Cardiovascular diseases are one of the most common causes of death in the world and in Poland, where they account for over two hundred thousand deaths a year. The predominant cause of mortality is myocardial ischemia. Atherosclerotic plaque reduces the patency of the vessel, leading to blood flow disorders, which contribute to a reduction in the number of nutrients supplied to the heart muscle and its inadequate nutrition. The patient experiences such a condition as a severe, choking pain in the chest that worsens i.a. at physical exertion. In the course of the disease, the plaque may also rupture and rapidly occlude a coronary artery, leading to myocardial infarction.

The standard management of coronary artery lesions involves pharmacotherapy, however, in some patients, invasive coronary angiography and coronary angioplasty, namely percutaneous coronary intervention (PCI), are also needed. PCI is the procedure allowing for the dilation of a narrowed or occluded coronary artery. Coronary angiography and PCI are performed under local anesthesia with the puncture of the radial, femoral, or brachial arteries. A special guidewire is introduced through the puncture, enabling the doctor to place a dedicated catheter with a balloon at the site of the stenosed coronary artery. Its inflation causes the dilation of the artery, and the effect achieved in this way is preserved by implanting a vascular prosthesis called a stent. Coronary angiography can be extended by performing a test based on the properties of near-infrared light called optical coherence tomography, which allows precise recognition of the atherosclerotic plaque structure with an extremely high imaging resolution down to the order of the size of a red blood cell.

Continuous blood flow in coronary arteries is not indifferent to the vessels' walls nor to the blood elements, especially platelets, which, according to preliminary research and laboratory experiments, may be activated due to the biomechanical forces acting on them. Activated platelets, have a greater capacity for aggregation, i.e. sticking together, which in turn can lead to occlusion of the artery and development of myocardial infarction. Recent studies revealed the possibility of estimating the magnitude of the biomechanical forces exerted by the circulating blood on the vessel based on coronary angiography alone, which is used to create three-dimensional models of the imaged coronary arteries, and then to estimate blood flow parameters using computational fluid dynamics modeling techniques. This allows checking to what extent the stenosis visible in the image actually has an adverse effect on the myocardium of the examined patient, and also enables the assessment of the magnitude of biochemical forces exaggerated by the circulating blood on the vessel.

However, the relationship between the forces acting on the vessel and the procoagulant blood parameters in the human coronary artery has not been evaluated yet. There is also little data evaluating the relationship between the biomechanical forces estimated in this way and the structure of the atherosclerotic plaque contributing to the stenosis. So far, it is known that the composition of the atherosclerotic plaque is directly related to the risk of its rupture or erosion. Understanding the relationship between plaque morphology, the degree of platelet activity, and the quantified forces exaggerated on the vessel will allow for a better understanding of the processes affecting plaque rupture and erosion leading to myocardial infarction.

In our project, we want to calculate the forces caused by blood flow using computational fluid dynamics modeling techniques and perform biochemical tests that will help us assess the degree of platelet activity and its relationship with the structure of atherosclerotic plaque. The aim of the project is to assess the correlation between the composition of atherosclerotic plaque, the concentration of biomarkers of platelet activation and plaque instability, and the shear forces exaggerated by the circulating blood on the artery wall. Due to the analysis of the above-mentioned factors and the results of imaging and laboratory tests, we will contribute to a better understanding of the processes occurring in narrowed coronary vessels that may cause a myocardial infarction in the future. The target outcome of the project will be the first such comprehensive work focused on the understanding of the molecular and biomechanical mechanisms associated with atherosclerotic plaque and platelets' activation within the stenosed coronary artery, using multimodality imaging and computational dynamics techniques. The obtained results will be important for the implementation of further - both laboratory and clinical - research aimed at improving the diagnosis and treatment of patients with coronary lesions in order to prevent cardiovascular events. We expect that the assembled data may contribute to the development of models for the prediction of thrombotic events based on coronary blood flow analyses as well as to future studies on potential shear-specific antiplatelet and antithrombotic therapies.