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THE OPPORTUNITY OF MAGNETIC INDUCTION TOMOGRAPHY MODALITY IN BREAST CANCER DETECTION

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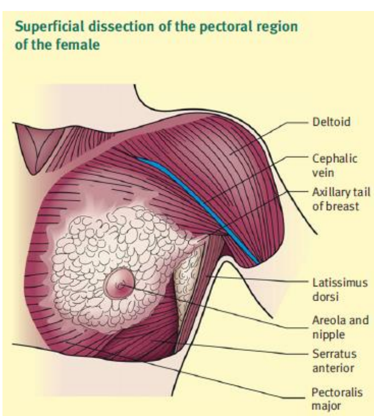
Graphical abstract



Abstract

The needs for non-invasive technique in breast cancer detection could enhance and preserve the future of medical field in Malaysia as well as countries around the world. Breast cancer has become the main concern nowadays not only for women but for man as well. In overall, the risk of women getting breast cancer is higher than man due to the denser tissue of breast in women compare to man. Beside the unawareness for the disease, the reason which contributes to this increasing number of breast cancer reported is also due to the limitations arising from modalities such as MRI, Mammography, ultrasound and other modalities. An alternative to current technologies should be improved for early detection and treatment which causes no physical harm to patients if possible. Thus, non-invasive and better technology in detecting breast cancer is very much needed in the current market. This paper will be discussing the insights of Magnetic Induction Tomography techniques in breast cancer detection.

Keywords: Breast cancer, magnetic induction tomography, non-invasive

1.0 INTRODUCTION

According to an article provided by the National Cancer Registry 2003, one out of every nineteen Malaysian woman stands the chances of getting breast cancer and this figure is nearly one in eighth for the Europe and the United States citizens. Despite the statistics shown in the article, the awareness of breast cancer is still low among Malaysians. Most of the time, patients only seek for the advices of doctor when the lesions have grown to a very big size although it is discovered in the early screening. Therefore, it is necessary to detect the breast cancer at the preliminary stage in order for further actions to be taken.

Non-invasive breast cancer system assesses have been discovered by a number of investigators and researchers over the years and the most common methodologies are by using Electrical bio-impedance, Microwave, Optoacoustic Imaging, Photoacoustic imaging and Hybrid of Thermoacoustic and Photoacoustic Imaging.

The present work gives a description of using magnetic induction tomography in the diagnosis of breast cancer. It begins with an overview of breast cancer, followed by breast cancer diagnosing techniques and conclusion of the study.

2.0 AN OVERVIEW OF BREAST CANCER

Women and men both have breasts, but women have denser breast tissue than men. Each breast lies over a muscle of the chest called the pectoral muscle. Female breast covers a fairly larger area compare to male. It extends from below clavicle bone to the armpit and across the breastbone or sternum. The breasts are visualized as a structure that has many sections called lobes and inside them are smaller subsections called lobules, which connect with the aforementioned lobes via thin tubes formally known as ducts [1]. A simple dissection of the pectoral region of breast is illustrated as in Figure 1 below.

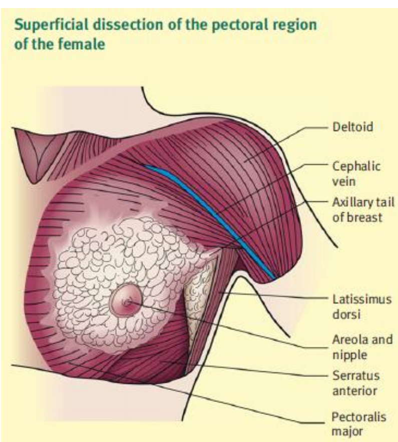


Figure 1 Anatomy of breast [2]

Breast tissues always change at different times during puberty, during menstrual cycle, during pregnancy and until after menopause. Its size and shape vary considerably among women. Some women have smaller amount of tissue with little breast fat while some other have larger amount of breast tissue and have larger breasts. Often one breast is slightly higher or lower, larger or smaller or shaped differently than the other. Besides that, lymph nodes in the axilla vary from woman to woman. It is divided into three levels according to how close they are to the pectoral muscle on the chest, where the first level and second level located at bottom part and middle part of armpit respectively, and third level located near to the center of the collarbone. Breast cancer usually spread from level one lymph nodes to level two and subsequently to level three [2].

The above descriptions facilitated in the further classification of cancer, which are; lobular cancer, cancer cells that arise from lobes; ductal cancer, cancer that arises from ducts; non-invasive cancer, cancer that has not spread elsewhere; and lastly invasive cancer, cancer that has spread to other body parts via metastasis [3]. Some less common cancer types are tubular carcinoma, medullary carcinoma, inflammatory cancers and mucous carcinoma [4].

Some risk factors affecting the breast cancer can be vary from age, early puberty, late menopause, high radiation exposure, race, obesity, no child or late first pregnancy and hereditary [5]. It might also can due to miscarriage or ethnicity where non-Hispanic white, Hawaiian and black women also has higher probability of getting breast cancer [1], [6]. Other speculated causes include abortion, no breastfeeding, usage of contraceptive pills, less fruits consumption, high fats dietary practices, alcohol and smoking habits. According to the Union International Cancer Control (UICC), the stages of breast cancer can be illustrated based on the size of tumor (T), presence of sentinel axillary lymph nodes and local invasion and evidence of distant metastasis (M) [1].

3.0 BREAST CANCER DIAGNOSING TECHNIQUES

3.1 Optoacoustic Imaging

Optoacoustic imaging involves detecting breast cancer through microvasculature. Through the process of angiogenesis and hypoxic blood, it was found that malignant tissues have enhanced oxygenated blood supply while benign tissues or fibroids have lesser blood supply. In short, this Laser Optoacoustic Imaging System (LOIS) works based on the pathological contrast of breast tissues through oxy and deoxy-haemoglobins concentrations. This whole system is setup in such a way that laser pulses transmitted at a point just above the tumor location will determine the contrast in between the tissues and tumor, and the receiver piezo element array is positioned at the bottom of the imaging area.

The advantages of optoacoustic imaging include high optical contrast between normal and malignant tissues that correlates with level of saturation of hemoglobin, high resolution and substantially improved sensitivity in the localization of less than 1 mm tumor [7]. Anyhow, this technique reduces accuracy in localization of the tumor and maximal depth penetration.

3.2 Photoacoustic Imaging

Photoacoustic imaging technique consists of nanosecond pulsed laser and an ultrasound system where the tissues absorb laser energy which results in rapid thermoelastic expansions and thus propagates a wideband ultrasound (US) wave. The wideband ultrasound wave will then be detected by transducers that convert them into electrical signals to be visualized as an image.

The benefit of using photoacoustic imaging is that its images are easier for further analysis compared with X-ray images. This technique is non-invasive which can reduce the unease of patients during the diagnostic and treatment processes. It is also able to enhance the resolution in the direction perpendicular to the imaging plane. Besides that, lesser peripheral equipment are involved in this technique, thus cheaper compare to other breast cancer detection techniques. It does not involves much physical and chemical exposure, thus more number of scans can be done for self-assurance. However, this method has limited angular view which can bring limitation during the analysis of the images. It involves longer measurement times compare to other detection techniques. The average duration between the scanning time and acquisition of result is long. On top of that, photoacoustic imaging has considerably low specificity and sensitivity.

3.3 Hybrid of Thermoacoustic and Photoacoustic Imaging

This hybrid technique combining both thermoacoustic and photoacoustic enable the system to obtain the dual contrast of microwave and light absorption imaging. This technique works by compressing the breast of patient which might cause the discomfort to the patient. First, breast is needed to be inserted into the front opening hole of the scanner. Breast is then compressed to obtain cylindrical shape with supporting plate at the rear opening of scanner. After everything is ready and in position, microwave will be kept behind of the scanner and horn antenna is pushed into the scanner from opening to irradiate radio frequency on the compressed breast. Breast holder cylinder is surrounded by ultrasonic transducers which will be held by an aluminum rotating cylinder. Rotating cylinder operates by stepper motor and worm-gear mechanism during the data collection. The scanner can be adjusted according to height and angle as desired with a metal frame [8].

This modality works by a combination of nonionizing radio frequency (rf) electromagnetic waves and visible near infrared (NIR) laser for breast cancer detection. Pure ultrasonography offers good spatial resolution but poor soft-tissue contrast [9], [10], but it works another way round for pure-rf imaging where it provides good imaging contrast but poor spatial resolution [11], [12], [13] Thus, combining these two give a better detection modality.

It allows three-dimensional (3D) image of the breast which involves nonionizing, high resolution, high contrast, low-cost method and usage of dry ultrasonic coupling instead of gel [8]. Compression pain can be minimized due to the scanner compress the breast using front nipple side which results in lesser pain instead of side breast. Eventually, it allows transducers to scan the cylindrical breast for full 360° to obtain 3D data set. Besides that, the compressed of breast in cylindrical shape enables the microwave and laser irradiation to penetrate the breast deep enough to chest wall [8].

One of the disadvantages of using a hybrid of thermoacoustic and photoacoustic is that various causes such as the size of the target object, conductivity of target object and microwave diffraction will result in distortion of image [8]. Furthermore, the reconstructed image of the breast may have different shape and larger size than the actual object [14].

3.4 Magnetic Induction Tomography

Magnetic Induction Tomography (MIT) is defined as an entirely non-contact inductive coupling between the sensors coils and breast. When signal propagates through the biological tissue, any change in the phase delay will be sense due to the sensitivity of the measurement which fully based on the phase shift approach [15], [16]. Besides, MIT analyzes the conductivity (σ), permeability (μ) and permittivity (ε) of biological tissues in order to investigate certain characteristics of those tissues [17], [18], [19]. Anyhow, the main concern is to analyze the conductivity of breast tissue as conductivity is a dominant parameter in biological tissue. In short, MIT technique has very good application prospect in biomedical noninvasive imaging and great potential in medical diagnostic.

3.4.1 Fundamental Concept of MIT

The used frequency is within the range from 1 MHz to around 10 MHz from the range of beta-dispersion region [16], [20]. At different frequencies, magnetic fields that generated by the excitation coil can determine the passive electrical properties (PEP) σ, ε and μ measurements from breast tissues [17]. From Figure 2, it shows the basic principle of MIT technique theoretically. In this technique, an object (breast sample) is well located at the center of an excitation and receiving coils. Alternating current will be induced after turn on the power supply to excite the excitation coil. Alternating current flowing in excitation coils will produce a primary magnetic field. An eddy current is induced in the object after generating a magnetic field of the transmitter coil. The eddy current is then detected by the receiving coil by the means of magnetic induction technique [21], [22]. The collected signal from the receiving coil which contains required information is then sent to phase detector circuit and amplifier [23]. The generated phase shift is used to determine the location and size of measured tissues [22]. In general, MIT is based on the perturbation of alternating magnetic field by conducting object. In this case, breast is the perturbation object.

The carried information is on the changes of k, the complex conductivity of the object which is given by [24].

$$k = \sigma + j\omega\varepsilon \quad (1)$$

where ω is the applied frequency.

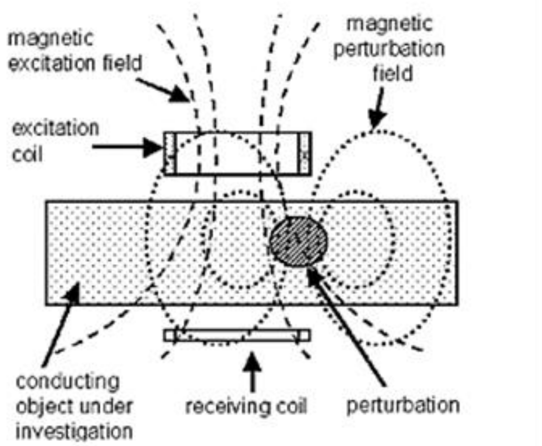


Figure 2 The principle of MIT [19]

3.4.2 Advantages of MIT Modality

Some advantages of using non-invasive breast cancer detection by modality magnetic induction tomography (MIT) are as follow:

1. MIT technique involves contactless and electrodeless measurement scheme which does not need to apply galvanic coupling between device and object during measurement for it offers no electrode-skin interface mechanism [25], [26], [16].

2. Unlike conventional modalities, MIT offers non-ionizing radiation technique which is safer for breast cancer patients [27], [20].

3. MIT technique provides a faster, non-complicated, low cost diagnostic and a system which is easy to design and implement.

4. MIT is highly sensitive to magnetic permeability characteristics of the biological tissue [28].

5. MIT is safer to be used in terms of electricity and easier to achieve protections safety and on top of that, patients don't get infected easily for this modality is non-skin contact method [19].

3.4.3 Challenges of MIT Modality

With using linear image reconstruction algorithm [29] to solve the nonlinear nature of electromagnetic field, it results in producing low resolution imaging by using MIT [30], [31], [32]. This algorithm works well for low contrast imaging but high resolution image needs nonlinear techniques.

Besides that, MIT modality is sensitive to noise [33][34] which there is a need to use electromagnetic screen to cover the hardware system from the interruption of noise which might cause errors in measurement [35], [36].

3.4.4 MIT Measurement Schemes

For high conductivity imaging such as metal, using measurement scheme of magnitude base can be applied since high conductivity material able to produce high secondary field which results in strong signal in relative to the noise at the receiving coil. Peak detector is among the reported technique for this scheme [37].

On the other hand, for low conductivity measurement such as biological tissue, magnitude base measurement is not suitable since the secondary field due to eddy current is low and usually mixed with noise signal. To overcome this problem, phase shift measurement has been proposed as the solution. This measurement scheme works by comparing the time delay between primary field with secondary field arrive at the receiver. The higher the conductivity of the material the longer time will take for the secondary signal to travel and reach the receiver [35].

4.0 CONCLUSION

Non-invasive imaging offers a great opportunity in medical field for diagnostic and treatment purposes. These techniques provide solutions to detect the breast cancer in the early stage before the cancerous tissues become more severe. From the literature, MIT is still under further research and theoretically MIT has been found to benefit mankind and has the capability to the current radiation base imaging due to its electrodeless, contactless and free from ionizing radiation issue.

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