MINI-REVIEW

Electrical Impedance Tomography as a Primary Screening Technique for Breast Cancer Detection

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Abstract

    Electrical impedance tomography (EIT) is a new non-invasive, mobile screening method which does not use ionizing radiation to the human breast. It is based on the theory that cancer cells display altered local dielectric properties, thus demonstrating measurably higher conductivity values. This article reviews the utilisation of EIT in breast cancer detection. It could be used as an adjunct to mammography and ultrasonography for breast cancer screening.

Keywords: Breast cancer - electro-impedance tomography - electrical impedance mammography

Introduction

Breast cancer is the most common cancer among women and leading cause of death worldwide, including Malaysia (Loh et al., 2011; Kulakci et al., 2015). The breast cancer accounts for 30-40% of all the cancers in women all over the world (Che et al., 2014; Kulakci et al., 2015). In Malaysia, about one in 19 women in this country are at risk for getting breast cancer, compared to one in eight in Europe and the United States (National Cancer Registry, 2006). According to World Health Organization, more than 30% of cancer deaths can be prevented (World Health Organization, 2009). Hence, the best way to put a stop to death is by early detection when treatment is more effective (Myoung et al., 2007).

There are two strategies for early detection of breast cancer: *i)* education on recognizing early signs of cancer and seeking prompt medical attention. *ii)* screening programmes to identify early cancer or pre-cancer stage before signs are recognizable (Ministry of Health Malaysia, 2009).

Currently, instrumental methods of breast disease diagnostics can be divided into two groups. To the first group belong X-ray mammography (MMG) and ultrasonography (USG). These methods are based on a study of the mammary gland anatomy. They determine the presence or absence of the pathology in the organ's structure (Renata et al., 2012). Result of study done by Chang et al. (2015) showed breast cancer survival rate in Korea has increased consistently due to the increasing using mammography among women.

To the second group belong diagnostic methods, based on physiology, on the peculiarities of metabolism in breast tissues in norm and pathology. These methods include electrical impedance tomography (EIT) (Renata et al., 2012).

As mention earlier, mammography is a method used for early detection of breast cancer. But, mammographic facilities are costly and available only at limited places (Vithana et al., 2015). Consequently, the new technology electrical impedance tomography (EIT) which is a relatively new imaging method that has evolved over the past 20 years is recommended (Hope et al., 2004). Electrical Impedance Computerized Mammograph MEIK" is an EIT system for breast diagnostics which has been approved for clinical usage in Russia.

Electrical impedance tomography (EIT) which is a noninvasive procedure using electrical impedance to image the human breast (Chakraborti et al., 2010). This scanning device does not emit any ionizing radiation thus it can be done on pregnant women by means of no age limit and not expensive (Kinouchi et al., 2002). Due to its mobility and using non compression technique it is appealing to patients.

The value of EIT is based on the diverse electrical storage potential of normal and pathologically changed tissues. These differences will allow to image differences in the tissue conductivity and permittivity inferred from the breast tissue electrical measurements. It consists of a handheld transducer and a computer screen that displays the images of the breast. Small currents are applied to a part of the subject's body through conducting electrodes attached to the skin and the resulting electrical potentials are measured and visualized (Renata et al., 2012).

As mention earlier, the MEIK device, using EIT technology, is radiation free, and since it is portable, the screening can be done virtually anywhere. This hand-held device consists of a compact array of 256 electrodes

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Table 1. HPE Findings Comparative Analysis

HPE*	Sensitivity		
	Mammography (MG)	Ultrasonography (USG)	3D Electrical Impedance Tomography
Fibrocystic mastitis	83.3%,	94.4%,	77.8%,
	95% CI 58.6% to 96.4%	95% CI 72.7% to 99.9%	95% CI 52.4% to 93.4%
Cyst	81.0%,	100%,	100%,
	95% CI 58.1% to 94.6%	95% CI 83.9% to 100%	95% CI 83.9% to 100%
Fibroadenoma	87.5%,	75.0%,	68.8%,
	95% CI 61.7% to 98.5%	95% CI 57.2% to 92.7%	95% CI 41.3% to 88.9%
Carcinoma	100%,	100%,	75.0%,
	95% CI 39.8% to 100%	95% CI 39.8% to 100%	95% CI 19.4% to 99.4%

*Histopathological Entities

Figure 1. Electrical Impedance Computer Mammography

and uses small electrical pulses (0.5 mA, 50 kHz) for the breast examination. The procedure continues for each electrode until 65,280 voltage measurements are taken within 20 seconds. The received data is reconstructed into direct-to-digital tomography conductivity images of the breast. Seven tomography slices are then created within 40 seconds at the depths of 0.4 cm to 4.6 cm to detect and isolate tumours. No materials like gel or ECG spray are required for the procedure (Ministry of Health, 2009) (Figure 1).

Experimental studies with Electro Impedance Tomography (EIT) have shown that significant changes occur in the electrical properties of breast cancer tissue compared to the surronding normal tissue (Martin et al., 2002; Zou et al., 2003). Some evidence has been found that malignant breast tumours have lower electrical impedance than surrounding normal tissues (Malich et al., 2001; Prasad et al., 2008). This observation has led to the proposal that electrical impedance could be used as an indicator for breast cancer detection (Cherepenin et al., 2001; Cherepenin et al., 2002; Athanasiou et al., 2007).

Methodology

Four databased were used for the literature search Pub Med, Medline, Cochrane, INAHTA. The search terms were, "*breast cancer*", "*Electro- Impedance Tomography*" and "*electrical impedance mammography*". Any primary

and secondary papers pertaining to "*Electrical Impedance Tomography*" or "*Electrical Impedance Mammography*" included in this technology review. Those which full text could not be obtained were excluded.

Effectiveness of EIT

A cross-sectional study was conducted to determine the diagnostic efficiency of 3D Electrical Impedance Tomography (EIT) as compared to Mammography (MG) and Ultrasonography (USG) in imaging the breast (Prasad et al., 2008). A total of 88 patients presenting with various breast complaints was examined using MG, USG and 3D EIT imaging system "*MEIK*". The sensitivity of 3D EIT in diagnosing different breast pathology was found to be less sensitive compared to mammography and ultrasonography (Prasad et al., 2008). Details of the analysis are shown in details of the analysis are shown in table 1.

The results of study showed that, no significant difference in sensitivity between mammography and ultrasonography (p=0.219), mammography and EIT (p=0.779), and ultrasonography and EIT (p=0.169). However, there was significant difference in the sensitivity of mammography compared to ultrasonography (p=0.042) and EIT (p=0.042) with regards to identifying cysts (Prasad et al., 2008).

In 2012, Raneta conducted a study among 808 patients on women from Slovakia found that the sensivity of EIT was 87%, lower than MMG (89%) and USG (91%), but this differences is insignificant. The specificity of the EIT and USG showed almost equal values (85% and 84%, respectively) and specificity of MMG reached 91%. Also, the findings of this study showed that, in combinations EIT + MMG and EIT + USG sensitivity increased to 96% and 98%, respectively. The specificity of EIT + MMG amounted to 79% and of EIT+ USG to 71% (Raneta et al., 2012).

Zain et al. (2014) done one study among 150 symptomatic women underwent EIT examination in Department of Radiology, Universiti Kebangsaan Malaysia Medical Center, Malaysia. Results of this study showed EIT had 64.4% of sensitivity using diagnostic Mammography (MG), 70.1% of specificity, 67.1% of positive and 67.5% of negative predictive value. However,

its specificity and positive predictive value increased from 70.1% to 76.3% and from 67.1% to 80% respectively when combination EIT, MG and USG were used (Zain et al., 2014). If the test results could not confirm the type of breast abnormality through MMG and US, additional biopsy procedure will take place. With respect to the histopathological findings (10 malignant and 13 benign lesions) 9 of 10 (90%) malignant lesions were correctly identified whereas 10 of 13 (76.9%) benign lesions were correctly identified as benign by EIT (3 of 13 benign lesions showed as false-positive findings) (Zain et al., 2014).

There are some factors which effect on mean electrical conductivity of EIT. For instance, in in study done by Zain et al. (2014a) showed that the mean electrical conductivity value of Malaysian women were increased with age, but this value is lower than the standard Caucasians (p<0.05). Also, their study showed there was strong positive correlation between ranked BMI and mean electrical conductivity value (rs=0.28, p=0.001).

Conclusion

In conclusion, based on the finding obtained from previous studies related to sensivity and specificity of EIT and comparing with mammography and ultrasound; it appropriate to use EIT for preventive check-ups of the female population between rounds of screening in order to isolate patients at risk; in examination of pregnant and lactating women and women with high risk of carcinogenesis (BRCA1, BRCA2 genes) and as an additional method

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