Reconstruction and finite element analysis of brain hemangioma model based on CT images

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Abstract. Cerebral haemangioma is a disease that seriously endangers the safety of human life. The law of its occurrence, development, and prognosis is still not completely clear. Therefore, it has attracted the attention of many researchers at home and abroad in recent years. In response to the above problems, based on the original CT data of cerebral aneurysm in patients with intracranial aneurysms, the article reconstructs the cerebral haemangioma model through Autodesk Remake 3D reconstruction software. And the finite element analysis software ANSYS CFD was used to establish the reconstructed finite element model of cerebral haemangioma. Hemodynamic analysis of the model was performed to obtain the distribution and change of velocity vector of blood flow field and pressure of blood vessel wall in the model of brain haemangioma. To investigate the hemodynamic mechanism of the formation, development and rupture of cerebral haemangioma and provide theoretical basis for clinical treatment.

1. Introduction
Cardiovascular and cerebrovascular diseases usually occur in some special parts of human blood vessels, such as the sudden narrowing of the blood vessel cross-section, the constricted structure of blood vessels, the bifurcation of blood vessels, and the sudden bending of blood vessels [1]. The common site of vascular disease is related to the hemodynamic factors such as the blood flow velocity and the pressure on the vessel wall. Therefore, the study of the relationship between hemodynamic factors and the genesis of brain haemangioma has drawn increasing attention from clinical researchers and has become a hot topic at home and abroad.

Based on the original CT data of cerebral haemangioma in a patient with intracranial aneurysm, this study reconstructed a three-dimensional cerebrovascular model and applied CFD technique to numerically simulate blood flow in a reconstructed brain haemangioma model. In addition, the hemodynamic mechanism of the formation, development and rupture of cerebral haemangioma is discussed to provide a theoretical basis for clinical treatment.

2. Human Brain Haemangioma Model Reconstruction
This article uses Autodesk series software for reverse reconstruction [2], the original blood data .stl format into Autodesk Remake software (Fig.1 for the blood still raw data). Autodesk Remake software

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is a software that converts pictures into 3D models. It has powerful functions such as repair, optimization, and clean-up. It can restore photos very well. Users can convert some photos or scan data into high resolution 3D mesh model. In this study, Autodesk Remake was used to transform the blood triangle slice still format into a quadrilateral mesh format, which was then imported into Autodesk Fusion for entity transformation.

Select the output model and select the advanced option to convert the trihedral mesh to a tetrahedral mesh output and save it. See Fig.2 for the mesh model of the blood model.

Figure 1. Blood raw data.

Figure 2. Mesh model of the blood model.

Import the exported .ob. format file into Autodesk Fusion 360, as shown in Fig.3. Selecting the transformation will transform the grid into solids. Fig.4 shows the process of materializing the surface of the model.
3. Establishment of a Finite Element Model of Cerebral Haemangioma

This paper applies ANSYS CFD software to the physical mesh of the reconstructed cerebrovascular model.

3.1. Generate a mesh model

The three-dimensional reconstruction model of cerebrovascular was introduced into the finite element analysis software to perform geometric inspection, identify the topological structure, define the exit entrance plane and the calculation domain, set the grid parameters, and perform grid division. You can get the mesh as shown in Fig.5.

3.2. Model parameter settings

In large blood vessels, the diameter of red blood cells is very small relative to the diameter of blood vessels, so blood can be considered to be a continuous fluid at this time. When the blood vessel diameter is greater than 0.5 mm, the flow shear rate of blood in the blood vessel is high, and the viscosity of blood can be considered as a constant, so blood can be regarded as an incompressible viscous Newtonian fluid. Perk told et al. [3] compared the flow of Newtonian and non-Newtonian fluids in blood vessels and found that there was only a small difference in the basic flow characteristics between the two, and the flow pattern remained basically unchanged. The simulated blood was therefore set as an incompressible viscous Newtonian fluid. Blood flow is steady, adiabatic laminar flow [4-6]. The blood viscosity coefficient is 0.0035Pas. The blood density is 1060kg/m³. Cerebrovascular is non-permeability, and cerebral vascular wall is rigidity. The entrance plane blood flow rate is 0.17m/s. And the inlet pressure is set to 100mmHg (13.332kPa). The outlet is set to pressure outlet. Blood flow follows the laws of conservation of mass and momentum, namely the continuity equation and the Nadir-Stokes equation:
\[
(\nabla \cdot \vec{V}) = 0
\]  

(1)

\[
\rho \frac{D\vec{V}}{Dt} = -\nabla P + \mu \nabla^2 \vec{V}
\]

(2)

Where, the \( P \) is pressure vector, the \( \vec{V} \) is the speed vector, \( \rho \) and \( \mu \) are fluid density and viscosity, respectively.

According to Murray's law, the outlet flow distribution ratio is determined by measuring the diameter of each outlet plane [7].

4. Simulation Results

After the parameters of the vascular model are set, the model is simulated and analysed, and the haemorrhagic flow dynamic parameters are visualized and processed to obtain the blood flow velocity vector diagram and the blood vessel wall pressure cloud diagram, as shown in Figs. 6 and 7.

As can be seen from Fig. 6, blood flow has always existed in the cerebral blood vessels, and there are whirlpools in brain haemangioma. This increases the time for blood cells and other particles to stay in the brain haemangioma, which increases the probability of deposition of these particles in this vascular segment and further increases the risk of vascular lesions.

It can be seen from the pressure wall map of the blood vessel wall in Fig. 7 that the wall pressure gradually decreases along the blood flow direction and gradually changes from red to blue. However, in the brain haemangioma, the distribution of wall surface pressure in the cervical region is not uniform, showing an increase in pressure at the neck of the tumour and an abnormal red colour, while other areas on the same horizontal line show a green colour. From the point of view of fluid mechanics, due to sudden changes in direction during blood flow, it is bound to receive a force to change speed. The reaction force of this force acts on the vessel wall at the neck of the tumour, which will cause the rupture of the blood vessel wall at the cerebral haemangioma to a large extent, causing harm to the human body. In the cerebral haemangioma, the pressure on the medial wall of the tumour was less than the lateral pressure, and the pressure on the wall of the cerebral blood vessel was not changed much.

Figure 6. Blood flow speed vector.
5. Conclusion
In this paper, the remodelling and finite element analysis of cerebrovascular models were studied, and the distribution and changes of blood flow velocity vector and blood vessel wall pressure in cerebrovascular models were obtained. Through numerical simulation experiments, it was found that there was a large vortex in blood flow in the tumour cavity of brain haemangioma. Vascular wall pressure is higher in the angiomandibular region, which increases the risk of vascular wall rupture of cerebral haemangioma, providing a reference basis and theoretical basis for the later research on cerebral haemangioma and the development of extravascular interventional procedures.

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