ARCH

Patient specific image-based computational modelling for improvement of short- and long-term outcome of vascular access in patients on hemodialysis therapy

The ARCH project aims at developing image-based computational modelling tools for surgical planning and management of vascular access, the surgical arterio-venous shunt used to connect patient circulation to artificial kidney, a critical component of renal replacement therapy. The modelling tools will be validated in real-world clinical settings and provided to clinical end-users through a distributed ICT infrastructure.

Objectives of the Project

More than 500,000 end-stage renal disease patients in Europe live on chronic intermittent haemodialysis treatment. A successful treatment critically depends on a well-functioning vascular access, a surgically created arterio-venous shunt used to connect the patient circulation to the artificial kidney.

The vascular access is subject to high rates of post-operative malfunction and is associated to long-term complications. Indeed, 15 to 20% of hospitalisations among end-stage renal disease patients are associated to vascular access-related complications, leading to extremely high healthcare and social costs.

ARCH has the goal of improving the outcome of vascular access creation and long-term function with an image-based patient-specific computational modelling approach.

More specifically, **ARCH** aims at:

- Developing a patient-specific computational tool for surgical planning of vascular access surgery and management of complications.
- Designing and deploying an ICT service infrastructure to make the tool available to clinical end-users.
- Validating the modelling tool experimentally and in real-world clinical settings.
- Developing non-invasive acquisition protocols for the collection of functional and imaging data for model patient-specific tailoring.
- Identifying major determinants of vascular access function and contributing to the definition of treatment strategies for prevention and management of complications.

Project Description

The working hypothesis for **ARCH** is that it is possible to tackle the problems concerning vascular access using a modelling approach, which accounts for anatomical, physiological and hemodynamic factors, and their complex interplay. The **ARCH** modelling strategy is made patient-specific by leveraging on non-invasive medical imaging techniques, such as magnetic resonance and ultrasound imaging, using state-of-the-art acquisition protocols and technology.

A detailed model of the patient's circulation, accounting for arterial and venous characteristics, vascular geometry and adaptation to changes in the haemodynamic environment, will be generated on the basis of the available information. In a pre-operative setting, the model will allow the prediction of post-operative flow distribution and short-term function for different types of vascular access, allowing the surgeon to plan the optimal access for the patient. During vascular access management, the model will allow prediction or early detection of complications, such as steal syndrome, intimal hyperplasia and cardiac overload, and will provide the surgeon with a guide for planning vascular access salvage.

ARCH is expected to advance the state-of-the-art in vascular access creation and management through the integration of clinical and imaging data, and patient-specific mathematical models.

The **ARCH** modelling framework will be consolidated in a computational tool provided to end-users (applied researchers and clinicians) through an ICT-based service infrastructure. Besides enabling remote access to the mod-

SCENARIO

Because of end-stage renal disease, a 50 years old human is enrolled in a chronic haemodialysis treatment program. One month before starting the treatment, MRI and ultrasound investigations of the upper extremity circulation and cardiac function are performed. From images and clinical data, the vascular surgeons use a computer based modelling tool, developed within the ARCH project, to examine vessel morphology and blood flow distribution. The system simulates the effect of surgical creation of an arteriovenous shunt that will be used to connect the patient to the artificial kidney machine, and allows to indicate the best surgical plan to optimise chances for vascular access maturation, long term function and to minimize changes in cardiac function.

elling tool, the infrastructure will provide advanced computational power and data storage and retrieval capabilities, allowing the implementation of surgical-planning strategies and the generation of outcome predictions in the clinical setting.

Within **ARCH,** strong emphasis is placed upon validation, which will be carried out at multiple levels. Computational models will be first validated experimentally using state-of-the-art in vitro set-ups. The modelling framework will then be thoroughly verified in-vivo on extensive datasets acquired from healthy volunteers and from patients.

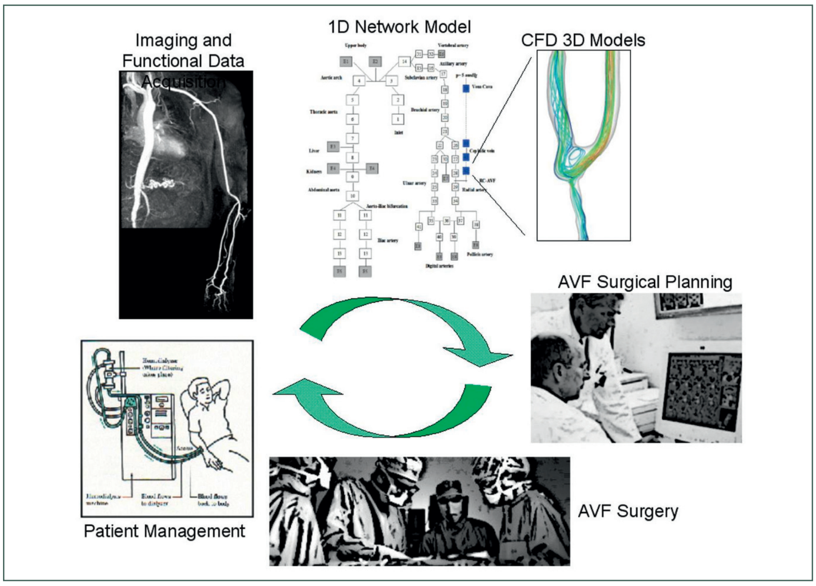
Finally, the **ARCH** modelling framework will be applied in the context of clinical follow-up studies focused on four major clinical challenges regarding vascular access creation and management, namely short-term maturation, long-term patency, steal syndrome and cardiac failure.

The studies will be designed to allow both calibration and validation of the modelling tool, and to lead to the identification of major determinants of vascular access-related complications.

Preliminary Results

During the first year, the following results have been obtained:

- Definition of imaging protocols for US and MRI, including a novel high-resolution non-contrast enhanced MR protocol for the vasculature of the arm.
- Development of image MR processing algorithms and tools for segmentation of arterial and venous vessels, centreline identification and network model generation.
- Development of interactive tools for editing vascular network models and generating meshes for numerical simulation.
- Development and validation of 0D and 1D models for simulation of patient-specific hemodynamics and AVF creation.
- Development and validation of a new CFD solver for high-Reynolds number flows.
- Set-up of a ICT research infrastructure, including a lightweight image and data exchange protocol and a new XML format for representing generic vascular networks.
- Analysis of requirements for use of a planning system in the VA clinical context.
- Implementation and start of a multicentre clinical study for the evaluation and follow-up of VA surgery.



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For published contributions and media see ARCH website:
www.vph-arch.edu

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Clinical image-based IT infrastructure