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Thermography – A Feasible Method for Screening Breast Cancer?

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A B S T R A C T

Potential use of thermography for more effective detection of breast carcinoma was evaluated on 26 patients scheduled for breast carcinoma surgery. Ultrasonographic scan, mammography and thermography were performed at the University Hospital for Tumors. Thermographic imaging was performed using a new generation of digital thermal cameras with high sensitivity and resolution (ThermoTracer TH7102WL, NEC). Five images for each patient were recorded: front, right semi-oblique, right oblique, left- semi oblique and left oblique. While mammography detected 31 changes in 26 patients, thermography was more sensitive and detected 6 more changes in the same patients. All 37 changes were subjected to the cytological analysis and it was found that 16 of samples were malignant, 8 were suspected malignant and 11 were benign with atypia or proliferation while only 2 samples had benign findings. The pathohistological method (PHD) recorded 75.75% malignant changes within the total number of samples. Statistical analysis of the data has shown a probability of a correct mammographic finding in 85% of the cases (sensitivity of 85%, specificity of 84%) and a probability of a correct thermographic finding in 92% of the cases (sensitivity of 100%, specificity of 79%). As breast cancer remains the most prevalent cancer in women and thermography exhibited superior sensitivity, we believe that thermography should immediately find its place in the screening programs for early detection of breast carcinoma, in order to reduce the sufferings from this devastating disease.

***Key words**: breast cancer screening, thermography, mammography*

Introduction

Breast cancer is one of the leading health problems in developed countries. A majority of fatal breast carcinomas is found in the age group of 40–59 years[1] and there has been an increase in incidence of breast cancer of more than 70% in the last forty years[2]. The effectiveness of treatment of breast carcinoma is inversely proportional to the size and spread of cancer at the time of diagnosis. Therefore, it is of vital importance to perform and improve the methods of its early detection. Survival of patients with diagnosed breast cancer depends on tumor size, biological characteristics, spread of disease and patient's age. Mammography has been the standard diagnostic procedure for detection of breast carcinoma in all breast cancer screening programs during the last 30 years[3].

The sensitivity of mammography mainly depends on the density of breast tissue, and for dense breasts, sensitivity decreases to approximately 40%, the fact which

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questions the reliability of mammography as the screening method for early detection of premalignant and malignant breast lesions in younger women (under the age of 55 years). In addition, the results of a recent study revealed the prevalence of dense breasts of about 50% in women up to the age of 50 years and the prevalence of about 30% in women older than 51 years. Interestingly, the results of the same study indicate a higher prevalence of carcinoma, interval carcinoma and poorer prognosis in the group of female patients with the dense breasts[4].

Thermography is biologically inert diagnostic method which measures temperature differences across the skin surface, using highly sensitive infrared camera. In oncology, the application of this method is based on biological characteristic of carcinogenesis – the rise in metabolic activity which is accompanied by an increase in surrounding tissue temperature.

Taking into account the results of recent studies, especially those pointing to the limitations of mammography in screening protocols for younger women, there is an urgent need for introduction of a screening method that could possibly overcome these limitations. The aim of this study was to evaluate thermography as a possible method for early detection of breast carcinoma, and to compare its sensitivity and specificity to that of mammography.

Subjects and Methods

Subjects

A total of 26 consecutive female patients who had scheduled breast surgery at the University Hospital for Tumors, Zagreb in 2009, were included in the study. The preoperative inclusion criteria included age above 35 years, diagnostic work up of performed mammography, ultrasound examination and fine-needle aspiration (FNA). All eligible patients were then examined by thermography prior to surgery with pathophysiological examination (PHD) of surgical specimen.

The study was approved by the Ethics committee of the University Hospital for Tumors in Zagreb, and all participants gave written consent to participate.

Methods

Ultrasound exams were conducted using a linear probe with a frequency distribution of 7.5–12 MHz (SDU 2200 Shimadzu). Mammography imaging was performed using Siemens 3000 Nova and all the images were reviewed by two radiologists. Mammography images were reviewed using Breast Imaging-Reporting and Data System (BI-RADS) – a quality assurance tool originally designed for use with mammography. The system is a collaborative effort of many health groups, but is published and trademarked by the American College of Radiology (ACR) to standardize reporting in which both breast are assessed and the worst result is notified. BI-RADS Assessment Categories are: 0 – Incomplete, 1 – Negative, 2 – Benign finding(s), 3 – Probably benign, 4 – Suspicious abnormality, 5 – Highly suggestive of malignancy, 6 – Known biopsy-proven malignancy[4]. Also, each breast was separately read and the findings was characterized by one of four attributes: microcalcifications (MC), parenchyma asymmetry (PA), new mass (NM), and distortion of architecture (DA)[5]. The cytology results were scored as: 1 – benign, 2 – benign with atypia or prolifera-

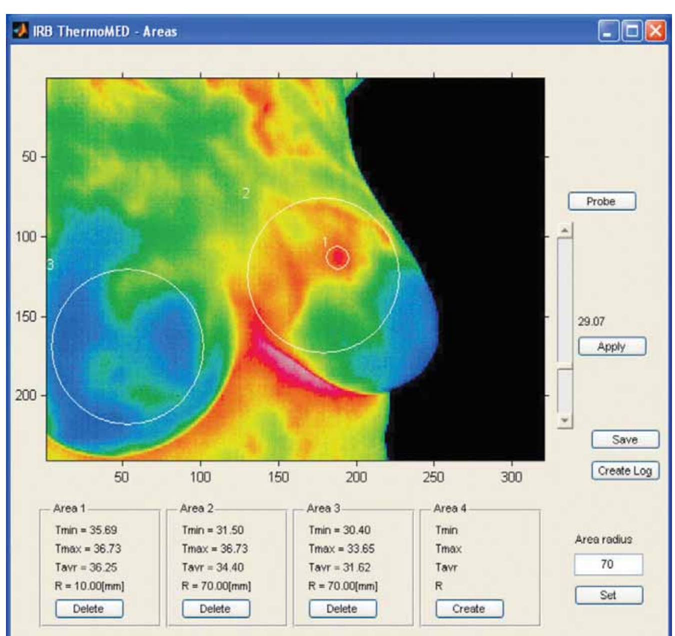

Fig. 1. Thermographic image of a patient with cancer of the left breast (TH5). The primary pathological area is highlighted by area 1 which evidently shows a greater temperature difference in comparison to the surrounding environment. Tmin – min. temperature, Tmax – max. temperature and Tavr – average temperature inside the marked area.

tion, 3 – suspected malignancy, 4 – malignancy. Pathohistological results (PHD) were documented as: 1 – benign, 2 – benign with elements of atypia, proliferation or inflammation, 3 – carcinoma in situ, 4 – invasive carcinoma[6]. Thermographic imaging was performed using a new generation of digital infrared camera – Thermo Tracer TH7102WL (NEC Sanei Instruments, Ltd., Japan). This thermovision camera contains an uncooled focal plane array detector (micro bolometer) with geometric resolution of 76800 pixels per picture (320x240). Spectral range is from 8 μm to 14 μm and the temperature range lies between – 40 °C and 120 °C (optional 500°C). The minimum detectable temperature resolution (difference) is 0.07 °C at 30 °C (Normal mode) and spatial resolution is 0.48 mm at measuring distance of 30 cm (IFOV 1.58 mrad). For remote control and transfer of data from infrared camera TH7102WL to a computer, we used the previously developed an open source thermoscan analyses software ThermoWEB (ThermoMED version)[7]. This software supports thermal analysis and image presentation, in numerical and graphical forms, of temperature values of any part of the surface inside the thermographic scan. The thermographic imaging was carried out by having the patient stand at a 0.9 m distance from the camera. According to standardized protocol, the patients raised their arms above the head and 5 images were taken: front, right semi-oblique, right oblique, left-semi oblique and left oblique, in order to obtain the images of complete breast skin area. After the images have been analyzed, they are graded using Marseille standardized reading protocols[8] in which each breast's image is placed into one of five thermobiological (TH) categories: TH 1 – Normal uniform non-vascular, TH 2 – Normal uniform vascular, TH 3 – Equivocal (questionable), TH 4 – Abnormal, TH 5 – Severely abnormal; and Hoekstra protocol – based on main (hot spot sign, global and periareolar heat, star vascular anarchy, edge and bulge sign) and secondary signs[9] (fragmented and close vascular anarchy, inverted »V« vascular pattern, transverse vascular sign, moa-moa sign, combination of pathological signs) (Figure 1). It was considered that breast lesions finding was positive if both TH2–TH5 Marseille scores and positive finding on Hoekstra descriptive protocol were present. The pathohistlogical findings of surgical specimens of the breast lesions were regarded as a gold standard for the diagnosis of the nature of the observed lesions.

Statistical analysis

Statistical review included calculating specificity and sensitivity of both mammography and thermography methods using the program »Simple Interactive Statistical Analysis« (http://home.clara.net/sisa/diaghlp.htm).

Results

Summary of the mammography, thermography, cytology and pathohistology findings for the 26 patients included in this study is shown in Table 1. Mammographic examination using BI-RADS classification revealed malignant or highly abnormal changes in 12 of 26 patients. When mammograms were analyzed using the four attributes scoring a total of 32 changes in 52 breast was found, 15 of which were classified as new mass (NM), 7 as microcalcification (MC), 5 as distortion of architecture (DA) and 3 as parenchyma asymmetry (PA).

Thermography scoring using Marseille categorization showed 19 changes as abnormal or severely abnormal (TH 4 and TH 5) in 26 patients, and Hoekstra descriptive protocol showed 17 main signs and 20 secondary signs of suspect malignant changes. Therefore, while thermography using Marseille and Hoekstra categorization detected suspect malignant changes in 19 and 37 patients respectively, mammography using BI-RADS assessment detected only 12 changes of which new mass (NM) was the most often found.

Cytological examination revealed suspected malignancy or malignancy in 19 of the 26 patients, 16 samples being malignant and 8 suspected lesion. Pathohistological (PHD) analysis revealed positive findings in 20 out of 25 patients with 12 *carcinomas in situ* and 13 invasive carcinomas (Table 1). Overall, cytological analysis and PHD correlated quite well with three cases in which cytological analysis revealed benign finding or benign finding with atypia or proliferation, while PHD analysis found *carcinomas in situ*.

The most striking finding is thermography detection of 5 carcinomas, confirmed by PHD, that were not found by mammography (patients 7, 9, 22, 24 and 26). Four of them were *in situ* carcinomas (patients 7, 9, 22, 24). This demonstrates high sensitivity of the thermography method and its ability to detect very small tumors that could be easily treated. Interestingly, patients 7 and 9 had positive mammography and thermography findings on one breast but thermography was able to detect the suspect changes on other breast as well (patient 7, 9) that later proved to be carcinomas *in situ*. Patient 22 had no positive finding on mammography but thermography detected secondary signs in both breast and carcinoma *in situ* was confirmed in left breast pathohistologicaly. Patient 24 had positive mammography finding on left breast but thermography showed main sign on right breast that were confirmed pathohistologicaly as carcinoma *in situ*. One of 5 diagnosed carcinomas was invasive carcinoma (patient 26) where mammography showed changes in left breast but thermography showed changes in both breast and pathohistology confirmed invasive carcinoma in the right breast. Five patients (17%) had carcinomas in both breasts of which 4 were carcinoma *in situ* and 6 invasive carcinomas (patients 9, 17, 18, 20 and 21).

In Table 2 summary of the patient's age and mammography, thermography, cytology and PHD changes is shown. The average age of patients was 49.42 years, which is the most demanding age group for mammography interpretation. While mammography detected 31 changes in 26 patients, thermography was more sensitive and detected 6 more changes. All 37 changes were subjected to the cytological analysis and it was found

TABLE 1
SUMMARY OF MAMMOGRAPHY, THERMOGRAPHY, CYTOLOGY AND PATHOHISTOLOGY FINDINGS IN PATIENTS UNDERGOING CANCER SURGERY

Patients		Mammography			Thermography			Cytology		Pathohistology	
					Marseille	Hoekstra					
No.	AGE	M-BIR	MA-R	MA-L	TH	TR	TL	CR	CL	PHD-R	PHD-L
1.	57	3		NM	3		S		2		2
2.	36	3		NM	5		M		2		2
3.	61	4	NM		5	M		1		3	
4.	53	4		NM	5		M		4		4
5.	50	4	DA		5	M		4		4	
6.	45	3	NM	DA	3	S	S	2	3	2	
7.	63	4	DA		4	S	M	2	3		3
8.	49	3		NM	4	M	M	1	2		2
9.	51	5		NM	5	M	M	3	4	3	4
10.	42	3		DA	5		M		4		3
11.	45	4		NM	5		M		3		4
12.	46	3		PA	3		S		4		4
13.	42	4		NM	3		S		3		1
14.	55	5	MC		5	M		4		4	
15.	54	3	NM		4	S		3		3	
16.	57	4		MC	4		S		4		3
17.	55	5	MC	MC	4	S	S	4	3	4	4
18.	42	5	MC	MC	4	S	S	4	3	4	3
19.	49	3	DA	DA	4	M	S	4	4	4	2
20.	51	3	MC	NM	4	M	S	2	4	3	4
21.	39	4	PA	NM	4	M	S	4	4	3	4
22.	46	2			3	S	S	2	2		3
23.	45	3		PA	3		S		2		3
24.	41	3		NM	4	M		4		3	
25.	48	3	NM		3	S		2		1	
26.	60	3		NM	5	S	M	2	4	4	2

AGE – age, M-BIR – mammography score by BI-RADS (0 – Incomplete, 1– Negative, 2 – Benign finding(s), 3 – Probably benign, 4 – Suspicious abnormality, 5 – Highly suggestive of malignancy, 6 – Known biopsy – proven malignancy), MA-R and MA-L (mammography attributes right or left; NM – new mass, DA – distortion of architecture, MC – microcalcification, PA – parenchyma asymmetry), TH – thermography score by Marseille protocol, TR and TL (Hoekstra sign for right or left; M – main sign, S – secondary sign S), Cytology (1– benign, 2 – benign with atypia or proliferation, 3 – suspected malignancy, 4 – malignancy) CR – cytology result right, CL – cytology result left, Pathohistology (1 – benign, 2 – benign with elements of atypia, proliferation or inflammation, 3 – carcinoma in situ, 4 – invasive carcinoma) PHD-R – pathology result right, PHD-L – pathology result left

that in 16 (43.24%) samples malignant alterations were present, 8 (21.62%) samples were suspected malignant, 11 (29.73%) were benign with atypia or proliferation while only 2 (5.4%) samples had benign findings. The PHD analysis found 75.7% malignant changes.

All collected data were statistically reviewed and showed that mammography sensitivity was 85% and specificity 84%, and proportion of true results were 85%, while thermographic results showed sensitivity of 100%, specificity 79% and proportion of true results 92% (at confidence interval CI 95%) (Table 3).

Discussion

The diagnosing of breast changes and evaluating its nature represents a continuing clinical problem, lacking the gold standard that would »ideally« correspond to pathohistological diagnosis of surgical specimens. In addition, the effectiveness of treatment of breast cancer is inversely proportional to the size and spread of cancer at the time of diagnosis.

Our study analyzed the ability of mammography and thermography to accurately detect breast carcinoma. It was shown previously that thermography has a sensitiv-

TABLE 2
CHANGES FOUND IN SAMPLES USING FOUR DIFFERENT ANALYZING METHODS

	RESULTS	
Mean age of patient	49.42	N (%)
Mammography	Microcalcifications	7 (22.58)
	Asymmetry	3 (9.67)
	Architectural distortion	6 (19.35)
	New mass	15 (48.38)
Overall changes seen with mammography	31	
Thermography	Main sign	17 (45.94)
	Secondary sign	20 (54.06)
Overall changes seen with thermography	37	
Cytology	Benign	2 (5.40)
	Benign with atypia or proliferation	11 (29.72)
	Suspected lesion	8 (21.62)
	Malignant alteration	16 (43.24)
Overall changes seen in cytology	37	
Pathohistology	Benign	2 (6.06)
	Benign with atypia or proliferation	6 (18.18)
	Carcinoma in situ	12 (36.36)
	Invasive carcinoma	15 (39.39)
Overall changes seen in pathohistology	33	

TABLE 3
SENSITIVITY, SPECIFICITY AND PROBABILITY OF CORRECT RESULTS OF MAMMOGRAPHY *VS.* THERMOGRAPHY

	Sensitivity	Specificity	Probability of correct results
Mammography	85%	84%	85%
Thermography	100%	79%	92%

ity and specificity of about 90%. However, the mentioned studies used older generations of thermographic cameras with lower temperature resolutions that could result in obtaining data of lower quality for interpretation[9]. The results of our study point out the possibility of obtaining better results using a thermographic camera with improved technical characteristics. In his study, Parisky et al.[10] reported 100% sensitivity for thermography but with a significantly lower specificity. This study was based on detection of malignant breast changes (*carcinoma in situ* and invasive carcinoma) only. In contrast, our study evaluated both, malignant and benign breast changes. In our study thermography detected 5 carcinomas that were not detected using mammography. It is important to stress that thermography also detects breast changes with atypia that could be seen as premalignant lesions[11]. Since thermography is a noninvasive, painless, inexpensive detection method, it is ideally suited screening method for detection of early stage changes. These could be observed in time, and if there is a progression, patients could be subjected to more aggressive diagnostic procedures and/or operative treatment. Therefore, thermography could help in discovering biological predisposition of possible future disease states (too right, too early)[12]. This possibility was raised by a prospective study looking at pathological thermographic results from a time period of 1–10 years[9]. Our results are in accordance with that study.

In the USA and some other European countries, biopsies are often performed under mammographic control, which is a far more aggressive and traumatic diagnostic method for patients[5]. However, the standard clinical protocol at the University Hospital for Tumors in Zagreb includes taking cytological samples of all discovered changes. Only after cytological results are obtained, surgical intervention can be recommended. In our study pathohistological evaluation confirmed 75.75% malignant changes by reviewing samples taken from 26 patients. This showed a good clinical evaluation and patient referral for surgical intervention. However, it is worth nothing the ability of thermography to detect *in situ* carcinomas that could be missed on cytological puncture.

It is significant to mention the difference between the number of changes seen in patients while using mammography vs. thermography. Using mammography examinations a total of 31 changes were seen in 26 patients compared to 37 changes detected using thermography. Comparisons of sensitivity and specificity of mammography and thermography indicate:

1. The absence of false negative results with the thermography method,
2. The discovery of 5 new carcinomas in 26 patients using thermography, in addition to today's standard clinical practice,
3. The possibility of using thermography imaging for detection of malignant changes in the early stages of the disease.

Early detection of breast carcinoma represents a very demanding situation for physicians who handle such cases both at the diagnostic as well as the therapeutic level. There is a very high need for non-invasive, reliable and applicable diagnostic procedures for the early discovery of breast disease. This brings thermography to the peak of interest of various specialists[9,10,12]. As breast cancer remains the most prevalent cancer in women, we believe that thermography will soon find its place in clinical practice. The search for new technologies and techniques for early discovery of breast changes, while still in curable stage, represents »*conditio sine qua non*« of future advancement in this area[9]. Our results indicate that thermography is a method of superior sensitivity at documenting the suspected breast changes. In our sample it had a sensitivity of 100% with a possibility to detect not only malignant but also benign lesions with malignant potential. Our results indicate that it would be prudent to use thermography as a primary screening method in detection of breast carcinoma. Due to its very high sensitivity, and lack of false negative findings, it is likely that this will lead to earlier detection of breast carcinoma and improve and extend lives of many women.

R E F E R E N C E S

1. BOUCHARDY C, FIORETTA G, VERKOOIJEN HM, VLASTOS G, SCHAEFER P, DELALOYE JF, NEYROUD-CASPAR I, BALMER MAJNO S, WESPI Y, FORNI M, CHAPPUIS P, SAPPINO AP, RAPITI E, Br J Cancer, 96 (2007) 1743. DOI: 10.1038/sj.bjc.6603783. — 2. ZNAOR A, HČJZ, 13 (2008). — 3. KUHL CK, JAMA, 299 (2008) 2203. DOI: 10. 1001/jama.299.18.2203. — 4. KERR M, New Study on Human Error and Breast Imaging. In: Proceedings (Radiological Society of North America (RSNA), 97th Scientific Assembly and Annual Meeting: Abstract SSA01--03, November 27, 2011). — 5. VENKATESAN A, CHU P, KERLIKOWSKE K, SICKLES EA, SMITH-BINDMAN R, Radiology, 250 (2009) 648. DOI: 10.1148/radiol.2503080541. — 6. ŠAMIJA M, JUZBAŠIĆ S, ŠEPAROVIĆ V, VRDOLJAK VD: Tumori dojke (Medicinska naklada, Zagreb, 2007). — 7. KOLARIĆ D, SKALA K, DUBRAVIĆ A, Periodicum Biologorum, 108 (2007) 631. — 8. GAUTHERIE M, Thermological Methods, (1985) 227. — 9. AMALU CW, A Review of Breast Thermography, Breast Cancer and Early Detection (2002), accessed 24.03.2011. Available from: URL: http://www.breastthermography.com/infrared_imaging_review.htm. — 10. PARISKY YR, SARDI A, HAMM R, HUGHES K, ESSERMAN L, RUST S, CALLAHAN K, AJR, 180 (2003) 263. — 11. SCHNITT SJ, Clin Cancer Res, 7 (Suppl.) (2001) 4419. — 12. KENNEDY DA, LEE T, SEELY D, Integr Cancer Ther, 8 (2009). DOI: 10.1177/1534735408326171.

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TERMOGRAFIJA – MOGUĆA METODA PROBIRA U PRAĆENJU RAKA DOJKE

S A Ž E T A K

Mogućnosti termografije u efikasnijoj detekciji raka dojke istraživane su u 26 pacijenata operiranih zbog bolesti dojke. Ultrazvučna, mamografska i termografska dijagnostika izvršena je u Klinici za tumore, Zagreb. Termografsko snimanje provedeno je korištenjem nove generacije digitalnih termalnih kamera sa visokom osjetljivošću i rezolucijom (ThermoTracer TH7102WL, NEC). Svakoj pacijentici učinjeno je pet standardnih snimaka: frontalna, desna i lijeva polukosa, te desna i lijeva bočna. U 26 pacijentica pronađena je 31 lezija mamografskom metodom dok je termografskom metodom nađeno 37 lezija, 6 više nego mamografijom. Svih 37 uzoraka pregledano je citološki te je ustanovljeno 16 malignih nalaza, suspektnih na malignitet bilo je 8, dok je 11 analiziranih uzoraka označeno kao benigno s atipijom i proliferacijom, a samo 2 uzorka su imala benigni nalaz. Patohistološkom analizom nađeno je 75.8% malignih promjena. Statističkom obradom svih rezultata ustanovljena je vjerojatnost ispravnog mamografskog nalaza od 85% (osjetljivost 85%, specifičnost 84%), dok je vjerojatnost ispravnog termografskog nalaza iznosila 92% (osjetljivost 100%, specifičnost 79%). Termografija je biološki inertna metoda visoke osjetljivosti koja može detektirati tumor dojke u stadiju *in situ* te bi hitno trebala naći mjesto u kliničkoj praksi ranog otkrivanja raka dojke.