

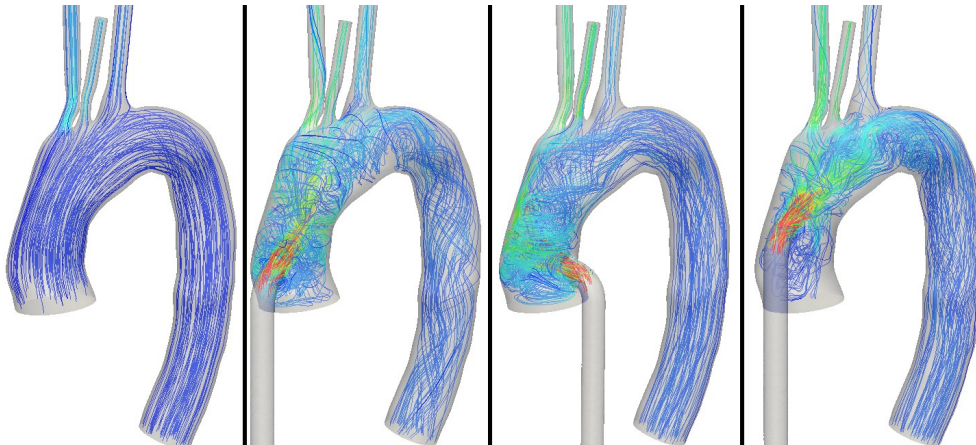


## Mathematical Modeling for the Circulatory System: Models, Equations, Applications

March – May 2017, Aula M – Ca' Vignal

### Lecturers

- A. Veneziani**, Emory University, Atlanta USA (mathematical and numerical modelling)  
**E. Toro**, Università' di Trento (mathematical and numerical modelling)  
**L. Antiga**, Orobix s.r.l., Bergamo (biomedical engineering)  
**L. Emili**, InSilico Trials LLC, Milano (biomedical engineering)  
**F. Auricchio**, Università degli Studi di Pavia (engineering)  
**Giuseppe K. Ricciardi**, Azienda Ospedaliera Univ. Integrata, Verona (clinician)  
**M. Marrocco-Trischitta**, IRCCS San Donato Milanese (clinician)



### Motivations

Numerical models have been recognized since decades to introduce a relevant added value to cardiovascular research, both for understanding physiopathology and for designing new devices and therapies. The predictive nature of mathematical models, solved by numerical tools on high performance computing architectures, opens significant and somehow revolutionary perspectives with a potential impact on clinical practice too. For instance, a surgical operation like the Left Ventricular Assisted Device (see the picture), consisting in an external graft added to the ascending aorta to replace the functionality of a malfunctioning valve, may be carried out in different ways (for the position of the anastomosis). Numerical tools may quantitatively assess the impact of the different options on the hemodynamics and eventually on the success of the surgery. This course intends to provide some fundamental concept of modeling the circulation, covering: the introduction of equations and initial/value problems relevant to the description of dynamics of interest; the methodological aspects for their numerical solution. Also, the course will cover lectures from an expert of medical image processing, a key step for the patient-specific modeling. Finally, lectures will be offered by biomedical engineers and clinicians who will provide the “end-user” perspective of numerical modeling for cardiovascular diseases, including new entrepreneurial opportunities coming from cloud computing and computer aided clinical trials.



## Schedule

### A. Veneziani (math)

**March 6<sup>th</sup>** (16.30-19.30 aula M) Introduction to the Cardiovascular System, Motivations, Blood as a fluid, Rheology, Flow regimes, Structure, Numerical Modeling of Fluid-Structure Interaction

**March 7<sup>th</sup>** (8.30-11.30 aula M) Numerical Modeling of Blood Flow – Numerical simulation of incompressible fluids with finite elements, Time advancing methods (projection and segregation schemes), Treatment of Defective Boundary Conditions

**March 9<sup>th</sup>** (8.30-10.30 aula M) An Introduction to Data Assimilation in Cardiovascular Modeling. Recall of stochastic filtering techniques (Kalman filtering). Variational Data Assimilation techniques. Showcases in fluid dynamics and electrocardiology.

**March 9<sup>th</sup>:** (10.30-13.30 Lab. Alfa) Hands On session in Computer Lab with FreeFem++

### L. Antiga (bioeng)

**March 31<sup>st</sup>:** Vascular Modeling ToolKit: a tool for patient specific image processing, geometrical modeling, meshing and computations.

### G.K. Ricciardi (clinician)

**April 7<sup>th</sup>:** Neuro-cardiovascular data assimilation from Magnetic Resonance

### F. Auricchio (bioeng)

**April 21<sup>st</sup>** – An advanced example of computer aided clinical trial: the iCardioCloud Project

### M. Marrocco-Trischitta (clinician)

**May 15<sup>th</sup>** – Geometrical classification of aortic arches and its impact in clinics

### E. Toro (math)

**May 22<sup>nd</sup>:** Reduced models for the Cardiovascular System, 1D models, 0D models

**May 23<sup>rd</sup>:** Geometrical Multiscale Modeling of the Circulation – coupling of 1D-0D models, 3D-1D models

### L. Emili (entrepreneur)

**May 25<sup>th</sup>:** Software infrastructures for *in silico* Clinical Trials

**Textbook:** L. Formaggia, A. Quarteroni, A. Veneziani, Cardiovascular Mathematics, Springer 2009

**Course material:** Additional notes will be indicated by the lecturers.

**Grading:** Students will have the option to do a small project/research with a final report or to work on a paper selected by the instructors and do an oral presentation in May-June 2017.