frontiers in Physics

EDITORIAL
published: 19 January 2021
doi: 10.3389/fphy.2020.626302

Editorial: Cardiovascular Physiology and Medical Assessments: Physics and Engineering Perspectives

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Keywords: hemodynamics, physics and engineering perspectives, cardiovascular physiology, medical assessments, blood flow analysis

Editorial on the Research Topic

Cardiovascular Physiology and Medical Assessments: Physics and Engineering Perspectives

Physics and Engineering perspective plays an important role in cardiovascular physiology and medical assessments. It utilizes the theory of physics and engineering to carry out physiological analysis, detect physiological dysfunction, diagnose disease, and guide remedial surgery. The medical physics and engineering field has enabled a more in depth understanding of cardiovascular physiology.

Let us start with 'Neural Regulation of Cardiac function,' which is carried out by the sympathetic and parasympathetic divisions of the autonomic nervous system. The sympathetic nerves to the heart are facilitatory, whereas the parasympathetic nerves are inhibitory; in certain regions of the heart, such as the ventricular myocardium, the effects of the sympathetic division are more dominant. The mechanisms of neural regulation of the heart can be investigated into, extending from regulation of heart rate in regular activity and heart rate variability in athletic manoeuvres, to reperfusion of the ischemic myocardial tissue.

Then in 'Bioelectrical Process in the Heart' the electrical activity is initiated in the SA node, and the impulse spreads throughout the atria via specialized internodal pathways, to the atrial myocardial contractile cells and the atrioventricular node. From the AV node, the electrical impulse spreads through the bundle of His, bundle branches, and Purkinje fibres to myocardial contractile cells in the ventricles, causing ventricular contractility for initiating left ventricular ejection. This bioelectrical activity is characterized by electrocardiography (ECG), and its signal processing enables cardiac diagnostics.

Now let us discuss 'Cardiac Perfusion.' For computing intra-myocardial blood flow velocity and pressure patterns, we can carry out myocardial perfusion SPECT imaging, prescribe the myocardial conductivity, and then do intra-myocardial flow analysis to determine the blood pressure and velocity distributions in myocardial segments. In this way, we can quantify decreased blood flow in the ischemic areas of the myocardium, which can lead to decreased ventricular contractility.

Finally, let us enter the left ventricle. Therein, 'assessment of subjects at risk of heart failure' is carried out by means of the governing equations of fluid flow, by which we can determine the flow patterns of velocity and pressure distribution in the left ventricle (LV), and thereby show how if adequate pressure is generated to open the aortic valve. For this purpose, we can use the vector flow mapping technique to generate flow velocity vector fields, by post-processing the colour doppler echo images. This information is then transferred to monitors in real time, in order to visualize abnormal flow patterns and to guide cardiologists in their diagnosis [1].

Edited and reviewed by:
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Specialty section:
This article was submitted to Medical Physics and Imaging, a section of the journal Frontiers in Physics

Received: 05 November 2020
Accepted: 27 November 2020
Published: 19 January 2021

Citation:
Wong KKL, Ghista D and Fortino G (2021) Editorial: Cardiovascular Physiology and Medical Assessments: Physics and Engineering Perspectives. Front. Phys. 8:626302. doi: 10.3389/fphy.2020.626302

This special issue focuses on how breakthroughs in physics and engineering have helped us to advance the understanding of cardiovascular physiology, and to make it more quantitative for the purpose of medical assessment [2]. Herein, we are providing a quantitative format of cardiovascular physiology and its medical assessment, based on physics and engineering perspective. This issue has four research articles, and we will now present the features of the papers.

In the first paper, 'Carotid Stiffness Assessment with Ultrafast Ultrasound Imaging in Case of Bicuspid Aortic Valve,' Goudot et al. have focused on the carotid stiffness assessment in the case of bicuspid aortic valve (BAV) by using ultrafast ultrasound imaging. Ultrasound imaging is the perfect follow-up implement for BAV patients, because of its radiation free technology, and its cost-effectiveness. Ultrafast ultrasound imaging (UF) permits show of the fit tissue movement at high time-related resolution, by utilizing plane wave transmitted with different tendency and a testing rate over 1,000 frames/s [3]. Then, Ultrafast Doppler acquired by processed data precisely evaluate the tissue velocities [4]. In this paper, they have compared the carotid flow parameters and carotid stiffness based on UF, in BAV patients and healthy subjects. Meanwhile, the deformation of the carotid arterial breadth during the cardiac cycle was described by UF-Doppler imaging. They measured the arterial distensibility, the maximal rate of systolic distension (MRSD), and wall shear stress (WSS). The computation of WSS was based on analysing the blood flow velocities near the carotid walls. A key point of the arterial wall remodelling is hemodynamic assessment of blood flow [5]. The absence of WSS alteration in the BAV patients could also clarify the lack of stiffness variation of the carotid wall. The specific morphology of the BAV could lead to the WSS modifications in the ascending aorta, with increased possibility of degenerative lesions observed in the aortic wall [6]. Compared with healthy subjects, it is remarkable that the carotid flow parameters and carotid stiffness are not changed in the case of BAV.

In recent years, many investigations have combined separate sensor sorts for pulse wave acquisition, such as pulse wave from the left forefinger, wrist, and second toe arteries. Although all these devices can detect and record arterial pulse waves, their operating modes and sensitivities are different, resulting in different shapes and timings of the pulse waves, leading to changes in diagnostic efficiency [7]. In the second paper, 'Quantitative Comparison of the Performance of Piezoresistive, Piezoelectric, Acceleration, and Optical Pulse Wave Sensors,' Wang et al. have compared and analyzed the radial, carotid, arterial femoral and digital signals under a series of conditions (three levels of contact force: light, medium, and heavy) and they used various pulse sensors to help make wise choices of the appropriate type sensor signals for recording arterial pulse waves. From the existing sensor types, they chose four: a piezoresistive strain gauge sensor (PESG) and a piezoelectric Millar tonometer (the first mentioned of two has the ability to scale contact force), a rounded diaphragm acceleration sensor, and an light reflection sensor. Thse four sensors were used to record the pulse wave signals of the left radial artery, carotid artery, femoral artery and digital artery of 60 subjects. In their studies, they found that the impact of contact pressure, measurement location, and ambient light on the pulse wave should be taken into account when monitoring the patients. Secondly, by comparing the four pulse wave sensors, it is found that the performance of the tonometer is the best, followed by the accelerometer, followed by PESG, and the optical sensor being the worst. Finally, there was significant difference among the four sensors in their waveform shapes and the timing of the arterial pulse wave and amplitude parameters. So in practice, different sensor types could be used, perhaps in combination according to the measurement site and the nature of the required signal analysis and in this way, the advantages of each can be better utilized.

The third paper is 'Topologic and Hemodynamic Characteristics of the Human Coronary Arterial Circulation,' authored by Schwarz et al. A fitting perception of the complex interplay of various factors contributing to coronary arterial flow needs a quantitative method based on the characteristics of the coronary network. Therefore, the purpose of their work is aimed at contributing a comprehensive quantification of the partial feature of the human coronary circulation. They employed a high-resolution imaging cryomicrotome to alternately cut and block-face the imaged frozen heart for 3D reconstruction of the left coronary circulation, and then analysed the flow in geometric topological, and topographic properties. Their model describes the flow at bifurcations of the vessel diameter. They have presented a method that dealt with the wide range of data on the partial features, to comopute the hemodynamics. Their findings set the stage for further research, containing structural conversion, integration of vasomotor responsiveness, and their effects on the supply to the left ventricle for its health maintenance.

The incidence of aortic dissection markedly increases with atherosclerosis and hypertension [8]. D-dimer, a specific degradation product of cross-linked fibrin, represents the coagulation and fibrinolytic system activation [9]. It is now commonly used in the diagnosis of pulmonary embolism [10], deep vein thrombosis [11], acute coronary syndrome [12], and acute aortic dissection [9,13,14]. The fourth paper, 'Association Between D-dimer and Early Adverse Events in Patients With Acute Type A Aortic Dissection Undergoing Arch Replacement and the Frozen Elephant Trunk Implantation: A Retrospective Cohort Study,' authored by Liu et al. is aimed to investigate the association between D-dimer levels and 90-day postoperative adverse events in patients undergoing arch replacement and frozen elephant trunk (FET), by using a multivariate Cox regression model containing all known associated major perioperative predictors. They have retrospectively analyzed the data of patients with acute type A aortic dissection undergoing aortic arch surgery and FET, from July 2017 to December 2018 at Beijing Anzhen Hospital. The D-dimer levels were evaluated within 24 h of admission. A total of 347 patients were included in the study. The median D-dimer level was 1.95 μg/ml (interquartile range, 0.77–3.16 μg/ml). The multivariable Cox regression analysis revealed that D-dimer level was independently associated with 90-day postoperative adverse events, after adjustment for confounding factors (hazard ratio = 1.19 per 10 μg/ml increase in D-dimer, 95% confidence interval: 1.01–1.41; P = 0.039). The Kaplan–Meier analysis revealed that the highest tertile (median 6.27 μg/ml) had more 90-day postoperative adverse events, compared with the median and lowest tertiles (P = 0.0014). Their results showed that increased D-dimer levels at admission were associated with 90-day postoperative adverse events in patients with type A aortic dissection undergoing arch surgery with FET. This indicates that such high-risk patients deserve close medical monitoring.

In summary, these four interesting papers have focused on current state-of-the-art advances in physics and engineering perspective in cardiovascular physiology and medical assessment. Their results provide readers with valuable information on the application of the theory of physics and engineering in cardiovascular physiology and medical assessments. We hope that this special issue will provide a platform for researchers and clinical physicians to collaborate on some research areas with the aim of promoting a more scientific medical study of cardiovascular physiology.

AUTHOR CONTRIBUTIONS

KW collection, organizing, and review of the literature; DG and GF preparing the manuscript, and manuscript review and modification.

FUNDING

This work was funded by National Natural Science Foundation of China (Grant No. 81771927).

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.