UNIVERSITÀ DI TRENTO
Dipartimento di Matematica

DOTTORATO

CYCLE 36th
ORAL DEFENCE OF THE PHD THESIS

Wednesday 6 December 2023 – at 9.30 am

Department of Mathematics
Seminar Room 1
The event will take place in presence and online through the ZOOM platform.
To get the access codes please contact the secretary office

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PhD Student in Mathematics

Numerical methods for efficient blood flow simulations: application to coronary artery disease

Abstract:
The development of efficient mathematical models and numerical methods for the study of haemodynamics is becoming increasingly prominent in the analysis of pathological states of the cardiovascular system. Computational models contribute to medical diagnosis processes, reducing the need of classical invasive medical techniques, which are not risk-free for patients and generate high healthcare costs.
The first part of this thesis focuses on the modeling and simulation of coronary blood flow, with emphasis on stable Coronary Artery Disease (CAD), a pathological condition that occurs when an abnormal narrowing builds inside coronary vessel walls. Our goal is to develop a CCTA-based Fractional Flow Reserve (FFR) model which incorporates clinical imaging and patient-specific characteristics to predict the haemodynamic behavior and properties of individuals, reducing the need for invasive measurements. A novel aspect of the proposed methodology is the inclusion of the pressure guidewire, used in clinical settings, and the assessment of its impact on local fluid dynamics and FFR predictions.
Thereafter, the second part of this dissertation is devoted to the development of numerical methods for the simulation of incompressible flows with particular emphasis on the simulation of cardiovascular haemodynamics. A novel implicit hybrid finite volume/finite element methodology for the efficient simulation of blood flow is proposed and validated. The implicit discretization of the transport-diffusion equations making use of an inexact Newton-Krylov method with an SGS preconditioner yields to an efficient scheme avoiding the severe CFL condition arising in explicit or semi-implicit methods for blood flow dynamics. Besides, the Ducros flux function employed for the nonlinear convective terms leads to a provably kinetic energy stable scheme of the advection terms. In addition, a staggered semi-implicit method for the simulation of incompressible flows in one-dimensional elastic and viscoelastic vessels is proposed. The convective stage is treated explicitly in time, while the diffusive and pressure stage are handled implicitly to avoid strict bounds on the time steps. The one-dimensional methodology is then extended to networks of vessels by introducing a local three-dimensional representation of the junction.

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CONTATTI
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