Stage de master: Investigation of lumped parameter models associated with MRI for the study of ischemia-reperfusion impact.

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In collaboration with J. Ohayon (PU, équipe BiomécaMot, TIMC, Grenoble)

Context:

In the context of STEMI, early reperfusion (percutaneous coronary intervention, PCI) is currently the most effective treatment to reduce infarct size (IS) resulting from Myocardial Infarction (MI). Although reperfusion reduces IS, it causes additional myocardial damage by itself. This process is called ischemia-reperfusion (I/R) injury [Bochaton, et al., 2021]. There is therefore a clear need to identify biomarkers to stratify MI patients at high risk of poor cardiac recovery [Berezin and Berezin, 2020], [Aimo, et al., 2019]. Although the utility of left ventricular ejection fraction (LVEF) in risk prediction has been extensively reviewed, deformation imaging as a more appropriate approach for overall myocardial functional and risk assessment [Smiseth Otto, et al., 2025] (notably through the quantification of dissynchrony [Lumens, et al., 2012]) has not yet find its way into routine clinical imaging. Several other measurements from imaging (geometrical, tissular) have been investigated. For example, contrast-enhanced cardiovascular magnetic resonance (CMR) is a non-invasive technique that allows the accurate assessment of infarct size, edema, and areas with persistent microvascular obstruction (MVO) or intramyocardial hemorrhage (IMH). MVO and IMH was shown independent predictors of adverse LV remodeling and major adverse cardiovascular events (MACE) [Carrick, et al., 2016].

Approaches using computational models have also been considered. In a cardiac modeling study, the statistical analysis of STEMI patients revealed that the required patient-specific contractility, normalized active tension and the systolic myofilament kinematics have the strongest explanatory power for identifying the myocardial function changes post-MI [Gao, et al., 2017]. Rumindo et al. studied ranges of subject-specific in vivo myocardial stiffness and contractility from 21 healthy volunteers [Rumindo, et al., 2020]. In his PhD thesis, Rumindo also investigated the impact of lesions onto the myocardial biomechanical properties [Rumindo, 2019]. Such biomechanical-based approaches use imaging data for the personalization and make assumption about the myocardial tissue, notably the fiber organization within the heart, and the pressure conditions. The complexity of those approaches requires to solve for a huge number of parameters within a complex optimization with large memory and computing power.

An alternative to these extensive computational pipelines is reduced-order (0D/1D) models that focus on physiological function without the need of detailed anatomical models. For instance, the CircAdapt model enables simulation of blood pressures, volumes, and flows in heart and circulation on a beat-to-beat basis [Arts, et al., 2005], [van Osta, et al., 2025]. The model is composed of modules, such as heart chambers, valves, blood vessel tubes and peripheral microcirculations. CircAdapt was notably used to generate imaging-based Digital Twins (DTs) of patients with LV mechanical discoordination [Koopsen, et al., 2024].

Objective:

The objective of the project is to investigate the adaptability of lumped parameter models to STEMI patients studied in MRI and their potential utility to predict recovery following reperfusion. We will consider the parameters required to individualize the models to a patient. The approach introduced in [Seemann, et al., 2019] to estimate patient specific pressure-volume (PV) loops from MRI volumes and brachial pressure could be combined to lumped parameter models. Derived parameters from CMR (volumes, strains) and models (e.g stiffness) will be analyzed collectively in their ability to stratify MI patients.

Methodology:

- Bibliography study: MI and ischemia-reperfusion biomarkers
- Investigation of a lumped parameter model e.g. CircAdapt and the individualization process
- Practical application on available MRI data
- Evaluation of the subject-specific MRI-based PV loop method to be combined the lumped parameter model
- Analysis of output parameters with longitudinal data.

Profile:

- Knowledge in computer modeling, numerical analysis, image analysis
- Programming skills in MATLAB, Python, and possibly usage of a solver of the type Abacus/Ansys/Comsol

Practical Information :

- 6 months from February-March 2026, ~550€ / month, Doua-LyonTech site.
- Possibility of pursuing a doctoral degree, depending on fundings

Application:

Send CV, motivation letter, and academic results to: patrick.clarysse@creatis.insa-lyon.fr

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