ME Seminar

Computational and Experimental Biomechanics: From Patient-Specific Modeling to Medical Device Development

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ABSTRACT

Understanding blood flow and its interaction with vascular structures is essential for investigating cardiovascular diseases and improving the design of medical devices. This requires an accurate representation of patient-specific anatomy, blood rheology, physiological loading, and the mechanical response of biological tissues. In this talk, I will present my research on cardiovascular and neurovascular mechanics, beginning with medical image-based anatomical reconstruction and computational studies of blood flow in patient-specific vascular geometries. Emphasis will be placed on the influence of non-Newtonian blood rheology on local hemodynamics, including velocity distribution, wall shear stress, flow separation, and recirculation in diseased arteries. I will discuss the application of computational fluid dynamics (CFD) and finite element analysis (FEA) to investigate aneurysms, stenosis, thrombosis, and blood damage in mechanical circulatory support systems. Building on these studies, I will present the application of mechanical engineering principles to the design and development of cardiovascular and endovascular devices, including catheters and blood-contacting systems. Selected examples will demonstrate the integration of numerical simulations, computer-aided design, additive manufacturing, and experimental techniques to evaluate flow characteristics, structural performance, and device-vessel interactions. Particular attention will be given to verification, experimental validation, and the translation of engineering requirements into functional prototypes.

Finally, I will discuss future research directions involving the integration of patient-specific anatomy, blood flow, tissue mechanics, and experimental measurements to develop validated digital twins for disease assessment, device optimization, and treatment planning. The broader objective is to advance computational and experimental approaches that support the development of reliable, affordable, and minimally invasive medical technologies

ABOUT THE SPEAKER

Dr. Sumit Kumar is a researcher specializing in computational biomechanics, cardiovascular fluid mechanics, medical device design, and patient-specific digital twins, including their verification and validation. He is currently a Research Associate in the Department of Biomechanics at the University of Nebraska Omaha, USA. Previously, he held postdoctoral research fellow positions at Harvard Medical School/Brigham and Women's Hospital, Boston, USA and Pennsylvania State University USA. He earned his Ph.D. in Biomedical Engineering from IIT (BHU) Varanasi. His research combines computer-aided design (CAD), computational fluid dynamics (CFD), finite element analysis (FEA), medical image-based 3D reconstruction, additive manufacturing, and experimental testing to study cardiovascular and neurovascular systems and develop medical devices. His work focuses on cardiovascular and neurovascular diseases (aneurysm, stroke, thrombosis, hemolysis & stenosis), patient-specific modeling, endovascular devices, catheter design & development, testing and validation.

Dr. Kumar has published his research in scientific journals and conferences and contributed to four patent applications, including two in the United States and two in India. He is working on Industry & Academia collaborative research grant for cerebral nerve stimulation project from Harvard & MIT Boston. He also worked as a co-founder of Acupace Technologies, a startup focused on developing engineering-based healthcare and disinfection technologies, where he gained experience in product design, prototyping, manufacturing, testing, regulations, and commercialization.



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