting, Partner 1 CNRS - CREATIS.
- Communications within the life science and HPC community in Switzerland through UNIGE - Partner 2.

Active involvement with the European VPH community

THROMBUS project was involved in the European VPH community via the VPH Network of Excellence

- An article about THROMBUS project devoted to the 6th VPH NoE has been published in the newsletter in July 2011 http://www.thrombus-vph.eu/news/thrombus-in-the-6th-vph-noe-newsletter.
- Some THROMBUS Partners were directly involved in the VPH community and are member of the VPH-Institute.
- THROMBUS project was well represented during VPH 2012 http://www.vph-noe.eu international conferences on computational biomedicine in London in September:

  http://www.thrombus-vph.eu/news/vph-2012-on-september-18th-%E2%80%93-20th-2012-in-london

  - COVALIA, Partner 5 and CNRS, Partner 1 - WP5: Oral presentation "A collaborative online system dedicated to the study of intracranial aneurysms"

- UvA, Partner 7 - WP4 : Oral presentation " Virtual Physiological Human Conference"
- GRS, Partner 6 - WP4: Poster "Towards Large Scale Simulation of Thrombus Formation in Stented Cerebral Aneurysm"

- THROMBUS project was represented (via the coordinator Guy Courbebaisse) at the 3rd VPH NOE Workshop on Toolkit Hands-on Training Medical Imaging Toolkit: http://www.creatis.insa-lyon.fr/Interoperability_workshop/Planning.htm#section4
- UvA – Partner 7 published the paper "Where do the platelets go? A simulation study of fully resolved blood flow through aneurysmal vessels" in the VPH Special Issue "The virtual physiological human: integrative approaches to computational biomedicine".

Exploitation of results

The overall goal for the exploitation of the project results is to promote innovation and to facilitate the use of the most innovative tools and methodologies by the largest public (medical and scientific).

All software developed in THROMBUS concerning Multiscale Numerical Simulation and Image Processing are open source and linked to VPH toolkit (CreaTools & GSEngine) and by the way will contribute to extend the potential of the VPH community (VPH NOE …).

In addition Image Processing software developed in the framework of CreaTools must be registered under CeCILL B licence. CeCILL (http://www.cecill.info/index.en.html) is the first license defining the principles of use and dissemination of Free Software in conformance with French law, following the principles of the GNU GPL. This license is meant to be used by companies, research institutions and all organizations willing to release software under a GPL-like license while ensuring a standard level of legal safety. CeCILL is also perfectly suited to international projects.

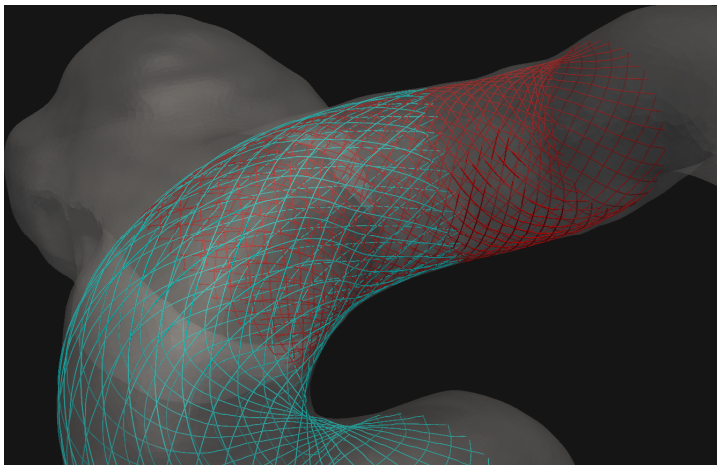


Figure 22. Telescoped FD stents

Regarding the industrial valorization, the European market of IA stent is targeted and the SFNR 2014 congress has been the opportunity to meet stent designers such as COVIDIEN Company interested by the patient-specific treatment. A first prototype has been deployed by CNRS partner (Figure 22) and the experience encourages the creation of a viable and attractive commercial base in order to diffuse the information to European potential buyers. The HCL and CHU Montpellier have been

responsible of the clinical exploitation of THROMBUS by promoting the End-User interface (HMI) and the Collaborative Online System (COS).

Moreover the validation of the project results contributed to the optimization of the FD stents and new design of medical devices.

Functionalities added to the COVALIA's existing solutions (COVOTEM-THROMBUS: 3D, 4D data management – Figure 23) have been developed during THROMBUS project; offer a range of market opportunities by integrating specific know-how within the COVALIA tools (Transfer agreement COVALIA- CNRS) in preparation.

Figure 23. COVOTEM - THROMBUS Collaborative Online System

To spread the information and the knowledge about project outcomes, THROMBUS has established a solid relation with European and international organizations. We have also established cooperation with European organizations promoting telemedicine in various projects such as LEAD ERA (e-health Market), INTERREG Programs…

At the medical point of view, the established network of neuroradiologists (Montpellier, Lyon, Paris, CHU Charleroi…) uses the Web interface developed by Thrombus with the objective to increase the number of patients in the data base of Thrombus. By this way, the number of treated patients increasing, it will contribute to optimize and validate the established score given the probability of a patient to be adapted to an endovascular treatment.

At the scientific point of view, several projects are also in preparation and will be submitted in the next months (transatlantic projects 'Leduc Foundation' …, European project 'FET'…). Also PhD students and engineers engaged for Thrombus continue to work on the project in order to publish the last results of Thrombus, to explore new concept or idea. Today we are generating a new HMI allowing the virtual stent deployment linked the procedure of the medical practitioner.

ULB partner continues to work with University of Mons, CARDIATIS Company with the patented in vitro test bench in order to progress in the understanding of the biological behavior of the blood in contact with a stent and the wall of aneurysms. CARDIATIS Company works in this direction o a recent concept of multi layers flow diverter.

But today, multicentre studies show that the benefit of an endovascular treatment for a patient is not obvious in a medium term. Thrombus highlights the fact that more information must be collected, in order to adapt a real patient specific treatment which can consist in a medicinal treatment, an endovascular treatment or a surgical treatment. Thrombus provided new concepts and new understandings allowing to progress on the rightness of the diagnosis. The developed tools will have a direct impact on more predictive, effective and safer healthcare; it seems that the obtained results will change some medical practices.

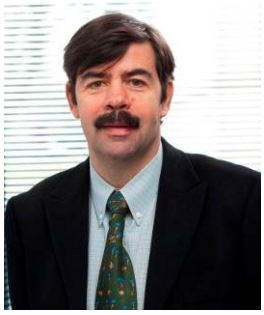
Address of the project public website and relevant contact details

Call FP7-ICT-2009-6 (STREP) - Objective ICT-2009.5.3: VPH GA N°269966

http://www.thrombus-vph.eu

TITLE: A quantitative model of thrombosis in intracranial aneurysms

PI: the Project Leader and Scientific Coordinator of **THROMBUS** is Guy Courbebaisse



Senior Project Leader of INSA de Lyon – CREATIS Laboratory.

e-mail: guy.courbebaisse@creatis.insa-lyon.fr – http://www.creatis.insa-lyon.fr/~courbebaisse

INSA LYON http://www.insa-lyon.fr

CREATIS http://www.creatis.insa-lyon.fr

CNRS http://www.dr7.cnrs.fr/

Websites referencing to Thrombus

Epractice	http://epractice.eu/en/cases/thrombus
Health domain of FP7	http://cordis.europa.eu/fp7/health/
BiomedTown	https://www.biomedtown.org/biomed_town/thrombus
VPH NOE	http://vph-portal.eu
	http://vph-portal.eu/fr/thrombus
VPH institute	http://www.vph-institute.org/
Cordis – FP7	http://cordis.europa.eu/projects/rcn/97461_fr.html
	http://cordis.europa.eu/result/brief/rcn/9694_fr.html

Participant number	Participant organisation name	Part. short name	Country	Logo
1- coordinator	**Centre national de la recherche scientifique – INSA Lyon** http://www.cnrs.fr/ http://www.creatis.insa-lyon.fr PI - Scientific Coordinator: Guy Courbebaisse EPM: Frédérique Foulon	CNRS	France	
SC	**Centre Hospitalier Régional Universitaire de Montpellier** (Subcontractor of CNRS) http://www.chu-montpellier.fr http://irras.net Scientists in charge: Alain Bonafé & Vincent Costalat	CHU-Montpellier	France	
2	**University of Geneva - Computer Science Department** http://www.unige.ch http://spc.unige.ch Scientist in charge: Bastien Chopard	UNIGE	Switzerland	
SC	**STROKELAB** (Subcontractor of UNIGE) http://www.strokelab.com Scientist in charge: Luca Augsburger	STROKELAB	Switzerland	
3	**Ecole Polytechnique Fédérale de Lausanne** http://www.epfl.ch/ http://lts5www.epfl.ch Scientist in charge: Jean-Philippe Thiran	EPFL	Switzerland	
SC	**Centre Hospitalier Universitaire Vaudois** (Subcontractor of EPFL) http://www.chuv.ch/rad Scientists in charge: Patrick Browaeys & Stefano Binaghi	CHUV	Switzerland	
4	**Université Libre de Bruxelles** http://www.ulb.ac.be/rech/inventaire/unites/ULB222.html http://www.chu-charleroi.be Scientist in charge: Karim Zouaoui Boudjeltia	ULB	Belgium	
5	**COVALIA SA** http://www.covalia.com Scientist in charge: Eric Garcia	COVA	France	
6	**German Research School for Simulation Sciences** http://www.grs-sim.de Scientist in charge: Joerg Bernsdorf	GRS	Germany	
7	**Universiteit van Amsterdam** http://uva.computationalscience.nl/ Scientist in charge: Alfons G. Hoekstra	UvA	The Netherlands	
8	**ev3 – COVIDIEN** http://www.ev3.net Scientist in charge: John Wainwright	ev3	France	
9	**Hospices Civils de Lyon** http://www.chu-lyon.fr/ http://www.chu-lyon.fr/web/Radiologie-nav_2177.html Scientist in charge: Francis Turjman	HCL	France	
10	**Universitat Siegen** http://www.uni-siegen.de http://www.mb.uni-siegen.de/sts/ Scientist in charge: Sabine Roller	USiegen	Germany	

2. Use and dissemination of foreground

Section A

Scientific publications

Template A1: list of scientific (peer reviewed) publications, starting with the most important ones										
NO.	Title	Main author	Title of the periodical or the series	Number, date, frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers (if available)	Open access Yes/No
1	Geodesic Active Fields - A Geometric Framework for Image Registration	D. Zosso	IEEE Transactions on Image Processing	Vol. 20, num. 5	IEEE Signal Processing Society	USA	2011	pp 1300-1312	http://dx.doi.org/10.1109/TIP.2010.2093904	No
2	Segmentation of Giant Cerebral Aneurysms Using a Multilevel Object Detection Scheme Based on LBM	Y. Wang,	IEEE Intern. Conf. on Signal Processing Communications and Computing, (ICSPCC)	/	IEEE Signal Processing Society	China	2011	pp 1 - 4	http://dx.doi.org/10.1109/ICSPCC.2011.6061695	no
3	Learning from Only Positive and Unlabeled Data to Detect Lesions in Vascular CT Images	M.A. Zuluaga	Medical Image Computing and Computer-Assisted Intervention MICCAI	Volume 6893	Springer Berlin Heidelberg	Canada	2011	pp 9-16	http://dx.doi.org/10.1007/978-3-642-23626-6_2	no
4	Harmonic Active Contours for multichannel image segmentation	V. Estellers	IEEE International Conference on Image Processing ICIP	11-14 Sept. 2011	IEEE	Brussels Belgium	2011	pp 3141 - 3144	http://dx.doi.org/10.1109/ICIP.2011.6116333	no
5	Two Complementary Approaches for Integrating a Lattice Boltzmann Flow Solver into Simulation Frameworks	J. Bernsdorf	Procedia Computer Science	Volume 4	ELSEVIER	Singapore	2011	pp 1014–1020	http://dx.doi.org/10.1016/j.procs.2011.04.107	yes
6	Efficient Algorithm for Level Set Method Preserving Distance Fct.	V. Estellers	IEEE Transactions on Image Processing	vol. 21, num. 12	IEEE Signal Processing Society	USA	2012	pp 4722 - 4734	http://dx.doi.org/10.1109/TIP.2012.2202674	no

7	CreaTools: a framework to develop medical image processing software. Application to simulate pipeline stent deployment in intracranial vessels with aneurysms	E.E. Dávila Serrano	Springer Berlin Heidelberg	Vol. 7594	International Conference, ICCVG 2012,	Poland	2012	pp 55-62	http://dx.doi.org/10.1007/978-3-642-33564-8_7	no
8	Optimization of flow diverters for cerebral aneurysms	H. Anzai	J. of Computational Science	vol. 3	Elsevier	The Netherlands	2012	pp 1-7	http://dx.doi.org/10.1016/j.jocs.2011.12.006	no
9	Interest of FD prostheses in the management of un-ruptured IA	X. Armoir	International Journal of Vascular Medicine	Vol. 2012	Hindawi Publishing Corporation	USA	2012	Article ID 654627, 5 pages	http://dx.doi.org/10.1155/2012/654627	yes
10	A rigorous and efficient GPU implementation of level-set sparse field algorithm	F. Galluzzo	IEEE International Conference on Image Processing (ICIP)	/	IEEE Signal Processing Society	USA	2012	pp 1705 - 1708	http://dx.doi.org/10.1109/ICIP.2012.6467207	no
11	Virtual deployment of pipeline flow diverters in cerebral vessels with aneurysms to understand thrombosis	L. Flórez-Valencia	MICCAI-STENT'12 The 1st International MICCAI-Workshop on Computer Assisted Stenting	/	/	France	2012	49-56 (electronic proc.)	http://hal.archives-ouvertes.fr/hal-00842724	yes
12	A Framework for the Numerical Simulation of Early Stage Aneurysm Development with the LBM	J. Bernsdorf	Sustained Simulation Performance 2012	/	Springer Berlin Heidelberg	Japan	2013	pp 115-122	http://dx.doi.org/10.1007/978-3-642-32454-3_10	no
13	A realistic Computed Tomography simulator for small motion analysis of cerebral aneurysms	S. Sepehri,	Engineering in Medicine and Biology Society 35th Annual International Conference of IEEE	3-7 july 2013	IEEE Engineering in Medicine and Biology Society	Osaka, Japan	2013	pp 5103 - 5106	http://dx.doi.org/10.1109/EMBC.2013.6610696	no
14	Direct detection of small motion from dynamic tomography images	S. Sepehri	21st European Signal Processing Conference	9-13 Sep. 2013	Eu. Signal Processing Association	Marrakech, Morocco	2013	-	http://infoscience.epfl.ch/record/190874/files/1569731091.pdf	yes

15	Where do the platelets go? A simulation study of fully resolved blood flow through aneurysmal vessel	L.Mountrakis	Interface Focus	vol. 3 no. 2	The Royal Society	UK	2013	20120089	http://dx.doi.org/10.1098/rsfs.2012.0089	yes
16	A Multiscale Approach for the Coupled Simulation of Blood Flow and Thrombus Formation in IA	S. Zimny	Procedia Computer Science	Vol 18	Elsevier	Barcelona	2013	pp 1006-1015	http://dx.doi.org/10.1016/j.procs.2013.05.266	yes
17	Fast Geodesic Active Fields for Image Registration based on Splitting and Augmented Lagrangian Approaches	D. Zosso	IEEE Transactions on Image Processing	Volume:23 Issue:2	IEEE Signal Processing Society	USA	2014	pp 673 - 683	http://dx.doi.org/10.1109/TIP.2013.2253473	no
18	Segmentation of the Thrombus of Giant Intracranial Aneurysms from CTA Scans with LBM	Y. Chen	Medical Image Analysis	Volume 18, Issue 1	Elsevier	France	2014	pp 1–8	http://dx.doi.org/10.1016/j.media.2013.08.003	yes
19	High-Resolution MRI Visualisation of Aneurysmal Thrombosis after Flow Diverter Stent Placement	B. Gory	Journal of Neuroimaging	In press	American Society of Neuroimaging	USA	2014		http://dx.doi.org/10.1111/jon.12110	no
20	Harmonic Active Contours	V. Estellers	IEEE Transactions on Image Processing,	Vol. 23, n° 1	IEEE Signal Processing Society	USA	2014	pp. 69-82	doi:10.1109/Tip.2013.2286326	no
21	Logarithmic Wavelets	L. Navarro	Chapter in book: Advances in Imaging and Electron Physics	In press	Academic Press	USA	2014			no
22	Design optimization of a flow diverter stent using several arterial configurations	T. Hayase	Journal of Biomechanical Engineering	In press			2014			

23	Combinational optimization of strut placement for intracranial stent using a realistic aneurysm	H. Anzai	Journal of Flow Control, Measurement & Visualization	In press			2014			
24	Validation of an efficient two-dimensional model for dense suspensions of red blood cells	L. Mountrakis	International Journal of Modern Physics C	Accepted	World Scientific	Singapore	2014		http://dx.doi.org/10.1142/S0129183114410058	no
25	S-LIP Wavelet Transform	L. Navarro	IEEE ICIP 2014	Submitted			2014			
26	Sensitivity Analysis of the direct detection algorithm for small motion detection directly from the raw non-process data	S. Sepehri	IEEE ICIP 2014	Submitted			2014			
27	Automatic multilevel segmentation of intracranial aneurysms in CT angiography images	Y. Wang	Transactions on Biomedical Engineering	Submitted			2014			
28	4D segmentation based on LBGK method	Y. Wang	Transactions on Image Processing	Submitted			2014			
29	CFD analysis of flow reduction induced by low porosity stent in IA: the non-patient-specific perspective	R. Ouared	Stroke	Submitted			2014			
30	Thrombus formation in IA	D.Ribeiro de Sousa	Nature Comm	In prepa			2014			
31	A sinogram-based small motion estimation algorithm from dynamic CT images, with application to aneurysm wall motion estimation	S. Sepehri	IEEE Trans. on Biomedical Eng	In prepa			2014			

32	Shear-induced RBC-enhanced Platelet Diffusivity	E. Lorenz	Physical Review Letters	In prepa			2014			
33	Full stent modelling and blood flow	L. Florez	CAF	In prepa			2014			
34	Determination and signal analysis of coronary wall shear stress: method and results	ULB	Circulation	In prepa			2014			
35	Macro-micro coupling	UNIGE – UvA	J. of Biomechanics	In prepa			2014			
36	Modeling a flow diverter as Porous media	UNIGE	J. of Biomechanics	In prepa			2014			
37	Modelling thrombosis in cerebral aneurysms	B.. Chopard	J. of Biomechanics	In prepa			2014			
38	Standard 2D Phase-Contrast MRI For Quantitative Assessment Of Hemodynamic Disturbance induced by Intracranial Aneurysms in Parent Vessel …	CNRS-CHU Montpellier	Radiology	In prepa			2014			
39	Effect of the gravity	ULB	Nature Medicine	In prepa			2014			
40	Modeling of Platelets aggregates formation and their evolution in 3D	K Zouaoui	Physical Review Letter	In prepa			2014			
41	Effect of aneurysm size and flow diverter implantation in the global and local cerebral aneurysm	CNRS	Annals of Biomedical Engineering	In prepa			2014			

42	Automatic Multilevel Segmentation of Intracranial Aneurysms in CT Angiography Images	CNRS	IEEE TBME	In prepa			2014			
43	Can gravity's effect on Red Blood Cells help in the treatment of intracranial aneurysm?	ULB CNRS UNIGE	Nature Medicine	In prepa			2014			
44	High Performance Computing In Hemodynamic Simulations In Patient Specific IA	USiegen	Int. J. for Numerical Methods in Biomedical Engineering	In prepa			2014			
45	Towards modelling the aneurysm wall motion – numerical efficiency	USiegen	International Journal for Numerical Methods in Biomedical Engineering	In prepa			2014			

Dissemination activities

List of dissemination activities								
NO.	Type of activities	Main leader	Title	Date/Period	Place	Type of audience	Size of audience	Countries addressed
1	web site	EPFL - Partner 3	Thrombus Project has been announce with a start news on EPFL webpage and on-line news channel: http://actu.epfl.ch/news/new-european-project/	01/08/2010	Switzerland	all	Worldwide	World
2	conference	HCL - Partner 9	Oral talk "Pipeline embolization device clinical initiatives » during ABC WIN Seminar	16-21 January 2011	Val d'Isère, France	Medical Doctors, Neuroradiologits	Congress	France
3	dissemination mailing list	CNRS- Partner 1 all Partners	open list, updated regularly	February 2011	worldwide	all	worldwide	World
4	Networking	CNRS - Partner 1	RT3S project (http://www.rt3s.eu) dedicated to real time simulation for safer vascular stenting	February 2011	Europe	Scientists	meeting	France, Italy
5	web site	Partner 2	The project is announced on the website of Stroke Laboratories, subcontractor of Partner 2, and the collaboration with THROMBUS project is mentioned	February 2011	Switzerland	all	worldwide	World
6	Networking	CNRS - Partner 1	Active involvement with the European VPH community, THROMBUS project is member of the VPH-institue: http://vph-institute.org	Since February 2011	Europe	-	Europe	Europe
7	Networking	CNRS - Partner 1	Meetings and/or call conferences have been organised with few of the actors of the FP6 @neurist project, such as Michel Rochettte from ANSYS France, Dr D. A. Rüfenacht, Hirslanden Klinik of Zürich.	Since February 2011	Europe	Scientists	meeting	France, Spain, GB, Switzerland
8	articles published in specialized press	ULB- Partner 4	An article "Le Projet Thrombus: Modéliser les anévrismes intracrâniens " has been published in "Le Journal du Médecin"	08/02/2011	Belgium	Medical doctors	Europe	Belgium

9	press release	CNRS – Partner 1	a press release has been sent in France on to specialized and local press: “Lancement d’un Projet Européen Scientifique pour les anévrismes intracrâniens : « Thrombus »”	March 2011	France	all	France	France
10	web site	CNRS – Partner 1	An article published on the website of “INSA”: “Laboratoire CREATIS” about THROMBUS project: http://www.insa-lyon.fr/fr/laboratoire-creatis	March 2011	France	all	Europe	France
11	web site	CNRS – Partner 1	An article published on the website of “INSA”: “Laboratoire CREATIS : lancement d’un Projet Européen Scientifique pour les anévrismes intracrâniens : « Thrombus » http://www.insa-lyon.fr/fr/media-/-presse/cp22032011/laboratoire-creatis-lancement-d-un-projet-europeen-scientifique-pour-les-a	22/03/2011	France	all	worldwide	France
12	web site	CNRS – Partner 1	Article published website of “La Gazette du Labo. http://www.gazettelabo.fr/breves/breves.php?id=1498	22/03/2011	France	Scientists	France	France
13	web site	CNRS – Partner 1	An article published on the website of “medical-news http://www.medicalnews-blog.fr/2011/03/traitement-des-anevrismes-intracraniens/	24/03/2011	France	Medical community	France	France
14	e-journal	CNRS – Partner 1	An article “Thrombus : nouvelle étude sur le traitement des anévrismes intracrâniens” published on the web site of “Maxisciences”: http://www.maxisciences.com/an%E9vrisme-intracr%E2nien/thrombus-nouvelle-etude-sur-le-traitement-des-anevrismes-intracraniens_mrm63722.html	24/03/2011	France	Scientists	Europe	France
15	web site	CNRS – Partner 1	An article published on the website of “CNRS”: http://www.dr7.cnrs.fr/spip.php?rubrique1318	28/03/2011	France	Scientists	Europe	France
16	Logo	CNRS-Partner 1	thrombus	April 2011	worldwide	All public	-	World

17	e-newsletter	CNRS – Partner 1	An article published in the weekly newsletter "La letter du CNRS Rhône-Alpes", sent to subscribers and published on CNRS' website.	01/04/2011	France	Scientists	Europe	France
18	Network	All Partners	THROMBUS project is involved in the European VPH community via the VPH Network of Excellence	Since May 2011	worldwide	Scientists	Europe	Europe
19	Articles published in specialized press	CNRS – Partner 1	An article published in the paper version of the magazine "HospiTV"	May 2011	France	Medical community	France	France
20	Articles published in specialized press	CNRS – Partner 1	An article "Mieux guérir l'anévrisme intracrânien" published in the paper version of the magazine "Manip info" ," issue 39 http://www.manip-info.com/	May 2011	France	Medical community	France	France
21	Articles published in the specialized press	CNRS – Partner 1	An article "Lancement d'un Projet Européen Scientifique pour les anévrismes intracrâniens" has been published in France in the e-magazine "L'Hospitalier", issue of May 2011, pp84-85, which has been sent to 12000 hospital contacts: http://www.zyyne.com/zf3;5968#/84/view	May 2011	France	Medical community	France	France
22	web site	CNRS-Partner 1	http://www.thrombus-vph.eu	Since 17/05/2011	worldwide	All public	Worldwide	World
23	e-newsletter	CNRS – Partner 1	The launch of THROMBUS website has been announced in the weekly newsletter "La letter du CNRS Rhône-Alpes", sent to subscribers & published on CNRS' website.	20/05/2011	France	Scientists	Europe	France
24	conference	Covalia - Partner 5	Oral talk "1st HIT Telemedicine Award : teleneurology during HIT Paris 2011 (Health Information Technology),"	21-24/05/2011	Paris, France	Medical Doctors	Congress	Europe
25	conference	HCL - Partner 9	Oral talk "Endovascular treatment of high flow fistulas: modelization of thrombus" during LINNC Live Interventional Neuroradiology & Neurosurgery Course	23-26/05/2011	Paris, France	Medical Doctors, Neuroradiologits	Congress	Europe
26	conference	GRS - Partner 6	Oral talk "A Lattice Boltzmann Multi-Scale Simulation Environment for Application in Medical Physics" during Seminar in Kyoto University Graduate School of Engineering Department of Aeronautics and Astronautics	June 2011	Japan	Students	Congress	Japan

27	conference	GRS - Partner 6	Oral talk “Outline of a Coupled Multi-Scale Approach for the Numerical Simulation of Early Stage Aneurysm Development“, Thrombus project presented at an international level : Tohoku University, Sendai (M.Ohta), EU-Japan Centre for Industrial Cooperation (T.Ichioka), Research Center for Advanced Science and Technology, The University of Tokyo (K. Nishinari)	June 2011	Japan	Scientists	Congress	Asia,USA, Europe
28	articles published in the specialized press	CNRS – Partner 1	An advertising article have been published in the French journal 'Innovation & Industrie' in the paper version, issue number 44 and on the website http://www.innovationonline.eu/cnrs--laboratoire-creatis-%28umr-5220%29~242c.html	June 2011	France	Indutrials	France	France
29	Conference	GRS - Partner 6	Oral talk "Two Complementary Approaches for Integrating a Lattice Boltzmann Flow Solver into Simulation Frameworks" during International Conference on Computational Science (ICCS 2011)	1-3/06/2011	Singapore	Scientists	Congress	Asia,USA, Europe
30	Conference	UNIGE – Partner 2	Oral talk "Multiscale modeling" during [BC]2, Basel (Computational Biology Conference)	23-24/06/2011	Basel, Switzerland	Scientists	Congress	Europe
31	E-newsletter	CNRS-Partner 1	An article about THROMBUS project has been published in the for the 6th VPH NoE newsletter http://www.vph-noe.eu/home	July 2011	worldwide	Scientists	Europe	Europe
32	Conference	GRS - Partner 6	Oral talk “Outline of a Coupled Multi-Scale Approach for the Numerical Simulation of Early Stage Aneurysm Development“ during Eighth International Conference for Mesoscopic Methods in Engineering and Science,	4-8/07/2011	Lyon, France	Scientists	Congress	Europe
33	Promotional material	CNRS-Partner 1	ballpoint pens and USB keys with the logo and the address of the website printed on the object	September 2011	worldwide	all	-	World
34	web site	CNRS-Partner 1	THROMBUS project participates to the Biomed Town Portal,https://www.biomedtown.org/biomed_town/thrombus	September 2011	worldwide	all	Europe	Europe

35	Conference	HCL - Partner 9	Oral talk “Computational Fluid Dynamics (CFD) models for intracranial aneurysms: Are they helpful for the clinicians?” during European Society of Minimally Invasive Neurological Therapy (ESMINT)	08/09/2011	Nice, France	Medical doctors	Congress	Europe
36	Conference	UNIGE – Partner 2	Oral talk "A possible approach to do stent optimization" during ICS11, (Intracranial Stent meeting)	08-11/09/2011	Shanghai, China	Medical doctors and scientists	Congress	Asia, Europe
37	Conference	UNIGE – Partner 2	Oral talk "Sciences computationnelles et projet CADMOS" during CADMOS Day	14/09/2011	Geneva, Switzerland	General public and Researchers	Meeting	Switzerland
38	Conference	EPFL - Partner 3	Oral talk "Harmonic Active Contours for multichannel image segmentation" during IEEE Int. Conf. on Image Processing	11-14/09/2011	Brussels, Belgium	Image processing community	Congress	Belgium
39	Conference	HCL - Partner 9	Oral talk ‘‘Current Techniques in the Neurology’’ during Academician E.N. Meshalkin Novosibirsk State Research Institute of Circulation Pathology (NRICP) ,Ministry for Health Care & Social Development of Russia	05/10/2011	Novosibirsk, Russia	Medical Doctors, Neuroradiologits	Congress	Europe
40	Conference	HCL - Partner 9	Oral talk ‘‘Traitement neuroradiologique des anévrismes et autres pathologies cérébrales (rétrécissement)’’ during Journées Nationales d’Etudes sur les Dispositifs Médicaux, Euro-Pharmat	11/10/2011	Lyon, France	Medical Doctors, Neuroradiologits	Congress	France
41	Interview Communication to general public	CNRS - Partner 1	THROMBUS coordinator has been contacted on by secondary school students of the La Martinière School in Lyon (France) to present THROMBUS project and to explain how to heal an aneurysm.	04/11/2011	Lyon, France	Students	School	France
42	Conference	Covalia - Partner 5	Oral talk "Telemedicine : innovation and research" during ANTEL (Nation Telemedicine Association)	17-18/11/2011	Paris, France	Medical doctors	Congress	France
43	Meeting	UvA - Partner 7	Collaboration between UvA and Frans van de Vosse and Jens Harting (TU Eindhoven)	December 2011	Amsterdam, The Netherlands	Scientists	meeting	The Netherlands
44	web site	Covalia – Partner 5	On the website of COVALIA Partner 5THROMBUS project is announced & a link to THROMBUS website is available	2012	France	all	Europe	Europe

45	Workshop	CNRS - Partner 1	Collaboration between THROMBUS project and the Department of Materials Science and Engineering, Harvard-MIT Biomedical Engineering Center, Edelman Laboratory / Garcia-Cardena Laboratory (Harvard Medical School)	13/01/2012	Lyon, France	Scientists	meeting	USA, France
46	Fact sheet	CNRS – Partner 1	A factsheet presenting THROMBUS project has been prepared in order to communicate and disseminate to the Community of the e-Health projects of the European Commission. The THROMBUS ID-card has been posted on the Europa website (ICT for Health pages) and will be distributed at events, etc.	February 2012	Europe	-	Europe	Europe
47	Workshop	CNRS - Partner 1	Collaboration between IRRAS consortium and THROMBUS project, on biomechanical wall properties of human intracranial aneurysm	01/02/2012	Montpellier, France	Scientists – Medical Doctors	meeting	France
48	e-newsletter	CNRS-Partner 1s	E-newsletter distributed to the THROMBUS dissemination mailing list via the website	02/02/2012	worldwide	Mailing list	-	World
49	Conference	UNIGE – Partner 2	Oral talk "Modeling and simulations using the Lattice Boltzmann Method" during 40th Speedup workshop	06/02/2012	Basel, Switzerland	academics, computational science	meeting	Europe
50	e-newsletter	EV3 – Partner 8	An article about THROMBUS project has been published on Covidien/Ev3 (Partner 8) internal website. This article has been included in Pulse recap newsletter, which has been distributed to all Vascular Therapies employees	13/02/2012	worldwide	all		USA - Europe
51	Conference	UNIGE – Partner 2	Oral talk "The lattice Boltzmann method and its applications to science and engineering" during the Hassan II Academy of Sciences & technology of Morroco	15-17/02/2012	Morroco	academics, computational science	Congress	Africa, Europe
52	Conference	HCL - Partner 9	Talk "PUFS, What did we learned ?" during KOL Codman	8-9/03/2012	Hamburg, Germany	Medical doctors	meeting	Europe
53	Exhibition	CNRS-Partner 1	THROMBUS management team has participated to the Brain Week 2012, a national event in France, in order to present THROMBUS project to the general public.	17/03/2012	Lyon, France	all	Public	France

54	Conference	UvA – Partner 7	Oral talk "Transport behaviour of platelets in intracranial aneurysms" during Computational Science Colloquium	30/03/2012	Amsterdam, The Netherlands	Staff, MSc and PhD Students Computational Science	congress	The Netherlands
55	Conference	HCL - Partner 9	Oral talk "STIC evidence" during SFNR 2012	2-4/04/2012	Paris, France	Medical Doctors, Neuroradiologits	congress	Europe
56	Conference	UvA - Partner 7	Oral talk “Platelet Transport Behaviour in intracranial aneurysms” during Young Scientists Conference	2-6/04/2012	Amsterdam, The Netherland	Computational Science, HPC	meeting	The Netherlands
57	Conference	UvA - Partner 7	Oral talk “Skipping redundant scales - Heterogeneous Multiscale simulations of suspension flow” during Young Scientists Conference, Amsterdam	2-6/04/2012	Amsterdam, The Netherlands	Computational Science, HPC	meeting	The Netherlands
58	Conference	HCL - Partner 9	Oral talk "Balloon and stent assisted coiling of intracranial aneurysms" during Ukrainian Association of endovascular neuroradiosurgey	26-27/04/2012	Kiev, Ukrain	Medical Doctors, Neuroradiologits Neurosurgeons	meeting	Europe
59	Poster	CNRS – Partner 1	Poster "CreaTools: applications and development framework for medical image-processing software" during ISBI Workshop on Open Source Medical Image Analysis Software	May 2012	Barcelona, Spain	Medical image analysis and computer science communities	congress	Europe
60	Workshop	CNRS - Partner 1	Guy Courbebaisse, as coordinator of THROMBUS project, has been invited to the “1st Study Group Meeting of the Giant Aneurysm Registry Group” in the Framework of a European Project	10-11/05/2012	Berlin, Germany	Medical Doctors	meeting	Europe
61	Conference	GRS - Partner 6	Oral talk "The Concept of Multi-Scale Simulation in Medical Physics" during ParCFD 2012 Conference	21-25/05/2012	Atlanta, USA	Scientists	congress	World
62	Workshop	CNRS - Partner 1	Collaboration THROMBUS – IRRAS, discussion about medical imaging	06/06/2012	Montpellier France	Scientists – Medical doctors	meeting	France
63	Conference	CNRS - Partner 1	Oral talk "Towards a more realistic model of the thrombosis is the goal of the Thrombus project - A multidisciplinary approach" during Innovative Care Workshop - Cluster I-Care	13/06/2012	Saint-Etienne, France	industrials, researchers and clinicians	congress	France

64	Conference	CNRS - Partner 1	Oral talk "A mathematical model of blood flow in intracranial aneurysms treated with endovascular devices" during American Society for artificial internal organs (ASAIO) conference	12-14/06/2012	San Francisco CA, U.S.A.	Scientists	congress	World
65	Conference	HCL - Partner 9	Oral talk "Different techniques of cerebral aneurysms stenting" during International neurosurgical Forum in Siberia	18-21/06/2012	Novosibirsk, Russia	Medical Doctors Neuroradiologits Neurosurgeons	Congress	Europe
66	Conference	UNIGE – Partner 2	Discussion between UNIGE and Prof Hans Herrmann, ETHZ, Switzerland	July 2012	Switzerland	Scientists	meeting	Switzerland
67	Conference	CNRS - Partner 1	Oral talk "CreaTools: applications and development framework for medical image-processing software" during Libre Software Meeting (RMLL)	7-12/07/2012	Geneva, Switzerland	Software developers & audience of potential users	meeting	Europe
68	Conference	GRS - Partner 6	Oral talk "Towards Multi-Scale Simulation of Early Stage Aneurysm Development" during ESMC 2012 Conference	9-13/07/2012	Graz, Austria	Scientists	congress	Europe
69	Conference	UNIGE – Partner 2	Oral talk " The design characteristics extracted from an optimal flow diverter in an ideal side-wall aneurysm using lattice Boltzmann method " during ESMC 2012 Conference	9-13/07/2012	Graz, Austria	Scientists	congress	Europe
70	Conference	UNIGE – Partner 2	Oral talk "Modeling Thrombosis in cerebral aneurysms" during DSFD 2012	23-27/07/2012	Bangalore, India	Physicists, applied math, engineers	congress	Asia, Europe
71	Workshop	CNRS - Partner 1	Discussion with the LCCRH (Laboratoire des Cellules Circulantes Rares Humaines - Institut de Recherche en Biotherapie) - On the possible role of the circulating endothelial cells in thrombosis of aneurysms?	18/07/2012	Montpellier, France	Scientists – Medical Doctors	meeting	France
72	Conference	CNRS - Partner 1	Oral talk "CreaTools: a framework to develop medical image processing software. Application to simulate pipeline stent deployment in intracranial vessels with aneurysms" during Int. Conf. Comput. Vision & Graphics – ICCVG 2012	September 2012	Warsaw, Poland	Image processing and computer graphics community	congress	Europe

73	Conference	CNRS - Partner 1	Oral talk "Blood flow simulation within Stented Intracranial Aneurysm" during ICFD2012, Ninth International Conference on Flow Dynamics	September 2012	Sendai, Japan	Scientists	congress	World
74	Conference	CNRS – Partner 1 COVALIA – Partner 5	Oral talk “A Collaborative Online System Dedicated to the Study of the Intracranial Aneurysms” during VPH 2012	September 2012	London, UK	Leading experts, phD students	congress	Europe
75	Conference	GRS - Partner 6	Oral talk “Towards Large Scale Simulation of Thrombus Formation in Stented Cerebral Aneurysm” during VPH 2012	September 2012	London, UK	Scientists	congress	Europe
76	Conference	UvA - Partner 7	Oral talk "Modelling the transport behaviour of platelets in intracranial aneurysms" during VPH 2012	September 2012	London, UK	Computational Biomedicine	congress	Europe
77	Conference	CNRS - Partner 1	Oral talk “A rigorous and efficient GPU implementation of level-set sparse field algorithm ”During ICIP’12 - IEEE International Conference On Image Processing	30/9-03/10/2012	Orlando, USA	Engineers and scientists in image processing	congress	World
78	Meeting	UvA - Partner 7	Collaboration Between UvA and Ed van Bavel (Amsterdam Medical Center)	October 2012	Amsterdam The Netherlands	Scientists	meeting	The Netherlands
79	Conference	UNIGE – Partner 2	Oral talk “Stent designs for efficient reduction of intra-aneurysmal flow with various aneurysms” during ICS 2012	October 2012	Madison, USA	Medical Doctors - Scientists	Scientists	World
80	Poster	CNRS - Partner 1	Poster and its oral teaser “Virtual deployment of pipeline flow diverters in cerebral vessels with aneurysms to understand thrombosis ” during MICCAI-Workshop on Computer Assisted Stenting	1-5/10/2012	Nice, France	Scientists in ICT biomechanics, medicine, sharing the interest for virtual stenting	congress	World

81	e-newsletter	CNRS - Partner 1	E-newsletter distributed to the THROMBUS dissemination mailing list via the website	18/10/2012	worldwide	Mailing list	-	World
82	Conference	CNRS - Partner 1	oral talk "CreaTools – COVOTEM - PALABOS" during 3rd VPH NOE Workshop on Toolkit Hands-on Training Medical Imaging Toolkit	22-24/10/2012	Lyon, France	Researchers and Engineers developing imaging algorithms	meeting	Europe
83	Conference	UvA - Partner 7	oral talk "A Window to the Microstructure: Simulations of Shear-Thickening and Shear-Thinning Suspensions" during Soft Matter Morning	14/11/2012	Amsterdam The Netherlands	Soft matter physicists from Dutch universities	meeting	The Netherlands
84	Workshop	UNIGE – Partner 2	Discussion between UNIGE and Professor Niels Kuster, ETH Zurich, ITET Department	December 2012	Switzerland	Scientists	meeting	Switzerland
85	Workshop	CNRS - Partner 1	workshop 'Behaviour of endothelial cells under strain' in the MIT - Edelman Laboratory (Harvard Medical School)	5-6/12/2012	Boston, USA	Scientists	meeting	USA - France
86	Conference	GRS - Partner 6	oral talk " Multiscale simulations on clot formation in cerebral aneurysms modelling an intraluminal thrombus " during 16th Workshop on Sustained Simulation Performance	10-11/12/2012	Stuttgart, Germany	Scientists / HPC industry (hard- and software)	congress	Germany
87	Poster	CNRS - Partner 1	Poster "Estimation de Flux Sanguin par analyse de Contraste de Phase en ARM", Journées scientifiques Nouvelles méthodologies en imagerie du vivant	11-13/12/2012	Lyon, France	Scientists	meeting	France
88	Conference	UvA - Partner 7	oral talk "Shear and RBC-Induced Diffusion of Platelets"during Computational Science Colloquium	25/01/2013	Amsterdam, The Netherlands	Staff, MSc and PhD Students Computational Science	congress	The Netherlands
89	YouTube THROMBUS account	CNRS-Partner 1	http://www.youtube.com/user/thrombusVPH/ videos about scientific results obtained within THROMBUS project are presented	February 2013	worldwide	all	-	World

90	Workshop	CNRS - Partner 1	Oral talk "Study of the coil effect within an intracranial aneurysm" during The Annual ELyT Lab Workshop	17-20/02/2013	Sendai, Japan	Scientists	congress	Japan, France
91	Conference	USiegen – Partner 10	Oral talk "Tendencies and strategies for compute and memory intense applications", 17th Workshop on Sustained Simulation Performance	12-13/03/2013	Tokyo, Japan	Scientists / HPC industry (hard-soft/ Japanese ministry MEXT	congress	Japan
92	Conference	GRS – Partner 6	Oral talk "Supercomputing in Medical Physics Research", 17th Workshop on Sustained Simulation Performance	12-13/03/2013	Tokyo, Japan	Scientists / HPC industry (hard- and software) / Japanese ministry MEXT	congress	Japan
93	Exhibition	CNRS-Partner 1	THROMBUS project has been again presented to the general public during the Brain Week 2013, a national event in France	16/03/2013	Lyon, France	all	public	France
94	Video	CNRS – Partner 1	Video of THROMBUS team on You Tube in order to present the project to a wide public http://www.youtube.com/user/thrombusVPH/videos	April 2013	World	all	Worldwide	all
95	Conference	ULB-Partner 4	Oral talk "Histoire naturelle de la formation du Thrombus" during SFNR 2013 (French Society of NeuroRadiology),	4–6/04/2013	Paris, France	Medical doctors	congress	Europe
96	Conference	UvA - Partner 7	Oral talk "Multiscale modeling of suspension flows using the Hierarchical Multiscale Method" during Multiscale Modelling and Computing Workshop	8-12/04/2013	The Netherlands	Scientists	meeting	The Nederlands
97	Workshop	CNRS - Partner 1	Oral talk "The medical imaging and biological processes for multi-scale modeling in health issues" during the joint workshop INSA-Lyon – RIKEN: Towards international and interdisciplinary collaboration	16/05/2013	Lyon, France	Scientists	meeting	Japan, France
98	Workshop	CNRS - Partner 1	Oral talk "Projet THROMBUS - Dispositif de Diversion de Flux - Réponse à une problématique clinique" durikn the 3rd Regional Meetings Industry-Research-Clinic (3e Rencontres Régionales Recherche - Industrie – Clinique Matériaux et process Bio - ingénierie des Tissus et Implants)	23-24/05/2013	Marseille, France	Scientists	congress	France

99	Conference	UvA - Partner 7	Oral talk "Fully resolved blood simulations in the service of thrombus formation research" during Computational Science Colloquium	31/05/2013	Amsterdam The Netherlands	Scientists	congress	The Nederland
100	Video	ULB – Partner 4	Demonstration of the test bench developed by the University of Mons and the University of Brussels supported by THROMBUS project. http://www.youtube.com/watch?v=KsyR_LHfVsc	June 2013	World	Scientists	meeting	Belgium
101	Conference	USiegen – Partner 10	Oral talk "A multiscale approach for the coupled simulation of blood flow and thrombus formation in intracranial aneurysms" during International Conference on Computational Science - ICCS 2013	5-7/06/2013	Barcelona, Spain	Scientists	congress	Europe
102	Conference	EPFL - Partner 3	Oral talk "A realistic Computed Tomography Simulator for Small Motion Analysis of Cerebral Aneurysms"during 35th Annual International Conference of the IEEE EMBS	3-7/07/2013	Osaka, Japan	Biomedical engineers	congress	World
102	Conference	UvA - Partner 7	Oral talk "Strong Anisotropy in Shear-induced RBC-enhanced Platelet Diffusion" during DSFD 2013 Discrete Simulation of Fluid Dynamics),	15-19/07/2013	Yerevan, Armenia	Scientists	congress	Europe
104	Conference	UvA - Partner 7	Oral talk "Shape memory and membrane fluctuations of an RBC in shear flow" during DSFD 2013 (Discrete Simulation of Fluid Dynamics),	15-19/07/2013	Yerevan, Armenia	Scientists	congress	Europe
105	Conference	USiegen - Partner 10	Oral talk "Numerical simulations of thrombus formation in patient specific aneurysms using different stent designs" during ICMMES 2013 conference (The 10th International Conference for Mesoscopic Methods in Engineering and Science)	22-26/07/2013	Oxford, UK	Scientists	congress	Europe
106	e-newsletter	CNRS - Partner 1	E-newsletter distributed to the THROMBUS dissemination mailing list via the website	12/09/2013	worldwide	Mailing list	-	World
107	Poster	EPFL - Partner 3	Poster "Direct Detection of Small Motion From Dynamic Computed Tomography Images" during EUSIPCO 2013, the 21st European Signal Processing Conference in Marrakech,	9-13/09/2013	Morocco	Scientists	congress	Africa, Europe
108	Web site	CNRS – Partner 1	THROMBUS project is presented on ePractice.eu and is one of the 'Editors choice 2013' in the eHealth domain: http://epractice.eu/en/cases/thrombus	October 2013	World	all	Worldwide	Europe

109	Conference	CNRS - Partner 1	Oral talk “Towards a more realistic model of the thrombosis A multidisciplinary approach” during “the conference “eHealth and the Brain - ICT for Neuropsychiatric Health”	5/11/2013	Brussels, Belgium	Scientists	meeting	Europe
110	Workshop	UvA - Partner 7	Oral talk“Transport of platelets in intracranial aneurysms” during mini-symposium on Modeling Biological Flows	11/12/2013	Eindhoven, The Netherlands	Scientists	meeting	The Netherlands
111	Workshop	CNRS - Partner 1	Guy Courbebaisse, Coordinator of THROMBUS project has been invited to present THROMBUS project and the results from the project. during the Bioengineering workshop in MATEIS laboratory	12/11/2013	Lyon, France	Scientists	meeting	France
112	Thesis	ULB-Partner 4	"Study and development of an in vitro technology for testing vascular tissues submitted to physiological pulsatile flow conditions"	14/11/2013	Mons, Belgium	Scientists	meeting	Belgium
113	Conference	UNIGE – Partner 2	Oral talk "Modeling Thrombosis In Cerebral Aneurysms" during ICFD 2013 (10th International Conference on Flow Dynamics)	25–27/11/2013	Sendai, Japan	Scientists	Congress	World
114	Conference	CNRS - Partner 1	Oral talk "Flow Analysis For Coiled Intracranial Aneurysms" during ICFD 2013 (10th International Conference on Flow Dynamics)	25–27/11/2013	Sendai, Japan	Scientists	Congress	World
115	Conference	UNIGE – Partner 2	Oral talk "Development of a program for Blood flow and cell behaviors based on LBM method " during ICFD 2013 (10th International Conference on Flow Dynamics)	25–27/11/2013	Sendai, Japan	Scientists	Congress	World
116	articles published in specialized press	CNRS - Partner 1	Guy Courbebaisse, as coordinator of THROMBUS project, has been interviewed by the Colombian journal Revista Sistemas ACIS	December 2013	Colombia	Scientists	Worldwide	Colombia, Europe
117	Conference	UvA - Partner 7	Oral talk "Transport of platelets in Intercranial Aneurysms” during Symposium Modelling Biological Flows, Technical University Eidnhoven	11/12/2013	Eindhoven, The Netherlands	Scientists	meeting	The Netherlands

118	Workshop	CNRS – Partner 1 & ULB Partner 4	Mathematics and Living Sciences worshop	8-9/01/2014	Venice, Italia	Medical Doctors - Scientists	meeting	Belgium, France
119	Workshop	UNIGE – Partner 2	Oral talk “Les automates cellulaires: une méthodologie de modélisation pour les systèmes complexes en science de la vie” during Mathematics and Living Sciences worshop	8/01/2014	Venice, Italia	Medical Doctors - Scientists	meeting	Belgium, France
120	Workshop	CNRS - Partner 1	Oral talk “ Analyse conjointe Temps-Fréquence de signaux biologiques ” during Mathematics and Living Sciences worshop	8/01/2014	Venice, Italia	Medical Doctors - Scientists	meeting	Belgium, France
121	Workshop	CNRS - Partner 1	Oral talk “Study of blood flow in cerebral aneurysm with coil” during 2014 ELyT lab Workshop	19-21/02/2014	Frejus, France	Scientists	congress	Japan, France
122	Articles published in specialized press	CNRS - Partner 1	“Flow Dynamics, Heat Transfers and Microfluidics (F)” in the Engineering and Science Lyon – Tohoku Laboratory ELyT Lab Progress Report	February 2014	France and Japan	Scientists	congress	Japan, France
123	Workshop	UvA - Partner 7	Invited presentation "Simulations of Dense Suspensions, Modelling and Computing Challenges", during JM Burgerscentrum Meeting on Numerical Methods for Multiphase Flow and their Applications	14/03/2014	Delft, The Netherlands	Scientists	Workshop	The Netherlands
124	Conference	All Partners	THROMBUS Finale Conference – special session during The 41st congress of the Société Française de NeuroRadiologie (SFNR - French Society of Neuroradiology)	03/04/2014	Paris, France	Medical Doctors, stent manufacturers	congress	Europe
125	Conference	CNRS - Partner 1	Oral talk “Projet Européen Thrombus” during SFNR 2014	03/04/2014	Paris, France	Neuroradiologists, scientist, stent manufacturers	congress	Europe
126	Conference	ULB-Partner 4	Oral talk “L'anévrisme cérébral et son thrombus” during SFNR 2014	03/04/2014	Paris, France	Neuroradiologists, scientist, stent manufacturers	congress	Europe

127	Conference	UNIGE – Partner 2	Oral talk "Simulation numérique de la formation du thrombus les anévrismes cérébraux" during SFNR 2014	03/04/2014	Paris, France	Neuroradiologists, scientist, stent manufacturers	congress	Europe
128	Conference	CHU Montpellier Partner 1	Oral talk "Imagerie médicale des anévrismes cérébraux" during SFNR 2014	03/04/2014	Paris, France	Neuroradiologists, scientist, stent manufacturers	congress	Europe
129	Conference	HCL - Partner 9	Oral talk "Thrombectomie : vite fait, bien fait ?" during SFNR 2014	03/04/2014	Paris, France	Neuroradiologists, scientist, stent manufacturers	congress	Europe
130	Workshop	All Partners	Business workshop open to designers of endovascular prostheses and neuroradiologists to present THROMBUS results and set up further collaborations	03/04/2014	Paris, France	Neuroradiologists, scientist, stent manufacturers	meeting	Europe
131	Workshop	CNRS - Partner 1	Oral talk "Vers un modèle biologique de le thrombose dans les anévrismes intracraniens" during the periodic workshop in the laboratory IMBL-CARMEN	17/04/2014	Lyon, France	Scientists	meeting	France
132	Conference	CNRS - Partner 1	Oral talk "Modelling of flow diverter & CFD" during Session 2 : CFD – FlowDiverter at ICS 2014	02/06/2014	Zurich, Switzerland	Medical Doctors - Scientists	congress	World
133	Conference	All Partners	THROMBUS Finale Conference – Session 10 : FP7 "THROMBUS" -Thrombus formation-CFD during ICS 2014	04/06/2014	Zurich, Switzerland	Medical Doctors - Scientists	congress	World
134	Conference	UNIGE Partner 2	Oral talk "Thrombus model" during ICS 2014	04/06/2014	Zurich, Switzerland	Medical Doctors - Scientists	congress	World
135	Conference	UvA - Partner 7	Oral talk "Transport of Platelets in Intracranial Aneurysms" during ICS 2014	04/06/2014	Zurich, Switzerland	Medical Doctors - Scientists	congress	World
136	Conference	CHU Montpellier Partner1	Oral talk "Medical Imaging, CFD and Thrombus" during ICS 2014	04/06/2014	Zurich, Switzerland	Medical Doctors - Scientists	congress	World
137	Collaboration/ research stay, joint PhD	GRS - Partner 6 & USiegen Partner 10	Intense exchanges between GRS and Marc Garbey, University Houston Texas on aneurysm-related simulations (joint PhD).	2010 - 2014	Houston, USA	Scientists	Meeting, research stay	USA Germany

138	Collaboration, visits	GRS - Partner 6	Exchanges between GRS and Makoto Ohta, Tohoku University, Japan, on blood flow simulations	2010 - 2012	Germany - Japan	Scientists	meeting	Japan - Germany
139	Meeting	UNIGE – Partner 2 & UvA - Partner 7	MAPPER project (www.mapper-project.eu) dedicated to a multiscale modelling methodology	2010-2013	Amsterdam, The Netherlands	Scientists	meeting	Europe
140	Lecture	GRS - Partner 6	SiSc Lab – application training for English-spoken master students Simulation Sciences	2010-2012	RWTH Aachen, Germany	international master Students	New lecture	Germany / world
141	Lecture	GRS – Partner 6	Block in lecture “From molecular to continuum II” for international study course “Simulation Sciences”	2011-2012	RWTH Aachen, Germany	international master Students	congress	Germany / world
142	Workshop	UNIGE – Partner 2	Communications within the life science and HPC community in Switzerland through UNIGE - Partner 2	2012-2013	Geneva Switzerland	Scientists	meeting	Switzerland
143	Lecture	USiegen – Partner 10	New lecture “Simulationstechnik I”, 2 blocks on thrombus formation and blood flow simulation	2013-2014	Siegen, Germany	Students	congress	Germany

Section B

Part B

Template B: List of applications for patents, trademarks, registered designs, etc.					
Type of IP Rights1:	**Confidential YES/NO**	**Foreseen embargo date dd/mm/yyyy**	**Application reference(s) (EP123456)**	**Subject or title of application**	**Applicant (s) (as on the application)**
Patent	NO	01/03/2013	EP13158858	Test Bench for In Vitro study of Aneurysm and Blood Vessels	Université de Mons

[1] A drop down list allows choosing the type of IP rights: Patents, Trademarks, Registered designs, Utility models, Others.

EUROPEAN COMMISSION
Directorate-General Communications Networks, Content and Technology

Sustainable and Secure Society
Health and Well-Being

Brussels,
CNECT H1/EGO/HBA ARES (2014)

Prof. Guy Courbebaisse
CREATIS
Bâtiment Blaise Pascal
7, Avenue Jean Capelle
F- 69621 Villeurbanne
France

Subject: **Result of the final review of the FP7 project 269966(THROMBUS)**

Dear Mr Courbebaisse,

Following the final review of your project held in Brussels on 26 May 2014 and based on the attached Review report of the experts, the Commission considers the project as completed pending the implementation of the recommendations enclosed in the Review Report.

THROMBUS has successfully achieved most of its objectives and technical goals for the final period with relatively minor deviations. The project progressed widely in Year 3, with a remarkable increase in producing scientific data and dissemination activities.

All the deliverables due in the 3rd reporting period were approved.

Please note that the assessment of the use of the resources made by the experts in point 3 of the report does not imply the acceptance of the corresponding costs by the Commission.

The eligibility of the costs claimed will be assessed by the Commission on the basis of the financial statements submitted by each beneficiary. You will be soon informed about the amount of the final payment of the financial contribution of the European Union according to Article II.5.8 of the grant agreement.

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All costs declared by a beneficiary can be subject to a financial audit pursuant to Article II.22 of the grant agreement.

According to Article II.23.8 of the grant agreement, you may make observations on the result of the review of your project within one month of reception of this letter.

Eduardo GONZALEZ OTERO

Project Officer

Enclosure: Review report

Cc: Gisele ROESEMS-KERREMANS,