

Description for the general public

Each of us has heard about hypertension. It is one of the most popular diseases of affluence and it is relatively easy to detect by repeating the pressure measurement over a few days with the use of a simple device. This examination can be performed by the patients themselves or with the help of a doctor. It turns out, that there are also other types of high blood pressure diseases that are more challenging to detect. An example is pulmonary hypertension, a dangerous disease characterized by increased pressure in the pulmonary artery, affecting approximately 1% of adults.

The pulmonary artery is an important part of the pulmonary circuit that transports blood from the heart to the lungs and back to saturate our blood with oxygen. With this artery, non-oxygenated blood (not only veins carry such blood!) leaves the heart on a short journey to our gas exchange organs. When the pressure in the pulmonary artery is dangerously high (mean pulmonary artery pressure - mPAP - greater than 20 mmHg), pulmonary hypertension is diagnosed and the patient is at risk of serious complications, including death. There are many causes of pulmonary hypertension, and some of them remain unknown. Therefore, it is difficult to diagnose this disease without taking a blood pressure measurement. This task is much more difficult than with the commonly known method of determining blood pressure. The standard for measuring pressure in the pulmonary artery is an invasive method of cardiac catheterization, which consists of inserting a tool into the heart chamber that enables appropriate tests to be performed. Due to its invasive nature, cardiac catheterization carries a risk of complications. The question then arises: is it possible to diagnose pulmonary hypertension without risking the patient's health and without incurring costs?

The answer to this question is deep neural networks and the processing of video and medical images. As part of the proposed project, we plan to develop new deep learning methods that will allow the prediction of mPAP based on imaging of the heart and surrounding blood vessels using magnetic resonance imaging (MRI). The project will be carried out in cooperation with scientists from The University of Sheffield and doctors from Sheffield Teaching Hospitals. Our partners have experience in using mathematical modeling to diagnose the disease we analyze. Over the past decade, they have collected several thousand MRI recordings, in various modalities that visualize blood flow or cardiovascular anatomy, along with tabular patient data. We plan to utilize this diversity of data to develop new methods for the non-invasive diagnosis of pulmonary hypertension.

At the initial stage of the project, we will use the most modern neural networks based on convolutional layers and the so-called transformers for the prediction of mPAP values from single recordings. The obtained results will serve as a benchmark for our further research. We anticipate that the use of multimodal learning will improve the quality of prediction. Therefore, based on existing architectures, we will develop new multimodal learning models that combine the features found in the recordings of the pulmonary artery and the heart muscle. Additionally, in the next stages of the project, we will increase the effectiveness of our models by adding modules that analyze tabular data. One of the main disadvantages of neural networks is that their predictions are difficult to explain (these are black-box methods). This is a very important aspect in the context of the application of such models in the healthcare sector. In the last stage of our project, we will work on the use of existing methods and designing new ones that will allow clinicians to understand the decisions made by the neural network.

The proposed project is innovative for several reasons. Firstly, to the best of our knowledge, there are no methods of predicting mPAP values directly from MRI recordings (in particular multimodal recordings). What is more, the developed neural networks, which at first glance narrowly apply, can be used for other problems of visual and tabular data processing (not only in the field of medicine). In the future, the project results could be used to develop a fully non-invasive method for calculating all measurements obtained during cardiac catheterization. This will help avoid the need for an examination with possible complications to diagnose other diseases such as congenital heart disease, cardiomyopathy, and heart failure.