Title of invention

Stroke Risk Assessment by Combining Image Analysis and Blood Flow Modelling

Description of the invention

Field of invention

The invention is directed to assessing the risk of stroke occurrence or recurrence using patient-specific information. Stroke is a leading cause of death globally, with over 50% chance of death or disability within 1 year after occurrence [1]. More than 85% of strokes are ischemic, meaning that they are due to a blockage in blood flow to the brain [2]. Ischemic strokes mainly occur due to an atherosclerotic plaque rupturing in cerebrovascular arteries.

Two important parameters affect the risk of plaque rupture and ischemic stroke: first, the plaque composition, and second, the hemodynamic stress exerted on the plaque by the blood flow. However, existing medical imaging modalities do not provide these information directly. Ultrasound (US), computerized tomography (CT), and magnetic resonance (MR) imaging are mainly focused on visualising the vascular lumen and grading the percentage of the narrowing in arteries. These modalities provide anatomical information, but very limited functional information. The functional information provided with common clinical tools is limited to velocity measurements (e.g. doppler ultrasound). Additionally, the plaque composition is commonly determined through a subjective guess based on the plaque appearance in ultrasound images. This is not enough for stroke risk assessment and could be a culprit for the current 25% stroke recurrence rate.

Therefore, there is a need for a method to determine hemodynamic parameters and plaque composition from patient-specific medical data to improve stroke risk assessment. This method helps neurologists in determining the optimum treatment plan for stroke patients or asymptomatic patients with a high risk of having a stroke.

Summary of the invention

The invention provides a method to obtain hemodynamic information and determine plaque composition from patient-specific medical data for stroke risk assessment. The method uses non-invasive, post-processing computing techniques to determine these information. The hemodynamics information may include velocity, pressure, shear stress, and any derivatives of these cerebrovascular arteries [3]. The plaque composition may include information regarding the extent of calcification or intraplaque hemorrhage (IPH) [4].

In one embodiment of the method, medical images obtained from the patient are analysed to segment the cerebrovascular anatomy. These medical images are typically volumetric angiographic modalities such as CT or MR angiography. The 3D reconstruction of cerebrovascular arteries based on these images is used as the geometry for a computational fluid dynamics (CFD) simulation to provide detailed hemodynamics information. These hemodynamic information may include pressure drop, fractional flow reserve (FFR), shear stress ratio (SSR), wall shear stress (WSS), or velocity ratio across the stenosis. Additionally, atherosclerotic plaques in cerebrovascular arteries are detected. Using image processing and computer vision methods, the composition of the detected plaques are determined. The

hemodynamic information is then combined with plaque composition to determine plaque vulnerability and classify the risk of ischemic stroke using an artificial intelligence system.

The method described here provides a more accurate risk assessment for stroke occurrence or recurrence compared to using only anatomical information. The method can be applied on existing medical data of patients without the need for receiving new tests. The non-invasive nature of the method limits the risks associated with invasive vascular measurements for determining hemodynamic information like the use of catheter-based pressure probes.

Brief description of the drawings

FIG. 1 is a flowchart of a method for providing hemodynamic and plaque composition information from a medical image according to an exemplary embodiment.

FIG. 2 shows segmentation of a vessel of interest from a cerebrovascular image, generation of a computational mesh, and obtaining patient-specific hemodynamic information after blood flow simulation according to an exemplary embodiment.

FIG. 3 shows segmentation of an atherosclertoci plaque in a cerebrovascular image, geometric analysis of the plaque burden, and plaque composition analysis according to an exemplary embodiment.

Detailed description of the embodiments

In an exemplary embodiment, patient-specific data such as medical images can be used for obtaining hemodynamic and plaque information that determine the stroke risk of the patient. Illustrated as a flowchart in FIG. 1, the medical image (numeral 1) can be used for vascular anatomy segmentation (numeral 2). A computational mesh is generated based on this segmented vasculature (numeral 3) that is used for blood flow simulations (numeral 4), which results in obtaining patient-specific hemodynamic data. On the other hand, patient-specific medical images can be used for detection and segmentation of atherosclerotic plaques (numeral 5). The dimensions of the plaque or its volume may be used for determining the plaque burden in the vessel (numeral 6). Additionally, the material composition of the plaque may be determined by image processing and machine learning (numeral 7). The hemodynamic information obtained from blood flow simulations (numeral 4) may be combined with plaque composition information (numeral 7) using an artificial intelligence (AI) model (numeral 8). The AI model may then be used for stratifying the stroke risk of the patient (numeral 9).

The cerebrovascular images used for obtaining hemodynamic information may be volumetric angiography images obtained for example through computerized tomography (CT) or magnetic resonance (MR) imaging, shown by numerical 1 in FIG. 2. The vessel of interest can be segmented and reconstructed as a three-dimensional (3D) object (numeral 2), which is then used for generation of a volumetric mesh (numeral 3). Blood flow in the segmented vasculature can be simulated using a patient-specific computational fluid dynamics model, the results of which may be shown with colormaps (numeral 4), or summary tables of important information, for example FFR, SSR, WSS, velocity ratio, or pressure drop across a stenosis. Hemodynamic information alone may be used for stroke risk assessment of the patient, or it may be combined through an AI model (numeral 8 in FIG. 1) with other risk factors such as plaque composition (numeral 7 in FIG. 1).

In addition to volumetric modalities like CT and MR, two-dimensional images like longitudinal and transverse B-Mode ultrasound may be used for stroke risk assessment. FIG 3. shows analysis of a longitudinal B-Mode ultrasound image (numeral 1) for segmentation of an athersclerotic plaque (numeral 2). The plaque burden, comprising of its axial, lateral, or volumetric dimensions can be calculated (numeral 3). Finally, the plaque composition (numeral 4) may be obtained by image processing and machine learning techniques, using measures and features such as plaque morphology and gray scale median in the segmented plaque area in comparison with an external database of labeled plaque information. This information may be used to determine the vulnerability of the plaque and its chance of rupture. Patient's stroke risk may be determined by using the plaque information alone, or with an AI model (numeral 8 in FIG. 1) that combines the plaque information with hemodynamic parameters obtained from the blood flow simulation (numeral 4 in FIG. 1).

Modification of the preferred embodiment

Different methods may be used for vascular image segmentation, mesh generation, and simulation of the blood flow. The boundary conditions for computational fluid dynamics simulation of the blood flow may be obtained from various modalities, such as Doppler waveforms for the carotid territory or phase contrast MR imaging for intracranial vessels. Plaque segmentation and composition analysis may also be based on various image processing and machine learning techniques.

References

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3. Steinman, David A. "Image-based computational fluid dynamics modeling in realistic arterial geometries." *Annals of biomedical engineering* 30.4 (2002): 483-497.
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Claims

A method for stroke risk assessment using image processing and blood flow analysis, the method comprising: information regarding hemodynamics in extra and intracranial cerebral vasculature and composition of atheroslcerotic plaques that may be used independently or in combination with other stroke risk factors.