



**MACROSCALE
COMPUTER MODELING**

Research Activities

Numerical Modeling

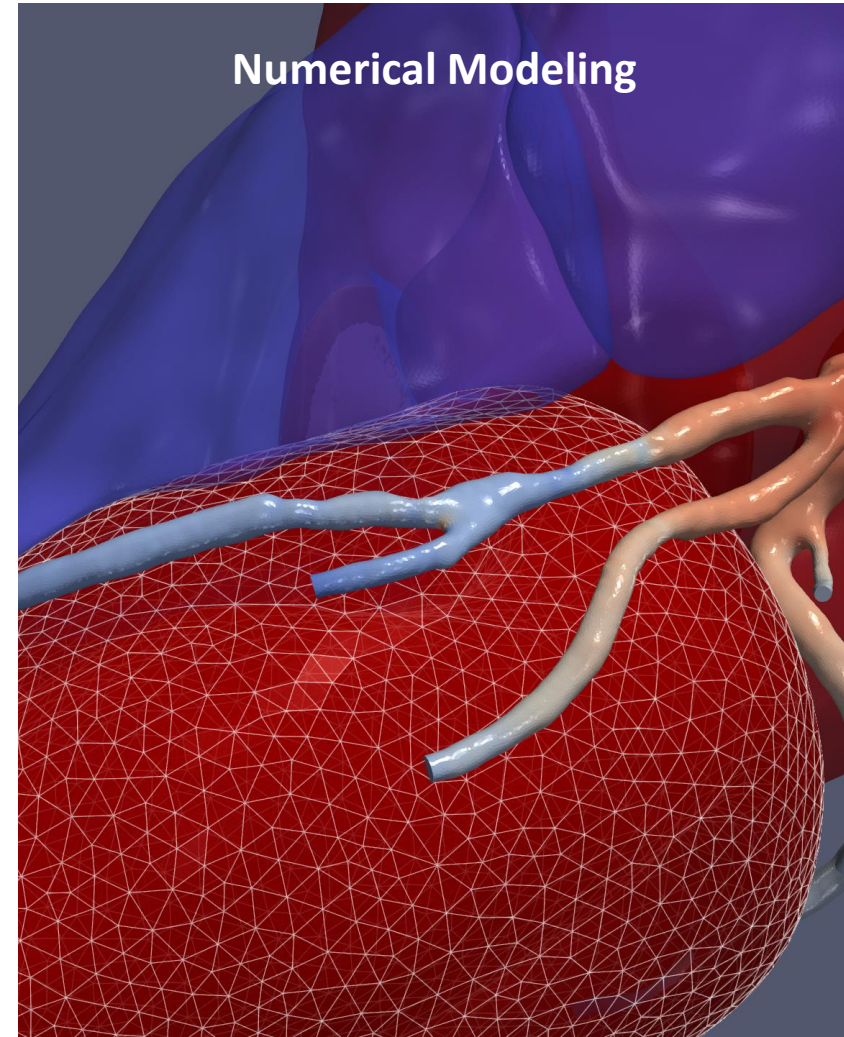
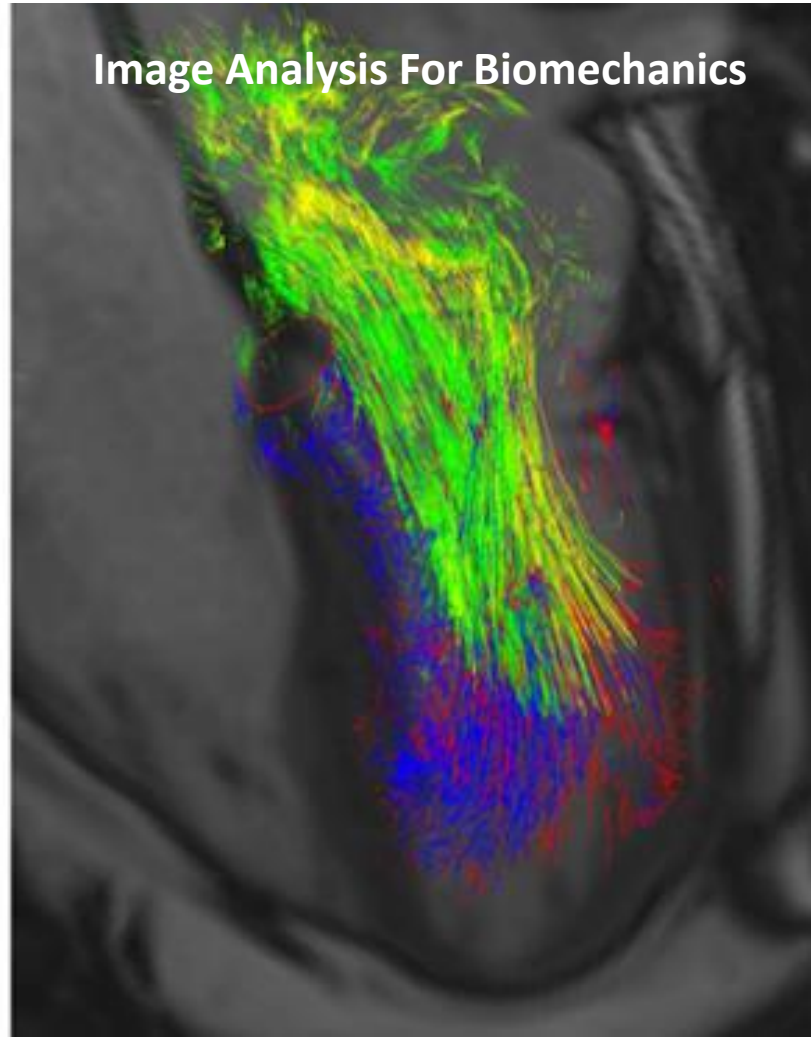


Image Analysis For Biomechanics



Mixed Reality for Interventions



Labs



Computational Biomechanics Laboratory



3D and Computer Simulation Laboratory



Team



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



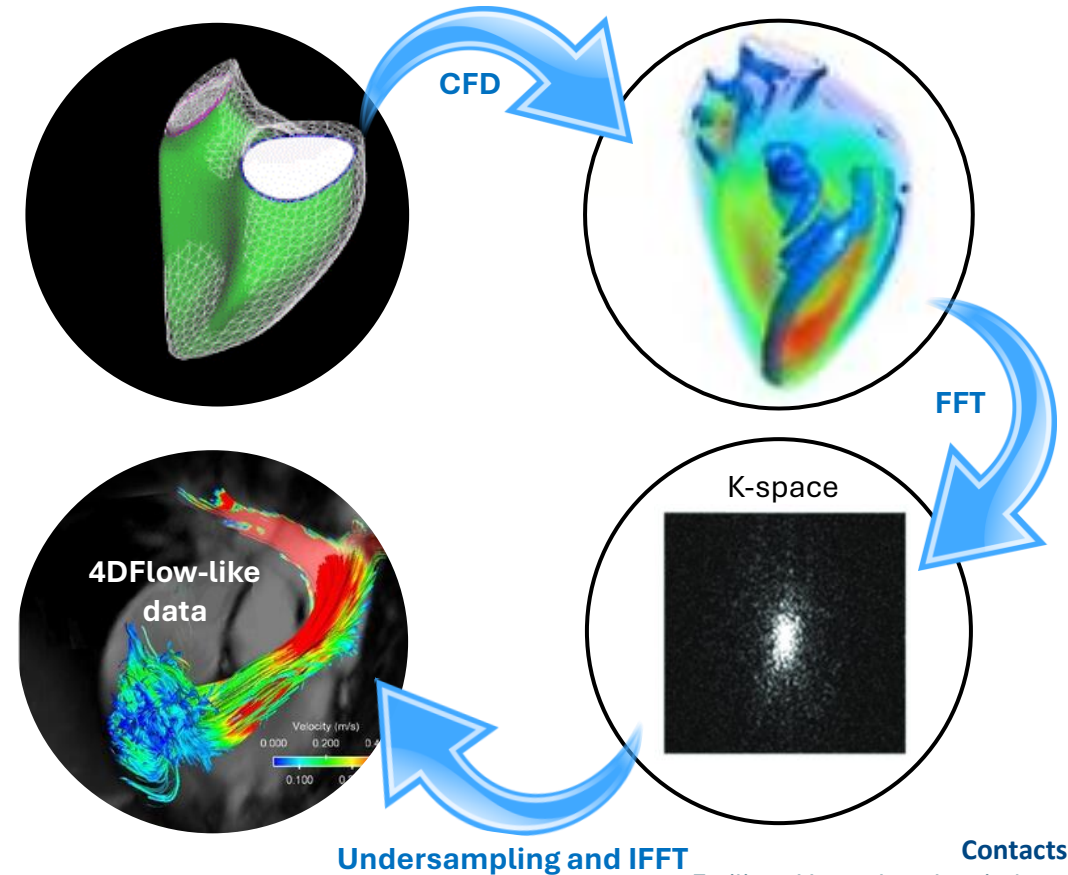
Obtaining data to train and test an AI model for the super-resolution and denoising of 4DFlow data

Background

- In a previous thesis work, a CFD simulation set-up was designed and tested to compute the intracavitary fluid-dynamics of the RV by imposing wall motion and inflow flow rates as BCs as measured from 3D ultrasound imaging.

Activities

- Extending the previous approach to compute RV wall motion from cardiac magnetic resonance imaging
- Running CFD simulations based on the previously designed set-up
- Extracting velocity from CFD simulations and transforming those in noisy and under-resolved 4DFlow-like velocity data
- Implementing, training, and testing a deep neural network to denoise and upsample real 4DFlow data



Background:
Saitta et al., 2024

Contacts:
Emiliano Votta, Ione Ianniruberto

Non-invasive pressure-volume loop of the left ventricle from in vivo magnetic resonance imaging

Context

Pressure-volume (PV) loop provide a comprehensive characterization of the left ventricle (LV) performance but its adoption in clinical practice is limited by the need for catheter-based invasive measurements. A non-invasive method has already proposed pairing LV volume from magnetic resonance imaging (MRI) and the LV pressure estimated based on a mathematical model of cardiac elastance relying on brachial pressure.

Primary aim

To reproduce non-invasive MRI-based PV loop analysis, also leveraging 4D Flow MRI data, evaluating the fidelity of the resulting metrics taking catheter-based LV pressure into account.

Technical requirements: familiarity with Matlab for image processing is recommended; knowledge of python is a plus.

Keywords: advanced MRI image processing, 4D Flow MRI, LV dysfunction, PV loop analysis, disease phenotyping.

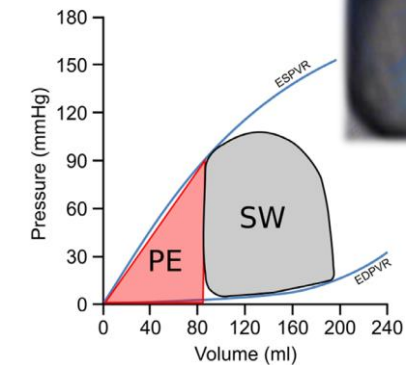
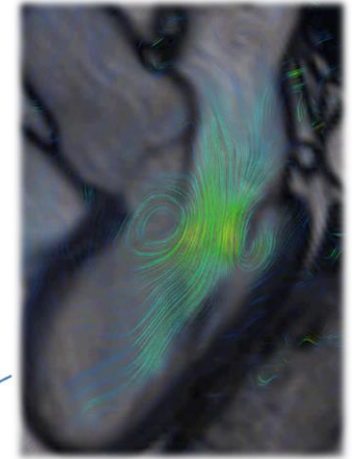
Background

1. [Seeman *et al.*](#) (Eur Heart J Imaging Methods Pract, 2024)
2. [Bastos *et al.*](#) (Eur Heart J, 2020)
3. [Seeman *et al.*](#) (Circ Cardiovasc Imaging, 2019)

Contacts

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This activity is promoted by the TRANSLATE project, funded within the “AdvaNced technology for Human centEred Medicine” (Anthem) initiative



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



C3D Lab
3D and Computer Simulation Laboratory



Anthem
Advanced Technologies for Human-centred Medicine



Ministero
dell'Università
e della Ricerca



Italadomani



PNC
Piano nazionale per gli investimenti
complementari al PNRR
Ministero dell'Università e della Ricerca

Improving the Estimation of Intraventricular Hemodynamic Forces from cine MRI: A Comparative Study with 4D Flow MRI

Context

Analysis of hemodynamic forces (HDF) associated with intraventricular fluid dynamics represents a novel tool to detect early alterations in left ventricle (LV) function. Though the analysis is generally based on 4D Flow MRI, a recent model has been proposed for estimating HDFs using conventional *cine* MRI images. However, this analysis is limited to the apical-to-based HDF and does not fully exploit the available MRI images, e.g., the short-axis stack.

Primary aim

To develop an improved pipeline for the estimation of HDFs in the LV fully exploiting *cine* MRI imaging and comparing their accuracy with respect to the corresponding ground-truth measurements coming from 4D Flow MRI.

Technical requirements: familiarity with Matlab for image processing is recommended; knowledge of python is a plus.

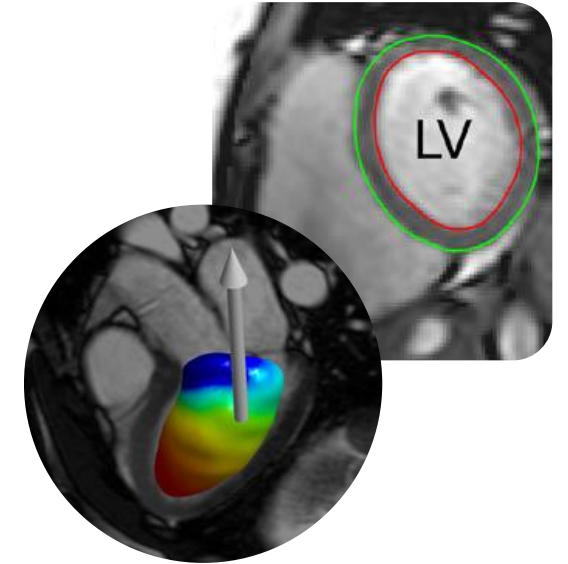
Keywords: advanced MRI image processing, 4D Flow MRI, LV dysfunction, hemodynamic forces, disease phenotyping.

Background

1. [Pedrizzetti et al.](#) (J Biomech, 2019)
2. [Hou et al.](#) (J Magn Reson Imaging, 2025)

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This activity is promoted by the TRANSLATE project, funded within the “AdvaNced technology for Human centEred Medicine” (Anthem) initiative



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

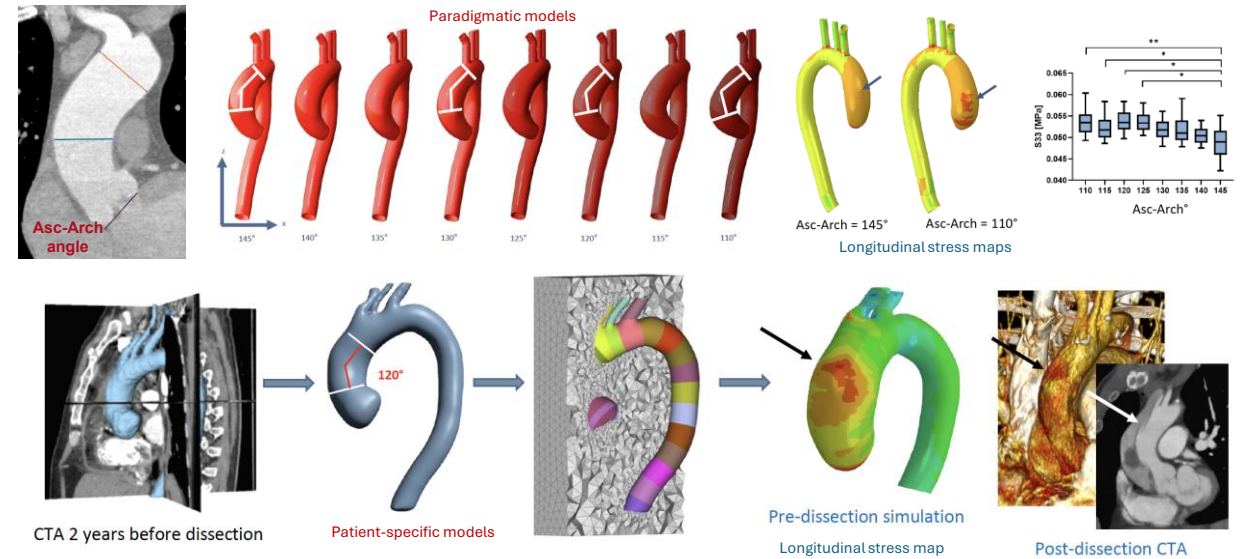


Testing if specific anatomical phenotypes are independently associated to increased stress levels in the ascending aorta

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

SOLD



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



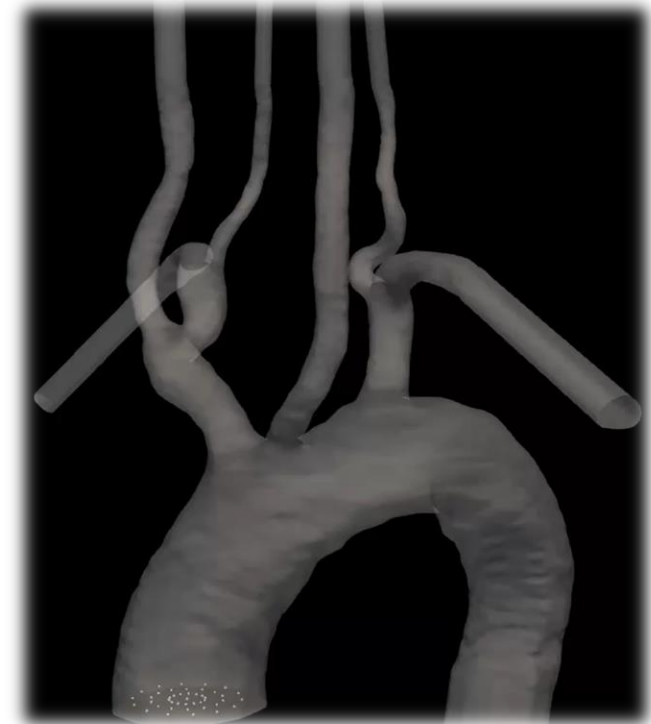
Quantitatively comparing the propensity of atherogenic brain embolism when performing TAVI in patients with different types of aortic bicuspid aortic valves (Type I, II and III)

SOLD

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



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](#)

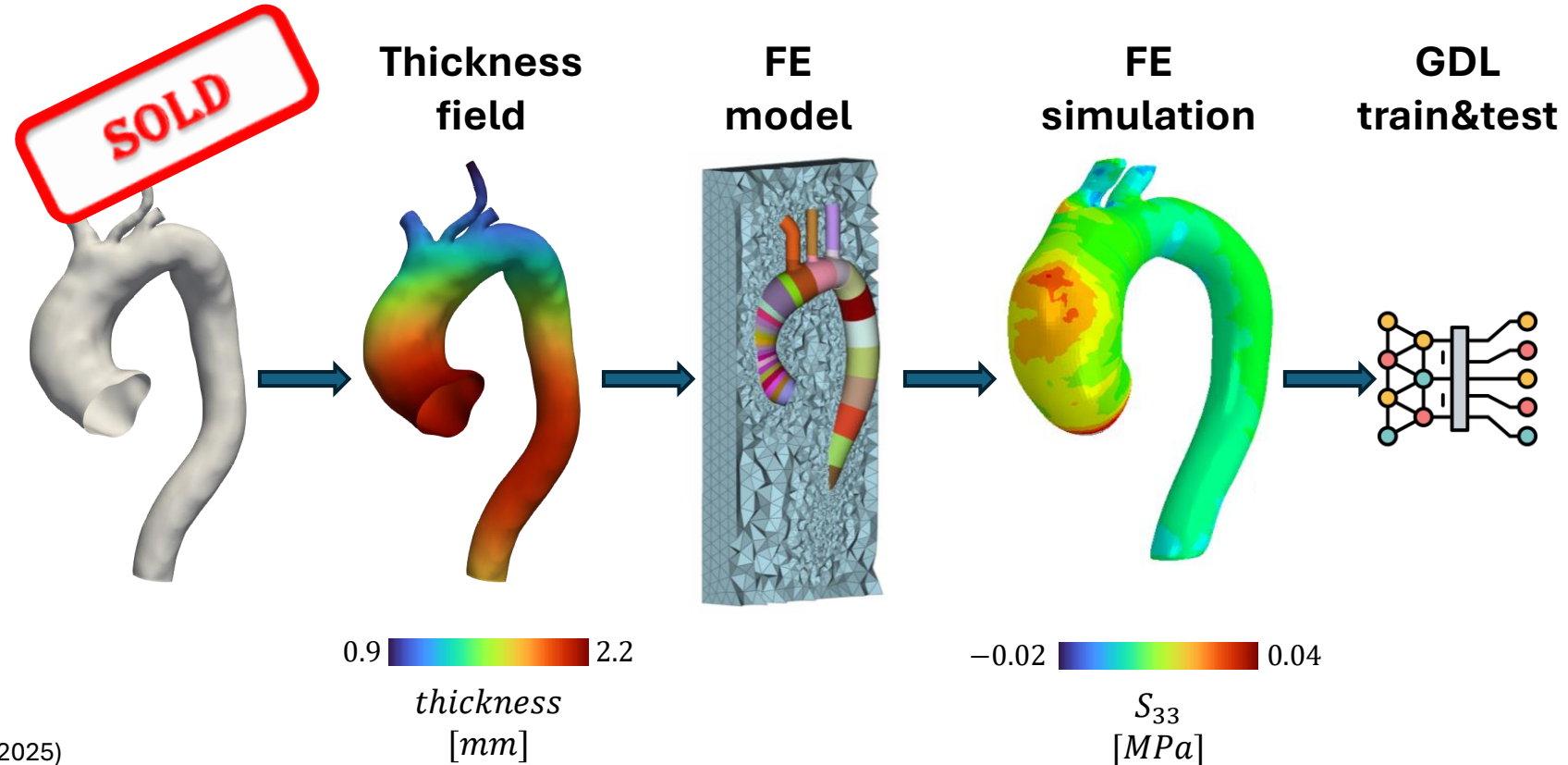
Impact of aortic thickness on the stress distribution: a finite element analysis to inform a geometric deep learning neural network



Development of several **finite element** (FE) simulations with various **patient-specific anatomies** and different **thickness fields**, along with training and testing a **geometric deep learning** (GDL) algorithm using the FE results

Activities

- **Literature analysis** on thickness variations in the aneurysmatic and dissected aortas [1]
- **Generation of FE models of thoracic aortas** with different thickness fields: constant physiological thickness, variable physiological thickness, variable pathological thickness [2]
- **FE simulations** of different patient-specific and thickness models using a previously validated model [3], extraction of the stress fields, and analysis of the results
- **Training and testing** of a GDL neural network (Pointnet++ and/or LabGATr) with the FE results [4]



Background:

[1] Debeij (2023)

[2] Armanini, Barbieri, Cattaneo, and Coppola, Bachelor Thesis (2025)

[3] Ianniruberto (2025)

[4] Di Filippo, Master Thesis (2024)

Contacts:

Emiliano Votta, Davide Astori, Ione Ianniruberto

Impact of the ascending graft implantation on the descending aorta: a prospective study of aneurysmatic patients



Performing FSI simulation for a cohort of 20 patients using a developed workflow. Performing statistical analysis of the obtained results to identify trends in the population.

Activities

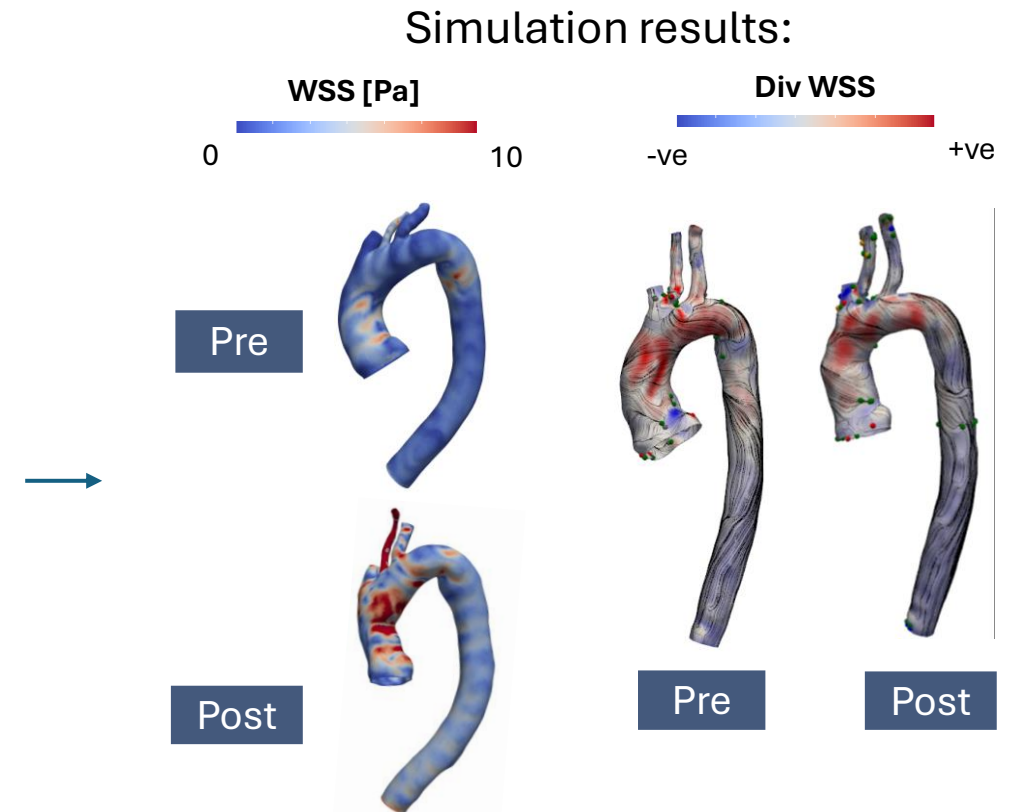
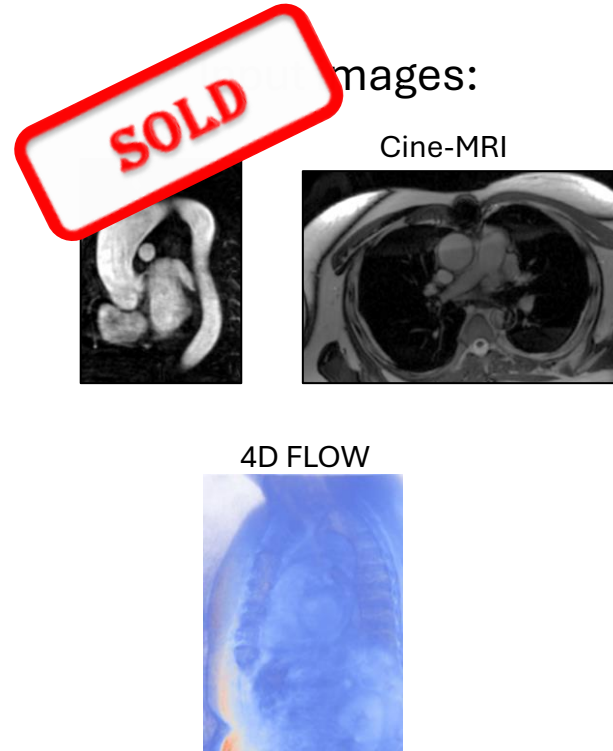
- **Literature analysis** on the clinical problem^[1]
- **Generation of FSI models of thoracic aortas** for each patient defining: boundary condition, material properties .
- **FSI simulations** of 20 patients with pre and post operative images for a total of 40 simulations ^[2].
- **WSS topological skeleton** computation, identification of fixed points and compression and expansion regions ^[3].
- **Results analysis** to identify trends in the population, focus on the **aortic wall** and on the velocity field.

Background:

[1] Palumbo (2020)

[2] Creazzo (2025)

[3] Arzani (2018)



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Linking Aortic Morphological Parameters to Abnormal Flow Dynamics in Patients with Marfan Syndrome

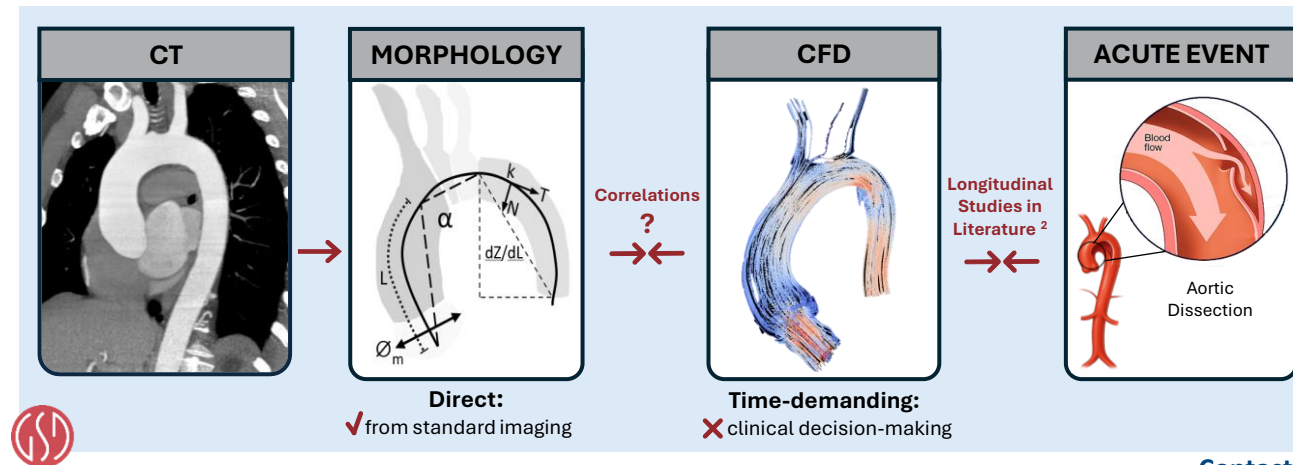
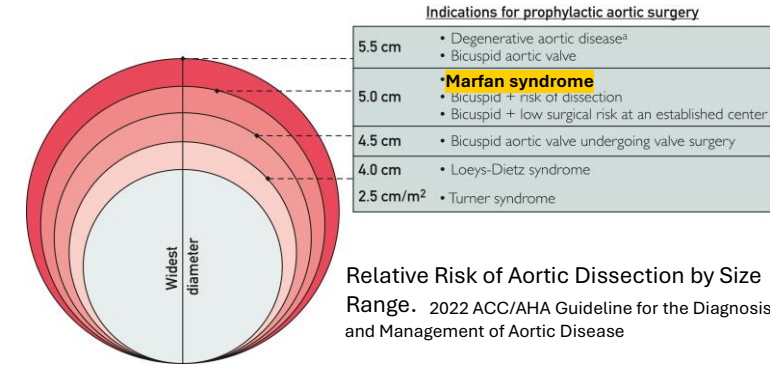


Identify morphological features that distinguish Marfan from non-Marfan aortas and correlate with hemodynamic indices associated with acute aortic events, using a high-throughput CFD-based analysis pipeline.

Clinical Context: Current surgical guidelines for Marfan patients rely mainly on aortic diameter, though 40% dissections occur below the threshold

Activities

- **Literature review** on **Marfan** aortopathy, hemodynamic alterations, and CFD-based risk indices.
- CT image **segmentation** of 40 control subjects (Mimics).
- Execution of transient **CFD simulations** on 35 Marfan and 40 control aortas using the established automated workflow.
- Extraction of comprehensive **morphological metrics**, including descriptors of aortic **root asymmetry**.
- Statistical analysis and **correlation** between morphological and hemodynamic indices to:
 - (i) differentiate Marfan and control groups,
 - (ii) identify within the Marfan group the patterns associated with acute dissection risk.
- Combination of relevant features into candidate **morphometric indices for risk stratification**.



Background:

- [1] 2022 ACC/AHA Guideline for the Diagnosis and Management of Aortic Disease
 [2] Pons R et al. *R. Soc. open sci.* 2020

Contacts:

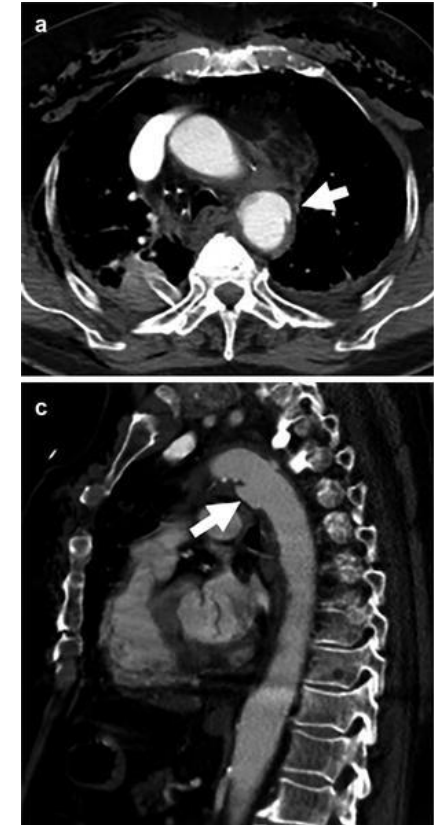
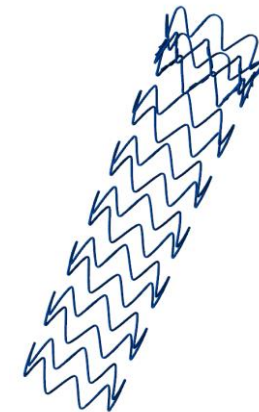
Emiliano Votta, Fabio Morelli, Ione Ianniruberto

Numerical finite element simulation of endovascular treatment for blunt thoracic aortic injuries (BTAI)



Primary Aims

- To simulate, using finite element analysis (FEA), the biomechanical effects of commercial thoracic endografts implanted at the aortic isthmus for blunt thoracic aortic injuries (BTAI). The following endografts will be reproduced – using photon-counting CT imaging – and their implantation compared based on FEA: *Zenith Alpha* (Cook), *Valiant* (Medtronic) and *TAG* (Gore Medical).
- To numerically investigate the effects of novel endografts geometrical designs, e.g., honeycomb structures, to identify a conceptual proof of concept able to minimize the biomechanical impact on the aortic wall in patients undergoing BTAI.



Background:

1. [Mazzaccaro et al. \(2023\)](#)
2. [Youssef et al. \(2020\)](#)



Contacts:

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Finite element modeling of TPVR procedures with self-expandable devices to support pre-procedural planning in the native/patched RVOT

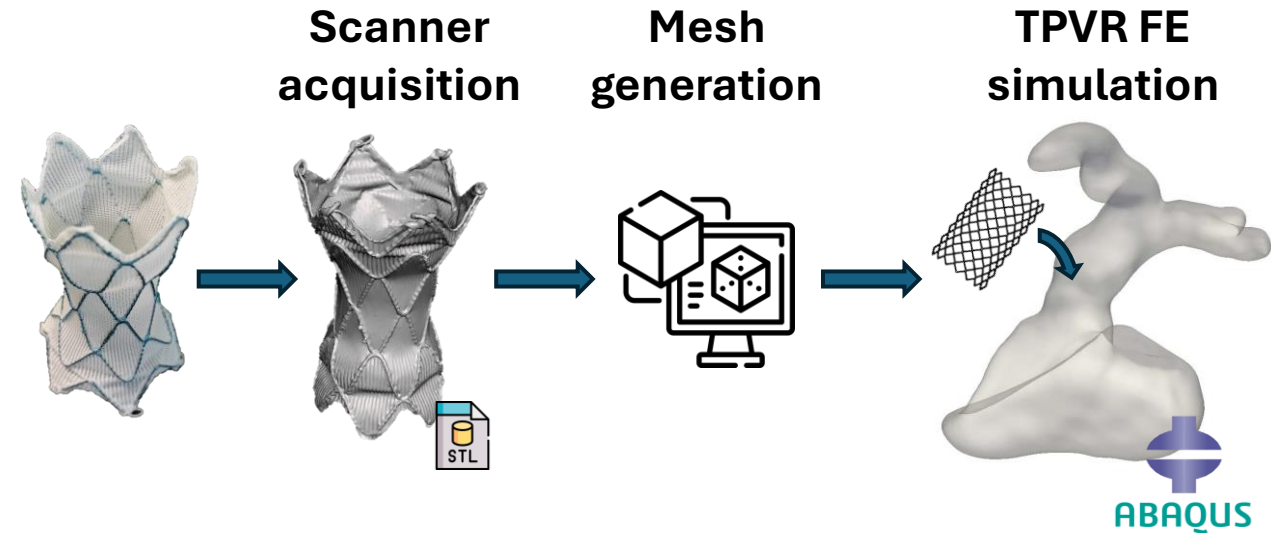


Development of an FE framework to simulate the expansion of the **Harmony™ valve** (Medtronic) in congenital patients with native or patched right ventricle outflow tract (RVOT) to predict the device's post-procedural stability

Activities

- **3D geometry reconstruction** of the Harmony™ valve: numerical mesh creation
 - **Reconstruction** of the **CAD** of the device from micro-scanner acquisition through a reverse-engineering approach
 - **Creation** of the **computational mesh** for the device, which includes **beam** elements for the stent struts and **shell** elements for the graft
- Development of a finite element (FE) framework to simulate the deployment of the self-expandable Harmony™ valve, based on previously established frameworks [1,2]
 - Preliminary FE simulation developed for a simplified case to **test the free expansion** of the stent
 - Testing the FE framework on a **patient-specific RVOT** anatomy (from Policlinico San Donato)

SOLD



Background:

[1] Gatti and Ludovici, *Master Thesis* (2025)

[2] Astori, *Master Thesis* (2022)

Contacts:

Emiliano Votta, Davide Astori

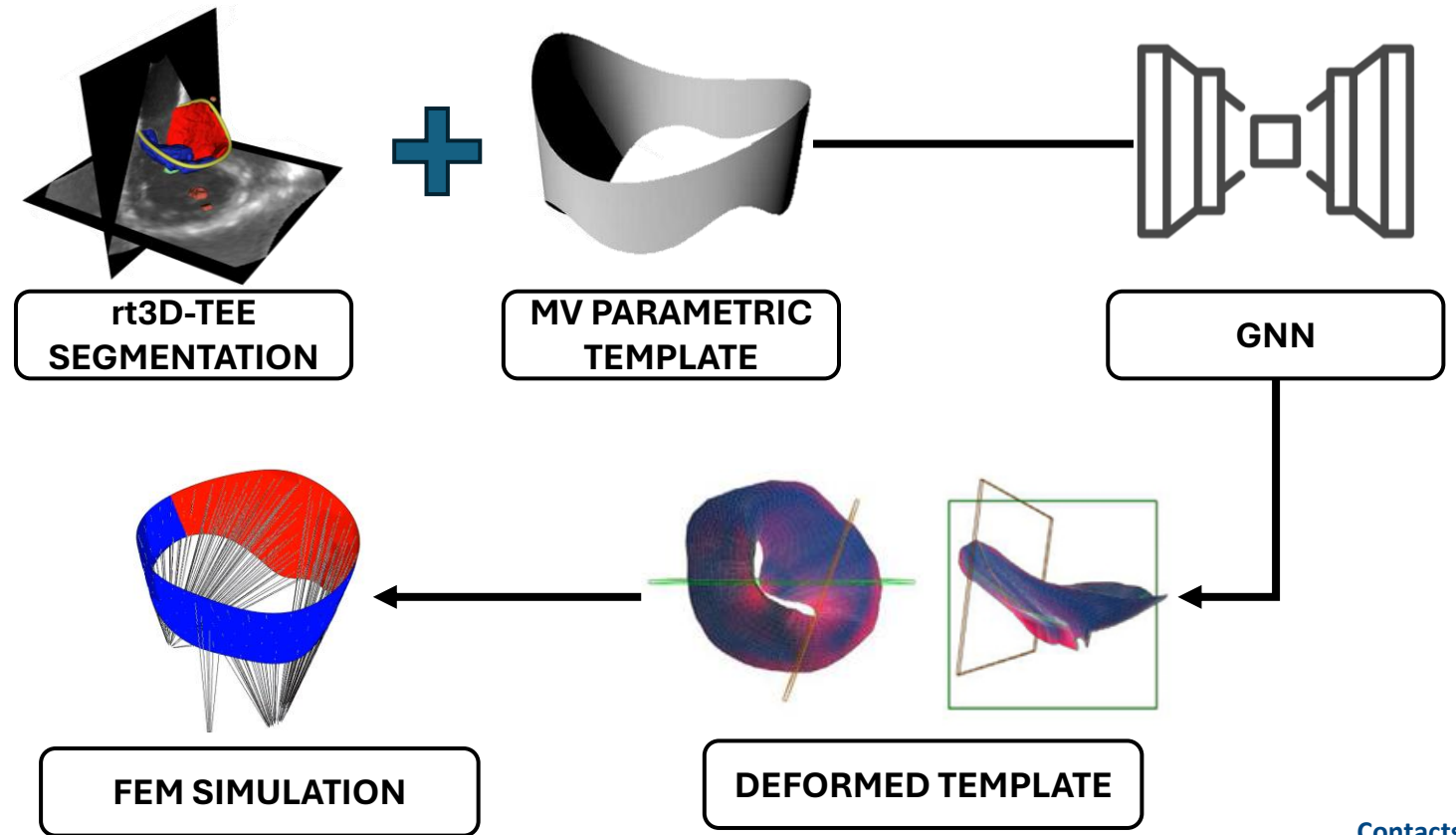
Patient-specific MV modeling for FE biomechanics using deep-learning-based template matching



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. \(2024\)](#)

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[Emiliano Votta](#), [Davide Tondi](#)

Advancing Mitral Valve Modeling: Accounting for the Active Contraction of MV Leaflets to Better Reproduce Mitral Valve Systolic Closure



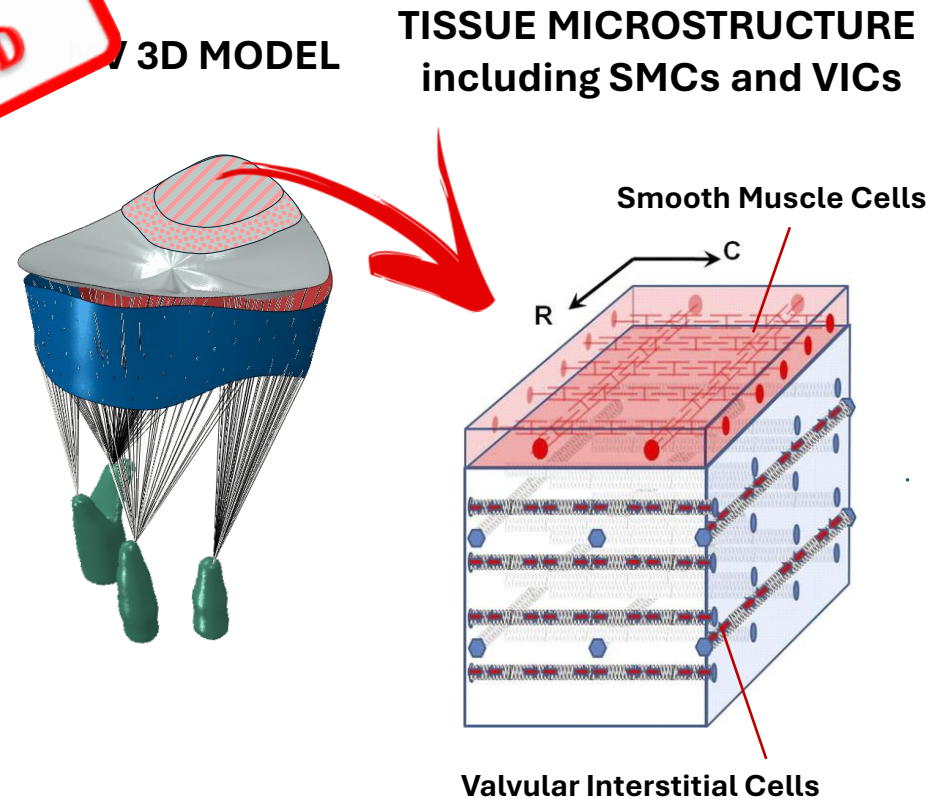
Developing and testing biomechanical strategies to accurately define the **material behavior of MV leaflets** in patient-specific FE simulations, enhancing the **predictive power of computational models**.

Activities

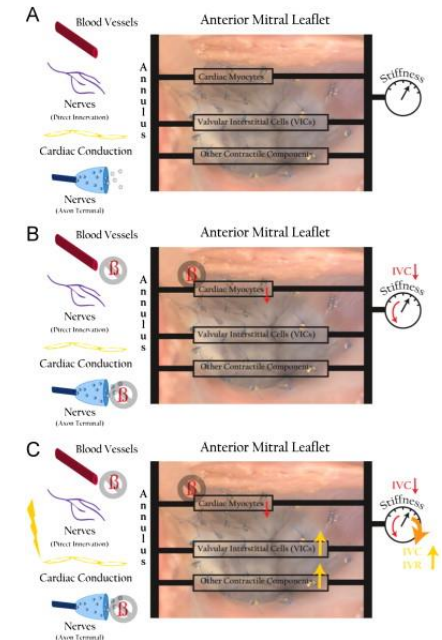
- Develop and test different approaches to define the **active stiffening** of MV leaflets, e.g.:
 - **Inverse FEA** with Bayesian optimization to estimate patient-specific material properties^[1].
 - **Prestrain** imposition to simulate active leaflet behavior^[2].
 - Constitutive modeling of leaflet tissue accounting for active stresses^[3].
- **Simulation and Validation** of Patient-Specific Models
 - Run finite element simulations incorporating the proposed biomechanical strategies.
 - Compare the simulated valve configurations against ground-truth 3D ultrasound (3DTEE) data to evaluate accuracy

Background:

- [1] Ross et al. (2023)
- [2] Liu et al. (2023)
- [3] Skallerud et al. (2010)
- [4] Itoh et al. (2009)



CONSTITUTIVE MODEL with active stiffening



Contacts:

Emiliano Votta, Davide Tondi

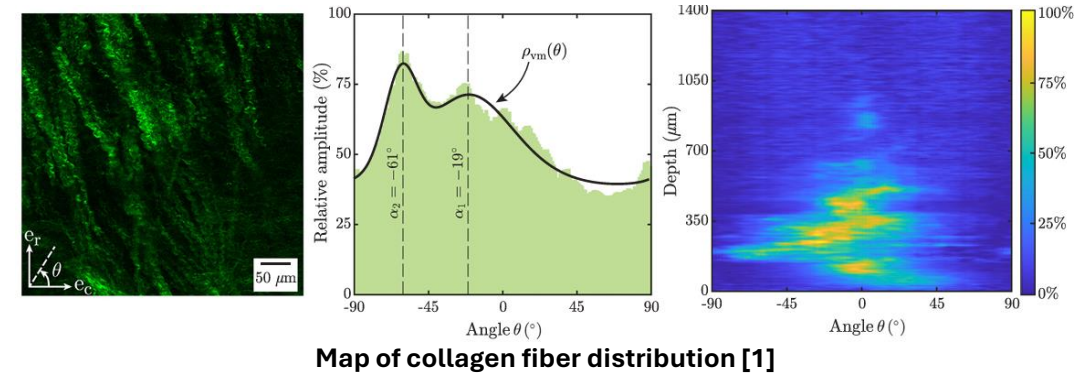
Mechanical Behavior And Collagen Structure Of Degenerative Mitral Valve Leaflets: Application To The Finite Element Modeling of Mitral Valve Repair



Development and integration of a constitutive model for **degenerative mitral valve prolapse** into a finite element model of the mitral valve, with **validation** in the context of **surgical repair** procedures.

Activities

- Implementation of Constitutive Model for Degenerative mitral valve (MV) Leaflets^[1]
 - **Extension** of the Holzapfel–Ogden constitutive framework to **incorporate altered collagen fiber distributions**^[2]
 - **VUMAT implementation** for integration of the constitutive model into the finite element solver (ABAQUS)
- Simulation and Validation Against Patient-Specific 3DUS Data
 - Model coupling with FE simulations of key surgical interventions^[3]:
 - Annuloplasty.**
 - Leaflet **triangular resection**
 - Neochordoplasty**
 - Use 3D transesophageal echocardiography (3DTEE) or 3D ultrasound data as **ground-truth geometries**

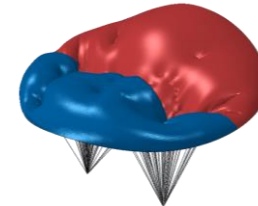


Map of collagen fiber distribution [1]

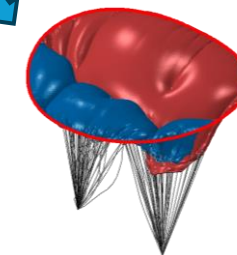
$$\Psi(I_1, I_4^*, I_6^*) = \Psi_{ISO}(I_1) + \Psi_{ANISO}(I_4^*, I_6^*)$$

Fiber dispersion contribution embed in the anisotropic invariants

PRE-OP
(MV PROLAPSE)



POST-OP
(MITRAL VALVE REPAIR)



Background:

[1] Sadeghinia et al. (2023)

[2] Holzapfel et al. (2015)

[3] Burns et al. [2021]

Contacts:

Emiliano Votta, Davide Tondi, Francesco Sturla

Impact of Access Site Selection and Leaflet Insertion Techniques on Mitral Regurgitation Correction Outcomes Using the NeoChord® System



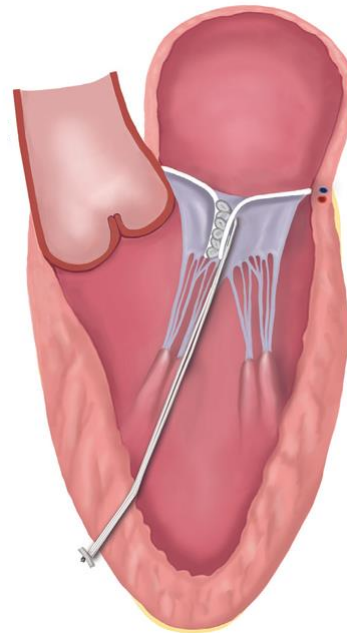
Evaluate the **transapical MV repair** using **Finite Element Modeling** and to determine the effect of the neochordal length and access site on the function of the Prolapsing Mitral Valve

Activities

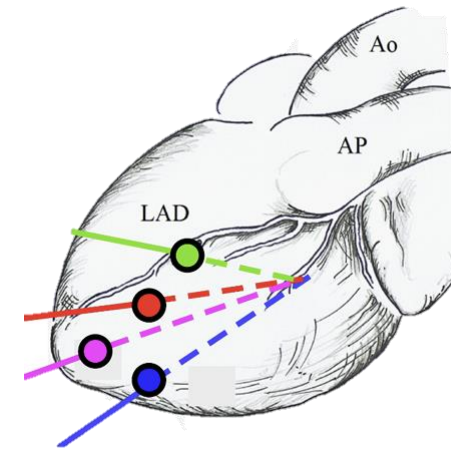
- **Study of left ventricle (LV) motion** relative to mitral position, to identify the **optimal access area**
 - Image analysis (CMR and 3DTEE) and valve reconstruction
- **Simulation and Validation** Against Patient-Specific 3DUS Data
 - Run finite element simulations incorporating the NeoChord system model^[1], with varying levels of tension and insertion angles^[2]
 - Compare the simulated valve configurations against ground-truth 3D ultrasound (3DTEE) data to evaluate accuracy



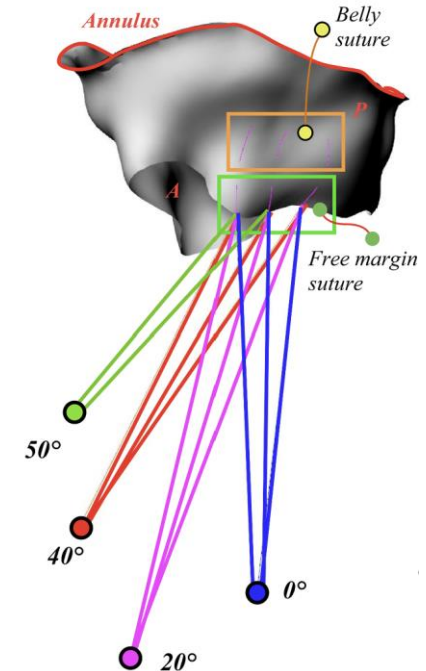
NeoChord System®



LV access sites^[2]



FE MV Model



Background:
NEOCHORD

[1] Gaidulis et al. (2018)
[2] Di Micco et al. (2022)

Collaborations:



Contacts:

Emiliano Votta, Davide Tondi

Transient CFD simulations for vorticity analysis in cerebral arteries: investigating flow patterns as a predictive marker for post-aSAH vasospasm



Develop and validate a computational fluid dynamics (CFD) workflow capable of capturing transient hemodynamic behaviour in vascular geometries, with a focus on vorticity patterns and their potential association with pathological conditions.

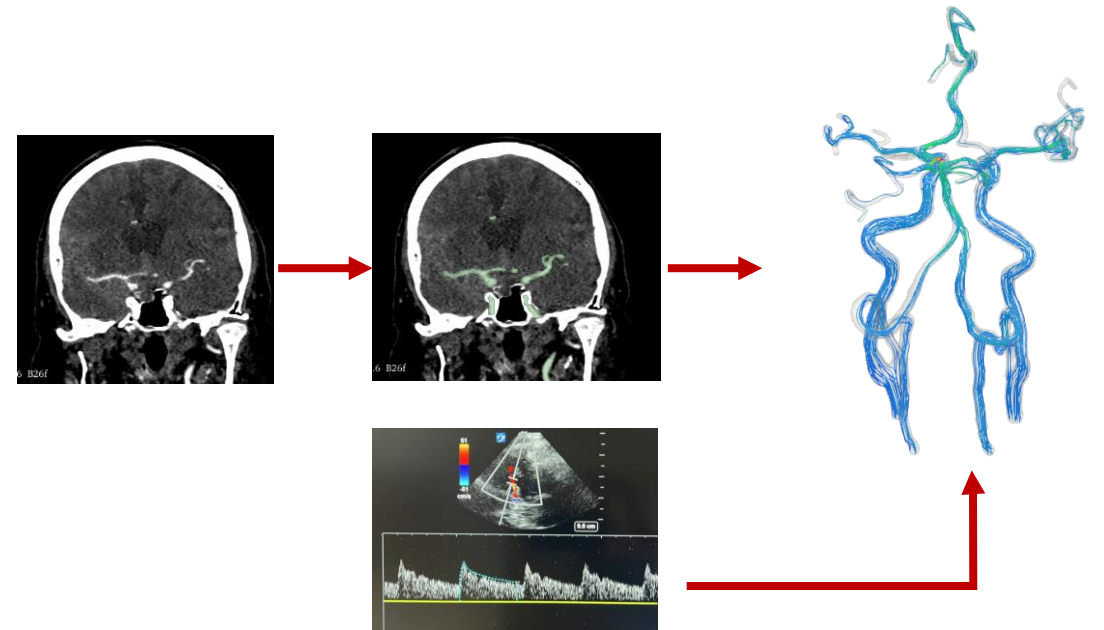
Clinical context: Aneurysmal subarachnoid hemorrhage (aSAH) is a life-threatening condition associated with high morbidity and mortality. Among its most severe complications, cerebral vasospasm, typically occurring between day 4 and day 14 post-hemorrhage, represents a leading cause of secondary neurological deterioration and poor outcome. Altered hemodynamics in the cerebral vasculature, have been hypothesized to play a role alongside biochemical cascades. Timely prediction of outcome through CFD simulation results can improve patient management and treatment outcome.

Activities

- Literature review on pathophysiology and existing CFD studies on cerebral circulation
- Geometry reconstruction of cerebral arteries from clinical imaging
- Setup of transient CFD simulations with pulsatile inlet boundary conditions
- Post-processing of vorticity fields across the cardiac cycle, with systematic comparison of systolic and diastolic flow structures

Expected outcome:

- A validated transient CFD pipeline tailored to cerebral arterial geometries
- Quantitative vorticity maps during systole and diastole
- Identification of flow features (recirculation zones, vortex shedding, elevated wall shear stress gradients) potentially linked to vasospasm onset or progression
- A methodological foundation for future patient-specific studies correlating CFD-derived hemodynamic indices with clinical vasospasm grading



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Coronary Artery Disease (CAD) assessment for patients with stents or calcified/soft plaques



Development of an automated framework to perform 3D reconstruction of coronary arteries from IVUS, with comparison of CFD-derived and morphological clinical indices to those obtained from CT.

Activities

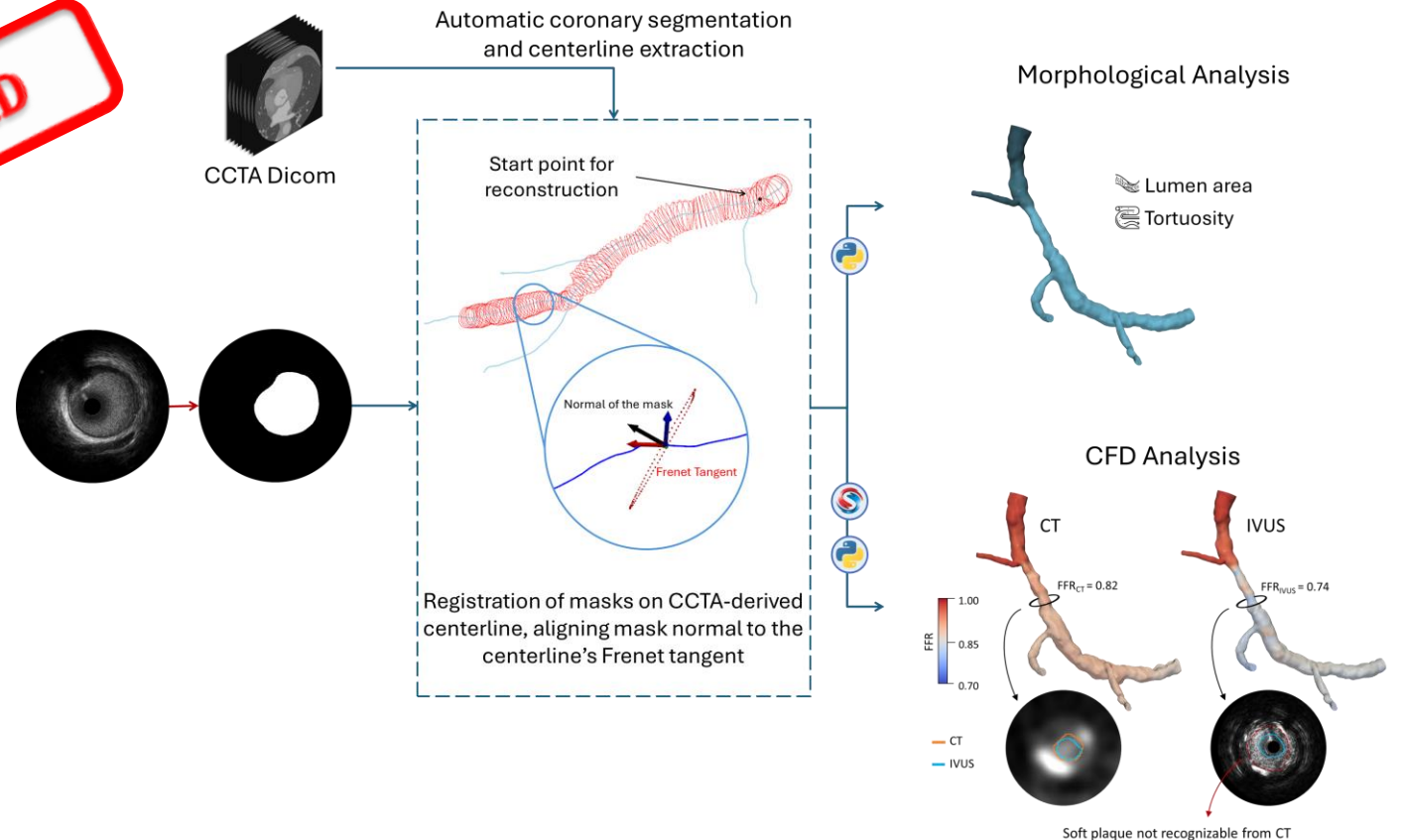
- **Literature analysis** on the clinical problem.
- Network optimization for automatic segmentation from IVUS [1].
- **Spatial registration** of lumen segmentation on coronary centerline extracted from CCTA images.
- **CFD simulations** of coronary models reconstructed from both IVUS and CT images [2].
- Extraction of **morphological** and **CFD-derived indices**.
- **Comparative analysis** of IVUS and CT performance in cases of stenting or calcified/soft plaques.

Background:

[1] [Mendizabal-Ruiz \(2013\)](#)

[2] [Nannini \(2024\)](#)

SOLD



Contacts:

[Alberto Redaelli](#), [Luca Mariani](#)

Quantitative evaluation of coronary remodelling index (RI) and plaque vulnerability



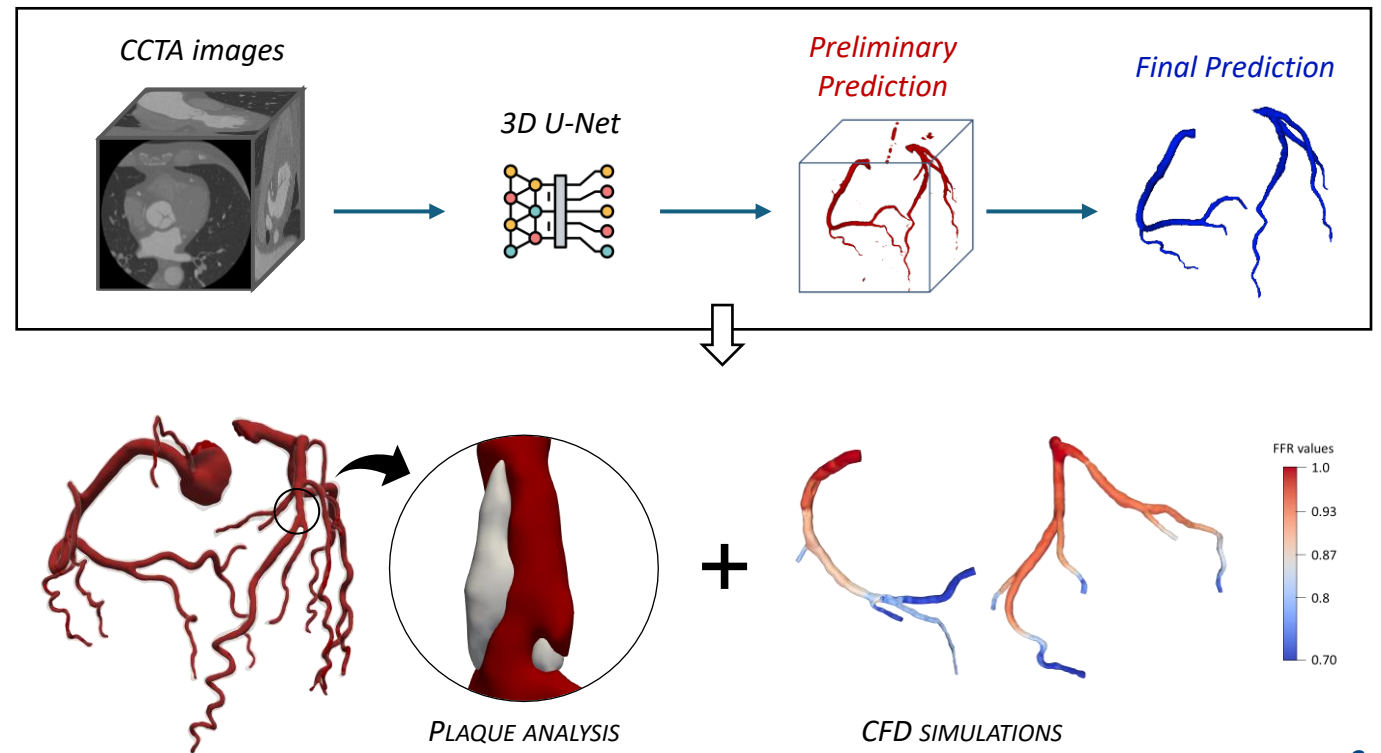
Developing a deep-learning pipeline to segment coronary lumen, wall, and plaques from CT images and perform patient-specific CFD simulations to evaluate the remodelling index and its association with plaque vulnerability.

Activities

- **Literature analysis** on the clinical problem^{[1][2]}
- Developing an automatic pipeline based on **deep-learning** to segment **lumen, wall** and **plaques**^[3]
- **CFD simulations** using an already developed in-house workflow^[4].
- Evaluation of CFD-derived indices, remodelling index (RI) and plaque vulnerability.
- **Results analysis** to identify trends in the population.

Background:

- [1] [Shah \(2003\)](#)
- [2] [Lee \(2012\)](#)
- [3] [Nannini \(2024\)](#)
- [4] [Nannini \(2024\)](#)



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Coronary labelling and tortuosity: impact on coronary hemodynamics



Developing methods for coronary artery segments labelling and tortuosity quantification, analyzing their effects on coronary hemodynamics using CFD simulations.

Activities

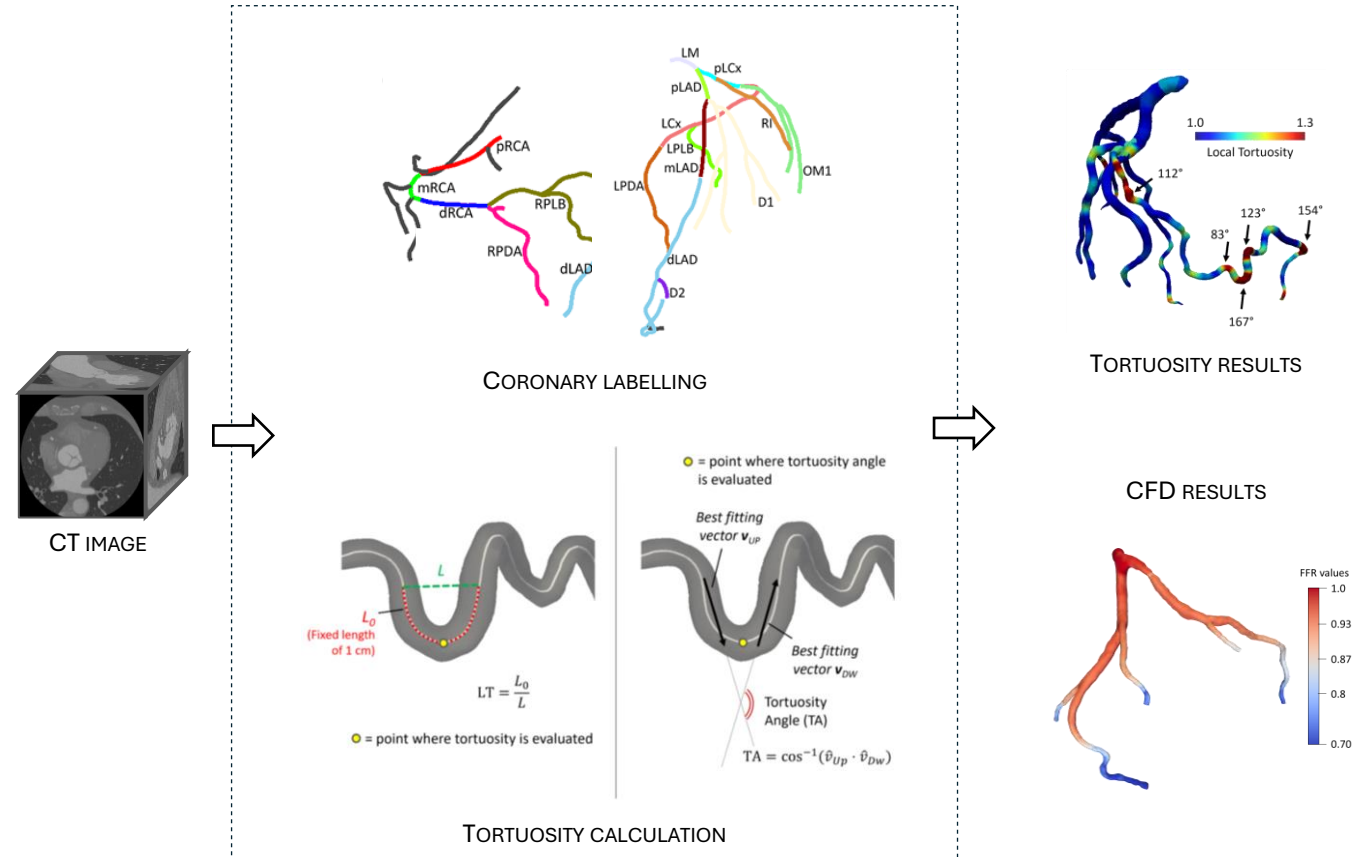
- **Literature analysis** on clinical problem
- Manual and automatic labelling of 16 coronary branches^[1]
- Vessel **tortuosity** analysis^{[2][3]}
- **CFD** simulations and **hemodynamic indexes** computation^[4]
- Analysis of the results

Expected outcome:

- Quantitative relationship between coronary tortuosity and local hemodynamics
- Automatic coronary branch labelling

Background:

- [1] [Li \(2024\)](#)
- [2] [Ferrari \(2024\)](#)
- [3] [Ferrari \(2025\)](#)
- [4] [Nannini \(2024\)](#)



Contacts:

Alberto Redaelli, Luca Mariani, Giulia Frigerio

CAD assessment using innovative Photon-Counting CT: balancing ultra-high resolution and radiation dose



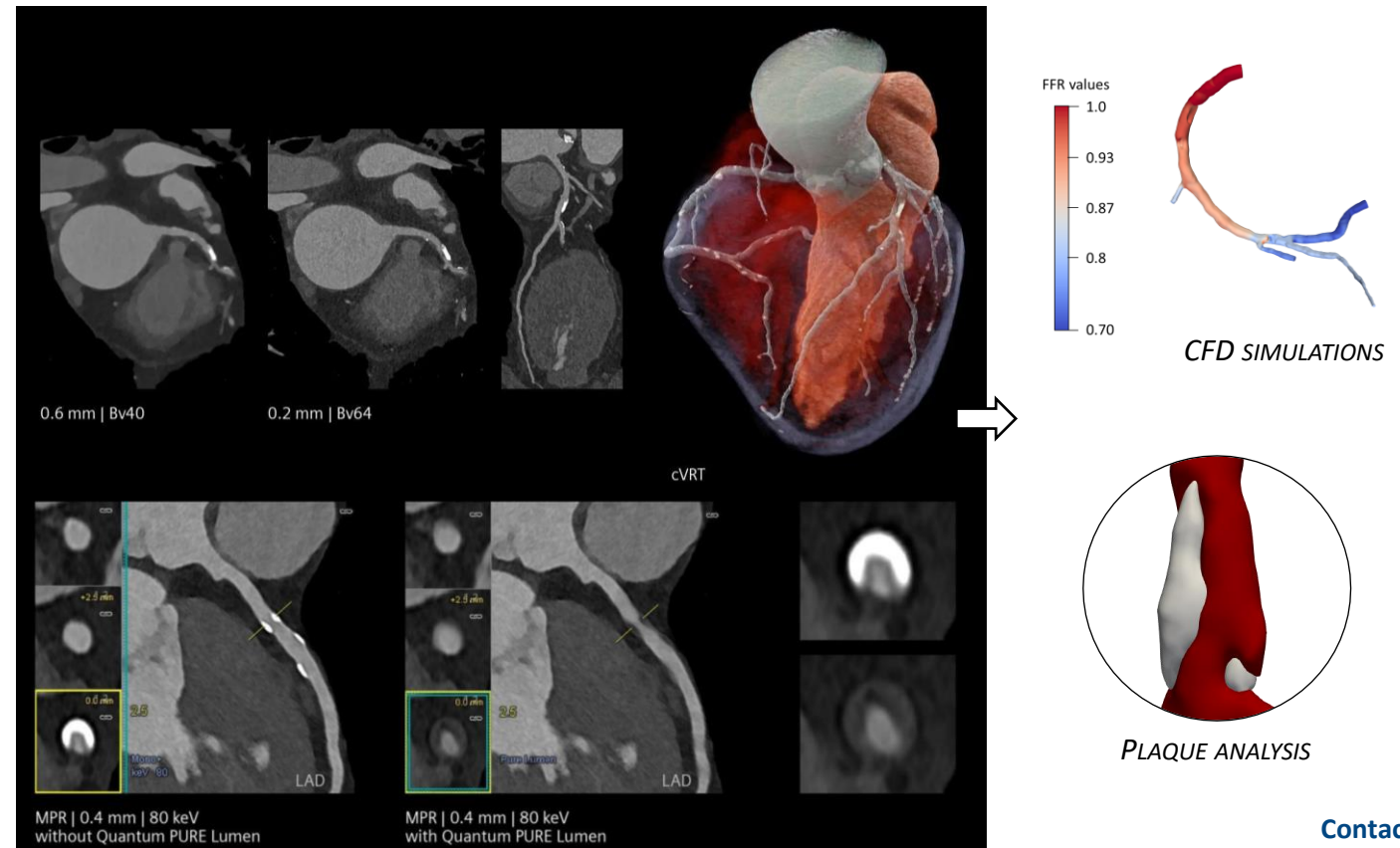
Comparing 0.2 mm ultra-HD and 0.4/0.6 mm standard-resolution PCCT images in coronary artery disease assessment using CFD simulations, focusing on image quality versus patient radiation exposure.

Activities

- **Literature analysis** on the clinical problem^[1]
- **Generation** of lumen and plaques model from images, defining corresponding properties.
- Performing **CFD simulations** using a developed workflow^[2].
- **Extraction** of WSS, TAWSS, vorticity, OSI and Topological skeleton **CFD-derived indices**^[3].
- **Results analysis** to assess the trade-off between enhanced plaque visualization and radiation dose reduction and to investigate correlations between CFD-derived indices and plaque characteristics..

Background:

- [1] [Flohr \(2023\)](#)
- [2] [Nannini \(2024\)](#)
- [3] [Pandey \(2020\)](#)



Contacts:

[Alberto Redaelli](#), [Luca Mariani](#)

Coronary Stent Evaluation with Photon-Counting CT: Diagnostic Advantages over Conventional CT



Comparison of lumen reconstruction accuracy and CFD-based hemodynamic parameters between PCCT and conventional CT for improved stent assessment in CAD.

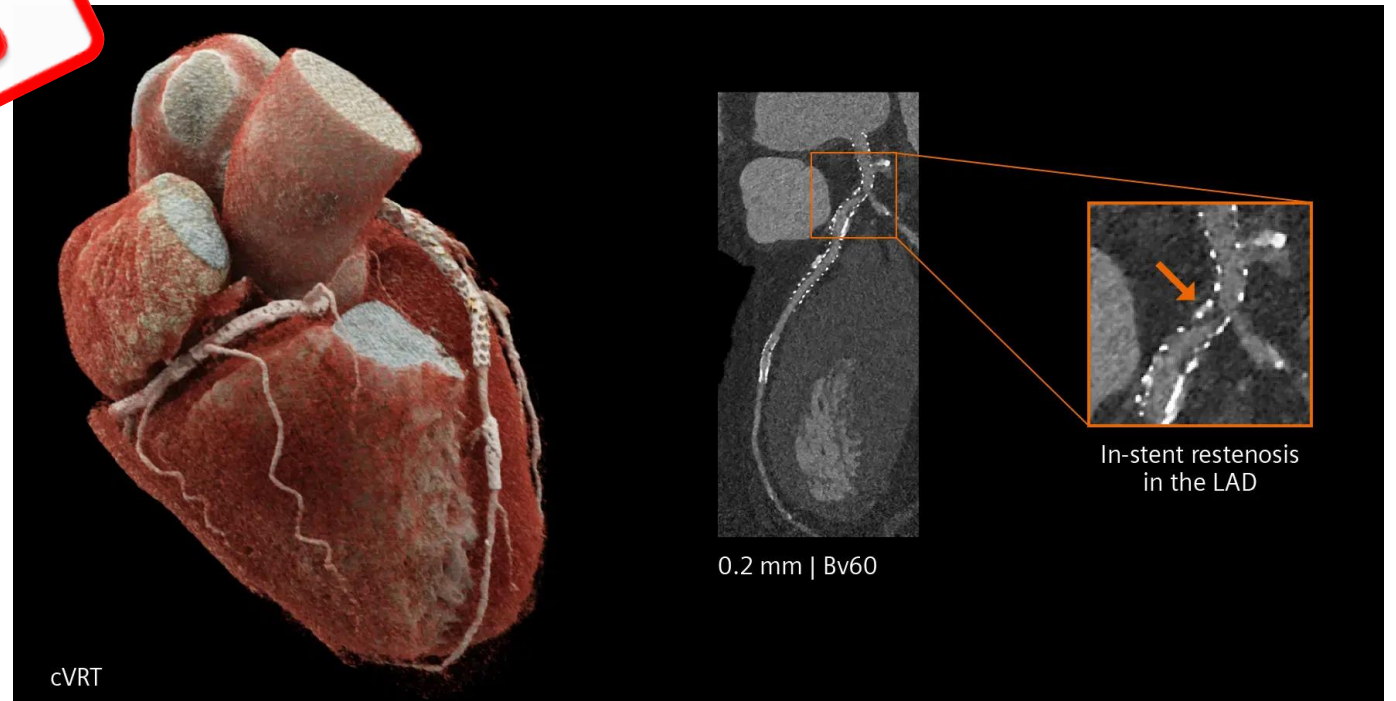
Activities

- **Literature analysis** on the clinical problem^[1]
- **Generation** of lumen, **stent** and plaque meshes from images, defining corresponding properties.
- Performing **CFD simulations** using a developed workflow^[2].
- **Extraction** of WSS, TAWSS, vorticity, OSI and Topological skeleton **CFD-derived indices**^[3].
- **Results analysis** to quantify the improvement of PCCT-derived CFD simulation over classical CT-derived simulations in presence of stents.

Background:

- [1] Flohr (2023)
- [2] Nannini (2024)
- [3] Pandey (2020)

SOLD



Contacts:

Alberto Redaelli, Luca Mariani, Giulia Frigerio

3D Coronary Reconstruction from 2D Fluoroscopy views for Hemodynamic Insights



Performing 3D reconstruction of coronary arteries from 2D fluoroscopic views obtained in the operating room. Derive hemodynamic indexes through CFD simulations.

Clinical context: Coronary artery disease is commonly assessed using invasive coronary angiography. In urgent cases, percutaneous coronary intervention with stent implantation is performed to reestablish perfusion in occluded vessels

Activities

- **Literature analysis** on clinical problem and 3D reconstruction techniques
- Image preprocessing, coronary **segmentation** and **3D reconstruction** from multiple 2D fluoroscopy views
- **CFD simulations** and **hemodynamic indexes** computation
- Analysis of the results

Expected outcome:

- Quantitative assessment of coronary physiology
- Potential support for interventional planning

Background:

Çimen et al. (2016), Vardhan et al. (2024), Nannini (2024)

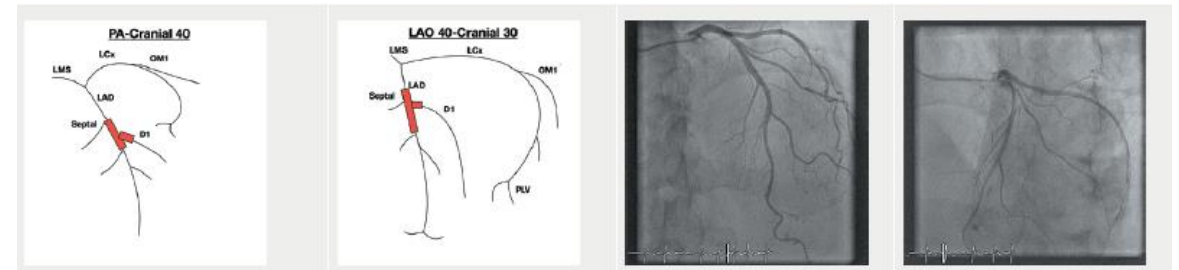
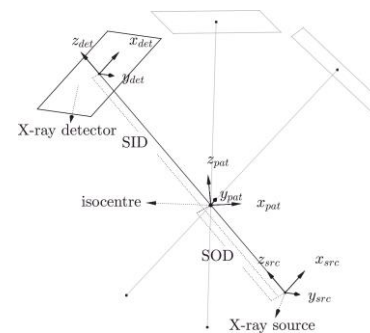


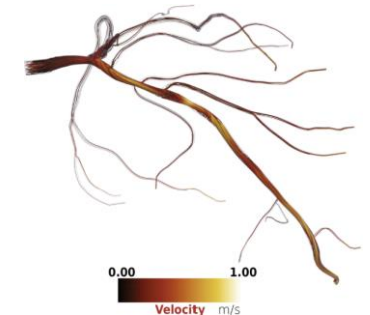
Image acquisition geometry



3D reconstruction



Hemodynamics



Experimental validation of Digital Stent Enhancement Technology



Develop and validate an experimental setup (phantom model) to assess the accuracy of Digital Stent Enhancement in detecting correct stent expansion.

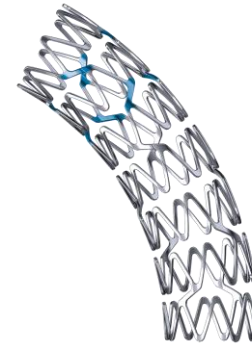
Clinical context: The Digital Stent Enhancement (DSE) technique combines multiple fluoroscopic images to improve stent visibility during percutaneous coronary intervention, enabling accurate evaluation of stent expansion

Activities

- Literature analysis
- Design and fabrication of an anatomical coronary phantom for angiographic testing
- Image acquisition using a C-arm system at different projection angles
- Testing and validation
- Quantitative analysis

Background:

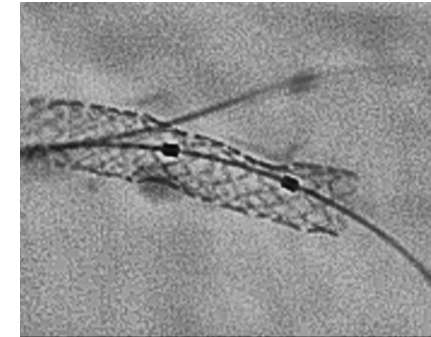
Figini et al., (2020), Blicq et al. (2013)



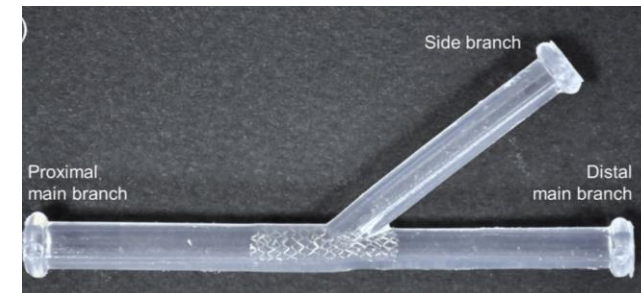
Coronary stent geometry



Expanded stent during PCI



Digital stent enhancement



Experimental Phantom

Contacts:

Alberto Redaelli, Giulia Frigerio, Luca Mariani, Fabio Morelli

Hematoma enlargement prediction in Traumatic Brain Injury (TBI) patients



Develop a computational tool able to automatically segment lesions and predict their progression in CT scans of patients that suffered traumatic brain injury

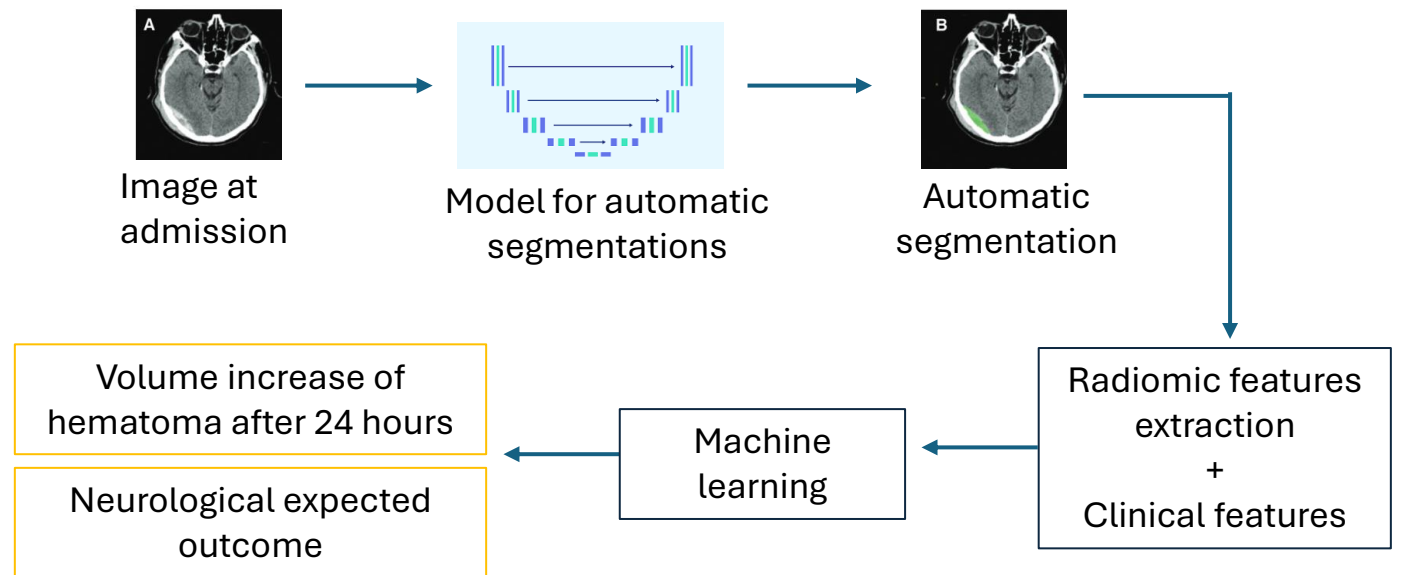
Clinical context: After a traumatic brain injury, cerebral hematoma progression is a frequent phenomenon within the first 24-48 hours. This can lead to neurological deterioration and worse functional outcomes. Identifying patients at risk of contusion progression can provide valuable information regarding the patient's clinical course and possible treatment and management strategies.

Activities

- **Literature analysis** on clinical problem
- Image segmentation of lesions
- Definition of AI model for automatic segmentation of lesions
- Extraction of radiomics features
- Definition of a machine learning that predicts hematoma progression using radiomic and clinical features

Expected outcome:

- Automatic segmentation of lesions
- Prediction of hematoma progression in terms of severity class and volume difference with respect to first time of observation and 24 hours after



Background:

[Zhang et al. \(2021\)](#), [Adatia et al. \(2021\)](#)

Contacts:

Alberto Redaelli, Elisabetta Criseo, Davide Milesi

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

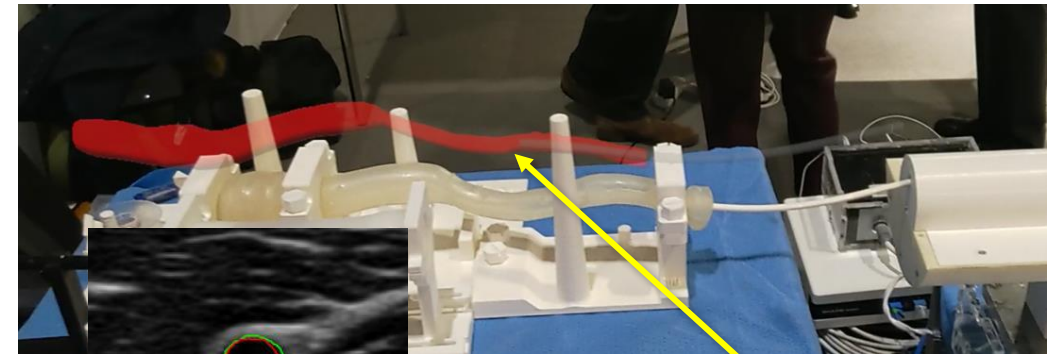
- Design and development of an in vitro set-up with
 - an anatomical phantom made of echogenic material to allow ultrasound (US) scanning;
 - a sensorised tool to mimic interventional catheters;
- Software Integration into AR Environment: calibrate and integrate robot-acquired US segmented images with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

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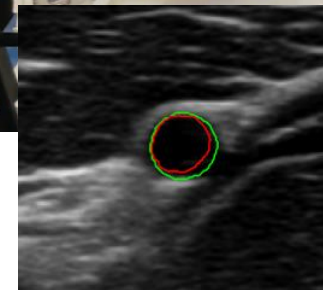
Components already developed:

- 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

Contacts:

Veronica Ruozi , Junling Fu

Background:

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

Impact of aortic morphology on the transcatheter intervention: Design and realization of a modular phantom to relate anatomy to embolic burden



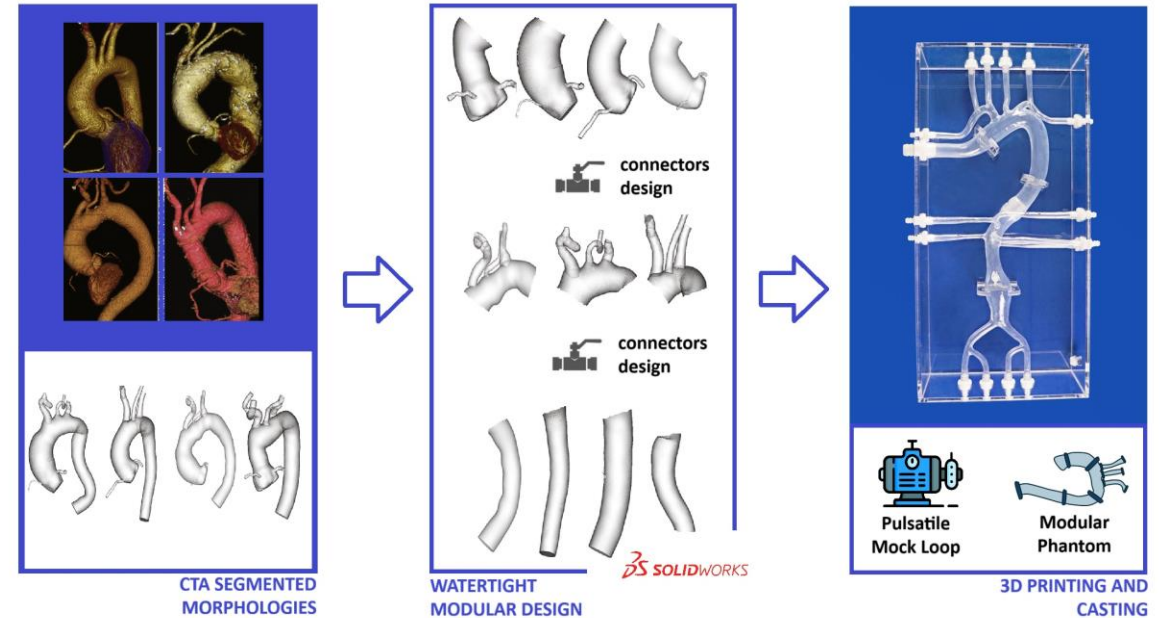
Design and fabrication of a modular and compliant phantom system that recreates diverse aortic morphologies and allows controlled simulation of standard TAVR/TEVAR procedures to map geometry to embolic burden

Embolic events are a major complication of TAVR and TEVAR. Aortic morphology or branching configuration have been hypothesized to influence risk, though evidence remains limited. Procedural planning requires morphometric descriptors, and existing in vitro studies are few, based on very simplified or single-case anatomies rather than systematic biological variability [1][2].

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Activities

- **Literature review** on tissue-mimicking materials and modular phantom design strategies.
- **Selection of representative aortic anatomies** (root, arch, branches, descending) covering a broad range of morphologies.
- **Conceptual design and CAD modeling** of modular phantom components, with attention to interchangeability, tightness and integration into the existing pulsatile loop.
- **Material selection, fabrication, and preliminary testing** of modules (mechanical fidelity, transparency, assembly robustness).
- **Initial validation experiments** within the loop (flow/pressure stability, imaging compatibility) to demonstrate feasibility.



Background:

- [1] Malone, F. et al. (2019) *J Biomech Eng.*
- [2] Ghovvati, M. et al. (2025) *Cardiovasc Eng Tech*

Collaborations:



I.R.C.C.S.
**POLICLINICO
SAN DONATO**

Contacts:

Emiliano Votta, Fabio Morelli, 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 the 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 mentor cannot guarantee to provide you with a proper review in due time