

Highlights

From the Clinic to Partial Differential Equations and Back: Emerging Challenges for Cardiovascular Mathematics

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In recent years, there have been great advances in mathematical and computational modeling of cardiovascular phenomena. The ultimate goal has been to develop predictive mathematical tools that can be used in medical decision-making and treatment. There have been notable successes in some areas: for example, extensive numerical simulation is used in some hospitals to plan pediatric heart surgery. However, further progress is needed for the use of mathematics-based clinical methods to become widespread and routine. Additional advances will require close communication and collaboration between mathematical scientists and physiologists in order to guide further developments most effectively.

To foster such interactions, the ICERM workshop “From the Clinic to Partial Differential Equations and Back: Emerging Challenges for Cardiovascular Mathematics” was held January 20-24, 2014, to bring together physicians, mathematicians, engineers and computer scientists to address modeling challenges in cardiovascular medicine. The workshop organizers represented a broad range of research communities, including industry, medical clinics, and government laboratories as well as university departments of engineering, computer science, and mathematics. Researchers from 10 countries (USA, Brazil, Spain, Italy, Switzerland, India, Sweden, France, UK, and Canada) representing over 40 research institutions participated in the workshop. The diverse backgrounds of the participants and their multi-disciplinary views of biomedical modeling contributed to the workshop’s unique “flavor.”

The main goals of the workshop were to review current trends and challenges in cardiovascular research and to promote discussion and collaboration among researchers with varying backgrounds. These goals were achieved through invited talks, tutorials, a speed-networking session, a poster session, and ample discussion time provided both after each talk and in a “wrap-up” discussion session at the end of each day. A reception at the end of the second day provided an opportunity for informal mixing.

The mix of distinct but related disciplines was fundamental both to enriching the range of expertise among the participants and to looking at challenging problems from different perspectives. For many participants, this workshop offered a unique opportunity to meet with experts in fields different from their own. Clinicians described medical problems in cardiovascular physiology, stimulating discussions and posing challenges for the mathematics community. Issues that they raised included aneurysm formation, vascular inflammation, cardiac resynchronization

therapy, coronary plaque progression, and decision-making in neuroradiology. Those more on the mathematical side presented work on cardiovascular applications that included multi-scale dynamics, fluid-structure interaction, shape and parameter optimization, model order reduction, data assimilation, uncertainty quantification, sensitivity analysis, and simulations on massively parallel computers.

Nearly all participants reported that they made new scientific connections during the workshop. Paolo Zunino, of the Department of Mechanical Engineering and Materials Science at the University of Pittsburgh, reported that several new collaborations fostered by the workshop have already had “significant impact” on his work. He mentioned in particular a new collaboration with Dexter Liu, head of Pharmaceutical and Biomedical Sciences at the University of Georgia College of Pharmacy, that is aimed at developing computational models to study hydrodynamic gene delivery to the liver, which can potentially be applied to cure important genetic diseases. Following the workshop, Zunino was invited to give a seminar on computational models for blood flow and mass transport in microcirculation at Emory University, where further exchanges with Dr. Liu took place, and the two of them have formulated a preliminary joint research plan.

Participants especially appreciated the mix of disciplines represented at the workshop, the excellent quality of the talks, the tutorial sessions, and the open discussion periods at the end of each day. Julie Philippi, an assistant professor in the Department of Cardiothoracic Surgery at the University of Pittsburgh, felt that “the single most important outcome for me was the opportunity to practice the languages of mathematics, computational modeling, and biomechanics with new colleagues,” adding that this was particularly timely for her as a junior faculty member. She viewed the tutorial sessions as “absolutely critical for interdisciplinary collaborations” and has integrated this format into interdisciplinary meetings at her home institution.

At the conclusion of the workshop, participants overwhelmingly expressed interest in having a “reunion” workshop in the not-too-distant future that will preserve the multi-disciplinary nature of this one.

For more information about the workshop participants, talks, and posters, see <http://icerm.brown.edu/tw14-1-pdecn>.

**Multiscale Problem:
From $O(10\text{cm})$ to $O(1\text{nm})$**

