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New AI platform can help assess vascular diseases

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An international team of scientists from Nanyang Technological University, Singapore (NTU Singapore), Brown University and the Massachusetts Institute of Technology (MIT) has developed an artificial intelligence (AI) platform that could one day be used in a system to assess vascular diseases, which are characterised by the abnormal condition of blood vessels.

The AI-powered platform combines machine learning and a specially-designed microfluidic chip with analysis of 2D video images of blood flow and the application of physical laws, to infer how blood flows in 3D. In tests, it accurately predicted blood flow characteristics such as speed, pressure, and shear stress, which is the stress exerted by the blood flow on the vessel wall.

The ability to determine these characteristics accurately could be a critical support for clinicians in detecting and tracking the progression of vascular diseases since the abnormalities that the platform could spot (such as an abrupt change in speed or shear stress of blood flow) may indicate the presence or progression of a vascular disease.

The platform and its proof-of-concept findings from the research team led by NTU President and Distinguished University Professor Subra Suresh, Brown Professor George Em Karniadakis, and MIT Principal Research Scientist and NTU Visiting Professor Ming Dao are reported in the Proceedings of the National Academy of Sciences of the United States of America on 22 March.

To validate the platform, the scientists tested it on simulated microaneurysms of the eye, using a microfluidic chip that is smaller than a thumbnail. Microaneurysms are bulges in the micro-scale blood vessels of a diabetic patient's eye, and are the earliest signs of diabetic retinopathy, the leading global cause of vision loss and blindless in diabetic working adults.

When the AI platform was given images of blood flow in a device that simulates microaneurysms, it successfully predicted the characteristics of blood circulation within it.

The AI platform and the microaneurysm-on-a-chip could one day help medical practitioners with monitoring vascular disease progression in humans and may be particularly useful for diseases of the body's smallest blood vessels.

Prof Subra Suresh, the study's senior author, said:

Currently, measuring the mechanics of blood flow in the smallest blood vessels requires sophisticated equipment and trained personnel. Our AI technology integrates images, experimental data, and the underlying physics, enabling microcirculation blood flow to be analysed easily and accurately to assess vascular injury and disease state. With this platform, we can now gain important mechanical information and insights into disease evolution mechanisms that were previously very cumbersome to extract."

While the platform was developed for microaneurysm monitoring, it could be adapted to monitor other diseases of impaired blood vessels, said the scientists.

Prof George Karniadakis, the study's co-corresponding author and professor of Engineering and Applied Mathematics at Brown University, said: "We tested our platform on microaneurysms, the earliest symptom of diabetic retinopathy, which is the leading cause of vision loss in working-age diabetic patients globally. Our ultimate goal is to use the platform in clinical settings for diabetic retinopathy diagnosis and prognosis as well as in other diseases involving impaired blood flow."

The team hopes to test their platform on clinical imaging data of microaneurysms in order to correlate the blood flow characteristics of microaneurysms to factors such as disease severity and potential risks.

The challenge of monitoring blood vessel disease progression

Despite rapid advances in imaging techniques such as retinal photography analysis and optical coherence tomography, it is not feasible to observe biological processes in microcirculation in real time, such as the rupture of a microaneurysm in the eye's blood vessels and the development of blood clots.

As a result, to learn more about how these diseases progress, scientists have been using traditional microfluidic devices - devices that shuttle around miniscule amounts of fluids in tiny channels carved into a microchip - to mimic the physiological conditions of a vascular disease. These existing methods, which either rely on visual image analysis, or the application of the physical laws underlying blood flow, do not provide an accurate assessment of blood flow characteristics, particularly in vessels with complex geometries, such as a microaneurysm in the eye.

The research team demonstrated the AI platform's capabilities on a microaneurysm-on-a-chip, a microfluidic device that the team designed to mimic blood flow in round microaneurysms, the most common type found in diabetic patients .

A 20-microlitre blood sample - about half a drop of blood - was loaded onto the chip, and a high-speed camera was used to capture images of blood moving through the microchannels.

The scientists found that their AI platform predicted the characteristics of blood flow such as speed, pressure, and stress exerted by the blood flow on the vessel wall in small, intermediate, and large microaneurysms more accurately and efficiently than existing computational methods.

The team believes their technology may become a powerful tool in the diagnosis and monitoring of microaneurysms using images taken from actual microaneurysms. It could also potentially be combined with microfluidic devices that simulate other types of disorders involving impaired blood vessels to predict blood flow characteristics and monitor other vascular diseases.