European Commission

ARTreat

ARTreat – Multi-level patient-specific artery and atherogenesis model for outcome prediction, decision support treatment and virtual hand-on training

ARTreat aims at developing a patient-specific computational model of the cardiovascular system, which will be used to improve the quality of prediction for the atherosclerosis progression and propagation into life-threatening events that need to be treated accordingly.

Objectives of the project

Obstructive lesions (atherosclerotic plaques) become clinically relevant when causing significant local changes that obstruct blood flow. In such cases, they are treated as anatomic problems, focusing only at restoring the specific lesion anatomy and allowing normal flow. However, every time a vasoactive drug is administered, or a lesion is inflated, or a stent is implanted, flow changes occur both locally and globally within the arterial tree, distally or proximally to an intervened lesion or in parallel vessels. Consequently, any intervention changes the local anatomy and blood flow dynamics, thus biologically triggering new sites of plaque formation and/or other mal-conditions on site.

ARTreat aims at modelling the mechanical and biological development mechanisms, leading to a better understanding of the process, its treatment, and the individualized prediction of plaque rupture and prognosis of stent re-stenosis.

ARTreat targets the following objectives:

- The development and validation of patient-specific three-level model of the vasculature, integrating artery anatomy, blood flow and particle dynamics that describe the formation and growth of atherosclerotic plaque.
- The development and testing of Treatment Decision Support Tools for assisting cardiologists in (a) selecting appropriate patient treatment and (b) stent positioning during clinical interventions.
- The development and testing of a virtual training environment for stent-positioning for interventional cardiologists.

Project Description

The ultimate goal of ARTreat is to develop a patient-specific computational model of the cardiovascular system, which will be used to improve the quality of prediction for the atherosclerosis progression and propagation into life-threatening events that need to be treated accordingly.
It will provide a three-level patient model describing the 3D arterial tree anatomy, the patient-specific blood flow and blood particle dynamics and the biological processes that lead to the creation and progression of atherosclerotic plaques.

ARTreat will apply the developed patient-specific model on two main applications: clinical decision support and training. ARTreat will produce two decision support tools to assist clinical cardiologists into providing personalized treatment selection and real-time, on- the-fly advice during invasive interventions, such as stent positioning. The aim is to minimize future therapy costs, by providing higher than ever personalized treatment support. The same patient-specific model will also be used to develop a real-case training simulator, which will support realistic hands-on training for skill development of clinical cardiologists.

Finally, ARTreat is coupled with advanced clinical support tools for plaque characterization, and the discovery of new knowledge; associations among heterogeneous data, that can improve the predictive power of the patient-model. It thus supports the medical expert into programming the accumulated knowledge into the existing model and generating an adaptive patient-specific computational tool.

Case study

ARTreat will focus on the study of two cases, the treatment of carotid stenosis, and the treatment of coronary stenosis with stent positioning. In the first case, the aim is to provide individualized guidance for the selection of the most appropriate treatment regime, either pharmaceutical or invasive intervention. In the second case, the aim is to provide suitable guidance as to the positioning, size and characteristics of the stent used for stenosis treatment, in order to avoid the development of future lesions due to structural changes caused by the invasive intervention and materials used. Coupled with simulation capabilities, ARTreat will also provide a virtual training environment for interventional cardiologists.

Results & Impacts & Preliminary Results Expected

ARTreat will contribute to the creation of the future healthcare services, which combine knowledge from the molecule/gene to the cell and the organ/system level. Its results are expected to impact on:

Healthcare productivity by

- Enhancing the skills and ability of cardiologists to take more informed decisions for the provision of more personalised and adequate treatments
- Enabling the easy accumulation of new knowledge and its quick introduction to the improved prediction capability system

Healthcare quality of service by

- Assisting in the provision of personalised treatments and elevating healthcare services
- Assisting the patient to better understand the effects of his/her actions to his/her health

Lives and Resource savings by

- Minimising future invasive interventions through the provision of greater predictive and assistive value services, and therefore minimizing the total cost of therapy
- Providing appropriate medical assistance to individualised problems and cases

Patient Safety by

- Optimising the medical intervention and preventing possible interventional errors

Healthcare Market by

- Providing a new healthcare product solution enhanced with more predictive power based on molecule-cell-organ level interaction knowledge
- Enhancing the introduction of new evidenced-based healthcare strategies
- Providing an environment for the testing of new interventional techniques and therapies
- Enabling integration of various resources and interoperability with other systems
- Contributing into the building of the next generation applications that allow the semantic interoperability of different systems to explain biological procedures

Preliminary Results
ARTreat has designed a scheme for blood flow simulations, including meshing algorithms, FEM solvers and post processing procedures. The outcome of this work is a poly-parametric study of blood flow simulations, investigating various boundary conditions, meshing details and blood modelling parameters. These simulations, in addition to a study regarding the influence of stent deployment to blood flow (Figure 1), has produced a quite enormous amount of data, which are currently processed in order to correlate them with both expected mechanical and biological outcomes.

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- Consiglio Nazionale delle Ricerche (Italy)
- Université de Paris 5 René Descartes (France)
- ASD Advanced Simulation and Design (Germany)
- Lanza & Thompson (Italy)
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KEYWORDS

Atherogenesis, Patient-specific modeling, Decision support treatment, Virtual training