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Research Article

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Comparative accuracy of Digital Infra-red Thermal Imaging(DITI) in breast cancer diagnosing

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ABSTRACT

Breast cancer is one of the leading causes of death among women. Early diagnosis can increase the survival rate in cancer patients. Digital Infrared Thermal Imaging (DITI) is a portable and non-invasive diagnostic technology that is non-contact, pain-free and radiation free procedure for breast carcinoma diagnosis. However, the link between disease and heat radiation is complex and in many cases even non-linear. The DITI shows sensitivity of 97.6%, specificity of 99.17%, positive predictive value 83.67% and negative predictive value 99.89% on breast thermography screening. The aim of this study was to review recent studies published on the application of infrared thermography for the evaluation of safety, effectiveness and diagnostic accuracy for breast cancer screening and diagnosis based on breast thermography. This work systematically examines the evidence on breast thermography as a tool for screening/ diagnostic test to assist in the investigation of abnormalities on a mammogram or ultrasound and to assess the risk of future breast cancer. It is concluded that there is currently insufficient evidence to recommend the use of DITI merely as a diagnostic tool. This inefficiency mainly causes during image acquisition, complicated processing and analyzing of the thermograms and most importantly, lack of standard protocols to guide the final prediction. Therefore, the demand for a proper image processing method is still an opened discussion. Future research on employing standardized imaging and reporting methods is still required.

Keywords: Breast Cancer; Digital infrared thermal imaging (DITI); Thermography; Diagnostic accuracy; Thermogram; Artificial Neural Networks (ANN)

INTRODUCTION

Breast Cancer has been considered as a prevalent type of cancer among women in developed countries for many years. However, since few decades ago, developing countries present high cancer incidences [1,2]. In addition, the World Health Organization (WHO) estimated that by the year 2030, one can expect 27 million new cases of cancer [3]. Breast cancer is the leading cause of cancer death among females in developing countries [4]. Early detection is the important priority as it can increase the survival rates significantly. Several diagnostic methods exist to detect the presence of breast cancer. Mammography is the common method of breast imaging as it has renowned "the gold standard method" for breast cancer detection but it is difficult to detect breast cancer in young women [5]. Thus, the use of a complementary diagnostic tool like thermography is a necessity during the breast cancer diagnostic procedure. It has been reported that small tumors (less than 1.66 cm in size), which are missed by mammography could be detected with breast thermography.

1.1 Background

Breast thermography is a non-invasive diagnostic method that captures the thermal variations of breast surface to help the early detection of breast cancer. Heat pattern changes reveal a good indication of machine health [6]. Pattern is not restricted to mechanical systems both electronic and biological systems follow the same pattern. Lahiri, Bagavathiappan, Jayakumar, and Philip (2012) [7] found that an abnormal pattern in infrared image can indicate a high risk for breast cancer development in the future. Recent improvement in digital infrared imaging by the US military indicates the potential of this technique as a breast imaging tool. Moreover, using artificial intelligence software to analyze images, has aided the resurgence of Digital Infrared Thermal Imaging (DITI). A recent study has shown that when state-of-the-art infrared technology was merged with advanced computer hardware and software technology, the sensitivity of breast cancer detection was 97% in 92 patients undergoing breast biopsy [8].

1. 2Concept

Thermography is a non-destructive technique which measures the emission of infrared radiation from an environment with the temperature above the absolute zero (-273 °C). It is defined as non-contact screening method for medical use. This technique is based on surface temperature of the breasts. The temperature variations and vascular changes may be the earliest signs of breast abnormality, using highly sensitive infrared cameras and sophisticated software to produce a heat map of the breast called a thermogram. [9,10]. This non-invasive, non-ionizing evaluation method offers both safety and comfort to the patient.

In contrast mammography, ultrasound, MRI, and other imaging tools are based on changes in the scattering traits of tumor [11].

Mammography, ultrasound, MRI and other imaging tools are primarily based on changes in the scattering/transmission traits of tumor with respect to the normal tissue. Heat pattern measurement, via thermography is even passive, i.e. no potentially harmful radiation is sent through the biological system, only the body heat is captured [12].

1.3 Motivation

Along with the improvements in thermal imaging camera technology and image processing methods, DITI looks more attractive as a portable diagnostic tool. Several clustering algorithms have been used to extract regions of interest with moderate success rates. Texture features have been extracted for the classification of breast abnormalities in conventional thermograms using artificial neural networks (ANN) [13] and support vector machine. Due to the improvement of computing machines and algorithms, the diagnostic accuracy will increase. Another benefit of using DITI is cost efficiency because it is a portable computer-aided diagnostic tool [14].

Thus, the aim of present study was to review the recent studies on breast thermography in order to evaluate its accuracy and the need for its usage.

EXPERIMENTAL SECTION

The usefulness of a special diagnostic approach depends on the ability to yield a correct diagnosis, the side effects and the cost.

To support our position, the paper is arranged as follows: the first two sections give an overview of the algorithms used in thermography, and the technique used for breast cancer screening; then, we discuss about the achieved results. At last we provide concluding remarks and the attempt for further studies in breast cancer imaging based on thermography. The infrared cameras use for taking images are included: AEG 256 PtSi, FLIR systems s45 or T400 and ICI7320P uncooled camera. In this paper, the images were taken by Flir, Thermo vision A-20 which detects signal spectrum 7.5-13 µm and the resolution of 160 × 120 pixels. The operating temperature range is from -20 ˚C up to 90 ˚C with temperature resolution ~ 0.1 ˚C.

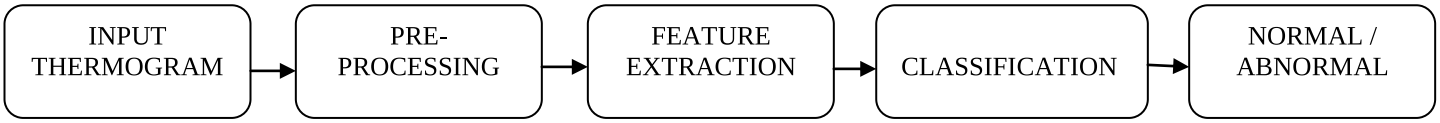


Fig.1

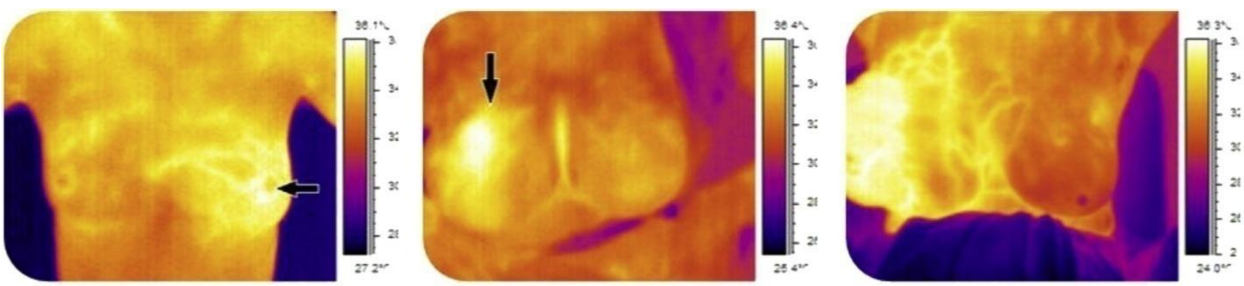
2.1 Block diagram

Fig. 1 shows the design steps and the logical connection between these steps. In this system, IR images will be pre-processed and their grayscale features will be extracted in different techniques. The extracted grayscale features will be analyzed with statistical methods to modify which features are more important to be considered for the classification step. The significant features are computed for the testing set of thermograms.

2.1.1 Pre-processing

The pre-processing step is based on color or morphological operators. In order to obtain more reliable temperature measurement, a standardized protocol was used for the IR image acquisition. This standardization is described in [15]. Breast thermograms are obtained according to the image protocol Fig 2.

M. Rassiwala et al. / International Journal of Surgery 12 (2014) 1439-1443



a: Suspicious abnormality on the left breast

b: Suspicious abnormality on the right breast

c: A case of proliferative lesion on the right breast

Fig. 2. a, b, c: Black arrows denote areas of hotspots having temperature gradient > 3 (potentially having breast cancer for $\Delta T \geq 3$)

2.1.2 Feature extraction

The feature extraction and data mining which deal with the correct segmentation of the object was studied. Many works focus on segmenting the areas corresponding to the left and right breast from the thermograms in order to obtain the information from region of interest (ROI) [16]. Features extraction in thermal images are mainly exploited by textures, entropies, Fourier Spectrum (FS) descriptors, Hu's invariant moments and Higher Order Spectra (HOS) methods [17]. Hu's invariant moment and Higher Order Spectra (HOS) are a shape feature-based object recognition method which it is shown experimentally that HOS yields higher accuracy [54].

2.1.3 Classification

Classifiers have been used widely in computer aided diagnosis systems [19]. The sample consists of patterns obtained from thermograms in a two class problem, the normal and abnormal groups. The main purpose of classification algorithms is to extract information, known as learning phase to decide to which category or class a new observation belongs.

2.2 Technique

The patient is made to sit in front of an IR camera after at least 15 min with no physical activity, in a cool carpeted chamber, with temperature around 21-25 °C . Infrared images of the breast are captured in three different views, namely Contra-Lateral, Medio-Lateral and Axillary. In order to make thermogram interpretation more objective, we can use rotational breast thermography. In this technique, breast is imaged from many views so that an abnormality will not be missed.

2.2.1 Artificial Neural Network (ANN)

To find the category or class of a new observation, automated classification algorithms are used. Artificial Neural Networks (ANN) are parallel-distributed information processing structure which model the functionality of small biological neural clusters ,and therefore they mimic human decision making. Once the ANN is trained, the output it generates for the validating sets will be compared to the desired outputs to evaluate the effectiveness of the ANN by calculating performance measures such as sensitivity, specificity, and the total accuracy [20].

RESULTS AND DISCUSSION

Thermography is well-suited for picking up tumors in their early stages or tumors in dense tissue and in these cases it outperforms other modalities such as mammography. A constant irregular thermogram carries a 22 times higher risk than its regular counterpart and it is 10 times more indicative than a first-order family history of the illness as a future risk signal for breast cancer. A pilot study [21] involved 1008 female patients of age 20-60 years that were being screened and had not been diagnosed with breast cancer earlier. Based on the subjects included in this study, accuracy of breast thermography came out as shown in Table 1. According to the below table, the performance parameters of the classifier can be calculated; specificity of 99.17% was achieved.

Table 1 Results Rassiwala, Muffazzal, et al. International Journal of Surgery 12.12 (2014): 1439-1443

Screening test results	Diagnosis		Total
	Diseased	Not diseased	Breasts
P	TP = 41	FP = 8	49
N	FN = 1	TN = 958	959
Total	42	966	1008

- *TN = Number of normal data classified as normal.*
- *FN = Number of depression data classified as normal.*
- *TP = Number of depression data correctly classified as they are.*
- *FP = Number of normal data classified as abnormal.*

Specificity: Sp = TN/(TN+FP)
Sensitivity: Se = TP/(TP+FN)
Accuracy: A = (TP+TN)/(TP+FN+TN+FP)

O. Faust et al. / Infrared Physics & Technology 66 (2014) 160–175

Authors [1]	Year [2]	MP [3]	PE [4]	A (%) [5]	Se (%) [6]	Sp (%) [7]

1 Author name and reference.
2 Year of publication.
3 Measurements and Procedure (MP).
4 Performance Evaluations (PE).
5 Accuracy (A) of the classification in percent.
6 Sensitivity (Se) of the classification in percent.
7 Specificity (Sp) of the classification in percent.

Fig. 3. Header structure of the result tables

Table 2 Breast cancer diagnosis results

O. Faust et al. / Infrared Physics & Technology 66 (2014) 160–175

Authors	Year	MP	PE	A (%)	Se (%)	Sp (%)	Classifier
Kolaric´ et al. [22]	2013	2b	2	92	100	79	-
Francis and Sasikala [17]	2013	3b	3	-	88.1	85.71	Artificial neural network
EtehadTavakol et al. [23]	2013	3b	3	95	-	-	An Adaboost classifier
EtehadTavakol et al. [24]	2013	3b	3	86	-	-	An Adaboost classifier
Zore et al. [25]	2013	2b	1	-	-	-	-
Nicandro et al. [26]	2013	4b	3	71.88	82	37	Bayesian networks
Sella et al. [27]	2013	3b	3	-	90.9	72.5	Support vector machine(SVM)
Francis and Sasikala [17]	2013	3b	3	85.19	88.89	77.78	ANN
Acharya et al. [28]	2012	3b	3	90	76	84	SVM
Boquete et al. [29]	2012	3b	4	-	100	94.7	-
Zore et al. [30]	2012	B	1	-	-	-	-
Acharya et al. [1]	2012	3b	3	88.10	85.71	90.48	SVM
Mookiah et al. [31]	2012	3b	3	93.3	86.70	100	DT and fuzzy classifiers
Kontos et al. [32]	2011	3b	2	-	25	85	ANN
Grubisic et al. [33]	2011	4b	-	-	-	-	-
Wishart et al. [34]	2010	3b	3	-	78	75	ANN
Wiecek et al. [35]	2010	3b	3	86.60	-	-	ANN

3.2 Limitations of Thermography

The present review has minor limitations that should be addressed. Although thermography is a useful diagnostic tool for early breast cancer detection, it should be used with other complementary methods [36]. In addition, although the portability of digital infrared thermal imaging shows the demands from rural areas, deploying this device needs a proper place and constant conditions for screening which it may be difficult and pricey. Moreover, the small number of included studies is another limitation of this review. Due to restrictions in imaging protocol, abnormality detection by conventional breast thermography, is often a challenging task. Higher resolution IR scanning and suitable computer-aided diagnosis systems will be a study case in limitations of thermography.

DISCUSSION

This paper reviews recent works (2010 - 2014) on breast cancer imaging based on thermography and it reveals the progress over the years in terms of accuracy, sensitivity and specificity. This progress was fueled by better sensors [37], diagnostic procedure, more computing power and a deeper understanding of processing algorithms [38]. The progress in this field is documented by two facts : (a) IR cameras are getting better and cheaper, (b) Computing machinery is getting ever more powerful and there are better algorithms [39,40]. It has been verified that abnormality was detected best in views where the tumor was less than 4.5 cm from surface [41]. Although the color representation of a thermogram can vary with temperature scale or with the applied color map, its related temperature remains constant. An important aspect is the use of a temperature matrix instead of pixel colors; then the image processing will be based on the temperature information instead of the intensity of the pixels.

The risk of getting breast cancer has tripled over the half century, therefore it is necessary to detect breast cancer at early stages for better treatment. Some limitations in using other medical tools like mammography i.e., waiting until the age of 50 to get the first screening and then only get one every two years, have led to a revision to use breast thermography as a contact-free, pain-free and radiation-free tool for imaging breast cancer. Similarly, high sensitivity has been reported by other works [1]. Utilizing this method, particularly in developing countries could be well suited as a non-invasive method, lower cost portable tool and other advantages [42,43].

CONCLUSION

In this study, results confirm the use of thermography with sensitivity 97.6%, specificity 99.17% and accuracy 99.1 % . These performance parameters are satisfactory in relation to the classification results reported by other exams like mammography [44]. Thereby, thermography could be proposed as a complementary tool for preliminary breast screening before mammography and biopsies. The results of this study support the use of DITI as an effective adjunctive test for breast cancer detection, especially in women under 50 years old. Being a portable tool, non-invasive, pain-free and non-ionizing procedure proposed breast thermography as a good screening modality for breast cancer, mostly in developing countries where the amount of patients suffering from breast cancer are numerous as well as it can be available in rural areas.

It is recommended that research should aim to determine the performance of thermography in asymptomatic populations before they are adopted widely into practice as a screening tool. Although the ANN model evaluates the health of the breasts, and classifies the images as normal or abnormal, it does not provide information regarding possible location of the tumor on abnormal images. A more sophisticated method utilizing more image features, as well as images taken from different camera views would be required to localize the tumor. As breast classification in thermography is still an open topic therefore future efforts could be oriented in using classification techniques for detection of breast cancer cases based on breast thermograms.

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