ADVANCED MULTI-MODAL ANALYSIS OF HEMODYNAMICS AND WALL MECHANICS IN HUMAN ARTERIES

Krzysztof Wojtas[1], Krzysztof Truchel[1], Radosław Rzepliński[2], Mikołaj Sługocki[2], Iwona Łopianiak[1], Beata Butruk-Raszeja[1], Krystian Jędrzejczak[1], Wojciech Orciuch[1], Paweł Gierycz[1], Paweł Krajewski[3], Arkadiusz Antonowicz[4], Tomasz Rusin[5], Piotr Piasecki[6], Bogdan Ciszek[2], Łukasz Makowski[1]

[1]Faculty of Chemical and Process Engineering, Warsaw University of Technology, Warsaw, Poland
[2]Department of Descriptive and Clinical Anatomy, Medical University of Warsaw, Warsaw, Poland
[3]Department of Forensic Medicine, Medical University of Warsaw, Warsaw, Poland
[4]Eurotek International Sp. z o.o., Skrzetuskiego 6, Warsaw, Poland
[5]Dantec Dynamics GmbH, Lessingstr. 10, Neu-Ulm, Germany
[6]Interventional Radiology Department, Military Institute of Medicine-National Research Institute, Szaserów 128, Warsaw, Poland

An understanding of arterial mechanics and hemodynamics is fundamental for predicting disease progression, optimizing endovascular interventions, and guiding patient-specific treatment. Modern advances in 3D printing, optical diagnostics, and flow visualization highlight that accurate representation of both vessel elasticity and local hemodynamic structures is essential for validating computational tools and interpreting complex cardiovascular pathologies [1]. This motivates the integration of different techniques, such as tensile testing [2], non-invasive laser measurements (PIV) [3], and CFD modeling of blood flow [4], to achieve a comprehensive description of arterial behavior. In this study, we combine experimental and computational approaches to characterize human arterial flow and deformation. Our experiments included particle image velocimetry (PIV) together with digital image correlation (DIC), enabling simultaneous quantification of velocity fields and wall displacement under pulsatile conditions. Although previous works demonstrated PIV in transparent or rigid vascular phantoms and provided CFD validation using micro-PIV [3,5], the integration of PIV with DIC on fully elastic, patient-specific arterial phantoms has not yet been reported. This novel combination captures fluid–structure interactions directly and yields validation data unattainable with rigid models. Results reveal differences in flow topology and deformation patterns between elastic phantoms and commonly used stiff 3D-printed geometries, showing the critical role of wall compliance in realistic hemodynamic representation. By merging various measurement techniques, this work outlines a framework for more accurate cardiovascular modeling. The demonstrated methodology supports the development of reliable patient-specific simulations and improved design of medical devices.

Research was funded by Warsaw Medical University and Warsaw University of Technology within the Collaboration Initiative Programme. The study protocol was approved by the Ethics Committee of the Medical University of Warsaw (number 194/2024) and Military Institute of Medicine-National Research Institute (number 34/WIM/2020).

References

1. doi:10.1515/psr-2024-0061
2. doi:10.3389/fbioe.2025.1554674
3. doi:10.3390/ma16031055
4. doi:10.3390/ma14237354
5. doi:10.3390/jcm13175115