From simulations to assimilations: challenges and perspectives of bringing cardiovascular mathematics to the bedside

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Mathematical and numerical modeling of cardiovascular problems has experienced a terrific progress in the last years, evolving into a unique tool for patient-specific analysis. In silico models are acknowledged to be not only complementary but also sometimes more reliable than animal models in representing specific pathologies. However, the extensive introduction of numerical procedures as a part of an established clinical routine and more in general of a consolidated support to the decision making process of physicians still requires some steps both in terms of infrastructures (to bring computational tools to the operating room or to the bedside) and methods. In particular, the quality of the numerical results needs to be carefully assessed and certified. In this scenario, an important research line quite established in other fields is the integration of numerical simulations and measurements in what is usually called Data Assimilation. A rigorous merging of available data (images, measures) and mathematical models is expected to reduce the uncertainty intrinsic in mathematical models featuring parameters that would require a patient-specific quantification; and to improve the overall quality of information provided by measures. However, computational costs of assimilation procedures - and in particular variational approaches - may be quite high, as typically we need to solve inverse problems, dual and possibly backward-in-time equations. For this reason, appropriate model reduction techniques are required, to fit assimilation procedures within the timelines and the size of patient cohorts usually needed by medical doctors. In this talk, we will consider some applications of variational data assimilation in vascular and cardiac problems and associated model reduction techniques currently investigated to bring operatively numerical simulations into the clinical routine. Work in collaboration with D. Giddens (GA Tech), W.R. Taylor (Emory), H. Samady (Emory).