Cancer Identification during Breast Surgery Using Electrical Impedance Spectroscopy Analysis

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Abstract: In this paper, electrical impedance spectroscopy (EIS) analysis was employed to evaluate the dielectric property of breast tissues. The complex impedance was recorded by a bio-impedance meter in the frequency range of 3 kHz to 1000 kHz. Non-linear Least squares regression was implemented to fit the measured data into Cole-Cole model. It was observed that significant differences existed between breast cancer and benign tissues.

1 Introduction

Breast cancer is the most common malignant tumour among women worldwide. It has been discovered that malignant breast tumors have significantly different impedivity than normal tissues [1-3]; therefore electrical impedance spectroscopy analysis has emerged as a promising indicator for breast cancer detection [4-5]. During a breast cancer excision surgery with ambiguous malignance judgment, the result of frozen biopsy during operation is adopted as a vital reference of the final surgery route (mastectomy or Breast-conserving operation). However, the method involves visual inspection and tissue pathology ('frozen sections') and fails to detect 12-25% of cancer during breast surgery, which means inaccurate tumour identifications lead to under- or over- treatments [6]. As the complimentary method of the frozen biopsy, EIS detector has the potential to be adopted as a hand-held real-time device which will undoubtedly facilitate clinical decision and help reduce erroneous decisions. Moreover, understanding the fundamental electrical property of breast tissues is vital important for some non-invasive impedance imaging techniques, such as electrical impedance tomography (EIT). In this paper, EIS analysis was applied to measure the electrical property of breast tissues in order to obtain some valuable *a priori* information for further research.

2 Methods

In vitro breast tissues were collected from 300 women under mastectomy. Tissue specimens identified by biopsy were categorized in three groups: breast cancer (CaB), benign fibro-adenoma (BFib) and non-hyperplastic mammary glandular tissue (MG). The complex impedance was recorded by a bio-impedance meter in the frequency range of 3 kHz to 1000 kHz. Non-linear Least squares regression was implemented to fit the measured data into Cole-Cole model:

$$R^* = R_\infty + \frac{R_0 - R_\infty}{1+(jf/f_c)^\alpha} \quad (1)$$

Three parameters were statistically obtained including characteristic frequency f_c, fractional power α and static/infinite impedance ratio R_0/R_∞.

Student's t-test was applied in this paper, which is appropriate for statistically analysing on small number groups with Gaussian distribution. Moreover, it is one of the standard and popular methods in medical statistics. Up to present, the sample quantity is still quite limited. For one specific sample, the measurement is affected by random noises which satisfy Gaussian distribution. Therefore, *t-test* can be applied to determine if two sets of data are significantly different from each other.

3 Results

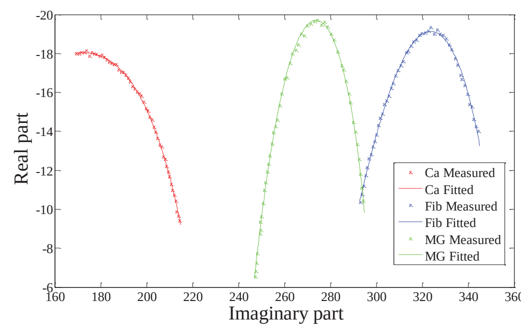

Figure 1: The typical bio-impedance spectroscopes of breast tissues. Spectroscopes are fitted to the Cole-Cole model.

4 Conclusions

In this paper, EIS technique was implemented to analyse the electrical property of breast tissue (Fig. 1). We found that the Cole characteristic frequency f_c is an excellent indicator of the presence of breast cancer since it has much higher value than normal tissues (Tab. 1). *Student's t test* showed that significant difference (p<0.05) existed between CaB and BFib for f_c and R_0/R_∞; while difference was observed between BFib and MG for R_0/R_∞ as well.

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Table 1: The mean average and standard deviation of tissue Cole-Cole parameters

Tissues	f_c (kHz)	α	R_0/R_∞
CaB	209.9 ± 144.6	0.57±0.16	1.80 ± 0.89
BFib	39.8 ± 30.6	0.53 ± 0.12	1.41 ± 0.17
MG	14.3±14.8	0.54±0.11	1.47±0.28

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