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ABSTRACT

Electrical Bio-impedance Tomography (EBT) is a home made non-invasive system designed to image breasts in the geometry of mammogram through applying alternating-current (AC) on the breast and measuring the voltage distribution that result, and by using computational methods one can reconstruct an image of impedance (Z) that corresponds to both the anatomy and pathology of the breast. With 64 stainless-steel electrodes, 26 breasts in 26 women have been scanned with this system using 4 mA root mean square (RMS) AC-current with frequency 1 MHz. Characteristic bio-impedance images emerged for mammographically normal and abnormal cases. We demonstrated the impedance breast images that correctly localized lesions. Using the visual criterion, the EBT system was able to identify 80% of the tumour cases, 67% of the abnormal cases, and 73% of normal cases. EBT appears to be promising in breast cancer screening, but improvements must be made before the system reaches its full potential.

KEYWORDS

Breast imaging, Electrical bio-impedance tomography, Mammography

1. INTRODUCTION

Breast cancer is the most frequently diagnosed cancer in females worldwide and the rates are increasing in developing countries [1], and in general, the earlier the tumour is detected and treated, the better the chances for survival. In the past recent years, mortality has been reduced significantly in part due to screening by medical images modalities [2]. The present gold standard for breast screening is the Mammogram [3]. Radiologists look through two dimensional image of the radio-density of the breast that reveals the internal structures and classify breast tissues using the American College of Radiology (ACR) system and Breast Imaging for Reporting and Diagnosis System (BI-RADS). Although mammograms are the present gold standard for breast cancer screening, (sensitivity - 71-87%; specificity 38%), they do have multiple shortcomings. First, since they cause cumulative x-ray exposure and they are difficult to use with dense breast tissue (prominent in younger women), mammography is mainly recommended for women over age 40 years old. Next, many women avoid mammograms since they find the breast compression uncomfortable and in some instances painful. Finally, since mammography has a high number of false positive results, many women must undergo the psychological trauma, physical scarring, and financial hardship of unnecessary biopsies [4, 5]. Instead of using x-rays to detect malignancies, another possibility is to use electricity to accomplish the same goal [6]. Electrical

Bio-impedance tomography (EBT) generates images of electrical properties, and it basically works in the following way: multiple electrodes are placed at the periphery of the tissue and known currents are applied. Using the known current and the resulting voltages, one can compute an image of the electrical bio-impedance of the tissue [7]. In the early eighties, Barber [8] constructed a relatively simple EBT system using 16 electrodes and applied a constant amplitude current at 50 kHz between two electrodes at a time. Differential voltages were recorded from adjacent electrodes. The images were computed using a method known as back-projection, a method that had been used with great success in the field of X-ray tomography. The image appeared to show bones, muscle tissue, and blood vessels. However, the resolution of the image was very low [9]. Some researchers such as Jossinet [10], one of the first researchers apply EBT to breast imaging, his group constructed an examination table designed specifically for the breast. It had a circular aperture with 16 electrodes actuated by pneumatic jacks. Although his group did successfully fabricate an accompanying current mode EBT system operating to 1 MHz, no in vivo breast images were published. Nevertheless, as stated before Jossinet performed many important ex-vivo experiments with excised breast tissue. In a recent study with 106 cases, he used two and four-point impedance measurements to distinguish carcinomas from both normal and other benign pathological breast tissue with carcinoma discrimination greater than 86% as confirmed by biopsy [11]. Morimoto's group [12] in Japan did successfully measure the impedance of breast tissue in vivo with the three-electrode method from 0 to 200 kHz. Initially, an invasive system was employed where a coaxial needle electrode was inserted into malignant cancers and fibroadenomas in situ. A large reference electrode was placed on the abdomen. The tissue was modelled as a lumped circuit with extracellular resistance (Re), intracellular resistance (Ri), and capacitance of the cell membrane (Cm). (Re) and (Ri) were found to be higher and (Cm) was lower in the malignant tumours compared with the fibroadenomas. Finally, several groups have simulated the process of generating electrical impedance images of the breast by applying a mathematical methods and algorithms such as J Forsyth [13], he proposed a method that has the potential to reduce errors by accurately modelling the patient breast shape. They develop methods for processing the data from the scanner and produce volume meshes that accurately matching the breast surface and electrode locations, which can be used in image reconstruction to improve the clinical value of EBT for breast cancer diagnosis. All the studies conducted by Jossinet, Morimoto, and Forsyth suggest that EBT is a promising modality to image breasts for malignancies. The success of these ex vivo measurements, in vivo experiments, and theoretical studies all justify the application of EBT to breast imaging as presented in this thesis. Although EBT probably will never detect anatomy to the same detail as mammograms, it does have the potential to distinguish tissue types that signify malignancy. The research goal of this paper is to investigate the diagnostic capabilities of the non-invasive in-vivo electrical bio-impedance measurements by a developing EBT scanning system for the breast to providing an informative images with relatively high resolution, where the early detection of breast tumors.

2. MATERIALS AND METHODS

2.1 EBT System Overview

EBT System consists of 64 stainless steel electrodes (8x8) array with 10 mm diameter spaced by 5 mm fabricated on a printed circuit board and embedded in a Plexiglas plate, Figure 1, these electrodes array connected to the main unit which consists of multi frequency alternating current (AC) voltage source, Microcontroller, Multiplexers, Analog to Digital Converter (ADC), divider circuit, peak detector system, and computer for running software.

Figure 1. Depicts the electrode array placed on the top plate and reference electrode placed at bottom plate.

A schematic diagram for EBT system is shown in Fig. 2, EBT was built to be extremely precise at application of any excitation pattern to the electrodes, and it can operate at any frequency up to 1 MHz. It is completely portable and self-contained. EBT works through operation sequences as follow; Bio-image Scanner V2.0 software (designed and developed using Microsoft Visual Basic .NET to control the hardware) sends an asynchronous message to the data acquisition system via USB forcing it to start its operation. The data acquisition system is a microcontroller based system activates one of the multiplexers to select one channel (electrode) and measure the analog voltage across the selected electrode and reference while disabling the other 63 ones. The measured (AC) analog voltage across the examined breast tissue is converted to the corresponding direct current (DC) value using the AC/DC converter circuit. The analog DC voltage converted to a digital value using the ADC converter module. The data acquisition system responds with a stream of data (64 units) representing the data from the electrode set. The software waits for this data stream to store, and export it to the last stage of image reconstruction software. The software saves this data in an ASCII-formatted text file using the Microsoft Visual Basic .NET file system capabilities. When the data stream ends, the software starts the image generating executable (plot_impedance.exe) via a simple communication with the windows shell. This part of the software (namely: plot_impedance.exe), Figure 3, was developed using MATLAB. The operation procedure of plot_impedance.exe as following; the software reads the text file that was created by the data acquisition software and translates the text contents into "double" format. It creates a matrix of integers with the size of 8x8 (each matrix element corresponds to an electrode). The software then performs 2D linear data interpolation between the data elements resulting into a new matrix with the size of (700x700) data elements. Finally the (700x700) two dimensional (2D) matrix is plotted using filled contours to output an image that represent the breast tissue.

Figure 2. A schematic diagram for Bio-impedance system hardware.

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