Study on Impedance Characteristics of the Breast Tissue and EIS Imaging

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***Abstract*—EIS (Electrical Impedance Scanning) is a new technique used in the diagnosis of breast cancer. The impedance characteristics of the breast tissue are the fundamentals of the technique. In our experiment the four-electrode measurement was facilitated by means of the model 1255B impedance analyzer, which was used to measure the multi-frequency resistivities of Chinese women's breast carcinomas and their surrounding tissuwa in vitro. From the data obtained, it can be seen that there existed significant differences in resistivity between the breast carcinoma and its surrounding tissues. The resistivity of the fatty tissue was the highest among the measured samples, then came the resistivity of the breast carcinoma and that of the gland tissues. Pathological analysis and interpretation were followed. Some features of EIS imaging for Chinese women which are different from those of the Western women can be illustrated by the measured data.**

Keywords — EIS, breast carcinoma, impedance spectroscopy; resistivity

I. INTRODUCTION

The Electrical Impedance Scanning (EIS) is a new non-invasive and irradiation-free technique, used in the auxiliary diagnosis of breast cancer. The technique is based on the differences in electrical impedance characteristics of breast tissues, especially those between cancerous tissues and healthy tissues. The previous studies[1-4] have indicated that the impedivity of cancerous breast tissues is much lower than that of the normal breast tissues; thus, the cancerous lesion is a "light dot" on the EIS image. This feature was verified by some clinical researches on EIS[5-10]. However, the situations are more complicated when EIS is used on Chinese women, which suggests the necessity to study the resistivity of Chinese women and to interpret the results obtained by means of EIS.

Our goal was set to reveal the differences in resistivity distribution for Chinese women and to discuss whether these differences would cause any effect on the EIS image.

In this study, we measured the specimens cut in the radial direction from the cancer block center, and after the measurement, all the tissues were sliced for the pathological examination to determine the organization type.

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II. MATERIALS AND METHODS

A. Materials

Tumor specimens used in this study were obtained from mastectomy surgeries performed in Xijing Hospital on 31 patients with infiltrating duct carcinoma. The specimens were taken in the radial direction from each patient's breast cancer core, and the cancerous tissues of the center region and the peripheral region around the center, and those 1cm and 3cm away from the margin of the lesion, and the adipose fatty tissue on the edge of the breast were obtained respectively. From each specimen, depending on its size, 2-4 cylindroid samples (6mm in diameter and 12mm in length) were excised.

After measured, all the fresh specimens were fixed in 10% neutral Formalin, embedded in paraffin, and sliced into 4 μm thick sections, which were then stained with hematoxylin-eosin for routine histological examinations.

B. Measuring methods

The metering equipment used in our experiment was the frequency response analyzer (Solartron 1255B Frequency Response Analyzer).

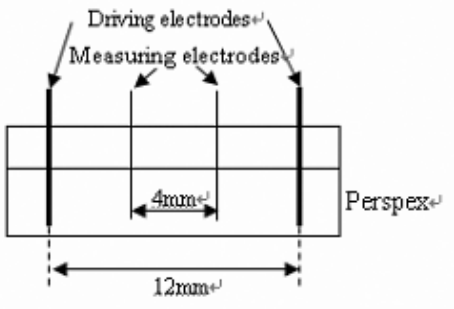

Fig 1. Measuring box

The measuring box (see Fig.1) made by ourselves of plexiglass was embedded inside a column cavity with the diameter of 6mm and length of 12mm. The samples were put into the cavity when measurements were performed. Two acicular silver measuring electrodes were used, with the

diameter of 0.5mm for each and the distance of 4mm between them. The two plate-type stainless steel electrodes were used as driving electrodes with a distance of 12 mm between them. The frequencies for the measurements ranged from 1Hz to 1MHz. Each measurement was completed within 2 minutes at 20℃.

In the experiment the tissue impedance R* was obtained through impedance analyzer Solartron1255B, and on the basis of the geometry size of the tissue, the resistivity ρ* of the tissue could be calculated by Formula 1, where S is the tissue's plan area; L is the tissue's length.

$$\rho^* = \frac{S}{L} R^* \quad (1)$$

III. RESULTS AND DISCUSSION

A. Resistivity of each kind of tissue measured

The resistivity of each sample was measured *in vitro*. It was found that the sample from the core of the breast cancer had a bulk of tumor cells and some necrosis spots (registered as the CA1 group); the sample from the tissue surrounding the cancer contained some tumor cells but no necrosis spots (registered as the CA2 group); the sample from the tissue 1cm to the block edge was generally mastopathy (registered as the MA group); the sample from the tissue 3cm to the block edge was the normal gland tissue (registered as the MG group), and the sample from the breast peripheral tissue was the adipose fatty tissue (registered as the AT group). Fig. 2 shows the curve of resistivity of each group changing with the frequency. The results at each frequency were averaged.

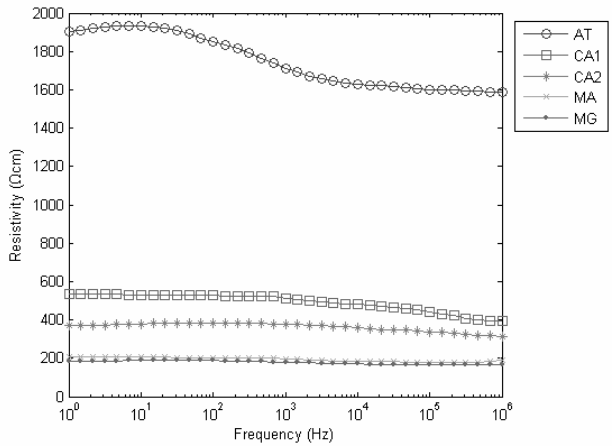

Fig 2 The resistivity of the measured tissue changing with frequency

Fig. 2 shows that the resistivity of the AT group is by far greater than that of any other group. It is quite steady below 100Hz, but drops with the frequency increasing. The resistivities of the CA1 and CA2 groups are in the middle of the five groups, with quite steady profiles in the low frequency area (<1KHz), and a dropping tendency with the frequency increasing. Among all the groups, the resistivities of the MA and MG groups are the lowest with pretty steady profiles within the entire measurement frequency range.

B. Pathology analysis on each kind of tissue measured

According to the results displayed under the light microscope (see Fig. 3), we found that different histological types and pathological features of the samples showed different impedance characteristics of the breast tissue. To make a better explanation, we divided all the measured tissue into three types. The first type was representative of the bulk of the tumor, including the central tissue (the CA1 group, see Fig. 3(a)) and that near the edge of the carcinoma (the CA2 group, see Fig. 3(b)). The second type of sample was mainly the glandular tissue, including both necrotic tissue (the MA group, see Fig. 3(c)) and the normal glands (the MG group, see Fig. 3(d)). And the third type was the adipose fatty tissue (the AT group, see Fig. 3(e)).

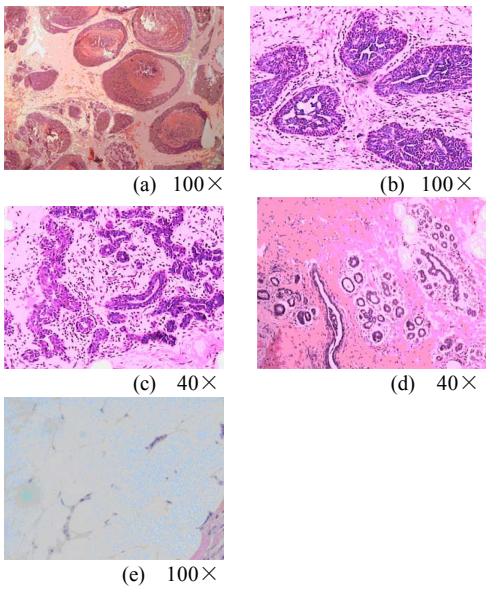

Fig. 3. Microscopic view of all types of tissue: (a) the tumor core tissue (b) the tissue near the edge of the carcinoma (c) the necrotic tissue (d) the normal gland (e) the adipose fatty tissue

The results showed that, the resistivity values of the first type were greater than those of the second, and those of the third type were the greatest among the three types. The explanations for the results are as follows: Firstly, the different results from different tissues suggested a possible relationship between tissue's electrical impedance and the physical metabolism and pathological development of the tumor. The cancer, as we all know, is featured by its highly atypical hyperplasia and diffused infiltrating of the cancer cells. This hypermetabolic condition and the absolutely increasing cell number might represent a higher resistivity than benign types. Similarly, according to the second type of tissue, the resistivity values in the necrotic tissue were higher than the normal gland, which might be due to the faster increasing numbers and the vibrant hyperplasia activity of the duct epithelium with or without tubular expanding in the necrotic tissue. The greatest value from the fat tissue might result from the lower ion concentration, stroma and water within the lipocytes, which increased the resistivity. And, another interesting thing we found is that inside the first type tissue, the carcinoma

contained much necrosis and showed a higher resistivity value than the one without necrosis (as shown in Fig. 3a and Fig. 3b), which might be attributable to the fact that the necrotic part contains more collapsed substances mixed with water.

From the pathological examination, we have found that both the fatty and the normal gland tissues can be regarded as the healthy tissue. The breast carcinoma tissue invades the periphery tissue through infiltrative growth, so it may invade either the fatty tissue or the normal gland tissue. There is different in resistivity between the fatty tissue and the normal gland tissue from our experimental data. The different sites where the carcinoma invades result the different imaging on EIS. From the principle of EIS, we may imagine that when the carcinoma invades the fatty tissue, a "light dot" may appear on EIS because of the resistivity of the cancerous tissue which is lower than that of the fatty tissue, and when the carcinoma invades the normal gland tissue, a "dark dot" may appear on EIS because of the resistivity of the cancerous tissue which is higher than that of the normal gland tissue. Some literatures [5]-[9] reported that the carcinoma may appear "light dot" on EIS. No "dark dot" of carcinoma on EIS has been reported. Our clinical experiments showed that some patients suffered form breast cancer appeared "dark dot". From the analyses above we know that the phenomenon of "dark dot" is reasonable.

IV. CONCLUSION

There are different in resistivity among carcinoma tissue, mastopathy tissue, normal gland tissue and fatty tissue of breast because of their different pathological states. The different invading sites of carcinoma bring the differences between the carcinoma and its surrounding tissues. Therefore different images appear on EIS. We may conclude that there is a new different feature in EIS image between Chinese women, and European and American women because of different culture, area and life style.

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