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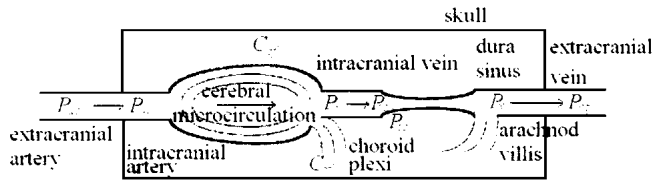,   ,   1   .

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Fig. 1   The hemodynamics model of cerebral blood and cerebrospinal fluid circulation

1   , L (< 20 cm)

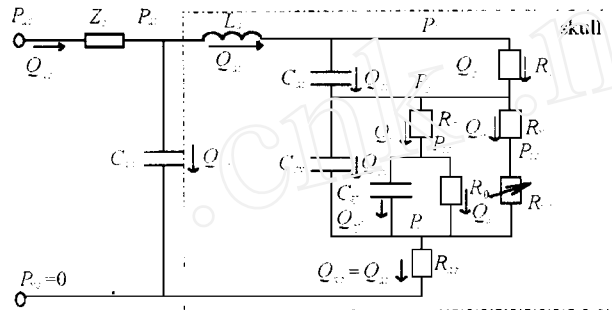L_p (> 250 cm)   ,   ,   2   .

2

Fig. 2   The electrical equivalent diagram of the hemodynamics model for
cerebral blood and cerebrospinal fluid circulation

2   4   :

1)   : Z_c C_{ao} ,

L_a , C_{ai} ,   ,

            R_c .   ,   Westerhoof   .

C_{ai} ,   .

2)   :   3   : (a)   ,

R_v ; (b)   , R_{vc} (t) ,

                ; (c)   , R_{ds} . C_{cv}

          ,   .

3)   : R_f ,

            R_0 , $R_0 < R_f$, C_{sf} .

4)   :   ,   ,   ,

    ,   .

2

            2   ,

$$D \frac{\mathbf{d}x}{\mathrm{d}t} = EX + \overline{b} \tag{1}$$

$$X = (Q_{ao} , Q_e , Q_{ai} , Q_{cv})^\mathrm{T}$$

$$\overline{b} = \left(-C_{ao}\frac{d(P_{a0} - P_{vs})}{dt}, 0, P_{a0} - P_{vs}, 0 \right)^T$$

$$D = \begin{bmatrix} -C_{ao} \cdot Z_c & 0 & 0 & 0 \\ 0 & C_{cv}R_0 & C_{cv}\frac{R_fR_v}{R_f+R_v} & -C_{cv}\frac{R_fR_v}{R_f+R_v} \\ 0 & 0 & L_a{}^3 & 0 \\ 0 & -C_{ai}R_c & C_{ai}R_c\left(1+\frac{R_v}{R_f+R_v}\right) & C_{ai}\frac{R_cR_f}{R_f+R_v} \end{bmatrix}$$

$$E = \begin{bmatrix} 1 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \\ -Z_c & -R_0+R_c & -\left(R_{ds}+\frac{R_fR_v}{R_f+R_v}+R_c\left(1+\frac{R_v}{R_F+R_v}\right)\right) & \frac{R_fR_v}{R_f+R_v} - \frac{R_fR_c}{R_f+R_v} \\ 0 & 1 & -\frac{R_v}{R_f+R_v} & \frac{R_f}{R_f+R_v} \end{bmatrix}$$

Fourier   (1) ,

$$x_i(t) = x_{i0} + \sum_{j=1}^{k}\left(x_{ij}\cos\left(\frac{2jt}{T}\right) + xe_{ij}\sin\left(\frac{2\pi jt}{T}\right) \right) \quad (i = 1,2,3,4) \tag{2}$$

$$b_i(t) = b_{i0} + \sum_{j=1}^{k}\left(b_{ij}\cos\left(\frac{2jt}{T}\right) + b_{ij}\sin\left(\frac{2jt}{T}\right) \right) \quad (i = 1,2,3,4) \tag{3}$$

$$X_j = (x_{1j}, ..., x_{ij}, ..., x_{4j})^T \quad (j = 1,2,...,k) \tag{4}$$

$$b_j = (b_{1j}, ..., b_{ij}, ..., b_{4j})^T \quad (j = 1,2,...,k) \tag{5}$$

$$X_j = (x_{1j}, ..., x_{ij}, ..., x_{4j})^T \quad (j = 1,2,...,k) \tag{6}$$

$$b_j = (b_{1j}, ..., b_{ij}, ..., b_{4j})^T \quad (j = 1,2,...,k) \tag{7}$$

(1)

$$\begin{bmatrix} X_j \\ X_j \end{bmatrix} = A_j^{-1} \begin{bmatrix} b_j \\ b_j \end{bmatrix} \tag{8}$$

A_j^{-1} A_j^{1} ,

$$A_j = \begin{bmatrix} -\frac{2j}{T}D & -E \\ -E & \frac{2j}{T}D \end{bmatrix} \quad (j = 0,1,2,...,k)$$

(8)   (2) , (4) , (6)   ,   (1) x_i ,

Fourier k 20.

3

P_{ic}

.   : P_{ic}

, P_{ao} , P_{ic} ,

P_{ao} P_{ic} . P_{ao}

,

P_{ic} R_{ds} P_{ic}

Q_{ao} .

3   ,   [3]   (3   " o "
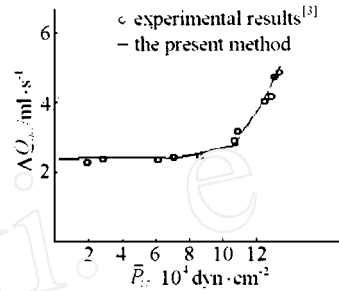
)   .

3   Q_{ao} Q_{ao}

$\overline{P}_{ic}$

Fig. 3   The relationship between the extracranial
artery blood flowpulse amplitude (Q_{ao}) and
the mean intracranial presesure ($\overline{P}_{ic}$)

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THE HEMODYNAMICS MODEL OF CEREBRAL BLOOD AND CEREBROSPINAL FLUID CIRCULATION

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Abstract   The high intracranial pressure (ICP) caused by many disease is very harmful in clinic. The ICP monitoring of patients is one efficient way to control the cerebral hernia, but in the clinical application the ICP accurately monitoring is usually invasive. A noninvasive method for ICP monitoring is highly expected in clinical medicine.

According to the investigation of the cerebrovascular, cerebral blood and cerebrospinal fluid dynamics. A hemodynamics model which describes the characteristics of the blood and cerebrospinal fluid flow in the cerebral circulation is set up. In the model, the arterial system is regarded as an elastic tube, the microcirculation as a resistance, the venous system as a collapsible tube, the dura as a rigid tube and the skull as a rigid chamber. The cerebrospinal fluid flows from microvascular to the cranial cavity and returns to the blood venus system at arachnoid villis.

Based on the dynamic model, a mathematical model with lumped parameters is proposed. Considering the electrical equivalent diagram of the model, the governing equations and the method to calculate the dynamics parameters are presented. By further analyzing the results from the equation, a diagram of the mean ICP and the extracranial artery blood flow pulse amplitude ($Q_{ao} = Q_{ao\max} - Q_{ao\min}$) is obtained. It may offer an auxiliary means for clinical diagnosis of the value of ICP. In this paper, the normal value of main vascular's indexes are calculated directly by known geometry parameters, while other indexes are obtained indirectly. Overall comparisons between the experimental and the theoretical results in ICP as well as Q_{ao} are satisfactory.

The relationship between ICP and the cerebral blood flow parameters is built through four equations, so their solution may be useful in ICP noninvasive monitoring.

Key words   intracranial pressure, cerebral circulation, hemodynamics, lumped dynamics' model