Clinical application of Electrical Impedance Tomography in the Present Health Scenario of India

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Abstract. Early detection of Breast Cancer is currently emerging as a big clinical entity requiring a non invasive, radiation less, harmless, cost effective diagnostic technique. Survival is improved if detected early. Breast Cancer is the second most common cancer in India. Health corporate system of India is urgently requiring a cost effective, noninvasive novel technique like "Electrical Impedance Tomography (EIT)" for screening large poor rural population of India for early diagnosis of Breast Cancer. EIT is the technique to visualize spatial distribution of Electro-impedance (or conductivity) inside the object, such as human body. A medical device which allows imaging of the distribution of conductivity in 3D in regions below the skin surface has been developed and tested. Its purpose is to enable early detection and preliminary diagnosis of breast tumors. The system uses a planar array consisting of 256 electrodes and enables obtaining images of the three-dimensional conductivity distribution in regions below the skin's surface up to several centimeters deep. The developed measuring system and image reconstruction algorithm can be used for breast tissue imaging and diagnostic, in particular for malignant tumor detection. Initially ten patients as control and ten patients with breast lesions have been studied with this new technique. It was found that electrical impedance mammograms from different groups has clear visual distinctions and statistically significant difference in breast glands conductivity. The results are quiet encouraging. EIT may emerge as the first line noninvasive imaging method of choice for screening large population for early detection of breast cancer.

1. Introduction

Breast cancer is the second most cancer in the women worldwide. Survival is improved if detected early. Therefore, early detection of breast cancer is of great clinical importance both from the angle of treatment and total cure. Various imaging techniques available for diagnosis of breast cancer are x-ray mammography, ductography, xeroradiography, thermography, ultrasound,CT Scan,MR imaging, isotope imaging and PET scanning etc. WHO has introduced different screening procedures for early diagnosis of breast cancer. X-Ray Mammography screening is the only currently known method and also is considered as gold standard. But X-Ray Mammography involves lots of ionizing radiations. Too frequent exposure can also be a cause of breast cancer. It is not advised for young patients below 30 years of age, pregnant women and in screening of large dense breasts. Moreover x-ray mammography/digital mammography machines are very costly and available only in main city areas. Other techniques like xeromammography and thermography are less sensitive. Remaining imaging procedures are too costly. Hence a non-invasive, radiation less cost effective technique like electrical impedance tomography/mammography is welcomed. Electrical impedance tomography (EIT) is an wonderful technique which provides a safe, non invasive way to visualize the electrical properties [1,2] of tissues inside a human body. An ingenious reconstruction algorithm and measuring approach introduced by Barber and Brown has been widely developed since 1980s. Basing on the fact that different tissues of human body have different electrical properties, EIT is able to image an anatomical

structures. But till recently medical EIT was able to produce only dynamic images, i.e images of conductivity changes that occurred between two consequent measurements. But for medical diagnosis of the different pathologies requires recapability of EIT system to image static objects inside a human body. The main difficulties in implementing EITs in clinical practice was the uncertainness of the human body shape, electrode spacing and low spatial resolution. Subsequently development of a fast and robust static EIT reconstruction method and efficient measuring equipment has made the implementation of EIT in clinical practice possible.

Application of this method to breast cancer detection requires a special design of the measuring system and image reconstruction algorithm, as imaging of a three-dimensional distribution of conductivity is required. The breast cancer detection device, electric impedance mammography machine designed and developed by the Institute of Radio-Engineering and Electronics of the Russian Academy of Science and is being currently marketed by TD-SIM Technika of Yaroslavl city, Russia. It is a 3D EIT system which consists of a compact of electrodes positioned over the tissues being measured, two additional electrodes placed remotely from the array of electrodes, a source of alternating current (AC), a means to measure potential difference and computing means to reconstruct and visualize the conductivity distribution as stack of tomography images [3,4]. Utilizing this new system, a complete 3-D diagnostic test takes 20 seconds for each breast totaling to 40 seconds for both the breasts. Seven tomographic image slices appear on a computer monitor within 40seconds at depths of 0.4cm to 4.6cm to detect and isolate tumors. These coronal images include tissue near the chest wall. This reconstruction process can be compared to CT or PET scanning but without radiation of any kind and at a significantly lower cost.

2. Materials and Methods

An electrical impedance tomography machine intended for imaging and diagnosis of pathological changes of the breast tissue is used. The system uses a planar array consisting of 256 electrodes and enables obtaining images of the three-dimensional conductivity distribution in regions below the skin's surface up to several centimeters deep. The electrodes are arranged in a round matrix with a diameter of 12 cm. The visual result is several cross sections of the medium, which are parallel to the electrode array and located at different depths. During examination the plane of electrodes is pressed against the breast and this increases the number of electrodes in contact with the breast and decreases the thickness of the tissue layer to be measured. In this study total ten patients as control and ten patients with breast lesions have been studied. The patients were of different age groups ranging from 20 years onwards. To begin with routine clinical history has been taken. Physical examination by palpable method has been done. Following physical examinations , the patients were prepared for electrical impedance mammographic examination. For this, the patients' breasts were evenly moistened with water, avoiding formation of droplets. Along with this the patient's wrists (where the corresponding electrode will be applied later) were moistened. Then electric impedance mammography examination were performed first in supine position followed by standing position. For each breast the study takes 20 seconds i.e., 40 seconds for both the breast study. Though initially the study has been done using 50 KHz electric potential, subsequently it has been seen that the clinical results are better if 10 KHz electric potentials are also used for both the breasts. Therefore, each breast has been studied by using 50 KHz and 10 KHz as well. After the study both visual and quantitative estimation of the data done. The impedance curve indicates the distribution type and quantitative representation of the conductivity of different tissues of the breast during measurement at that particular frequency. Each impedance peak was analyzed for: a) Mean electric conductivity, b) Presence of shift from the central line, c) Whether it is symmetrical or not?, d) Whether it is unimodular or multi-modular?. The patients were studied by ultrasound and at times by ultrasound Doppler. Wherever possible the x-ray mammography correlation has been done.

3. Results and Analysis

It has been found that electrical impedance mammograms from different age groups had clear visual distinctions and statistically significant difference in breast glands' conductivity. In grey scale, changes from dark to light indicates from low electric conductivity to high electric conductivity. Increased conductivity areas has been seen as white spot. The conductivity increased from fat to cancer. For quantitative estimation, the differences of conductivity distribution between the normal

group and from the group with the breast tumour/malignancy has been studied. It was found that results were varying along with the different hormonal status during the cycle. The ladies who were taking oral pills/contraceptives the impedance results varied. Out of 10 patients with the breast lesions 3 patients had fibroadenoma which is shown in Figure 1, 3 patients had cystic lesions, 2 patients had ductal carcinoma, 1 had micro calcifications and 1 had breast tuberculosis. In this cases it is found that the patients with the asymmetrical distribution of the conductivity almost always had multi-modular conductivity curve. This type of findings indicated malignancy. Benign lesions had always unimodular curve and symmetrical distribution of the curve, which is depicted in Figure 2. According to conductivity values the inference also could be drawn. The findings were correlated in most of the cases with the ultrasound scanning, an example of which is depicted in Figure 3. In few cases x-ray mammography study also were correlated, as shown in Figure 4. The diagnosis of the breast pathology was confirmed post surgical biopsy specimens/fine needle aspiration cytology. It is been seen the electric impedance findings if correlated with the ultrasound scanning the provisional diagnosis of the breast diseases/pathology could be done.

4. Discussion

It is an well established fact that every organ in the man's body posses its own electrical characteristics, which in turn defines electrical conductivity of the tissues of that organ and surroundings. This characteristics are well defined and varied in electrical properties of both intravascular and extravascular fluid. The electrical impedance mammograph makes it possible to obtain images of electroconductivity distribution of biological tissues along several cross section of a human body, thus defining the areas with abnormal values of electroconductivty [3,4]. Implementation of the popular screening programs also helps to an greater extent. One of the most important Etiology of breast cancer is ionizing radiation. Presently various imaging techniques like x-ray mammography, ductography, xeroradiography, thermography, ultrasound,CT Scan,MR imaging, isotope imaging and PET scanning etc are available. Out of these, x-ray mammography is considered as gold standard for detecting breast cancer. All these techniques are costly and not available at village level. Besides, it becomes unaffordable for public health sector to screen large population at village level involving a high cost.

India is a developing country. The majority of its population are rural based. The costly machine like x-ray mammography (which is considered as gold standard for screening for early detection of breast cancer) is available only in city areas. Moreover the procedure is very expensive and can not be afforded by majority of the village people. It is seen that the village women with the breast complaints whether it is major or minor undergo psychological trauma. Sometimes hormonal fluctuations causing breast problems can force the poor village people to run to city areas to undergo many costly diagnostic techniques and at times surgical biopsy procedures. Ultimately after undergoing all costly diagnostics techniques it is found that this segment of patients did not have any breast tumours/malignancy, it was only a hormonal problem, which did not require at all the help of costly techniques. Hence a screening technique like electrical impedance mammography will have a significant role in removing the fear psychosis of breast cancer from the mind of poor village people. Moreover in countries like India where the electrification in rural areas are not very proper and availability of electricity at all the times are uncertain, there the technique like electrical impedance which can run on UPS system will be of great value. Following screening of large population, only somebody suspected of pathology of breast can be referred for further investigation and management.

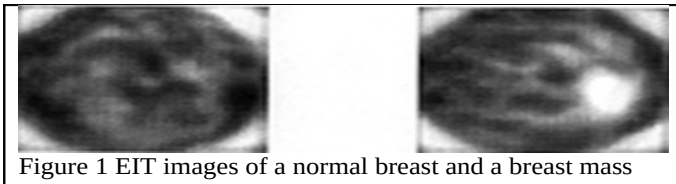

Figure 1 EIT images of a normal breast and a breast mass

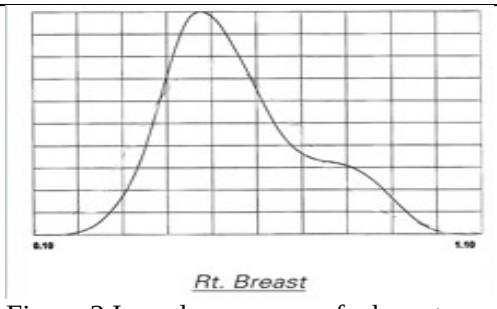

Figure 2 Impedance curve of a breast mass

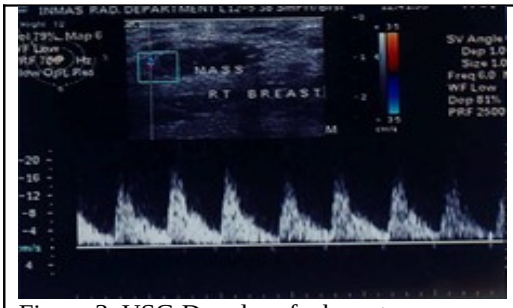

Figure 3. USG Doppler of a breast mass

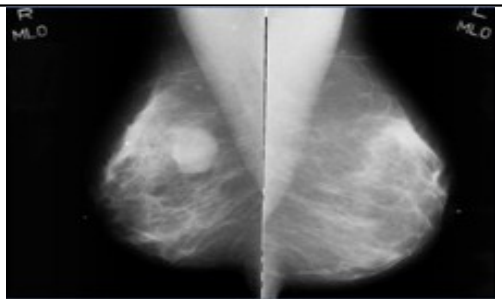

Figure 4. X-Ray Mammography showing breast mass

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