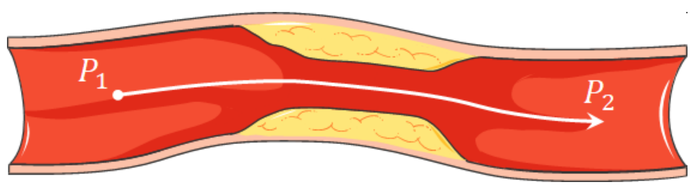
Ph.D. project, 2023 – 2026

Pressure Loss in Arterial Stenoses,
Measurement by Doppler Ultrasound and Artificial Intelligence

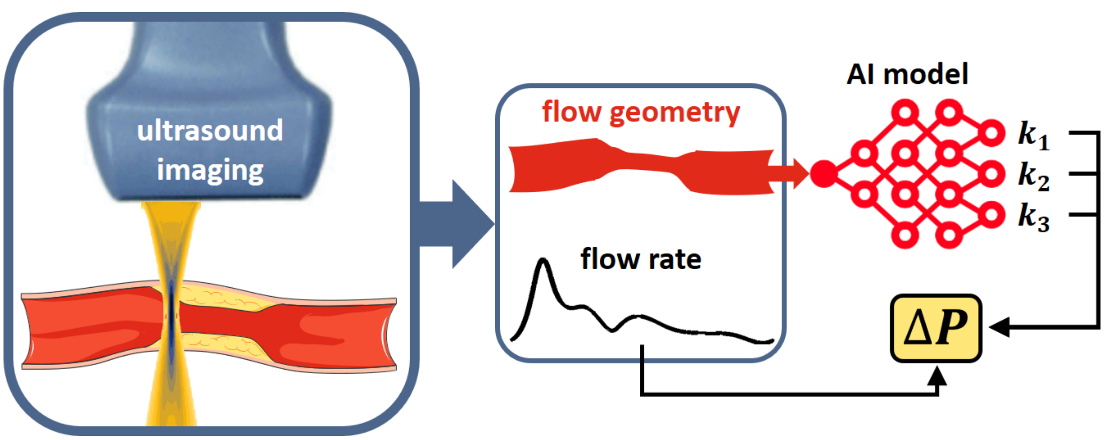
Clinical context: This Ph.D. project involves the evaluation of the severity of vascular narrowing (stenosis). The measurement of pressure loss ($\Delta P = P_2 - P_1$) associated with vascular stenosis is usually performed by catheterization, an invasive medical procedure consisting of inserting a thin tube into the bloodstream.

Objective: The objective will be to develop and experimentally validate a new non-invasive technique for the measurement of pressure loss in vascular stenoses. This technique will be based on ultrasound imaging and artificial intelligence and will meet the clinical requirements.



A stenosis (vascular narrowing) induces a pressure loss (ΔP).
We aim at estimating this pressure loss noninvasively by Doppler ultrasound and artificial intelligence.

Methodology: The pressure loss in vascular stenosis can be written as a function of the flow rate (Q) as follows: $\Delta P = k_1 Q + k_2 Q^2 + k_3 \partial Q / \partial t$ [1]. The parameters k_1, k_2, and k_3 are scalars that mostly depend upon vascular geometry. The goal will be to estimate these three parameters from the vascular geometry determined by ultrasound imaging. The estimator will be an artificial intelligence (AI)-based model.



The three parameters k_i will be estimated from an AI model whose inputs will be ultrasound-derived flow geometry and flow rate. The pressure loss ΔP will then be deduced.

The AI model will be trained from CFD (computational fluid dynamics) 2-D axisymmetric simulations. To this end, hundreds of stenosis geometries will be simulated with COMSOL using a k-ϵ turbulent regime. In this Ph.D. project, the student will first simulate blood flows in axisymmetric geometries to generate a large $\{stenotic\ geometry - \ k_i\}$ paired dataset. Once the AI model will be trained and validated with other CFD simulations, the Ph.D. student will perform *in vitro* experiments in stenotic flows. Geometries and flow rates will be measured with a clinical ultrasound machine. The pressure losses estimated from the AI model will be compared with those measured by pressure wires. Depending on the progress of the project, asymmetrical 3-D geometries will then be addressed.

[1] Young DF, Tsai FY. Flow characteristics in models of arterial stenoses—II. Unsteady flow. Journal of biomechanics. 1973 Sep 1;6(5):547-59.

Keywords:	computational fluid dynamics, machine/deep learning, ultrasound imaging, *in vitro* experiments
Expected skills:	fluid dynamics, programming in Python, knowledge of a machine/deep learning library, experimentation
Project duration:	3 years funded by “école doctorale MEGA”
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