Application Research on Imaging Technique of Electrical Resistance Antibody in the Medical Imaging Evaluation of Primary Central Nervous System lymphoma

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Abstract
Imaging technique of electrical resistance antibody is based on that the conductive properties of different materials show different biological tissues and structures, which has the characteristics of low cost, easy to carry, small size and fast imaging speed, but its imaging resolution is low, so it is often used as a supplementary means of medical imaging. Because the clinical manifestation is complex, the misdiagnosis rate of primary central nervous system is high. The whole process monitoring of PCNSL diagnosis and treatment can be realized by using the imaging technique of electrical resistance antibody, which can provide guidance for the treatment of the whole process. Through the establishment of shell model that covered the brain, skull, scalp, skull and cerebrospinal fluid layer, the theoretical basis of EIT image reconstruction was obtained in the incentive mode. In the application of EIT, the PCNSL system module design included the excitation module, measurement module, signal processing module, system control module, drive module and imaging module. A total of 21 patients who were diagnosed with PCNSL in a hospital from June 2012 to November 2015 were selected. MRI scan and EIT examination were performed before operation in 21 patients, and postoperative follow-up was monitored by EIT.

Through the evaluation and analysis of imaging, it can be seen that in the PCNSL diagnosis and treatment, the misdiagnosis rate of EIT technology is high, and can be replaced with MRI, which has the advantages of convenient and quick, more convenient for the patient's clinical monitoring.

Keywords: EIT, lymphoma, image evaluation, PCNSL.

Introduction

With the improvement of people's living standard, the medical level also has the rapid development. In the process of diagnosis and treatment, the doctors pay more attention to the patient's clinical manifestations and image information. Through the comprehensive judgment of the two, it can be a clearer understanding of the patient, which has a very important significance for the patient's whole process of diagnosis and treatment. Department of neurosurgery related diseases have the characteristics of high mortality and high disability rate. The accurate and timely diagnosis of the disease is very important to patients, which can directly affect the patient's survival rate and the condition of the development of the disease [1]. Compared with MRI, CT and other imaging techniques, the resistance antibody layer imaging technology is relatively small in clinical applications because of its low resolution, but it has the characteristics of low cost, convenient and fast imaging speed and so on. Primary central nervous system lymphoma is a rare non-Hodgkin lymphoma of the brain. Because of the disease characteristics of its diagnostic difficulties and the rapid development, the PCNSL has a high rate of misdiagnosis and a high rate of death, which makes people's attention more and more[2]. In recent years, the incidence of PCNSL is gradually increasing, and the disease is also a threat to people's health. Through the research of the imaging technology of the electric resistance antibody layer, the working principle is analyzed and the image model which is suitable for PCNSL is constructed. According to the actual cases in a hospital, the application value of EIT technology in PCNSL is discussed, which has a positive effect on the application of EIT in the diagnosis and treatment of PCNSL.

The related research on imaging technique of electrical resistance antibody and primary central nervous system lymphoma

Imaging technique of electrical resistance antibody: The electrical resistivity tomography (EIT) has been studied as early as nineteenth Century, which was mainly used to study the properties of the material. In 50s of last century, H.P. Schwan found the relationship between biological tissue and its structure, electrolyte content and water content, and the RC model was established by K.S. Cole. EIT technique was successfully used to measure the cardiac output of the heart by N.G. Kbicek. After many years of development, EIT technology has been gradually mature [3]. Compared with CT imaging technology and MRI imaging technology, EIT has smaller size and lower cost, which is not only convenient to carry, but also can achieve the general function of CT and MRI imaging technology. The imaging resolution is relatively low, but it still can be used as an effective supplementary means of medical imaging. Comparison of EIT technology with other medical imaging techniques is shown in table 1. From table 1 we can see that EIT has the characteristics of perfect function, low resolution imaging, fast imaging speed, minimally invasive to the human body, low instrument cost and inspection cost, and easy to use, which makes the technology have a very strong practicability[4]. In addition, EIT can reflect the physiological status' changes of biological tissue in a short period of time and display them through the image, which has a very important value for the diagnosis and treatment of disease, such as the use of EIT technology to display the human body tissue impedance distribution image, the human body organ physiological activity image, and its application scope is also more and more wide[5].

The basic working principle of EIT system is shown in fig. 1. The two ends of the rectangular conductor with a uniform conductivity are respectively e1 and e2 electrodes. Constant current source I is existed between the two electrodes, with uniformity distribution of the current density, the potential line parallel to the x axis and the potential line and the current line are orthogonal.

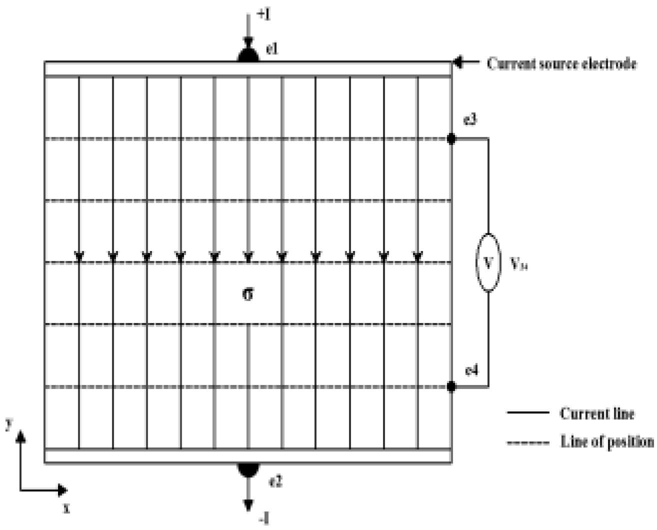

Fig. 1: The basic principle of the EIT system (rectangular conductor)

Table 1
Comparison between EIT and existing imaging techniques

Technical name	Imaging features	Traumatic	Imaging velocity	Spatial resolution	Inspection fee	Instrument cost	Simple and convenient
Impedance tomography	Functional imaging	Not obvious	40ms	Difference	Low	Low	Simple and convenient
Ultrasound imaging	Anatomy and functional imaging	Not obvious	＜1s	Preferably	Higher	Higher	More complex
MRI	Anatomy and functional imaging	Not obvious	20m	Preferably	High	Expensive	Complex
PET or SPECT	Functional imaging	Cell damage	20m	Good / poor	Higher	Very high	Complex
γ-camera	Functional imaging	Cell damage	5m	Commonly	Higher	Higher	Complex
X-ray CT	Anatomical imaging	Cell damage	2m	Preferably	Higher	Very high	Complex
X-ray plain film	Anatomical imaging	Cell damage	＜1s	Good	Low	Low	More complex

If the electrical conductivity of the conductor is σ , when the electrodes e3 and e4 are placed on the right side of the conductor, and measure the voltage at both ends with a high input impedance voltmeter. The cross-sectional area of the conductor is A, and the distance between electrodes is L , and it can be obtained:

$$R_{34} = \frac{V_{34}}{I} = \frac{L}{\sigma A} \quad (1)$$

As above, when the spherical conductor with a diameter of r is placed in, it will directly lead to the distortion of the current line and the potential line. Since e3 and e4 are constant current excitation, the resistance is reduced, and the voltage between the two becomes smaller. When an insulating material is placed, the current line will be dispersed, so that the voltage between the two becomes large.

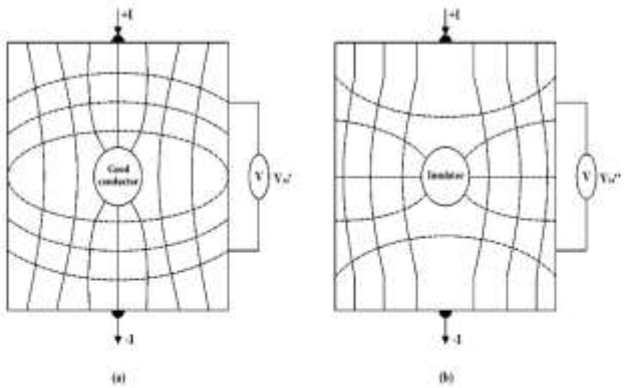

Fig. 2: The distribution of the current line and potential line (a-good conductor, b-insulator)

Assuming the average conductivity of good conductor between e3 and e4 is σ', it can be obtained using the Ohm's law:

$$R_{34}' = \frac{V_{34}}{i} = \frac{L}{\sigma A} \tag{2}$$

Combined with formula (1), it can be concluded that:

$$\sigma' = \sigma \cdot \frac{V_{34}}{V_{34}'} \tag{3}$$

In the same way, it can be concluded about the insulator that:

$$\sigma'' = \sigma \cdot \frac{V_{34}}{V_{34}''} \tag{4}$$

It can be seen that the changes in the conductivity of the inner conductor can be inferred from the change of the conductivity and the boundary voltage, which is the basic principle of EIT image technology. The body membrane has the same conductivity and resistance. This property will be changed with the change of cell activity, further leads to the electrical properties of human tissues and cells of different parts with the change of time and space, which provides the biomedical foundation for EIT technology, so that it can be used in medical practice [6].

Because the body's tissues, organs and cells have different water content and electrolyte content, they have different resistivity. With the water content as an example, the water content is less, the resistivity is higher, so the bone has the maximum impedance value, and the blood and cerebrospinal fluid have the minimum impedance value. The impedance rate of different parts of the human body is shown in the following table:

When the lesion occurs in the normal organs or tissues, the conductivity will be significantly changed, which can make the EIT technology be able to accurately monitor and inspect the health status of the human body, and has played a positive role in clinical medical diagnosis and treatment.

Primary central nervous system lymphoma: Primary central nervous system lymphoma (PCNSL) is a rare malignant tumor of the central nervous system, which was first seen in 1930s. The patients with diagnosis increased year by year, the incidence has increased by several times in recent decades, which is a serious threat to human health [7]. As a kind of lymphoma, according to the international classification standards, PCNSL are divided into high stage, medium stage and low stage, and now commonly used is the new classification released by WHO in 2001 [8].

According to the existing literature, we can see that most of the PCNSL patients are non-Hodgkin's lymphoma, with B lymphocyte type as the main type, there is also non-T or non-B cell type. Compared with other lymphomas, PCNSL pathology is malignant, diagnosis is relatively difficult, and the disease is developing rapidly with relatively high mortality rate, which makes people have to pay more attention to the treatment of PCNSL [9]. At present, the proportion of PCNSL in the whole central nervous system tumors is less than 3%, that is, the incidence is about 0.046/ million people, and the incidence rate is increasing year by year. From the onset of the age stage, the age of PCNSL incidence is from 45 to 70 years old, with the peak in the age of 60 years [10].

In view of the general pathology, PCNSL is substantial, white or yellow, light red, the boundary is not clear, no capsule, soft tissue sections are homogeneous, and the morphology is accordance with the changes of non-Hodgkin's lymphoma [11]. The tumor cells show diffuse distribution, uneven density, or loose or dense infiltration to the surrounding normal brain. Small lymphocytes are filled in the vascular lumen, and there are glial cells produced by the proliferation reaction in the center and the edge of the tumor [12]. The morphology of the tumor cells is relatively single, but the cell is larger, the cytoplasm is less, the nucleus is round, and the chromatin is stained deeply [13].

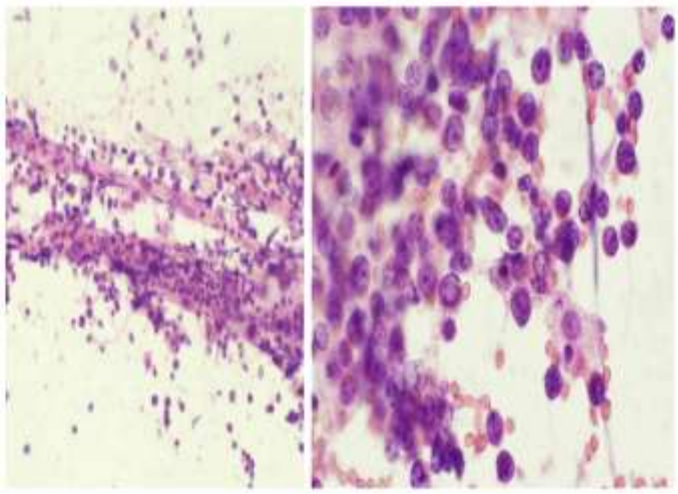

Fig. 3: Tumor cell microscopic image

Because the pathological characteristics of PCNSL are not obvious and prone to misdiagnosis, so the diagnosis needs to combine the results of the chemical examination of the immune tissue to determine.

Table 2
Typical value of human tissue resistivity(20kHz-100kHz)

Number	Tissue	Resistivity(Ωm)	Number	Tissue	Resistivity (Ωm)
1	Longitudinal skeletal muscle	1.3-1.5	8	Bone	166
2	Transverse skeletal muscle	18-23	9	Lung	7.3-24
3	Longitudinal myocardium	1.6-5.8	10	Fat	21-28
4	Transverse myocardium	4.2-51	11	Liver	3.5-5.5
5	Gray matter of the brain	2.8	12	Blood	1.5
6	Cerebral white matter	6.8	13	Plasma	0.66
7	cerebrospinal fluid	0.65			

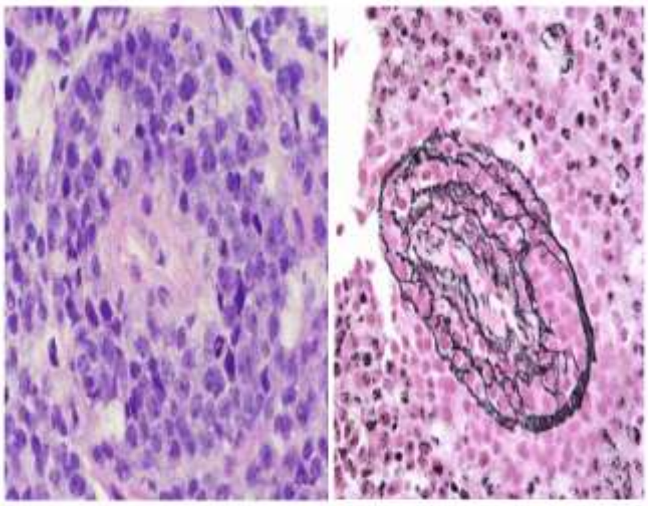

Fig. 4: Immunohistochemical staining

In clinical manifestation, PCNSL is a malignant intracranial tumor, which mainly affects the brain parenchyma. Some patients may be immersed and into the nerve root, spinal cord and brain dura. Its clinical manifestations are complex, there is no very obvious specificity, and the performance is different according to patients with different age and the body's immune status [14]. The common initial symptom is increased intracranial pressure, such as dizziness, vomiting, headache and so on. At the same time, it's accompanied by hemiplegia, visual impairment, aphasia and other limitations of neurological deficits, and other symptoms of incontinence, memory loss and other clinical manifestations[15].

Commonly used imaging techniques include CT, MRI, and other auxiliary such as blood, cerebrospinal fluid and other ways of diagnosis[16]. When CT is used to scan, the lesions are located in the occipital, parietal, frontal and deep brain tissues around the ventricles, even density or high density, with clear boundaries, rare calcification and cystic degeneration. And it will appear obvious uniform enhancement for the lesion enhanced. For the MRI scan, the signal is with uniformity, mostly round and lumpy, few irregular, mostly clear tumor boundaries, rare cystic degeneration and calcification, and immunodeficiency mostly shows heterogeneous enhancement ring for the enhanced lesions[17].

The diagnostic criteria for PCNSL are generally consistent with the following. Confirmed by pathological histology and immunohistochemistry, some patients undergo stereotactic biopsy; In the short term, the symptoms of the spinal canal and the intracranial lesions are the first episode; To exclude secondary diseases through the examination of the body parts, bone marrow and blood; Lymphoma is not found in other parts of the 3 month after diagnosis[18]. Due to the high degree of malignancy of PCNSL, its treatments are mainly surgery, radiotherapy, chemotherapy, the combination of radiotherapy and chemotherapy and hormone therapy, and what kind of specific treatment will be chosen according to the pathological situation.

Today, with the development of science and technology, the PCNSL treatment has made great progress. The combination of chemotherapy can be used to keep the 5 year survival rate of nearly 40%, but the current PCNSL either from the diagnosis or treatment is a major medical problem [19].

Application of EIT in the imaging evaluation of primary central nervous system lymphoma

EIT model establishment and reconstruction algorithm: To make the medical imaging applications of the primary central nervous system lymphoma, the first needs to establish a physical model to describe the geometry of the head and determine the conductivity parameters, but the real head model is relatively complex both theoretical derivation and concrete calculation [20]. A concentric sphere model with different complexity is established, such as the three-shell, the four-shell, and the multi-shell model, which contains a plurality of different conductivity values. Taking the three shell model as an example, the head model is divided into three layers from the inner to the brain, cerebrospinal fluid and scalp. When the four-layer model is adopted, the skull is also included, and the model parameters are shown in the following table.

Table 3
Four concentric circle model parameters

Organization	Brain	Cerebro spinal fluid	Skull	Scalp
Relative radius	0.8400	0.8667	0.9467	1.0
Electrical conductivity s/m	0.33	1.0	0.0042	0.33

The brain electric field is considered as a quasi-static field. Assuming the regional media that needs to solve is divided into uniform and with the regional sub. The spontaneous electrical activity in the body is not considered, and the solution can meet the Laplasse equation. Set the scalp radius is 10 cm, and the excitation current 1mA is used to analyze the four concentric circle models. The surface electrode potential distribution curve of the four-layer head model in the adjacent excitation mode is shown in Fig.5, with 192 boundary nodes, and the vertical coordinate is the distribution of surface potential (unit V). It can be seen from the figure, the difference of the conductivity is great through the skull.

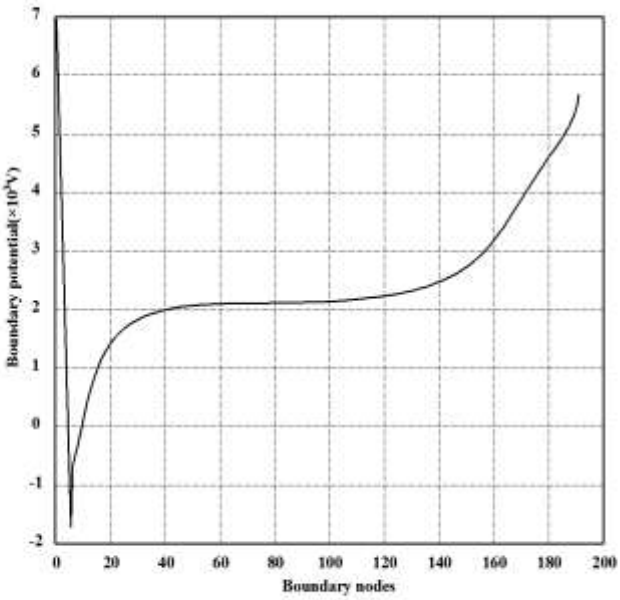

Fig. 5: Boundary node potential of the four layer head model

In the same way, the electrode potential distribution curve of the four-layer model under the relative excitation mode is shown in fig. 6.

The core part of EIT imaging system is the image reconstruction algorithm, and the existing image reconstruction methods have dynamic EIT and static EIT. Because of the dynamic EIT using back projection algorithm, the noise in the measurement data can be eliminated effectively, and the data acquisition system is required to be low, so it is often used as an algorithm for real-time EIT imaging. The first consideration is given to the use of the Ohm's law of continuous homogeneous medium:

$$J = \sigma E \tag{5}$$

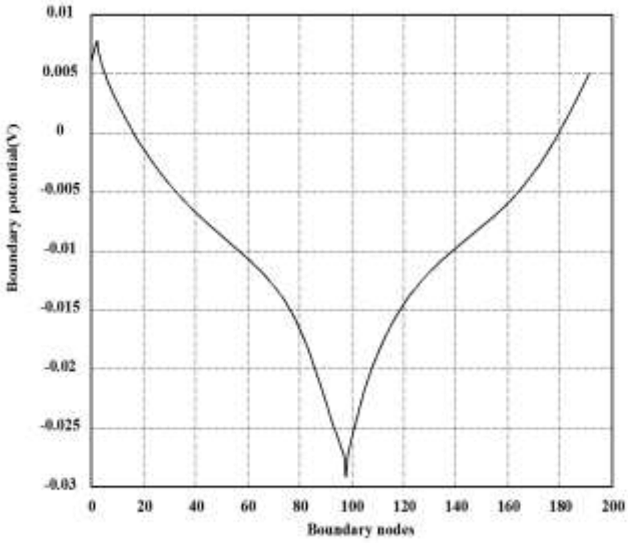

Fig. 6: The boundary node potential of the four-layer model of the relative excitation mode

In the formula (5), $E = -\nabla\phi$, the current source is not considered in the medium:

$$\nabla \cdot J = 0 \tag{6}$$

The different forms of σ can be concluded, respectively, when it is a constant and is not constant:

$$\nabla^2\phi = 0 \tag{7}$$

$$\nabla\sigma \cdot \nabla\phi + \sigma \cdot \nabla^2\phi = 0 \Rightarrow \nabla^2\phi = -\frac{\nabla\sigma \cdot \nabla\phi}{\sigma} \tag{8}$$

Formula (8) can be regarded as a Poisson equation, and $\frac{\nabla\sigma \cdot \nabla\phi}{\sigma}$ is regarded as a description of the distribution of current source. In a given the distribution of σ, to solve the problem of the distribution of the potential ϕ is solving the formula (7) of the solution, which is the basis of image reconstruction.

Given a closed region, set its boundary to c, and it can be obtained according to Gauss's divergence theorem:

$$\int_\Gamma G \cdot ds = \int_\Omega \nabla \cdot G dv \tag{9}$$

In the consideration of two arbitrary vectors, and use $\phi\nabla\Phi$ instead of G, with $\sigma\nabla\Phi$ instead of $\nabla\Phi$, there are:

$$\int_\Gamma \phi\sigma\nabla\Phi \cdot ds = \int_\Omega \sigma\nabla\phi \cdot (\sigma\nabla\Phi) dv + \int_\Omega \sigma\nabla\phi \cdot \nabla\Phi dv \tag{10}$$

Assuming that Φ is the solution of the formula (7) Laplasse equation, there are:

$$\int_\Gamma \phi\sigma\nabla\Phi \cdot ds = \int_\Omega \sigma\nabla\phi \cdot \nabla\Phi dv \tag{11}$$

Φ is the region and the boundary electric field, the current is injected from the electrode a to b, and the $\sigma\nabla\Phi$ indicates the current density. When the area is passive, there are:

$$\int_{\Gamma} \phi\sigma\nabla\Phi \cdot ds = I_{ab}(\phi_a - \phi_b) = I_{ab}\phi_{ab} \qquad (12)$$

If the unit current is input, the measured voltage is expressed by g, and the current is injected from the electrode c to d:

$$g = \phi_{ab} = \Phi_{cd} = \int_{\Omega} \sigma\nabla\phi \cdot \nabla\Phi dv \qquad (13)$$

Formula (13) reflects the relationship between the conductivity distribution of the medium and the boundary voltage, and is also an important theoretical basis of the reconstructed impedance image.

Application of EIT in primary central nervous system lymphoma: In clinical practice, because the main pathological changes are concentrated in the brain layer for the primary central nervous system lymphoma, so EIT technology is used for the study on the potential distribution line and the boundary potential in the head region. By constructing real head model vector bitmap, image processing, segmentation and information extraction are used to make the completion of the whole structure of the scalp, skull, cerebrospinal fluid, the brain even the neck contour map, and the reconstructed structure model is shown in Fig. 7. 1mA's constant current excitation signal is applied to the model, and the distribution of the field in the field can be obtained. In addition to the conductivity of the aforementioned scalp, brain, skull and cerebrospinal fluid is different, the neck conductivity also has differences, for 0.33s/m.

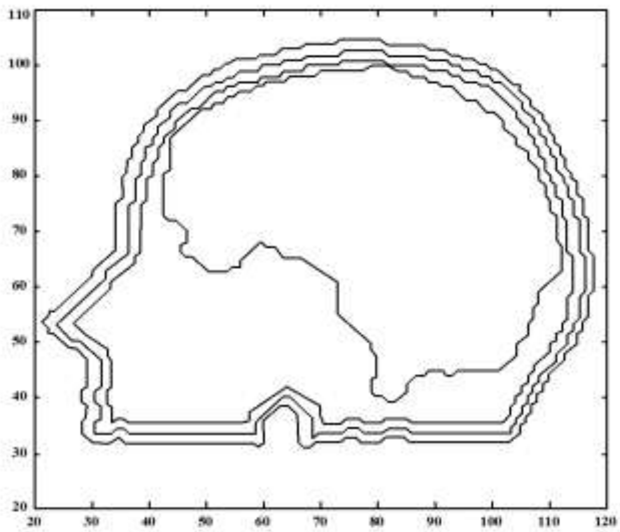

Fig. 7: Reconstruction of real head structure model

In order to realize the application of EIT technology in medical imaging of central nervous system lymphoma, EIT system is required to have considerable accuracy, stability, speed and quickness, and the reconstructed image quality has a very important influence on PCNSL. Therefore, it needs to carry out the design of EIT hardware system. In the design, the following several questions must be considered: (1) Due to the poor directivity within the current field established in human tissue and the complex current distribution, the skin contact impedance may cause errors, it is necessary to improve the directivity and focusing the incident current; (2) For the excitation mode, the output impedance of the current source is large, otherwise it will have a large error, and a reasonable current source with high output impedance should be designed; (3) The real and imaginary parts of human tissue impedance are rich in complex physiological information and pathological information system, therefore, it needs a higher frequency of excitation; (4) Measuring circuit requires the signal to noise ratio and high sensitivity; (5) To meet the clinical real-time image monitoring, EIT needs to be able to achieve fast imaging, and the time of data acquisition and image reconstruction required is not greater than 40ms. The structure of electrode EIT system is shown in fig.8.

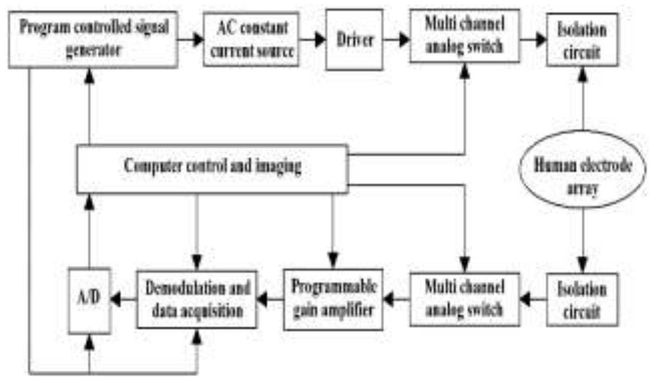

Fig. 8: Reconstruction of real head structure model

The modular design of EIT system mainly has incentive module, measurement module, signal processing module, system control module, drive module and imaging module. Among them, the excitation module has the characteristics of high output impedance and low noise with the frequency range of 10KHZ-100KHZ; The surface potential test is completed by the measuring module, and then amplified and sent to the signal processing module to process the signal; Signal processing module includes the A/D conversion, acquisition system, synchronous demodulation, filtering, etc.; System control module can make real-time synchronization control, and complete the image construction with the imaging module, by the control of the computer and related software; The driving module loads a constant current signal which is generated by the excitation module on the excitation electrode, which comprises a multi-channel switch, an isolation circuit, etc.

Case analysis: In order to further study the application of EIT technology in the evaluation of PCNSL medical image, patients diagnosed as primary central nervous system lymphoma and treated with surgery are collected from June 2012 to November 2015. The case group is analyzed. The influence of different medical imaging on the diagnosis and treatment of the patients are compared with and the application value of EIT technology is analyzed.

The patient's inclusion criteria is as follows: Postoperative patients are defined as patients with PCNSL, preoperative exclude pleural involvement in patients, preoperative blood routine is normal, no family history of blood disease, excluding systemic superficial lymph nodes and abnormal. According to the inclusion criteria, the final total of 21 patients are included in, including 12 men, 9 women, men and women ratio of 1.33:1. Age of onset is 26 years old -59 years old, and the average age of the patients is 45.7 years. All patients are hospitalized, and the average number of days is 24.7 days.

In 21 patients, all have symptoms of intracranial hypertension, with headache and dizziness, 2 cases of severe headache, 4 cases of memory loss, 3 cases of visual loss, 1 cases with intermittent seizures, 2 cases of fever, 2 cases of aphasia. In 21 cases, 7 cases are multiple, 14 cases solitary, 6 cases located in the parietal lobe, 5 cases in the thalamus, 2 cases in the occipital lobe, no spinal cord or cerebellar region. The tumor is like fish meat during the operation, the tumor is nodular tumor growth, and peripheral edema of tumor is obvious, 4 cases near the ventricle, no tumor invasion and skull.

MRI scan and EIT examination are performed before operation in 21 patients, and EIT is monitored during and after the operation. The structure of the EIT system is shown in fig. 9.

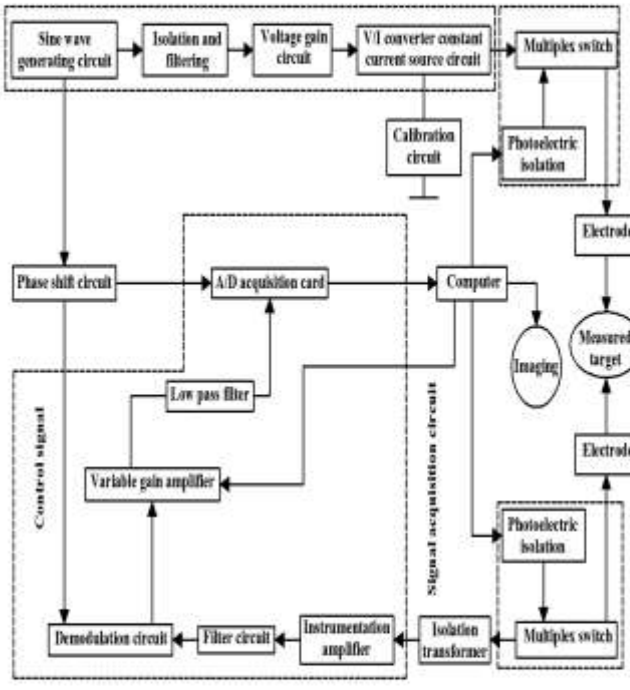

Fig. 9: Reconstruction of real head structure model

It can be seen through the image data, in the 21 patients, 16 patients have nodular enhancement, 16 cases have clear boundary and obvious edema around, and 5 cases have a relatively poor boundary between the boundary and the surrounding brain tissue. In the preoperative diagnosis, in 21 cases, 11 cases are lymphoma, 6 cases of metastatic tumors, 4 cases of gliomas, and the misdiagnosis rate is 47.6%.

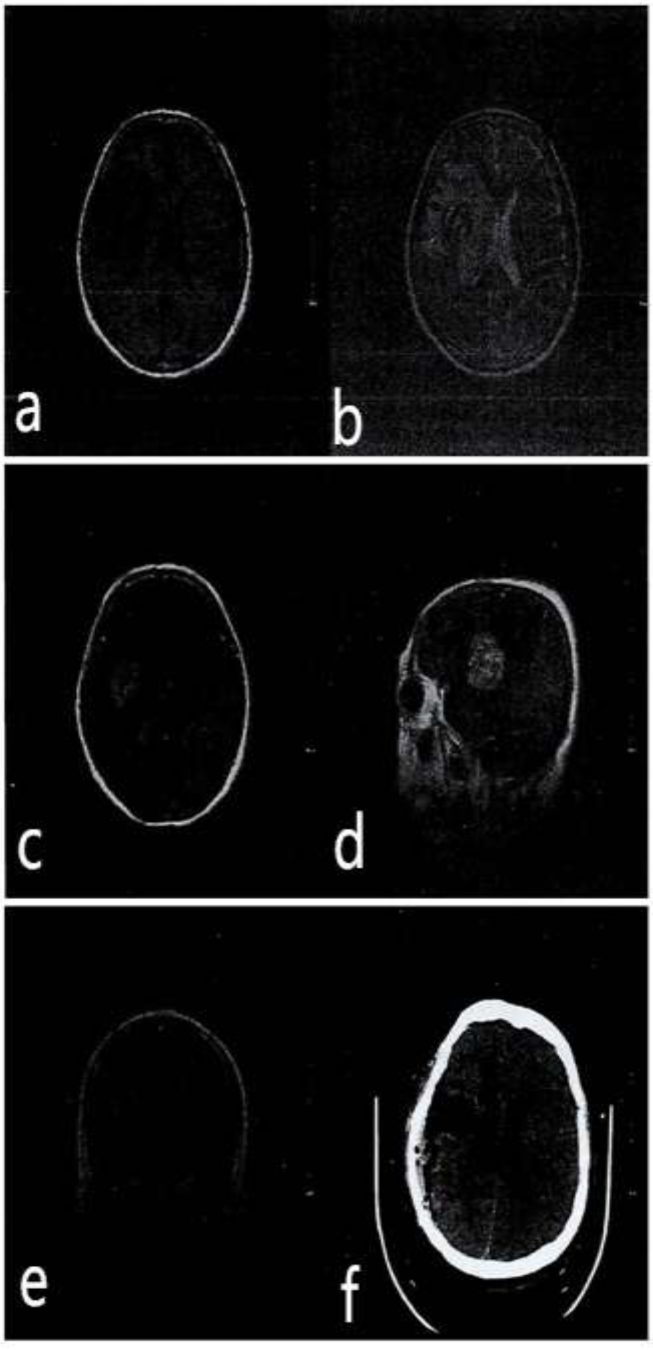

Fig. 10: Imaging data of patients

Detailed analysis of the medical image in fig. 10 is as follows. In fig. a, the boundary between tumor and surrounding tissue is not clear, but the edema is obvious, and the median line is slightly left; There is obvious edema around Fig. b; Fig. c shows tumor enhancement uniformly, the border of the tumor and the brain tissue around the tumor can be seen, hard texture tumor; fig. e and fig. d show enhanced uniform, which is the coronal and sagittal position enhanced; fig. f is the postoperative review, and the tumor edema zone around is more obvious, and the whole tumor is total cut under the naked eye.

Through the evaluation and analysis of the image, we can see that the misdiagnosis rate of EIT in the diagnosis and treatment of PCNSL is very high with 47.6%. This includes reasons of complex PCNSL clinical manifestations and imaging characteristics, and reasons of the low resolution of EIT images, and therefore it needs to further enhance the imaging effect of EIT technology. But comparing the image data of the EIT medical technology and MRI image data, the conclusions of the two are equivalent, which indicates that the evaluation of EIT in medical imaging and MRI can be replaced by each other in a certain extent, without significantly change the evaluation results of medical imaging And in the intraoperative and postoperative imaging examination, EIT system has a more convenient and quick advantage, it is more convenient for the patient's clinical monitoring. In particular, for patients who need real-time clinical monitoring, it can allow doctors to understand the patient's condition in a timely manner, and take effective measures in time.

Conclusions

The use of medical imaging technology for PCNSL diagnosis and treatment is helpful for the treatment of patients and health recovery, which can give full play to its characteristics of imaging speed, small trauma, low cost, convenient and so on. After analyzing the working principle of EIT technology, the overall structure of the head is reconstructed, and the optimization design of the main module of the EIT system is completed. Combined with the actual cases in a hospital, 21 cases of PCNSL patients diagnosed during the period of June 2012 ~ November 2015 are all carried out the whole brain MRI scan and EIT examination, intraoperative and postoperative follow-up EIT monitoring. After analysis, the ratio of male to female ratio is 1.33:1, the average age is 45.7 years, and all the patients are hospitalized in 21 cases. Through the evaluation and analysis of imaging, it can be seen that the rate of misdiagnosis is high when the EIT technology is used for PCNSL, so it is needed to further improve the imaging effect of EIT technology. But through the comparison and analysis of the image data and MRI image data of EIT technology, the medical conclusions obtained from the two are equivalent, which can be replaced by each other in a certain degree. In the intraoperative and postoperative imaging examination, EIT system has the advantages of more convenient and fast, more convenient for the patient's clinical monitoring.

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