PhD thesis at LBMC

Experimental Investigation of Ascending Aortic Wall Rupture Properties to Characterize the Critical Pressure of Aortic Dissection

CONTEXT

This thesis is part of the ADRIS (Aortic Dissection Risk from Internal Structure) project, funded by the ANR and starting in 2025.

Aortic dissection is one of the most prevalent catastrophic cardiovascular events. **The ADRIS (Aortic Dissection Risk from Intramural Structure) project aims to predict the risk of type A aortic dissection in patients by analyzing both the intramural structure of the aorta and biomarkers from blood samples**. The project follows a four-step process: characterizing tissue rupture risk through mechanical testing of ex-vivo human tissue, understanding the role of micro-defects in the onset of dissection using synchrotron X-ray tomography, developing a multi-scale biomechanical model of the dissection process, and analyzing biomarkers to correlate with mechanical properties and defect density. This integrated approach will enable probabilistic prediction of dissection based on the structure and composition of the aortic wall.

By combining these experimental and computational findings, ADRIS aims to create a clinical scoring system that can predict aortic dissection using readily available medical data. The project will provide clinicians with a tool to better assess dissection risk, supporting decision-making for patient monitoring and treatment. Additionally, the ADRIS project will enhance the understanding of the biochemical and mechanical processes involved in aortic dissection, with the potential to advance medical imaging techniques and influence future technological developments in cardiovascular healthcare.

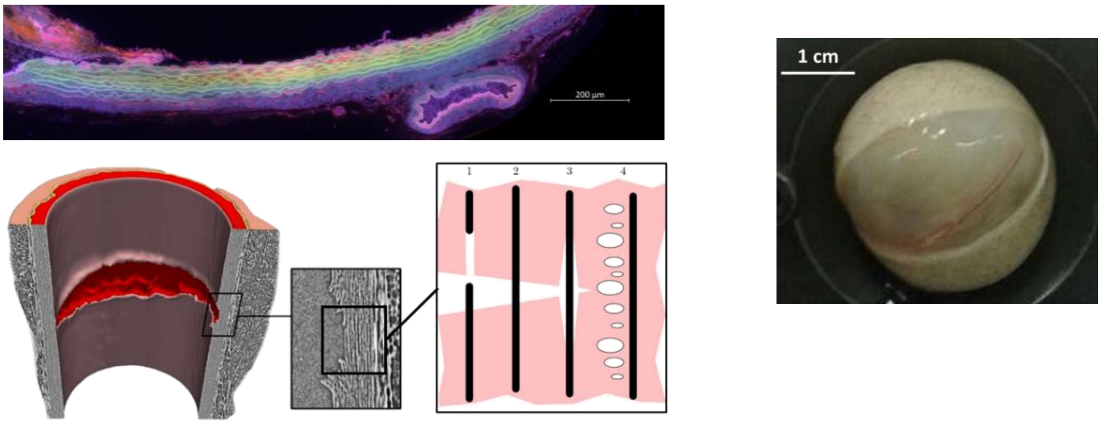
POSITION DESCRIPTION

We are seeking a candidate to perform the biomechanical evaluation of aortic tissue rupture properties associated to the quantification of the tissue microstructure, in particular the presence of micro-defects. The primary benefit of this project lies in the accessibility of fresh tissue from various patient groups. The challenges to overcome during this project are:

- To develop an experimental model for aortic dissection based on a bulge inflation test, reproducing in-vivo pulsatile tensions within the tissue and compatible with X-ray imaging;
- To perform an experimental campaign, including tensile, peeling and bulge inflation tests, on ascending aortic fresh specimens extracted from four patient groups;
- To evaluate the potential correlations between the rupture properties of the various groups and their microstructure quantified from histology and s-CT imaging.

You will be co-supervised by Dr. Aline Bel-Brunon (LBMC, Univ. Gustave Eiffel) and Dr. Baptiste Pierrat (SAINBIOSE, Mines St Etienne).

During this project, you will be in interaction with a consortium of researchers in biomechanics, biology, X-ray tomography as well as clinicians (cardiac and vascular surgeons).



Top left: Confocal microscopy image of a rat aorta (histology performed at Sainbiose), used to characterize local defects and collagen structure; bottom left: Micro-CT image of the aortic lamellar structure from Brunet et al., 2023) and a conceptual model illustrating how mechanical damage could be reproduced; right: Bulge inflation test from a previous study showing layer delamination before complete failure.

RESEARCH OBJECTIVES AND METHODOLOGY

The aim of this PhD project is to evaluate the correlations between tissue microstructure and critical pressure in order to deduce the risk of aortic dissection. To achieve this goal, several steps will be considered:

1. **Development of an experimental bulge-inflation set-up** that reproduces in vivo conditions (stresses and frequency) compatible with X-ray imaging;

2. **Experimental biomechanical campaign** on specimens from the four groups, including tensile, peeling and bulge-inflation tests;

3. **Bulge inflation campaign at ESRF** on 10 frozen-thawed samples from one group;

4. **Post-processing of experimental data** to extract identified mechanical properties and critical pressures.

5. **Quantification of tissue microstructure**, including micro-defects between lamellae, from histology and s-CT images.

6. **Investigate potential correlations** between tissue microstructure and mechanical/fracture properties.

This work will be carried out in close collaboration with a postdoctoral fellow dedicated to the modelling part of the project.

QUALIFICATIONS

Master’s or Engineering degree in mechanical engineering, biomedical engineering, or a related field.

A first experience in mechanical testing, and/or design of experimental devices or finite element analysis will be a major plus.

Proficiency in programming (e.g. Python, MATLAB) for data analysis.

Fluent communication in an international background and ability to work in an interdisciplinary team.

POSITION DETAILS

Duration and Location: **36 months** at LBMC (UMR_T9406 Univ Eiffel / Univ Lyon 1)

Expected start date is **September 2025**

APPLICATION PROCEDURE

Candidates are invited to submit the following documents:

- Detailed CV
- Cover letter highlighting relevant experience and motivation for the research project
- A reference letter from an academic or industrial professional (optional but recommended)

Applications should be sent to: Dr. Baptiste Pierrat (baptiste.pierrat@mines-stetienne.fr) and Dr. Aline Bel-Brunon (aline.bel-brunon@univ-eiffel.fr)

Deadline for application: **10 June 2025**

SAINBIOSE

The SAINBIOSE Unit (SAnté Ingénierie BIOlogie Saint-Etienne) combines researchers from Jean Monnet University, Mines St Etienne, the French Blood Establishment, and the Saint-Etienne University Hospital. Its research focuses on osteo-articular biology, soft tissue mechanobiology, and hemostasis-thrombosis. SAINBIOSE includes 48 permanent researchers and 37 technical staff, organized into two teams, and trains 58 PhD students. In the past five years, it has produced 100 publications annually, filed 6 patents, developed 3 software tools, and launched 2 startups. The "Soft Tissue Biomechanics" group, led by Prof. S. Avril, conducts numerical, clinical, and experimental studies on the mechanical behavior of biological tissues and their interaction with medical devices. The lab is equipped with experimental tools such as uni- and bi-axial tensile machines, optical field measurement systems, and microscopy devices. SAINBIOSE collaborates with a strong academic network and partners with companies such as Thuasne, Sigvaris, and Medtronic.

LBMC

The Laboratory of biomechanics and impact mechanics (LBMC, UMR_T9406) is a joint unit between the University Gustave Eiffel and the University Claude Bernard Lyon 1. The LBMC gathers more than 80 members (45 staff members, around 30 PhD students and 10 research assistants and post-docs), in addition 20 trainees are welcomed every year. LBMC members have complementary skills in impact biomechanics, structural mechanics, uncertainties, tissues biomechanics, anatomy and surgery, physical ergonomics, movement analysis, musculoskeletal biomechanics.

Based on societal challenges, the LBMC leads researches, on two themes:

- Facilitating travel (automated vehicles, autonomous travel)
- Maintaining good health (functional capacities, the repaired body: the implant in its environment).

It has unique experimental platforms :

- For movement analysis (e.g. instrumented treadmill, seat conformer, …),
- For impact characterization (e.g. high-speed loading testing machines, Split Hopkinson bars, …),
- For biological materials characterization (dedicated facilities, robot arm, …).

Among its flagship projects, the LBMC coordinated the european project PIPER (FP7), is abdomen center of expertise for the worldwide project GHBMC since 2008, coordinates the national project ENA (autonomous shuttle). The LBMC is involved in the Virtual Physiological Human Institute (VPH) and the BOHNES network. In 2019, the LBMC founded, with its partners from Canada (Québec), the associated international laboratory EVASYM (anatomo-functional evaluation of the musculoskeletal system).