MACROSCALE COMPUTER MODELING

Research Activities

Numerical Modeling

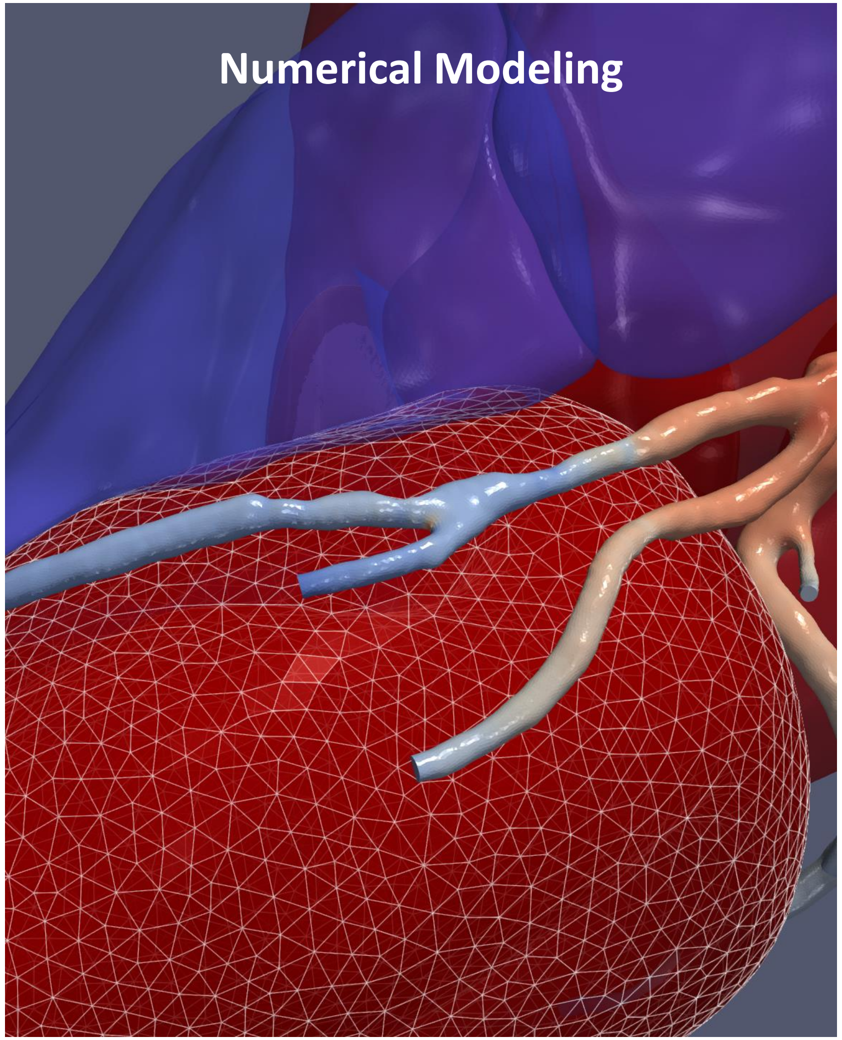
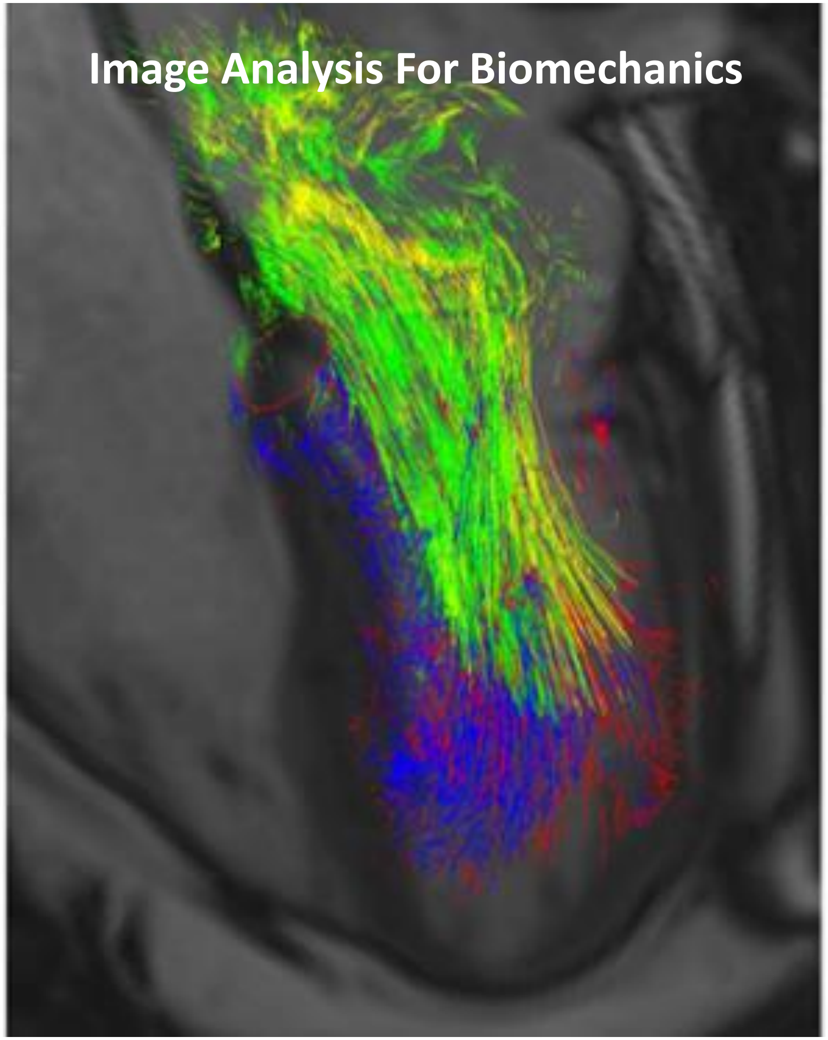
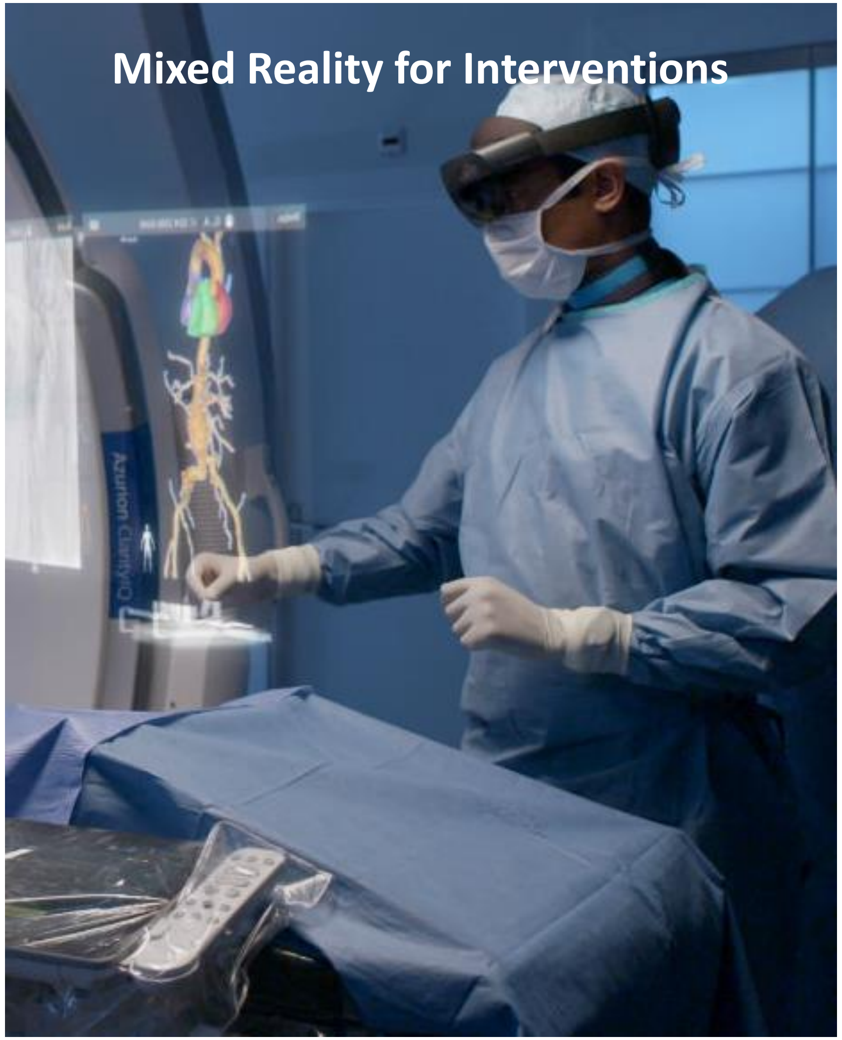


Image Analysis For Biomechanics



Mixed Reality for Interventions



Labs

Computational Biomechanics Laboratory

3D and Computer Simulation Laboratory

Team


I.R.C.C.S. POLICLINICO SAN DONATO
I.R.C.C.S. POLICLINICO SAN DONATO
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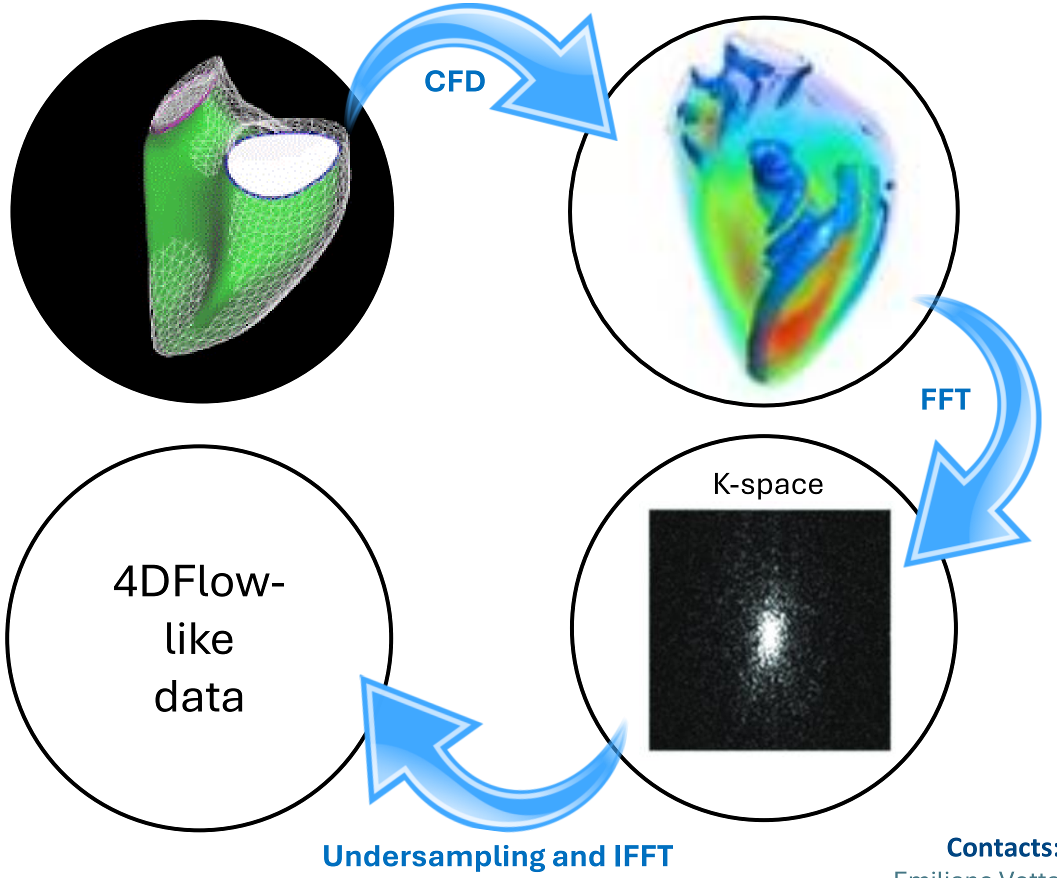
Davide Milesi
Davide Tondi
Alessandro Albanesi
Luca Mariani

Intracavitary fluid-dynamics in the right ventricle: generation of 4DFlow-like data through CFD for a population of healthy subjects

Obtaining data to train and test an AI mod… SOLD …uper-resolution and denoising of 4DFlow data

Activities

- Starting from RV geometry and motion patterns obtained via 3D ultrasound for a population of subjects, generating variants characterized by, e.g., emphasized or reduced wall motion, enlarged or reduced intracavitary volume, etc.
- Defining a suitable simulation protocol accounting for wall motion and for closure/opening of heart valves
- Running CFD simulations for each real subject and for each variant
- Extracting velocity data and transforming those in noisy and under-resolved 4DFlow velocity data



Background:
Saitta et al., 2024

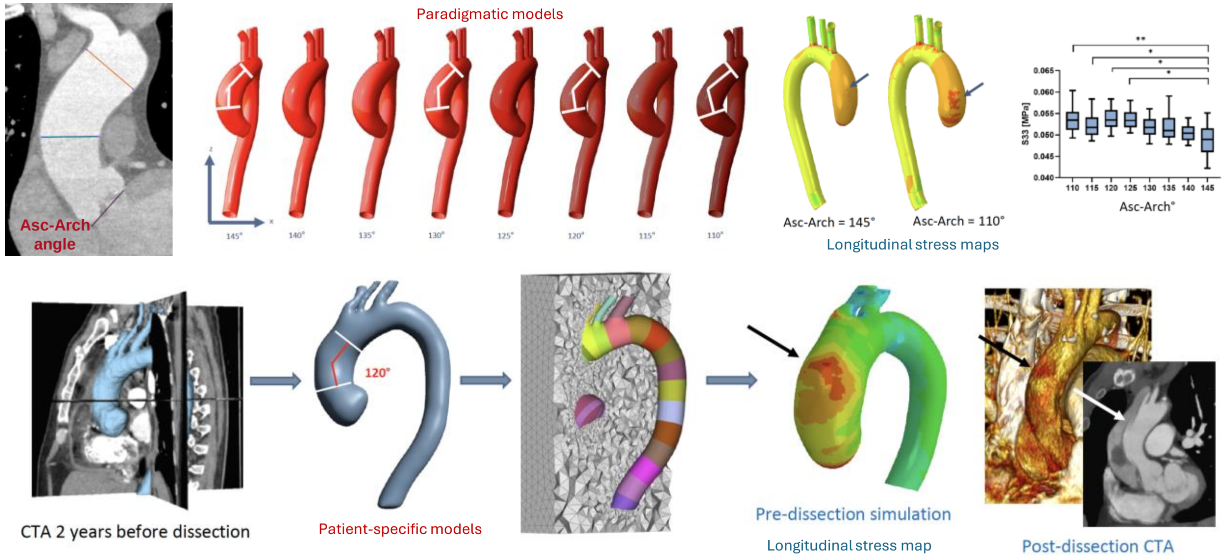
Contacts:
Emiliano Votta

FEM-based assessment of the role of aortic arch anatomy on the risk of type A aortic dissection

Testing if specific anatomical phenotypes are independently associated to increased stress levels in the ascending aorta

Activities

- Expanding a previously developed pipeline to generate 3D anatomical models of the aorta to include the possibility to model different arch types
- Testing the working hypothesis through systematic finite element simulations on different anatomical models
- Completing the study by assessing aortic wall biomechanics in patient-specific models obtained from CT-scans



Background:
Ianniruberto, Master Thesis 2024

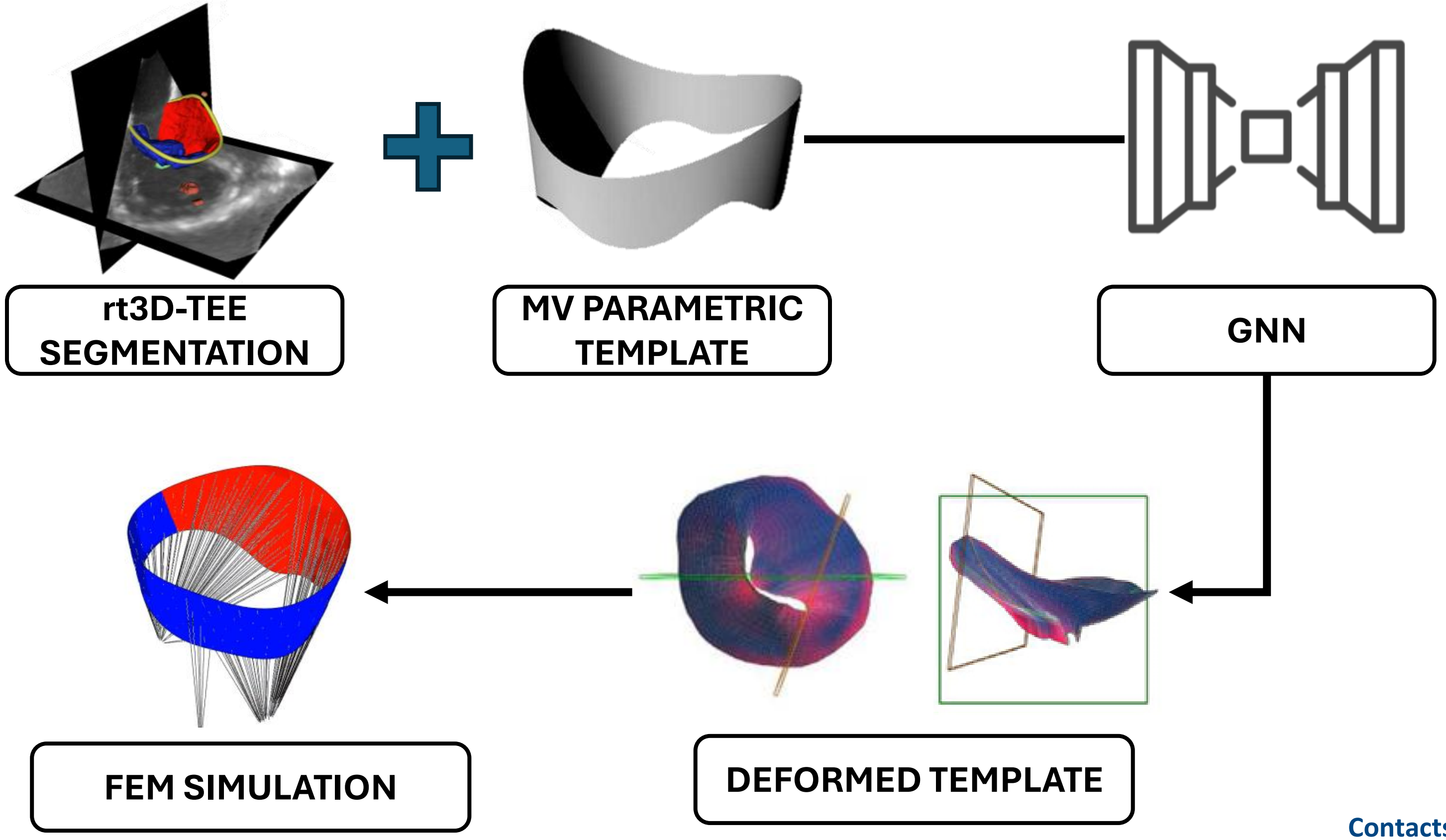
Contacts:
Emiliano Votta

Patient-specific MV modeling for FE biomechanics using deep-learning-based template matching

Developing an AI-based tool to rapidly segment 3D ultrasound data and generate a discretized geometry of the mitral valve suitable for finite element analyses

Activities

- Identification of the optimal segmentation strategy for obtaining data to input into the network.
- Design of the MV template.
- Implementing and training an end-to-end deep learning-based method (GNN) for reconstructing the mitral valve from 3D-TEE data, through a template-matching strategy.
- Test the implemented method's 3D reconstruction versus automated MV reconstruction from manual segmentation



Background:

Pak et al. (2024)
Ivantsits et al. (2024)

Contacts:
Emiliano Votta, Davide Tondi, Riccardo Munafò

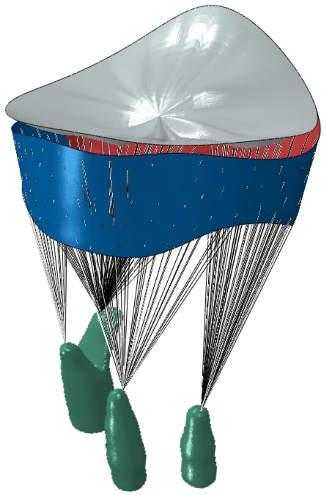
Advancing Patient-Specific Mitral Valve Modeling: Computational Techniques for Material Characterization in Finite Element Simulations

Developing and testing biomechanical strategies to accurately define the material behavior of MV leaflets in patient-specific FE simulations, enhancing the predictive power of computational models.

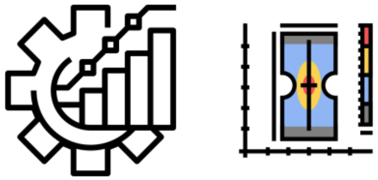
Activities

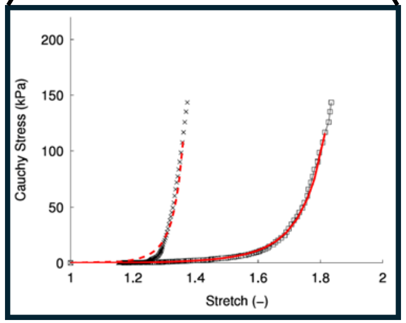
- Develop and test different approaches to define the material behavior of MV leaflets, such as:
  - Using REBAR elements to model anisotropic reinforcement.
  - Using inverse FEA with Bayesian optimization to estimate patient-specific material properties[1].
  - Imposing pre-strains to simulate active leaflet behavior[2].
  - Modeling the active contraction of the anterior leaflet through a user-defined material model
- Simulation and Validation Against Patient-Specific 3D US
  - Run finite element simulations incorporating the proposed biomechanical strategies.
  - Compare the simulated valve configurations against ground-truth 3D ultrasound (3DUS) data to evaluate accuracy

MV 3D MODEL

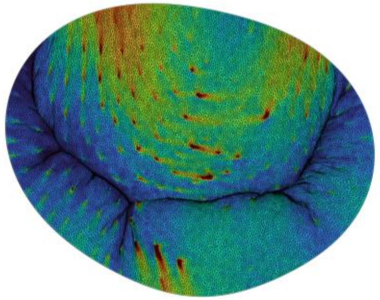


MATERIAL OPTIMIZATION AND MODELING





FE ANALYSIS



Background:
[1] Ross et al. (2023)
[2] Liu et al. (2023)

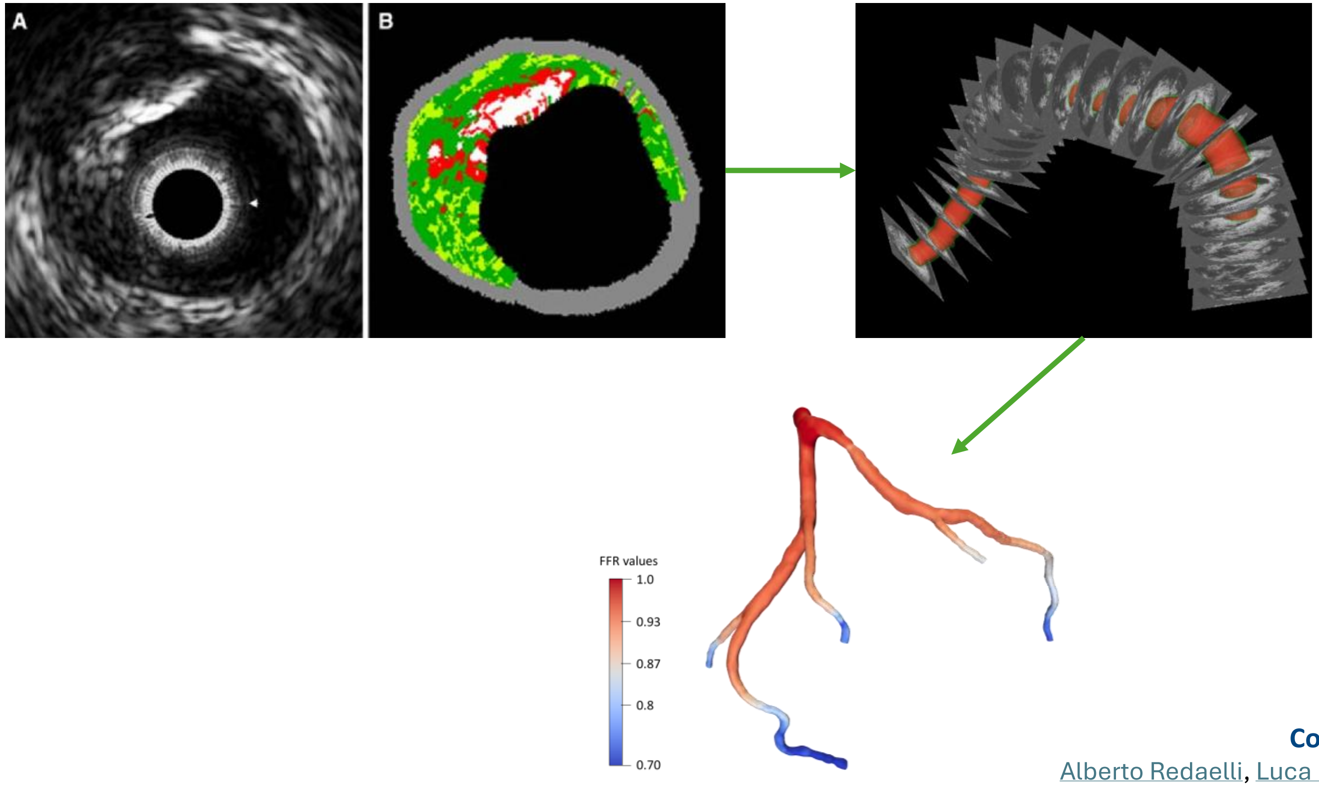
Contacts:
Emiliano Votta, Davide Tondi, Francesco Sturla

Patient-specific chronic heart disease assessment from IVUS

IVUS-based Plaque Morphology Analysis and CFD simulations in patients subjected to CAD

IVUS Activities

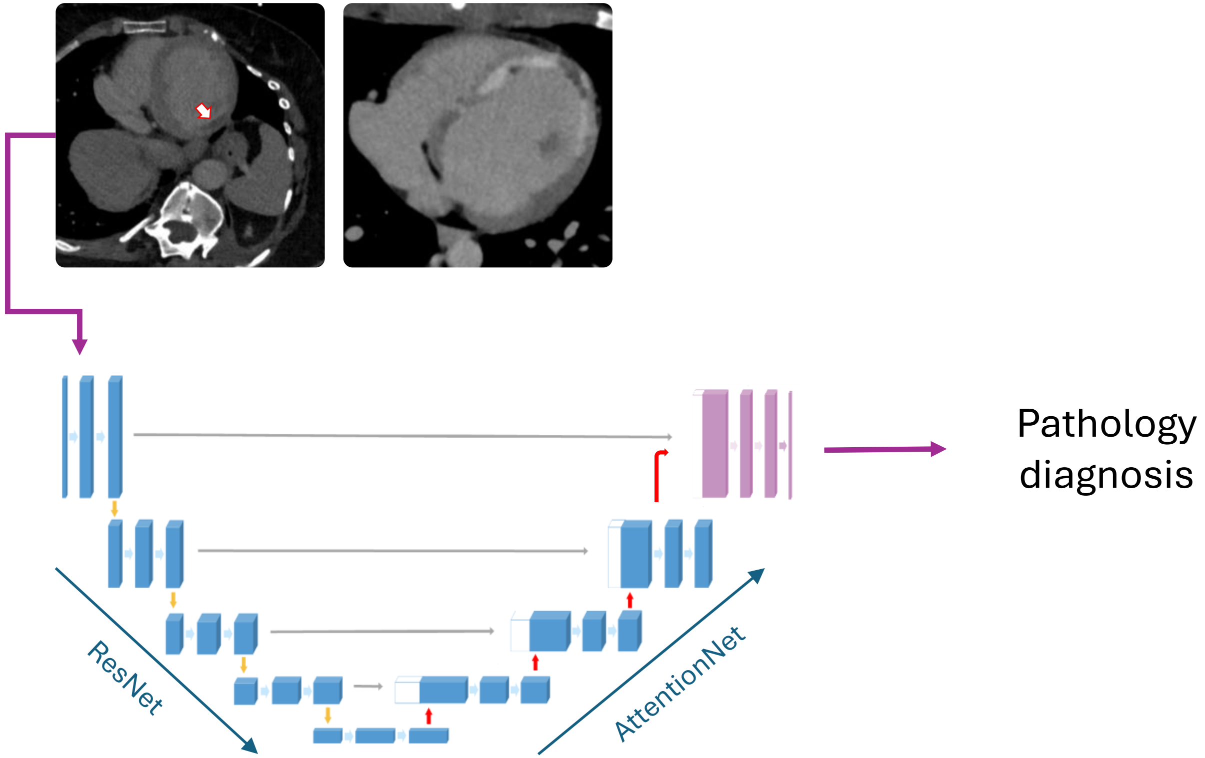
- Starting from IVUS images, perform vessel lumen, vessel wall and plaque segmentation.
- Spatial ROI coregistration of images on coronary centerline extracted from CCTA images.
- Image analysis to study plaque morphology
- CFD simulation and framework validation against CCTA-based CFD simulations



Contacts:
Alberto Redaelli, Luca Mariani

Patient-specific chronic heart disease assessment from PCCT

PCCT image analysis for patient stratification in Acute Heart Disease



PCCT Activities

- Use the high-resolution PCCT images to perform AI-based image analysis with the aim of achieve stratification of patient affected by acute heart diseases

Contacts:
Alberto Redaelli, Luca Mariani

Development of a Physical-Augmented Simulator for Endovascular Catheterization

Developing a platform that integrates physical components and an Augmented Reality (AR) environment to simulate endovascular catheterization procedures

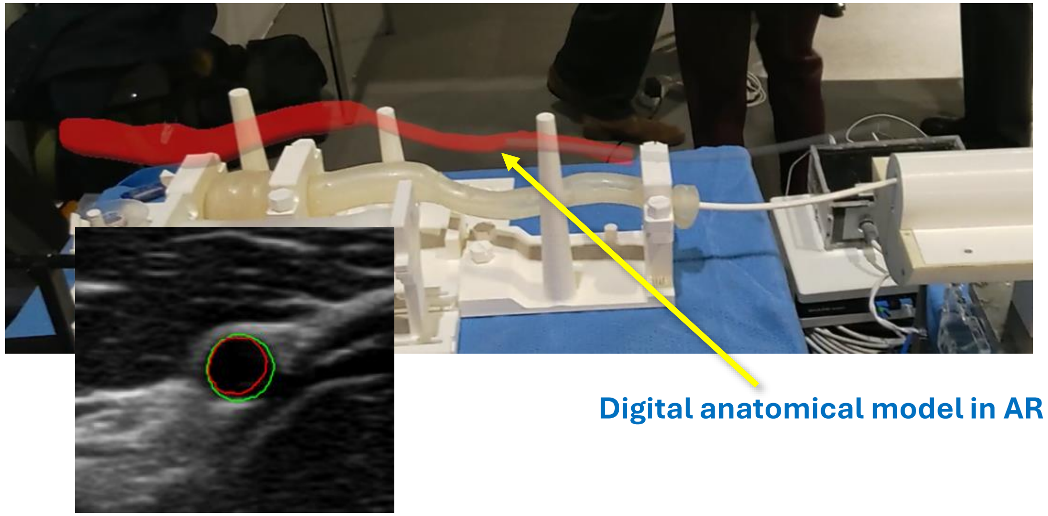
Activities

- Design and development of an in vitro set-up with:
  - an anatomical phantom made of echogenic material to allow ultrasound (US) scanning;
  - a sensorised tool to mimic interventional catheters;
- Software Integration into AR Environment: calibrate and integrate robot-acquired US segmented images with the anatomical model (physical and virtual);
- Testing and Validation: perform controlled in vitro experiments to validate the simulator.

Components already developed:

- A U-Net for automatic vessel segmentation from ultrasound images
- Real-Time FEM simulation of vessel deformation induced by catheter contact

Current in vitro set-up



Digital anatomical model in AR

Vessel segmentation from US

Background:
www.artery-project.eu
Ronneberger et al., 2015

Contacts:
Veronica Ruozzi , Junling Fu

Automatic segmentation of sovra-aortic vascular tree for computational modeling of embolic travel trajectories from the aortic arch to the brain

SOLD

Quantitatively comparing the propensity [illegible]genic brain embolism when performing TAVI in patients with different types of aortic [illegible]omies (Type I, II and III)

Activities

- Segmenting sovra-aortic vessels from computed tomography (CT)
- Developing an automatic pipeline based on deep learning to segment sovra-aortic vessels from computed tomography (CT)
- Quantifying blood flow field in the sovra-aortic vessels through CFD
- Performing particle tracking analyses

Collaborations

I.R.C.C.S. Policlinico San Donato

THE UNIVERSITY OF UTAH

TU Delft

Background:

Wasserthal *et al.* 2023, Saitta *et al.* 2022, Tatari *et al.* 2024, *Marrocco-Trischitta et al. 2022*, *Carr et al. 2013*, *Mukherjee et al. 2016*

Contacts:

Emiliano Votta, Selene Pirola, Francesco Sturla

Policy (Prof. Votta)

Starting your thesis

- **No specific enrollment criterion (as, e.g., mean mark>27, mandatory background, etc.)**
- **1 month test period –** once you pick a thesis project, we'll test you over a month. You'll be asked to complete tasks that will tell us about your capability to acquire and apply skills that are relevant to the project. In this period, somehow, you'll test us as well.
- Advice: although not mandatory, it could be a good idea to select a project **when you have the time to start working** on it or at least to work on the test period

During your thesis

- **Build knowledge and competences** (with our help)
- **Become independent and become <u>the</u> expert** of your project topic

Ending your thesis

- **You decide when and how to tackle the final defense** (we can advise you, but you have the last word)
- **Start thesis review at least 1 month before the deadline for the thesis upload –** otherwise, your menthor cannot guarantee to provide you with a proper review in due time