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Medical Imaging Techniques in Early Detection of Breast Cancer

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Abstract

Breast cancer in human is the most commonly diagnosed malignancy and it is termed as the second leading reason for deaths among women in Asia and other developing countries. The chances of cancer detection in human body have improvised as 1 in 6, which is much better than earlier days. The hard truth in reality so far has been the existence of cancer is the evidence of external lump or tissue and followed by a biopsy. In the process, the suspicious lump is detached by a surgical elimination under a microscope by a pathologist. This paper attempts to bring all the Imaging techniques that have emerged in the last decade, which has enabled the medical practitioners for early detection of breast cancer in order to avoid difficult and costly procedures.

Keywords

Mammography, micro calcifications, radiologists, detection, density, sonography, micro-calcifications

Introduction

The demise in women among the age of 38 - 58 is mainly due to breast cancer. It has been proved that early detection of cancer in breast can be an effective method for reduction in mortality. The identification of micro-calcifications acts as a vital task in early finding of breast cancer. Micro-calcifications are the only mammographic indication of dreaded breast disease. Much research has been done to read images and analyze the digital content, which would enable the radiologists in identification of abnormality. Since a decade, many promising mechanisms have been evolved, such as wavelet-based approaches, fuzzy logic and support vector machines etc. The objective of this study is to assess the enhancement mechanisms pertaning to micro-calcifications for attaining improvised results as shown in figure 1. By making small structures more visible, the radiologist can be assisted in detecting a pool of calcifications. If the properties of lumps are made more obvious then the radiologist would determine cealrly, to acertain the calcifications are malignant or benign [1, 3].

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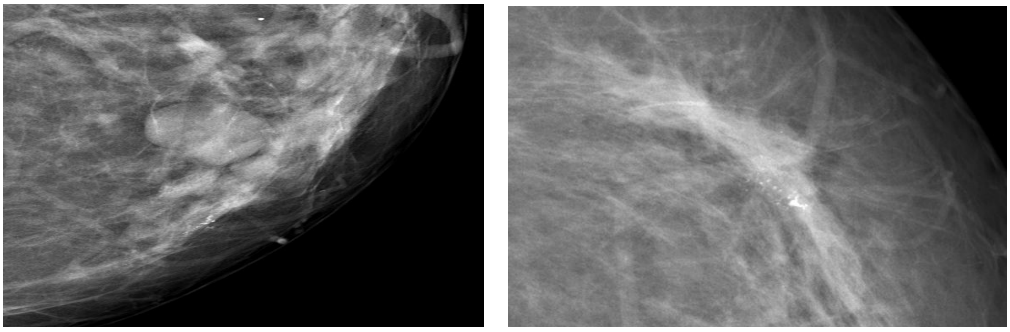

Figure 1: Examples of abnormalities: (a) Round mass with circumscribed margins. (b) Fine clustered calcifications.

The breast cancer detection and screening by radiologists is subjected to choosing some percentage of women for referral based on found irregularity in the mammograms presented. In view of attaining higher specificity, radiologists do not focus on every abnormality they come across. Therefore, not all the cancers detected initially can be graded as malignancy but case-by-case review is needed to avoid impending interpretation failures. It has been noticed that evidences that failed on interpretation are more common reason for missing cancer detection screening rather than omission. During analysing missed out cancer cases earlier, the outcome of screening can be improved subsequently. In the recent past computer aided detection (CAD) methods have been inducted as a means to shun perception errors [6, 5, 10]. This technology has gathered extensive acceptance in image screening domain. On the other hand, CAD equipment does not deal with the crisis of interpretation failure in screening. The major goal of this paper is to understand mechanisms and to incorporate in order to optimize classification process for a better performance on regions recognized as suspected. Figure 2 depicts various type of micro-calcifications found in breast cancer. Study of such lumps shown in the figure would extend to determine experimentally how this detection would lead to decision making in screening and estimate the degree of increase in lump as compared to the former detection. Basing on the above the detection of masses and distortions, which are vital patterns associated with invasive cancers are focused and the decision can taken for further investigation and treatment.

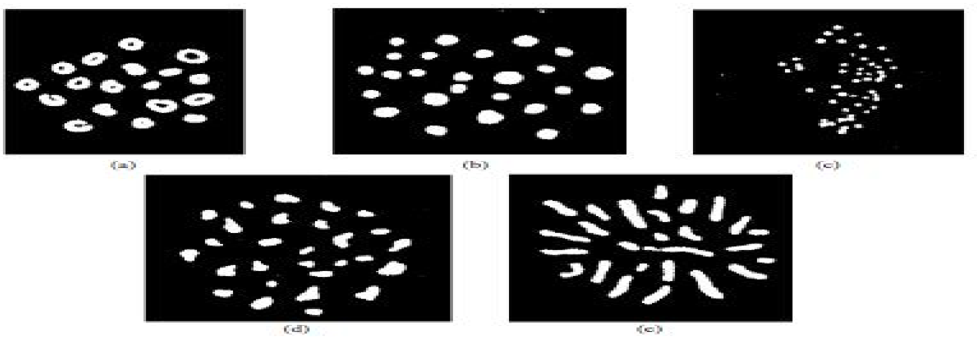

Figure 2: Typical micro-calcification examples/shapes (a) Rings-always benign. (b) Circular and various sizes, smooth border-frequently benign. (c) Pulverulent sometimes Malignant. (d) Granular with various sizes and shapes, irregular bordermalignant. (e) Vermicular and typically malignant

Methods existing and emerging for early breast cancer detection

The existing methods such as in X-rays domain mechanisms are very random and are notified as standardized yet .the accuracy is always being subjected to scrutiny. The capability to interpret the results changes from radiologist to radiologist. Most of the methods have low specificity. As a result, it tends to show many false positives that would drive many patients into severe mental trauma. It is found that chances that a lump found in screening and later sent for biopsy would turn out into malignant is mere 22% to 34%. The density values of cancer regions are similar to that of normal tissues and thus show up lack in contrast differentiation. The excessive exposure to X-rays may damage DNA cells, hence patients must be cautioned in this regard. The following are the new methods of breast cancer detection with their merits and disadvantages [3, 4, 7].

MRI Imaging

High Field MRI

To diagnose disease, magnetic resonance method uses radio waves and magnetic fields. Patients are asked expose to the MRI machine for atleast 30 minutes for capturing the images required. Later the images are presented to the MRI machine, and subjected to a strong magnetic field [2, 8]. The method consists of infusing contrast enhancing dye like matter into the patient’s bloodstream and using magnetic resonance imaging to supervise the way in which this material is taken up and reacted by the tumor tissue.

This enables the expert to distinguish between tumor and suspicion part/mass in the body. The suspected parts of the breast possess different form and persist special contrast from a normal tissue. The MRI, can be 5 times more informative than X-ray mammography and has ability to showcase 80% better image capturing capabilities. However, MRI is not cheaper and most of the population in developing countries cannot afford to undergo such examination frequently.

Similar to MR guided biopsy, some systems employ open configuration imaging systems with MR, which consists (0.5T) low-field superconducting magnet of an open configuration that allows admittance to the field. The system was built with the main motive of guiding therapies in a real-time environment. The radiologist has a choice of selecting the image plane during the procedure for flexibility [8, 10].

Digital Imaging

In digital imaging, the image is created when a detector absorbs the x-rays and transforms them to an electrical signal equivalent to each pixel. When images are digitally acquired and displayed, film is no more required. This enables the experts to store, retrieve and process the image digitally. Digital imaging can be grouped in number of ways as depicted in the literature below.

I. Stereotactic imaging

Stereotactic breast biopsy measures are currently commercially offered as digital mammography technology. Stereotactic biopsy mechanism makes use of small-field digital detectors, and propose radiologist the skill to target a lesion identified during mammography. This would help expert to exactly place a needle into its center, and to remove tissue samplings. The patient is offfered with cheaper option by the virtue of stereotactic biopsy. It is also less invasive and exhibit more acceptable process that women can avail. Nevertheless, this method is difficult to implement and sustain [4, 12].

II. Single Energy X-ray technique

This novel method is called diffraction-enhanced imaging (DEI). It creates appreciably sharper images, more comprehensive pictures of breast tissue, which could completely improve the efficiency of mammography. The new imaging method makes use of single-energy X-ray source. This method is still experimental, and many works need to be done before it can be tested on multiple patients.

III. Reconstruction using 3D digital

The 3D technique is an improvement on digital technology; it is used in hospitals across the world to guide needle biopsies to diagnose breast cancer. The Stereotactic breast biopsy works with the digital detectors and are used very commonly, which help in guiding probes that obtain tissue samples. The image quality of these systems is good, and the adapted systems can generate three-dimensional or two-dimensional images of the breast. This technique can advance the precision of mammographic diagnoses but it is a costlier option [3, 15].

IV. Tomosynthesis

Tomosynthesis method acquires multiple images as the x-ray tube is moved in an arc pattern above the stationary breast and digital detector. The total radiation dose required for processing the full image of the breast is approximately equivalent to the amount used for a single film screen mammogram. Sharp foucus and illumination can be introduced by adding and shifting the images. It can probably bring each plane of the breast into good focus. Tomosynthesis has the possibility to improve the specificity of mammography by reducing the contribution of normal fibroglandular breast to facade the presence of a lesion. The potential benefit will be biggest in women with radiographically dense breasts. Through tomosynthesis, multiple images are obtained using FFDM with changing X-ray tube orientation. Typically, the detector remains in place to yield focused view of the region of interest. Exposures are taken as the orientation considered. Each sample is exposed through fewer doses. This method generates three-dimensional images that can be viewed as individual dynamic pieces of images. Tomosynthesis need lesser breast compression duration and pressure than an ordinary mammogram which provides the patient much comfort.

V. Computer aided analysis

The digital mammography recommends merits such as the association to computer aided diagnosis systems, because digital information is accessible in an arrangement that is compatible to CAD systems. These images are compatible to image processing algorithms like denosing, enhancement, extraction and classification for further processing and analyzing the image. The computer may automatically draw a margin around areas of irregular contrast and assisting the radiologist's to pay attention to the suspicious regions. The techniques such as pattern recognition and small object detection can also be used to detect micro calcifications in digitized mammograms. The National Cancer Institute has envisioned that digital mammography is the developing technology with the maximum prospects and impact on management of breast cancer.

Ultrasound Imaging

I. High frequency Sonography

Sonography has the facility to exhibit margins and internal texture, and is often considered more fully than mammography. Most importantly, this makes it possible to diagnose simple lumps in the breast. In patients, sonography also makes it likely to boost or decrease doubt that a lesion is malignant and to more precisely map the degree of tumor within the breast [13,14].

II. Vascular imaging with Doppler effect

Carcinomas of the breast have revealed prominent variations of vascularity, which are needed for increased metabolism. Doppler imaging allows investigation of regular and pathological vascularisation in the breast. The practice is non-invasive, fast and easier. Color is used to code the blood velocity or volume. Neoangiogenesis is a mechanism that is used by the Doppler with the Doppler effect to trace the blood flow and finding malignant tumors. Two types of Doppler ultrasound exist: power and color. The power Doppler ultrasound is better for tracking intralesional blood flow. Study has found that 99% of malignant lesions contained blood vessels and that 96% of benign lesions showed no color Doppler marks, representing that color Doppler marks should justify a biopsy.

III. Contrast Imaging

Ultrasound contrast imaging is a new technique in which a "contrast agent" where in gas microbubbles is infused intravenously. The microbubbles functions as echo-enhancers, which causes the received signal to be longer and bigger in the cancerous tissue than in the benign lesions. The cancerous part also exhibit trait of vascular morphologic features, with additional vessels visualization in relation to the lesion. Contrast imaging can be successfully used with vascular imaging. The signal-to-noise ratio is markedly enhanced and diagnostic confidence is amplified. Ultrasound imaging using microbubble contrast agents will certainly open up new opportunities [5].

IV. Sonoelasticity

The idea behind this method is to visualize in real time the rigidity or firmness of tissues and organs by depicting the tissue's movement in reply to an applied vibration source. Consequently, solid or dense tumors that are unnoticeable by conventional ultrasonography often can be visualized in sonoelasticity imaging by the merit of their altered vibration reaction. Ultrasonography (US), also termed as sonomammography, is very often used to image palpable masses in the breast or as a follow-up examination for random results on a mammogram. The existing technology engages a handheld transducer located on the breast surface by a technologist and rotated around the image of breast below the transducer. Small change in orientation of the beam would ignore an image part or focus area. The usual probe is 1 cm x 6 cm, which makes it difficult to cover the whole surface of a breast in a trustworthy fashion for screening. The universal form of ultrasound is B-mode, which uses sound waves, bounced tissues to create an image of the breast. The strength of each echo establishes the intensity of that point. From these echos, two-dimensional images are produced, generally about 32 images per second are produced, permitting the real-time imaging. Various tissues can be recognized by brilliance and illumination. Ultrasound is mainly used to characterize lesions, to identify clear masses that are difficult to be seen on mammograms. It is also appropriate for scanning dense breasts. B-mode ultrasound is also used to direct biopsies. Compound imaging combines many Ultra Sonic images into one. In this way it decreases the quantity of ruin, mess, noise, and shadowing, hence yielding a higher quality with a smoother image. Compound imaging improves tissue, margin visualization, low-contrast lesion con-spicuity and internal architecture visualization. Although improved in eminence than B-mode US, and it is evident that compound imaging is subject to blurring, and it restrains shadows that can be used to determine malignancy [4].

Nuclear Imaging

Nuclear medicine techniques give functional images based on molecular properties. These methods do not show unfavorable effects of temming from breast density. In addition, these techniques need little or no breast compression. Nuclear medicine techniques are costly and expose the patient to radiation, which is not desirable for high-risk patient.

I. PET Imaging

Positron emission tomography (PET) uses generally F-fluorodeoxyglucose i.e. glucose metabolism to detect cancer. PET has well-established good reputation for the detection of malignancy, particularly in metastatic disease in solid organ tumors. PET can also measure methionine metabolism, using L-methyl-C-methionine, and hormone receptors. Another radiotracer F-luoro-L-thymidine (FLT), that has been used to measure thymidine kinase-1 activity, which is associated with S-phase DNA synthesis FLT uptake is less reactive than the irritation caused by needle biopsy, providing an gain in similar situations. Imaging normally takes place 40 to 60 minutes past injection and it is seen that waiting for longer increase the rate of detection. It is evident that PET imaging in the effected place with the help of a breast-positioning device enhances the modality's cancer detection rate. PET can be very useful in follow-up examinations and recurrence scanning for the whole body. In their study, Lind and colleagues has found a standard sensitivity of 96% and a specificity of 77%. Patients are injected with a glucose that is blended with radioactive tracer. It has been found that cells that undergo additional metabolic activity signify traces of disease and cancer. Positron radioactivity released by the radio labeled glucose is marked and documented by a PET camera. This is further processed and reconstructed by computer so that the parts of greater metabolic activity glow alike CT scan. This method is highly expensive and the limited availability of the traced isotope makes the use of PET scanning unrealistic. PET imaging allow doctors to expect results within about a week of initiating hormone therapy, if women is willing to respond. In some countries, a PET scan is required to conclude whether a cancer has widened prior to a patient undergoes surgery [6, 11].

II. Sestamibi imaging

The most regularly reported tracer applied to breast imaging is Tc-99m-sestamibi. This is a radioactive isotope, regularly attached to biologically active molecules, and is frequently infused into patients. These radiopharmaceuticals are developed to focus at a specific part of the body to be analyzed. A gamma camera is used to transform the radiopharmaceutical emissions into valuable diagnostic images that demonstrate mutual function and anatomy. Such kind of scanning of the breast is considered to be very effective in huge breast cancers but its role in investigating armamentarium of breast imagers still remains unestablished. A comparison with sonography is made and found that the negative aspects of SMM has outdone its high detection accuracy, and has indicated that it would not replace sonography. In a study it is found that SMM has detected more cases of multifocal and multicentric cancer than mammography and ultrasonography is difficult to implement in all countries.

Bio Imaging using Electrical Means

This technique is designed to assist in the detection of early phase tumors and pre-cancerous lesions without concerning X-rays or discomfort to the patient. Changes in cellular water content and cell membrane features cause a note worthy change in the tissue electrical impedance, enabling cancerous and also pre-cancerous lesions which can be easily visualized in the image. Procedures resemble an ultrasound with no physical uneasiness nor exposure to radiation. The system is specifically effective in detecting breast tumors in younger women who have denser breast tissue, which cannot be simply examined with conventional mammography [15].

Imaging with Optical Diffusion

Image analysis with light in Near Infrared (NIR) has attained much interest in this decade, due to the very high potential of probing tissue oxygenation, metabolism, non-invasively and it also employs relatively low cost instruments. This technique uses non-ionizing radiation. Tissue has a little absorbing window in the NIR that permits light penetration of numerous centimeters employing laser power. The information obtained depends on the shrinking characteristics of breast tissues at observable and near-infrared wavelengths and can be used to establish tissue malignancy [2, 7].

Prospects of imaging in breast cancer investigation

The Digital mammography is used primarily in the U.S. and Canada (but is also used in Europe) frequently. Bioelectric imaging is used frequently in the European countries. PET imaging is extensively accepted in Europe, but has restricted usage in US. MR imaging is also used in the U.S. and in Europe. But based on the cost of diagnosis, most of the countries opt for a particular method.

I. High risk of true positives: Demand for cheap and agile methods of detection

The medical domain experts must teach women on impending or relative risks and also to advice for possible precautions to be considered. This would help in review most significant risk factors for breast cancer. The factors are namely country of birth (high in North America and northern Europe but low in Asia), age (risk rises with age), and individual family history. Then adapt the imaging technology to the patient.

II. Awareness in usage of Digital Imaging is growing worldwide: For the past few years, NASA has worked with the National Cancer Institute (NCI) to apply the latest advancement in the imaging technologies to develop digital mammography systems keeping in view the next generation of high-resolution, high-contrast digital mammography systems, which are expected to find smaller breast cancers.

III. Transferring Technologies from the collaborating efforts with Medical Community: Scientists form the intelligence community, working in close collaboration with leading medical researchers, applied a neural network, modeled after human brain cells, neurons and developed to find targets in military surveillance images, to the problem of detecting micro calcifications in mammograms. Preliminary results generated by this joint team of scientists to establish that this neural network technology could be used to improve the correctness of breast cancer detection in many folds with the state-of-the-art computer-aided diagnosis (CAD) currently available in radiology.

IV. Usage of Virtual Reality Applications in Women's Health: Advanced imaging technologies and three-dimensional (3-D) visualization is the foundation of virtual reality. As a medical innovative application, virtual reality captures previously acquired image from any known method, such as a CT scan, MRI scan, ultrasound etc. . Then creates a full 3-D image using a high speed computer. This 3-D image is now the "information equivalent" of the organ or tissue(i.e. breast in this context) [7, 9]. In some cases, the military state-of-the-art technologies are more than a decade ahead of medical applications. A sincere effort to further speed up cooperative efforts between investigators, people at large and the medical society is needed if the nation is to take gains of multifold use imaging technologies.

Conclusion

The newer breast imaging techniques such as high-resolution ultrasound imaging, MRI imaging, and digital mammography with the aid of computer analysis hold the assurance of better cancer detection in the future. These methods can used based on feasibility and affordability by the patient. In the meantime, because these technologies are not in mainstream diagnosis, the patients should look out breast imaging facilities with multimodal imaging potential. The medicine community must also give importance to the digital processing potential, which is emerging fast and as a cheaper option for developing countries. It is also felt that women, particularly aging women should always be ready for self-examination and consider effortless mammographic examination time to time.

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