Cost-Effective Breast Cancer Screening to Reduce Mortality Rates of Women in India: A Revolution

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Abstract: Background: Breast cancer is one of the leading cancers among world women. Early detection and early treatment improve the survival rate of the women. In India, breast cancer is primarily identified only at later stages that increase the burden of mortality. Thus, in many developing countries, there exists the scarcity of cost-effective breast cancer screening systems.

Methods: In this paper, we have comprehensively analyzed the limitations of the existing diagnostic tools and overviewed the advancement of microwave technology in breast cancer detection. The principal focus is to augment the survival rate of the women by detecting the cancers at the early stage.

Findings: The comparative studies on sensitivity and specificity values are performed on different diagnostic tools. Microwave-based screening holds 96% sensitivity and 98% specificity values, which certainly reduces false positive and false negative rates. The detection rate is also high as 98% that enables to identify undersized tumors.

Conclusion: Microwave Technology is able to detect the early-stage cancers effectively and the performance exceeds with existing techniques.

1. Introduction

Over the past decade, Breast cancer has become one of the greatest health concerns among world’s women [1, 2]. The trouble of breast cancer is increasing every year and it is expected to across 2,000,000 by the year 2030 [3]. Further, past studies reveal breast cancer incidence rates in India are lower than other developed countries like UK (25.8 / 95 per million). However, mortality rates in India are nearly equal to UK (12.7 / 17.1 per million) [4]. The global reason for high mortality rates in India is the diagnosis of cancer at advanced stages. Mammogram, most common breast cancer screening tool used in India [5]. But mammogram has certain limitations, which shows 50% False positive and 38% False negative results for high fibroglandular breasts [6]. Moreover, mammograms operate at X-ray frequency which is ionizing in nature and hence it is not advised for young women. In addition to mammogram, ultrasound, Magnetic Resonance Imaging (MRI), Poisson Emission Tomography (PET) be available for breast screening. The efficiency to detect the breast cancer has the trade-off with cost. Though PET screening is highly efficient in detecting cancer, the radioisotopes used in the procedure cause radiation which stimuli the adverse effects in breast tissue. Thus, India lacks in highly efficient low-cost breast cancer screening tool. The mortality rates can be reduced by early
detection breast cancer with appropriate treatment.

The intention of this paper is to focus on shortfalls in existing breast screening techniques in India. The heart of the paper showcases the microwave-based breast screening and its contribution towards reduced mortality rate of women.

This paper provides significant contributions
1. Comprehensive analysis of current screening technique limitations
2. The advent of microwave technology for breast screening – Enables Early breast cancer detection and improves the survival rate of the women with suitable treatment.
3. Existing Screening Methods

2. Breast Examinations:

In spite of screening tools, one can examine Self Breast Examination (BSE) [7] to deduct the presence of lumps in the breast. The Healthcare professionals primarily undergo Clinical Breast Examination (CBE) toward screen the breast cancer. Moreover, women in developing countries like India are not educated to perform self-examinations. Thus, a strong definite need is required to educate the young women on BSE by Healthcare professionals, awareness groups. Highly literate women with BSE can easily suspect even minor palpable lumps and consultation with medical experts paves the way to detect cancer at the early stage. In both examinations, it is difficult to identify the non-palpable lesions and its malignancy.

Mammography:

The mammography is one of the most common breast cancer screening being followed in India. Mammography is a specialized imaging tool that use x-rays to examine the breast. x-rays are ionizing in nature, and it is not recommended for young women to undergo frequent screening. Especially, in young women x-rays are not easily penetrated in high fibro-glandular dense breast tissues [8]. However, breast is compressed between two plates of mammogram machine to produce the better results, that cause uncomfortable pain for the women. Mammography produces high false positive and false negative rates respectively. Moreover, sensitivity and specificity values are highly varied with breast density, age, menstrual cycle phase and so on. The limitations in mammography end up with over diagnosis and over the treatment of cancer which is a serious threat to the survival of women [9,10]. Many studies have concluded that mammogram screening is more suited for the women above the age of 50 years because of fatty breast tissues. It well to be noted that both mammograms (screen– film and digital) detect the cancers only at stage II, which is again the burden for the elder women to pursue high dose treatments. Besides, a mammogram does not evaluate the cancer cells in the underarm lymph nodes and thus metastatic sites are unnoticed. The primary tumors in underarm that are not perceived during diagnosis may cause secondary effects in other parts of the body.

Ultrasound:

Ultrasound is used in adjunct with mammography to uncover the abnormalities in the breast. It uses high-frequency sound waves and helps to distinguish solid mass or fluid-filled cysts. There is no radiation involved in ultrasound and hence it is more suited for pregnant women. The reason is quite obvious, that mammography fails to interpret the young women breast because of rich milk glands. The suspicious findings in ultrasound are inconclusive that is the main crisis of imaging tool. The effectiveness of the ultrasound primarily depends on the
experience of sonographer [11-13] and it always requires biopsy as its complement. The breast density is pertinent issue in ultrasound which results in decreased sensitivity and causes difficulty in breast cancer diagnosis.

**Magnetic Resonance Imaging (MRI):**

Breast screening with Magnetic Resonance Imaging (MRI) uses strong magnetic fields and radio frequency to create detailed images of the breast. MRI can be used as supplement tool for mammography or ultrasound to determine the extent of cancer in the breast. MRI Breast imaging uses gadolinium-based contrast agent to enhance the quality of an image. Gadolinium has not proved to be safer, and it has serious side effects like nausea, vomiting, headache, paresthesia and so on. The contrast agents are sensitive to benign breast lesions [14,15]. In correlation with mammography and Ultrasound, MRI has higher sensitivity (88%) and specificity (67%) rate. Neoadjuvant Chemotherapy with MRI monitoring is being offered to breast cancer to evaluate the tumor and its prognosis [16]. It also highly efficient to sense invasive ductal carcinomas, which have a type of breast cancer with women in India. MRI Breast Screening requires highly specialized system and skilled radiologists to quantify the findings. MRI is expensive and thus it is preferred for high-risk women. Moreover, it is not advisable to undergo MRI in case of implantable metal devices such as pacemakers and so on. MRI fail to spot the calcium deposits in the breast which could be a sign of benign stage of cancer [17].

**Poisson Emission Tomography (PET):**

Poisson Emission Tomography is a Radionuclide imaging which gives one step forward in cancer detection and it is discussed in [18-21]. The radioisotopes, F- fluorodeoxyglucose (FDG) is used as radio tracker to detect cancer. The main advantage of radionuclide imaging is better to stage diagnosis which is often predicted by metabolic changes of cancer cells. It is also best suited for metastasis cancer analysis. PET imaging is an important tool to diagnose recurrence of cancer or to evaluate the treatment response. PET yields high lesion to background ratio to produce high contrast images. The PET imaging is generally time consuming and requires 60 to 90 minutes after the injection [18]. The subject has to lie in the prone position to have better cancer detection. The radionuclide is sensitive to radiation which is undesirable. Unlike, other imaging techniques, PET is also hard to identify small cancers and hence it is contradicted to become useful screening tool.

Though Biomedical Technology provides imaging tools in different flavors, none is superior to other. The highly accurate imaging tools have a trade-off with cost. High-priced modern technology is not preferred by economy class population in developing countries and increases the mortality rates. The lack of cost-effective healthcare system has attracted the attention of researchers. Utilization of microwaves for breast screening has become growing body of current research. The mainstay of this paper provides cost-effective breast screening tool, that can be easily fingered by the people. With this regard, microwave screening aids early breast cancer detection with proper treatment planning and thus alleviate survival rate of the women.

3. **Microwave Antenna Technology**

Microwave Breast Screening (MBS) is a promising early detection procedure for breast cancer. The past review of microwave-based screening is presented in [22-25]. The new approach is to use the wearable jackets for breast cancer screening. The proposed method
operates in Industrial, Scientific and Medicine (ISM) frequency band (2.45 GHz). This ISM band frequency is non-ionizing and does not cause radiation. MBS is harmless and it can be repeated at numerous times to obtain a better diagnosis. MBS exploits electromagnetic properties of the normal and carcinogen tissues. When compared to normal cells, the cancer cells exhibit high values of electromagnetic properties and results in large amount of microwave scattering.

The microwave breast screening can be recommended to be one of the medical oncology practices for better patient management. The workflow of the management is shown below Figure 1.

![Figure 1. Overview of Microwave-Based Breast Screening](image)

Generally, in existing screening technologies, the subject lies in the prone position to undergo breast examination. The prone position is less flexible and requires a change in gantry dimensions for different women. As a result, a wearable, antenna-embedded jacket-like screening system has been developed to reliably detect early breast cancer. Then the support is provided at the bottom of the jacket to hold the breast in proper stand position with the nipple at the center as a reference.
point. The antennas are positioned carefully with the greatest number in the high incident upper outer quadrant of the breast. The antenna-integrated jackets are designed for different breast sizes. The number of antennas increases with increase in size to envelope the surface area of the breast. The antennas are excited with the non-ionizing microwave signal. When microwave signal impinges on breast tissue, carcinogen tissue results in high amount scattering due to the presence of the high electromagnetic property. The scattered signals are collected back and processed to detect the breast cancer. The numerical values and results manipulated in host computer are transmitted to the server. The medical experts validate the observations and communicate the results to respective person through wireless device.

Microwave breast screening is a profound technology to detect the early breast cancers. This could seriously cut down mortality rates by providing appropriate treatment at the early stage. When compared to existing modalities, MBS is cheaper and hence it is easy to access for the population. In addition, it also provides improved patient management for medical oncologists.

| Age group | Number of breast cancer patients |
|-----------|---------------------------------|
| <20       | 3121                            |
| 20-40     | 302848                          |
| 40-60     | 454289                          |
| 60-80     | 5679                            |
| >80       | 3324                            |

4. Results And Discussion

Experimental studies are performed with simulated breast phantoms. The investigations are carried out for primarily occurring Invasive Ductal Carcinoma (IDC) by considering different tumor dimensions, position, orientation and stages of cancer. The sensitivity and specificity values are analyzed to evaluate the performance of different diagnostic techniques. The microwave signals scattered from breast tissues are received by Radio Frequency Analyzer and processed to obtain the tumor size, location, orientation from scattering values of the microwave signal. The stage of the breast cancer can be classified by using the SEER breast cancer repository. SEER Database holds the details of the patient who underwent the diagnosis in the calendar years 1973 through 2016. It is quite observed that women in the age group of 40-60 are greatly suffered from breast cancer and it is shown in Table. 1. At this age, it high risks to undergo heavy dose treatments like radiation therapy, Chemotherapy to suppress aggressive nature of women breast cancer. As a result, an early breast cancer detection tool is essential. The database holds 119071 benign stage and 650190 malignant stage records. MBS considered a wide variety of early breast cancer condition for analysis. The different test case data are analyzed and classified using SEER repository.
The efficacy of MBS technology is evaluated by comparing its detection rate with existing technology. The results of various technologies are summarized in Table 2. Data from studies show the MBS is able to detect the breast carcinoma with an accuracy of 98% with sensitivity and specificity values as 96% and 98% respectively.

MBS technique shows the high potential benefit of low cost, efficient and ease of access for the patients. It also lends the helping hands to reduce pains of radiologists who encumber with large volumes of data to make diagnosis.

Table 2. Comparative studies of various diagnostic techniques

| Performance Parameters | MR [14] | US [14] | MRI [14] | PET [18] | MBS |
|------------------------|---------|---------|----------|----------|-----|
| Accuracy               | 85      | 97      | 94       | 92       | 98  |
| Sensitivity            | 22      | 21      | 67       | 91       | 96  |
| Specificity            | 86      | 87      | 64       | 93       | 98  |

5. Conclusion

In this paper, we presented MBS, that overcomes the shortfall in existing breast imaging tools. MBS takes the opportunity to detect early breast cancer and reduce global mortality rate to great extent. The performance of the proposed technology has been tested with prototype models. The simulation results corroborate that MBS has 98% Accuracy with high sensitivity and specificity values. As a result, MBS outperforms today's state-of-the-art breast screening tools. The next forward step in our research is to undergo real time testing on women and validate its performance.

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