The stiffening of vasculature is primarily a result of aging, during which the large elastic arteries undergo diameter expansion, thickening of the arterial wall. Within the wall, an increased deposition of the structural protein known as collagen and the highly elastic protein fibers termed elastin combined with its fragmentation and degeneration are observed. Stiffening of the arteries are also a results of coronary artery diseases, systolic hypertension, stroke, atrial fibrillation, and many other conditions.

The assessment of the stiffness of the arterial system is a valuable diagnostics index used also for the prediction of cardiovascular morbidity and mortality.

The arterial system is responsible for delivering oxygenated blood to capillaries and thereby to all tissues. Though the pressure generated by the heart differs substantially within the cycle, the capillaries receive nearly a steady flow of blood during systole and diastole. It is the elasticity of the arteries that buffers the pulsatility of the flow and pressure shielding the small vascular beds from the destruction by the sharp pressure gradients.

This feature is a result of the anatomy of the arterial system that consists of two groups of vessels:

- large elastic (aorta, iliac, carotid) whose distortion allows them to store blood during systole and expel it to the periphery during diastole

- muscular arteries (femoral, tibial, brachial, coronary) which change their tone as a result of a contraction of the smooth muscle layers. The function of these muscles is to stabilize the flow by constriction or dilation.

The different elastic behavior of these two groups influences the propagation of the pressure wave generated by the heart and contributes substantially to the reflected component thereof. During systole, the pressure wave travels forward (distally) with relatively low velocity. When entering the muscular arteries, the wave propagates forward with larger velocity but a reflected wave is also generated. This wave travels backward (towards the heart). Both forward and backward waves interact. For healthy young subjects, the reflected wave returns to the aorta in late systole and early diastole, enhancing the coronary flow. Aging and some diseases result in an enhanced stiffness of the vasculature. The result is an increased pressure wave velocity and the shift of the time of arrival of the reflected wave towards systole peak increasing the systole pressure.

The existing methods of measuring the stiffness of the artery system rely on the measurement of the velocity at which the pressure wave travels along the vasculature and produce the global values of the stiffness averaged over a large portion of the vasculature.

Some cardiovascular diseases may locally change the stiffness of the arteries which can at different sites respond differently to aging, hypertension, and pregnancy. Thus, methods of noninvasive evaluation of the local stiffness are often of interest in the diagnostics of the arterial system. The project seeks to retrieve noninvasively the local stiffness of the walls of the blood vessels. In the first step, the problem is investigated on a test rig (phantom). The applied method relies on the development of a model of blood flow in the artery whose wall may be deformed as a consequence of the mechanical load coming from the blood. Parallel to this, the deformation of an artificial blood vessel will be measured using an ultrasound scanner. The difference between the numerically simulated deformation of the vessel and its measured counterpart will be minimized by iteratively modifying the stiffness of the walls of the artificial artery used in the numerical model. The result of this procedure will be the stiffness of the wall defined by a material property known as the Young modulus.

The reliability of the computational model will be investigated using a technique known as uncertainty quantification and sensitivity analysis yielding the error margins of the obtained results. This will give an insight not only to the accuracy of the model but also on the impact of uncertainty of input parameters on the results.

The final step of the project will be the medical experiment where the deformation of the carotid (neck) artery under the cyclic pressure load generated by the heart beat will be traced using the USG scanner. From this deformation the stiffness of the artery will be retrieved by minimization of the difference between the measured and simulated results.

The project will be executed in a consortium consisting of the Silesian University of Technology, Norwegian University of Science and Technology (NTNU) and Gliwice Municipal Town Hospital 4.