IR thermography monitoring for cancer research

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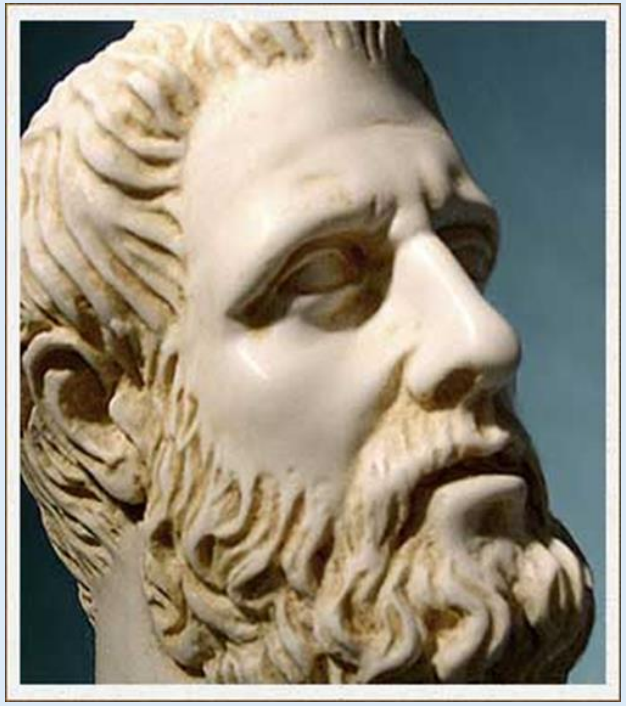
Outline

- Introduction
- M. Gautherie and thermopatolgy of breast cancer
- Simplified grading scale for IR breast thermography at CIB
- Conclusion

Brief introduction

History of Thermography



- As a medical science, Thermology was first documented around 400BC by **Hippocrates**. He wrote ***"In whatever part of the body excess of heat or cold is felt, the disease is there to be discovered".***
- Digital Infrared Thermal Imaging was initially developed for military applications in the late 1950's.
- Since the end of the Cold War, Infrared Thermal Imaging has been made commercially available.
- In 1982 the FDA approved medical thermography as an adjunct screening tool in medicine.

Definitions

- **Thermology** is the medical science that derives diagnostic indications from the thermal patterns of the human body.
- **Thermography** is the process of medical infrared imaging or the mapping of the thermal pattern(s) of the human body.
- **Thermogram** is, literally, a “heat picture”. It is the image that is captured by an infrared thermal imaging camera

How is Thermography Different?

1. Thermography “sees” the heat associated with inflammation and is, therefore able to capture real-time physiology, or function of the body.
2. Other imaging modalities (X-Ray, MRI, CAT Scans, Ultrasound) see structure, not function.
3. Thermography can detect changes in physiology before they become symptomatic and manifest structurally.

Why Is There Increased Blood Flow?

1. The Body is in the process of **REPAIRING /HEALING**
2. The Immune System is **FIGHTING INFECTION**
3. **ANGIOGENESIS**

The physiological changes taking place involve increased (or decreased) blood flow

→ Increased blood flow manifests as inflammation and increased heat .

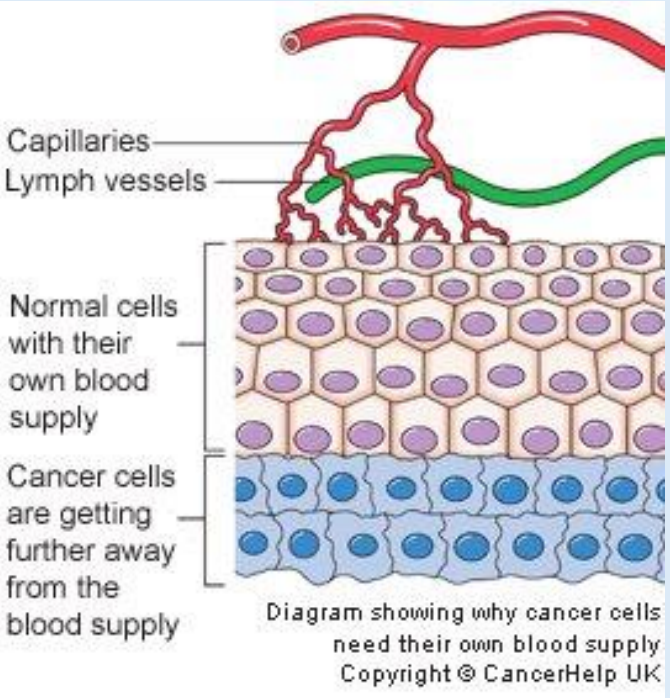
→Decreased blood flow manifests as “colder” areas

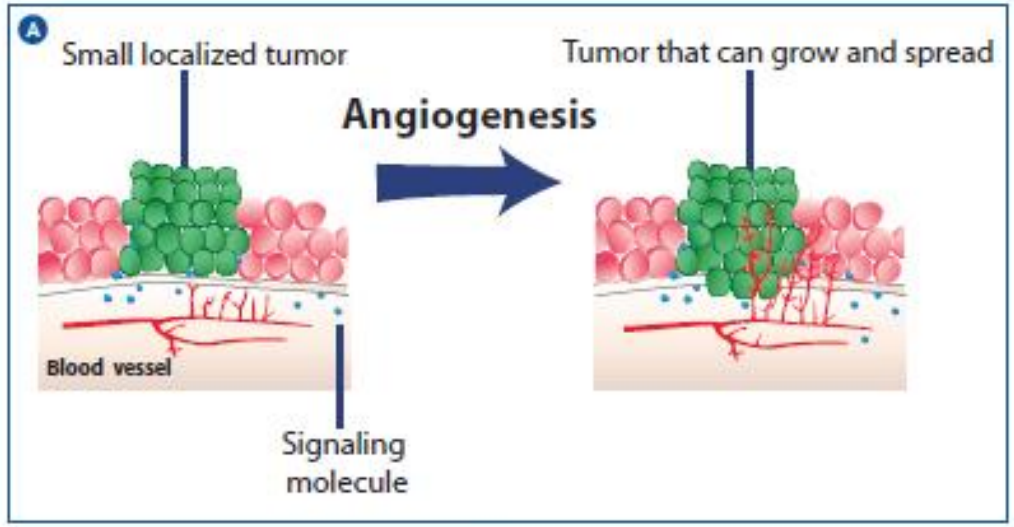
Why Is Thermography Effective?

We know that -

1. Inflammation is a precursor to disease.
2. If inflammation is identified in the body, steps can be taken to reduce it and prevent onset or symptoms of disease and potentially even reverse it.
3. Thermography detects the heat involved with inflammation!

Angiogenesis





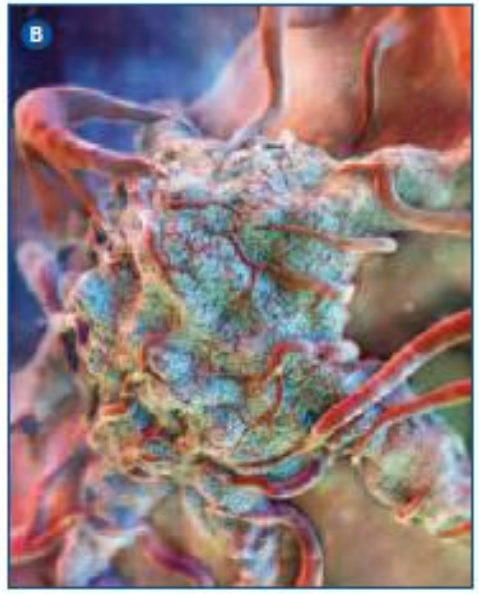


Figure 9 – Tumor angiogenesis: Tumor angiogenesis refers to the growth of new blood vessels that infiltrate cancerous tumors, supplying the tumor with nutrients and oxygen. Angiogenesis occurs in response to the tumor sending out signals to the tissues surrounding them, which triggers blood vessel proliferation (A). Blood supply is important to tumor growth and metastasis (spread), and tumors are closely associated with their blood supply, as seen in this computer stimulation (B). Image credit: National Cancer Institute, Corporate Press, and Science Photo Library

M. Gautherie and thermopatolgy of breast cancer

THERMOPATHOLOGY OF BREAST CANCER: MEASUREMENT AND ANALYSIS OF *IN VIVO* TEMPERATURE AND BLOOD FLOW

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Gautherie M, "Thermopatology of breast cancer: measurement and analysis of in vivo temperature and blood flow," Ann New York Acad Sci, 1980, vol. 335, 383– 415.

In spite of continuous progress in thermographic techniques as well as in standardization of examining conditions and image analysis, however, many physicians still hesitate to consider thermography as a useful tool in clinical practice.

This attitude is somewhat amazing for those who have a long experience in thermography. It may be explained considering that physical and biological bases are not familiar to the physicians.

In the present state of the art, all options should be considered for developing research and teaching in thermopathology, starting from the basic knowledge of thermophysics and thermophysiology. This is certainly the only way of improving the acceptance

Our experience now concerns about 65,000 breast patients from which there were more than 4,000 with a carcinoma. Statistical evaluations have been performed every year with a view to correlate thermal anomalies with physical, X-ray, and histologic characteristics of diseases, especially cancers.

Background remarks

Infrared imaging or breast thermography was introduced into medicine in the late 1950s.

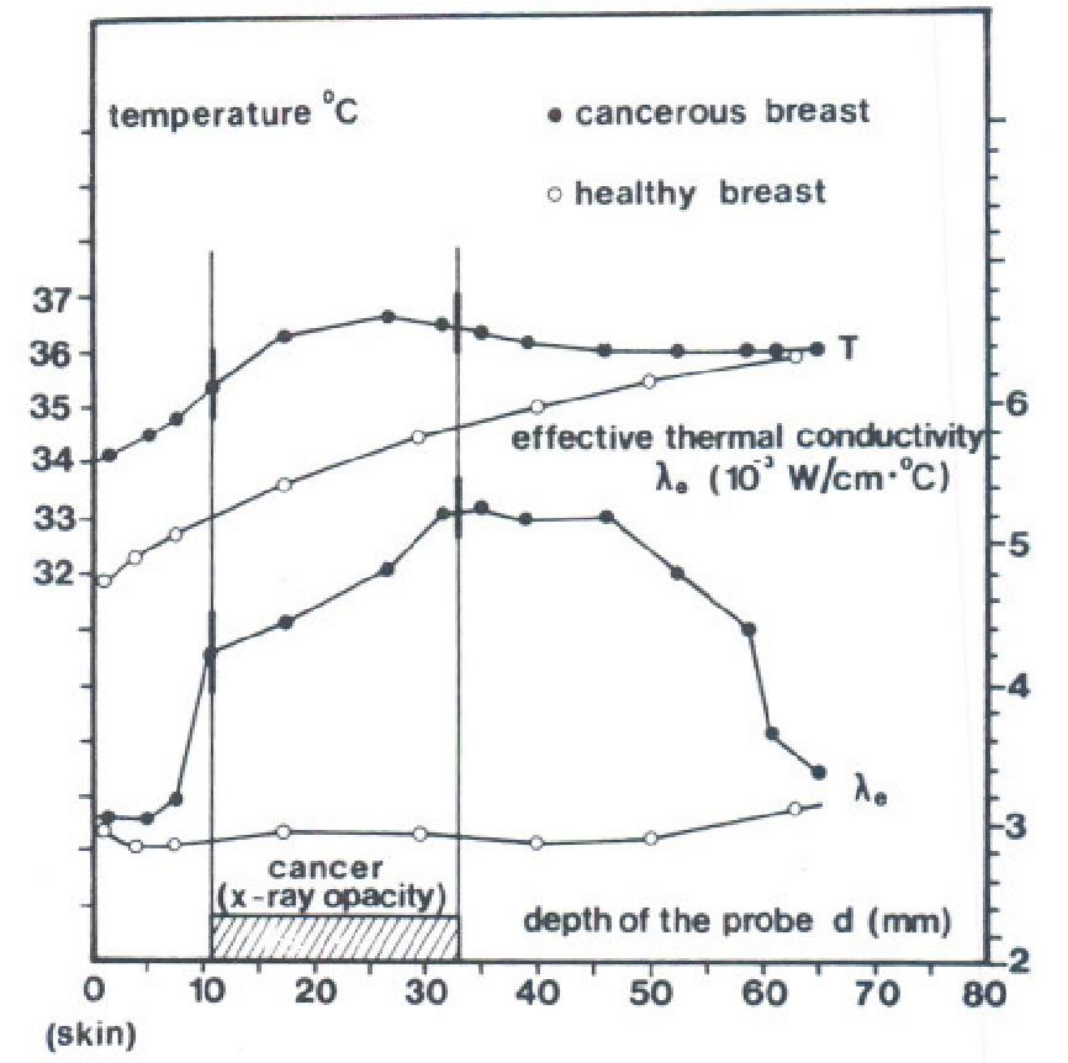
The sensitivity of infrared technology has greatly improved ($\Delta T \approx 0.05\text{-}0.5\ ^{o}C$).

Early studies involved applications in the detection of breast cancer.

Breast cancer detection is possible by infrared imaging due to the differences in metabolic heat generation of healthy and cancerous tissue.

FDA approved 1982 adjunctive diagnostic breast cancer screening.

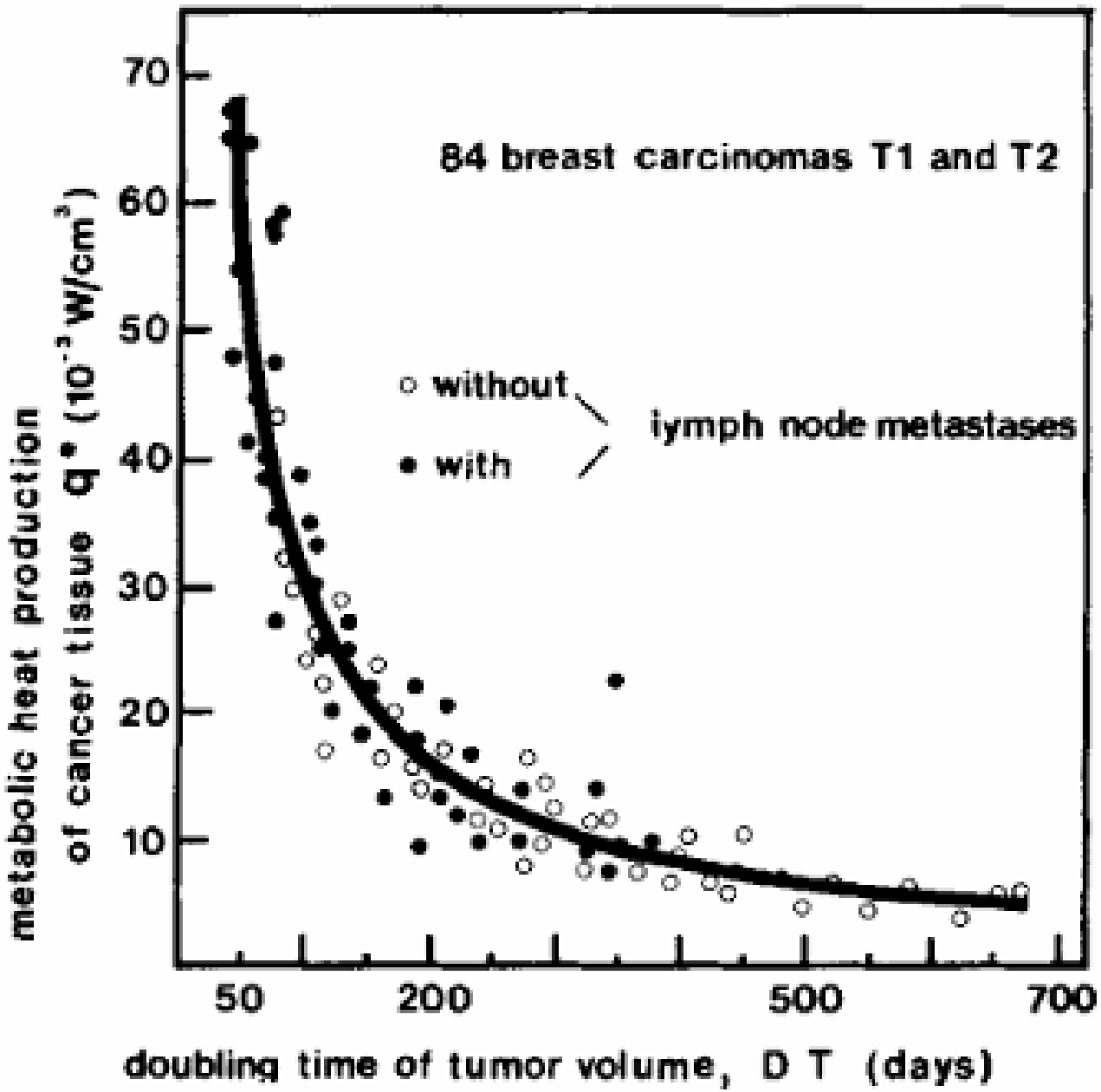
Metabolic heat production of breast tumors



a) **Temperatures are much higher in the cancerous breast than in the contralateral healthy breast. Thermal conductivity in the healthy breast is approximately constant in most cases except at the site of larger blood vessels.**

a) **Increase of temperature and blood flow in and around the tumor are well correlated**.

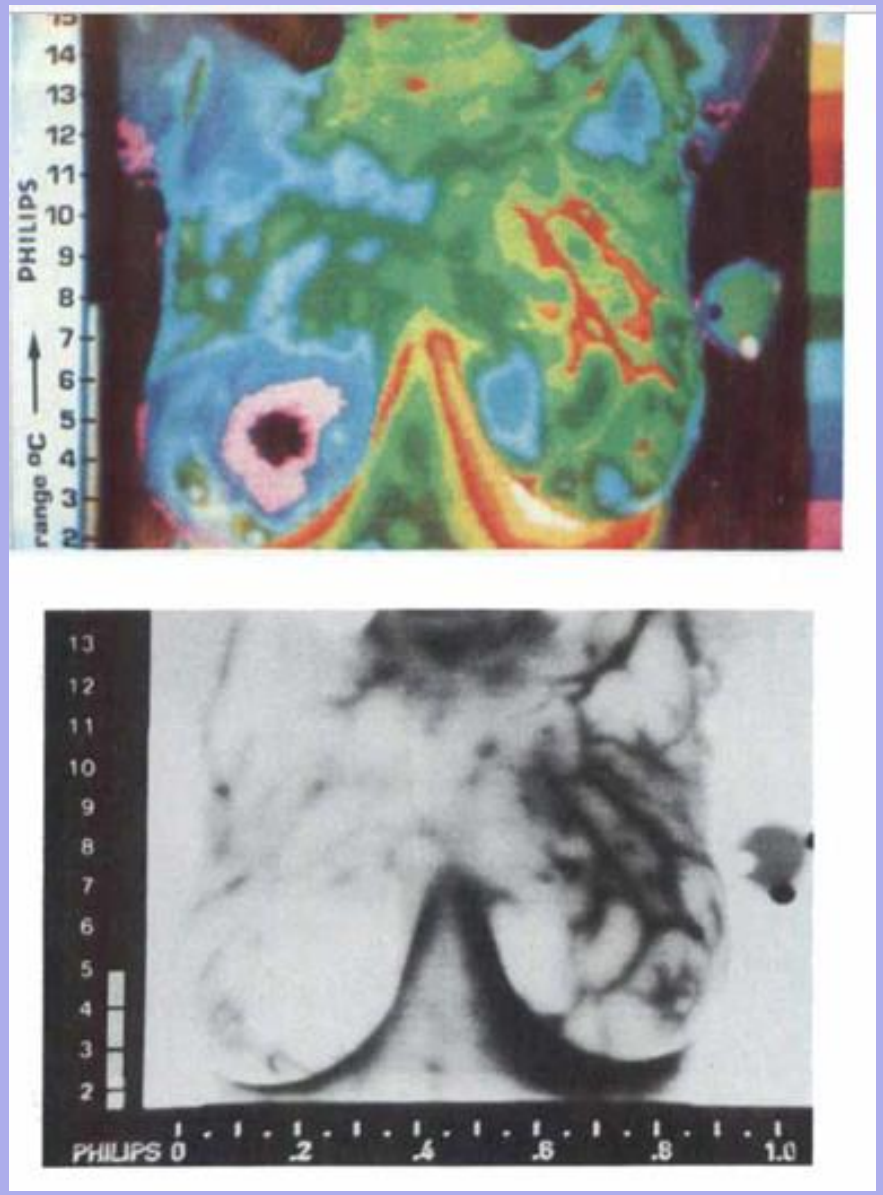
Gautherie M, “Thermopatology of breast cancer: measurement and analysis of in vivo temperature and blood flow,” Ann New York Acad Sci, 1980, vol. 335, 383– 415.



Growth rate and metabolic heat production of breast carcinomas.

A relationship between metabolic heat production of cancerous tissue and the doubling time of tumor volume (Gautherie, 1980).

a) Cancers with fast growth rate (DT 150 days) and intense metabolic heat production (20 x l0-3 W/cm3).
b) Cancers with slow growth rate (DT 250 days) and low heat production (10 x l0-3 W/cm3).



Thermographic Examination. Numerous vascular hyperthermia in the upper quadrants of the left breast, with irregular topography, more intense in the upper inner quadrant (+2.5 °C compared with mean thermal level of the left breast) (temperature difference between each color: 0.8 °C); strong thermal asymmetry between left and right breast; hyperthermia of the left nipple and areola (+0.5 °C with respect to contralateral area); total hyperthermia of the left breast, very intense (-3 °C with respect to the right breast); no local hyperthermia in the area of the palpable tumor. Conclusion: stage Th IV; class 43 (prognostical classification: high probability of rapid growth rate). Gautherie M, 1980.

$$c\frac{\partial T}{\partial t} = \nabla(k \cdot \nabla T) + \omega_b \cdot c_b \cdot \rho_b(T_a - T) + q_m$$

k is the thermal conductivity of tissue, ρ_b and c_b are the density and the specific heat of the blood, ω_b is the blood perfusion rate (ml/s/ml), q_m is the metabolic heat generation rate (W/m^3), T_a is the arterial blood temperature, and T is the local temperature of the breast tissue. The temperature of the arterial blood is approximated as the core temperature of the body.

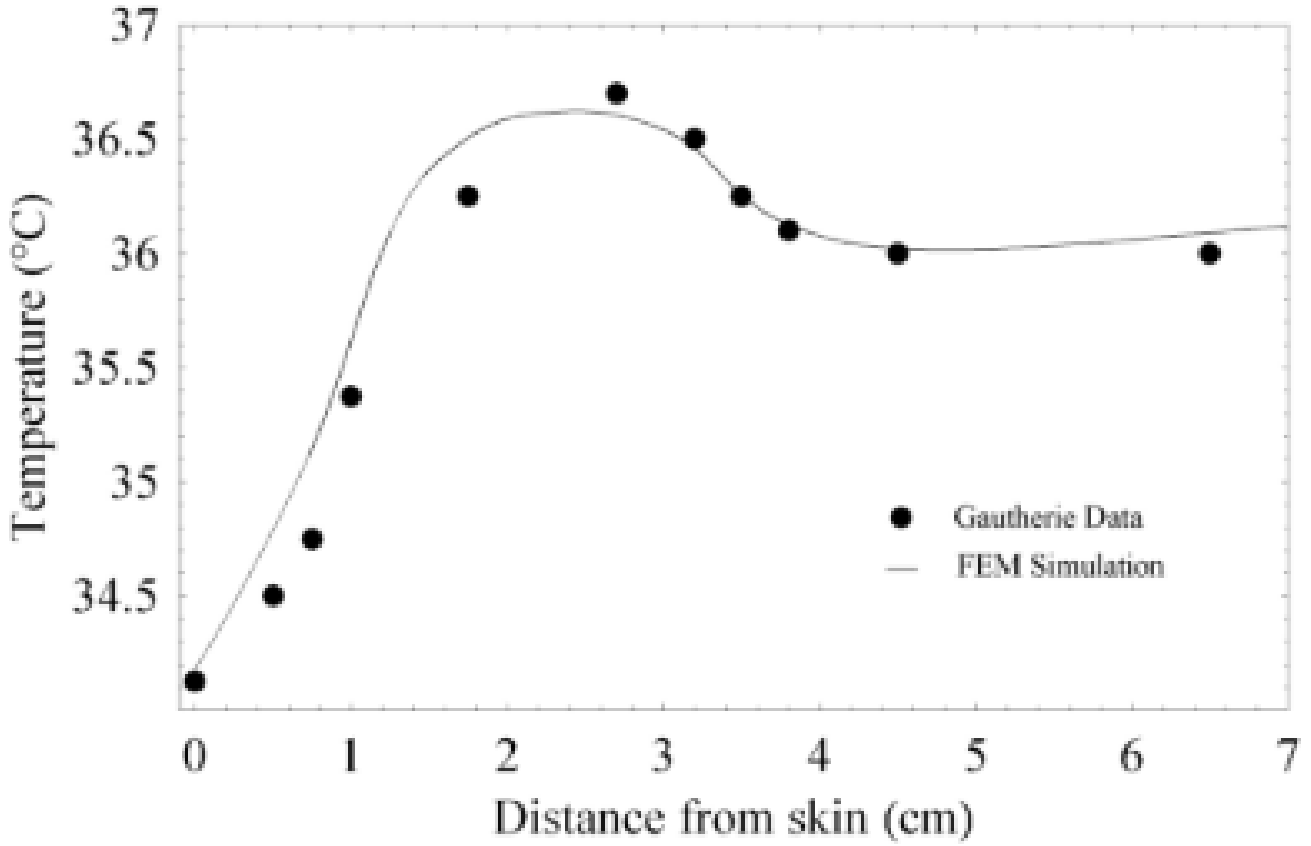


FIGURE 2. Temperature distribution obtained using a finite element simulation of a 2.3 cm tumor with its center located 2 cm deep from the skin surface compared to experimental data.

F. J González. RMF 53 (4) 323–326

Simplified grading scale for IR breast thermography at CIB

Simplified grading scale for IR breast thermography using as a first-line component of a multi-imaging breast cancer detection strategy

V. Chernov, E. Martín-del-Campo-Mena, G. Chernov, and M. Barboza-Flores

The motivation of the present work is to develop a simple grading scale (mild, moderate or severe) for estimation of an asymmetry level of breast thermograms. The scale should help to distribute test subjects into three groups. The first group, with mild asymmetry, will be supposed to have no thermographic abnormalities. Persons from the second group, moderate asymmetry, will be asked to receive a second thermography exam within 3 to 6 months. The third group, individuals with severe asymmetry, will be referred to a medical doctor and receive the second thermography exam within 2 to 3 months.

Thermography Centro de Imagenología Biotérmica (CIB) Universidad de Sonora

Participants from two groups:

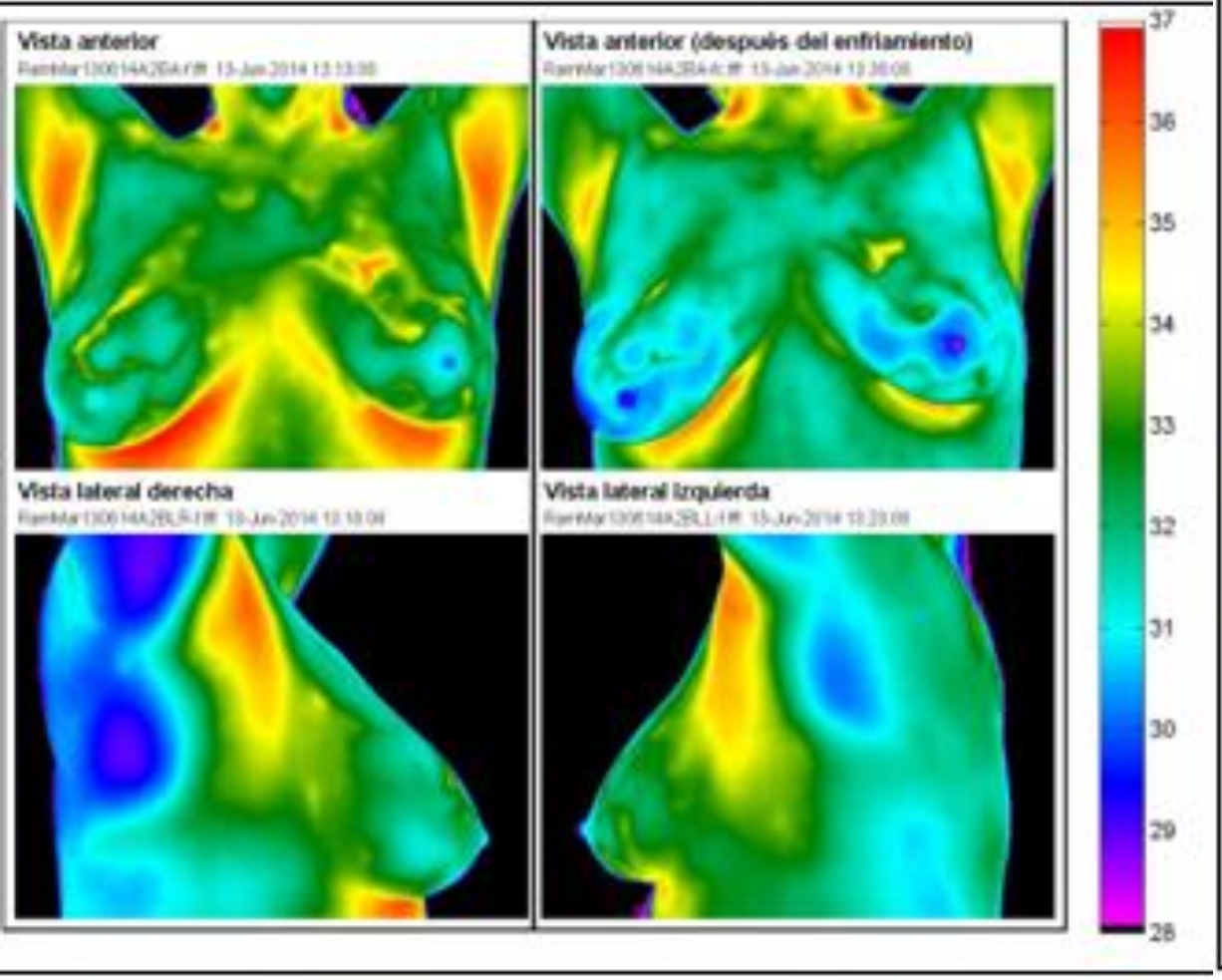
a) The first group consisted of 246 volunteer women. This group was considered as symptom-free free women aiming to establish normal temperature ranges for selected ROIs and features.

b) Second group consisted of 54 patients with breast cancer which were provided by an oncologist who has specializing in the study of breast thermography since 2008. All the cancer cases were confirmed by an open biopsy, which is considered the gold standard diagnostic method for breast cancer.

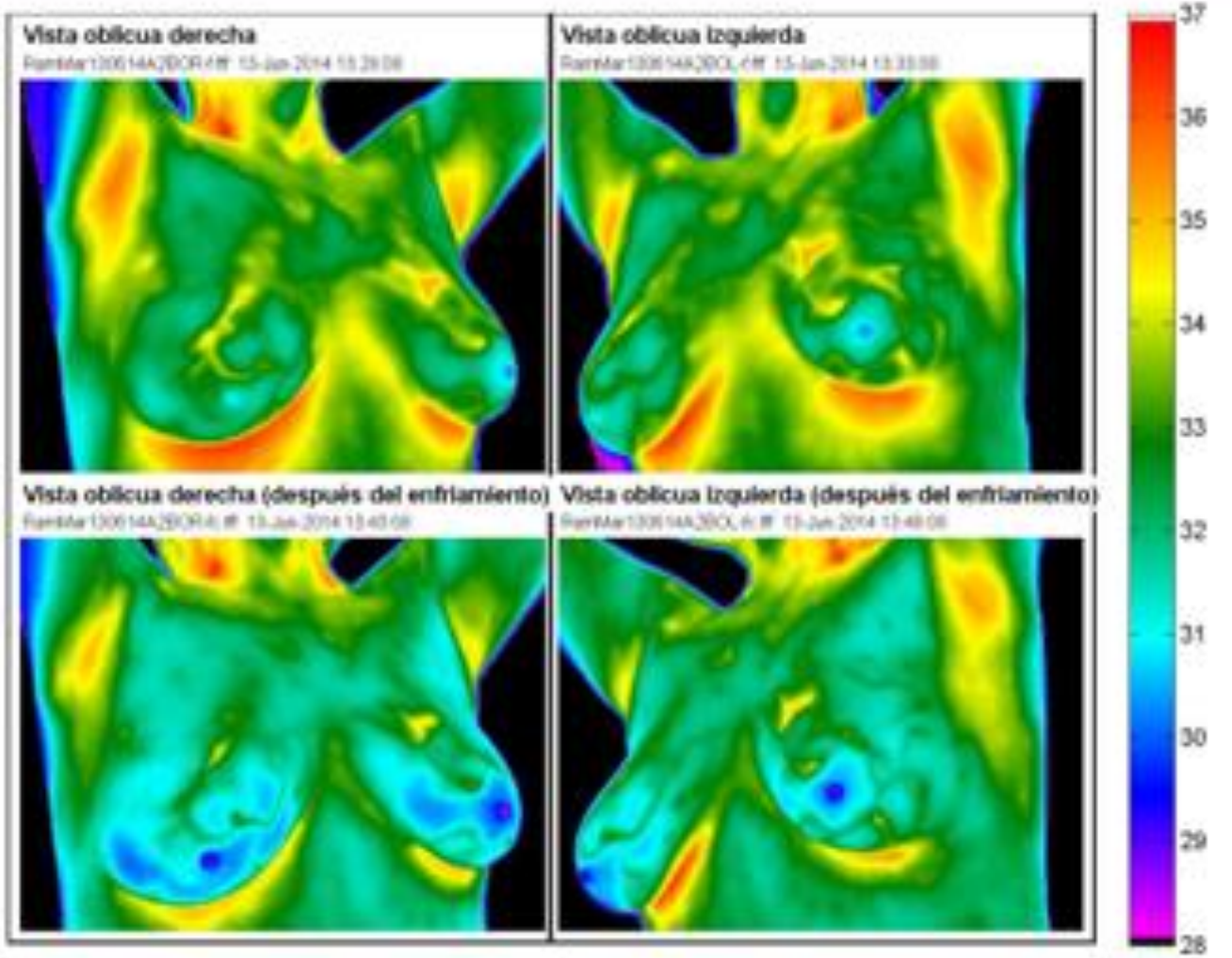
Image acquisition

The volunteer women (the first group) participants were examined using Flir (SC655, spectral range 7.5– 13 µm, resolution 640 × 480 pixels) or IRIS Elite (spectral range 7.5–13 µm, resolution 320 × 240 pixels) digital infrared cameras. The oncologist's patients were examined with Flir A40 camera (spectral range 7.5–13 µm, resolution 320 × 240 pixels). The thermograms were taken at a distance of about 1 m in a closed room at 23 ± 2 ºC and a relative atmosphere humidity less than 50 %. Five IR images of the breast were taken during a thermography exam: anterior view, two oblique and two lateral views (left and right).

Anexo 1. Imágenes termográficas



CENTRO DE IMAGENOLOGÍA BIOTÉRMICA



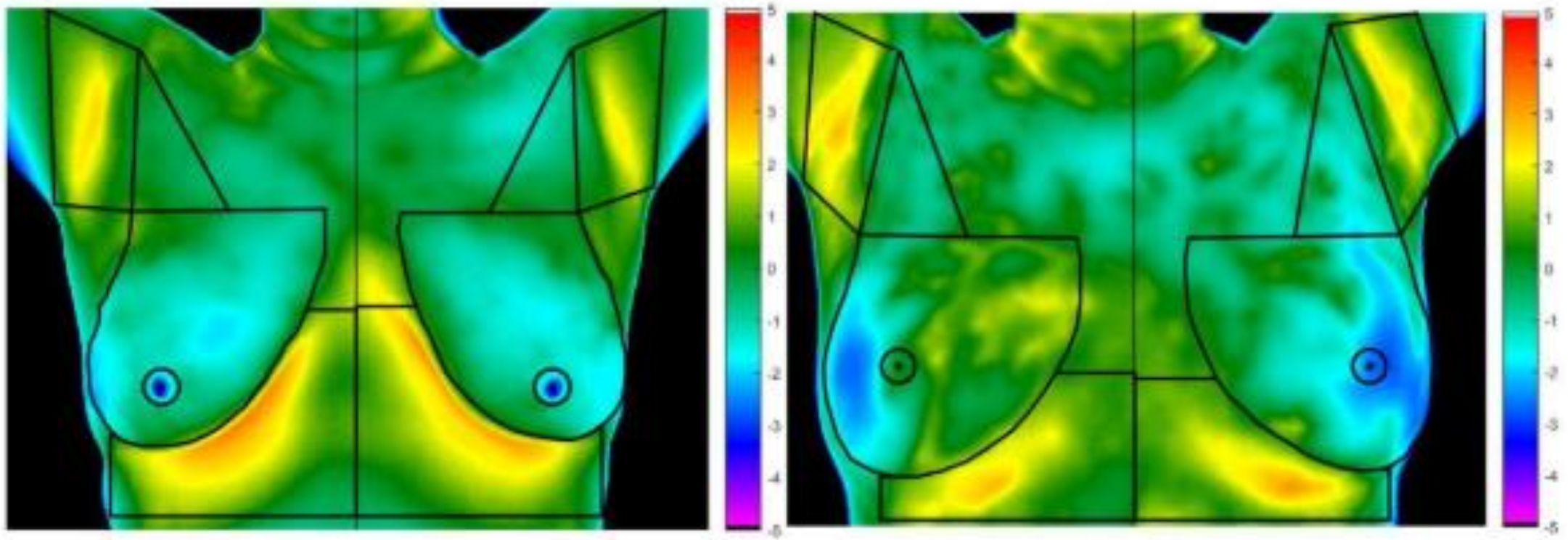


Figure 1. Thermal breast image (anterior view) of symptom-free women with mild (left) and severe (right) levels of asymmetry. The black lines limit five ROIs on each breast, which are nipples with areolas, breasts, axillary tails, axillas and submammaries. The temperature scales indicate the difference between the surface temperature and the mean temperature of the image (on the body area).

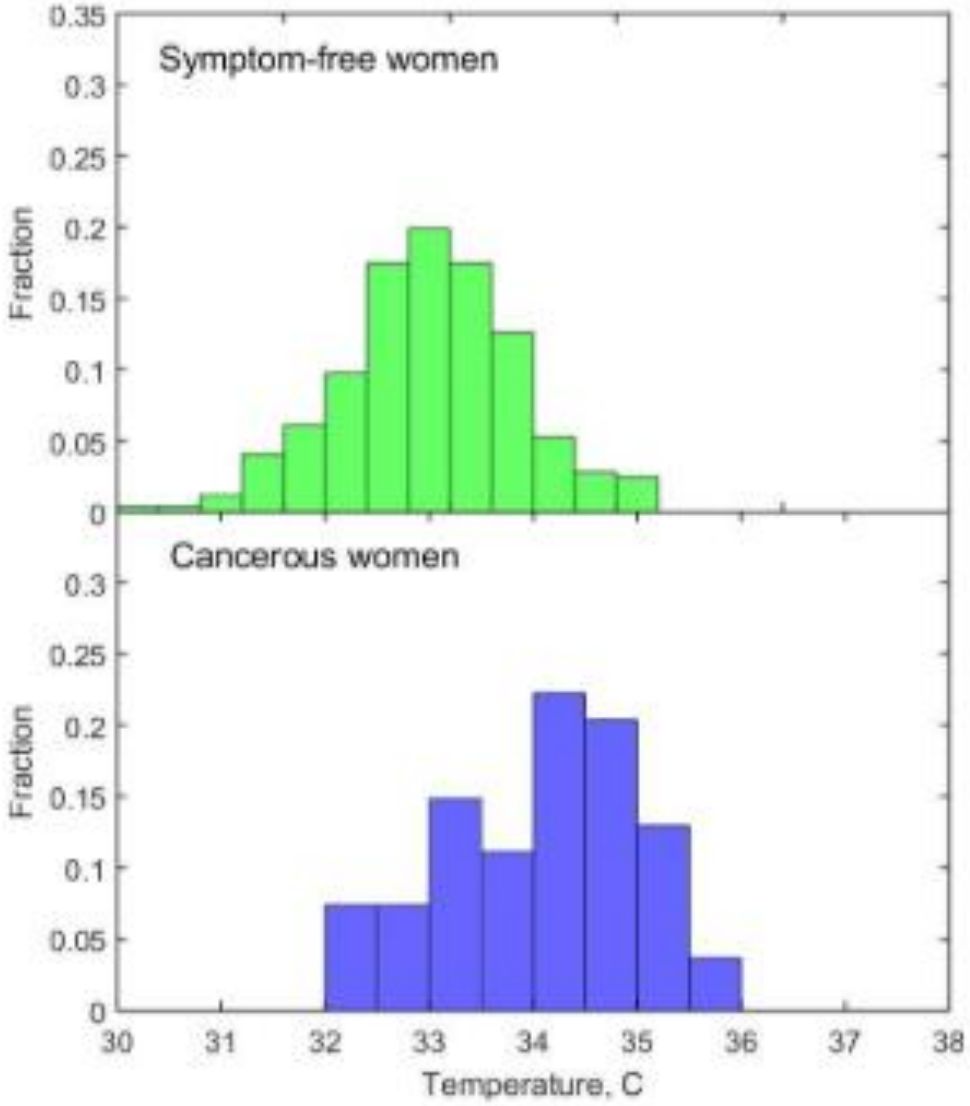


Figure 2. Frequency distribution histograms for body temperature of symptom-free and cancerous women.

Table 1. The average absolute and relative respect to Tb temperatures of ROIs for symptom-free women.

i	ROI	Right side, °C		Left side, °C	
		$T_{i,av} \pm SD_i$	$(T_{i,av} - T_b) \pm SD_i$	$T_{i,av} \pm SD_i$	$T_{i,av} - T_b \pm SD_i$
1	Nipple with areola	32.4 ± 1.4	-1.3 ± 0.8	32.2 ± 1.5	-1.4 ± 0.9
2	Breast	33.2 ± 1.2	-0.5 ± 0.4	33.1 ± 1.3	-0.6 ± 0.4
3	Axillary tail	33.4 ± 1.2	-0.3 ± 0.4	33.3 ± 1.3	-0.4 ± 0.4
4	Axilla	34.7 ± 1.0	1.0 ± 0.7	34.5 ± 1.1	0.9 ± 0.8
5	Submammary	34.7 ± 1.1	1.0 ± 0.6	34.8 ± 1.0	1.1 ± 0.6

Table 4. The average absolute and relative respect to T_b temperatures of ROIs for cancerous women.

i	ROI	Cancerous side, °C		Non-cancerous side, °C	
		$T_{i,av} \pm SD_i$	$(T_{i,av} - T_b) \pm SD_i$	$T_{i,av} \pm SD_i$	$T_{i,av} - T_b \pm SD_i$
1	Nipple with areola	34.1 ± 1.4	0.0 ± 0.9	33.0 ± 1.4	-1.1 ± 0.9
2	Breast	34.2 ± 1.2	0.1 ± 0.6	33.5 ± 1.2	-0.6 ± 0.5
3	Axillary tail	34.0 ± 1.0	-0.1 ± 0.4	33.7 ± 1.2	-0.4 ± 0.6
4	Axilla	34.7 ± 0.9	0.5 ± 0.6	34.5 ± 1.0	0.4 ± 0.6
5	Submammary	35.0 ± 1.1	0.6 ± 0.7	34.9 ± 1.1	0.7 ± 0.5
	Hyperthermia*		2.6 ± 0.9		1.3 ± 0.7

(*) The difference between the maximal temperature of one breast and the mean temperature of the contralateral one

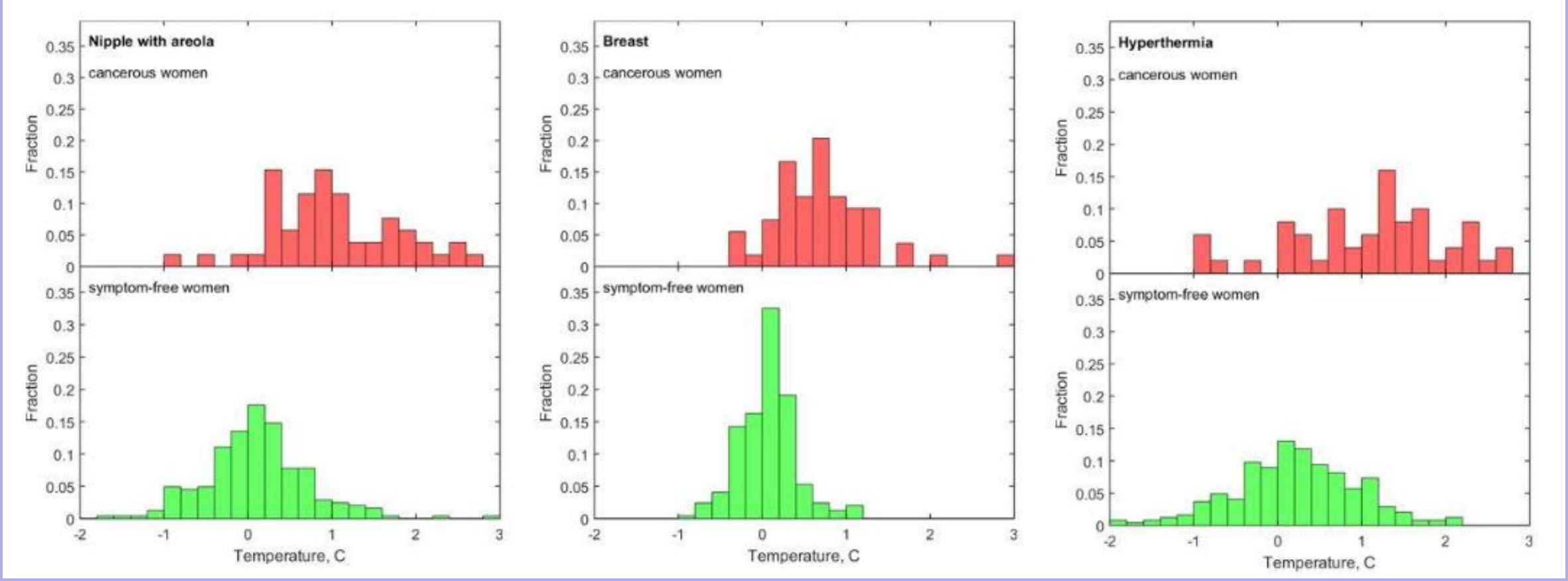
Table 2. The average mean temperatures of ROIs respect to T_b and their differences between right and left sides for symptom-free women.

i	ROI	$(T_{i,av} - T_b) \pm SD_i$	$\Delta T_{i,av} \pm SD_i$	Limit value of ΔT_i		
				mild	moderate	Severe
1	Nipple with areola	-1.4 ± 0.9	0.1 ± 0.7	< 0.8	0.8 ± 1.5	> 1.5
2	Breast	-0.5 ± 0.4	0.1 ± 0.3	< 0.4	0.4 ± 0.7	> 0.7
3	Axillary tail	-0.4 ± 0.4	0.1 ± 0.4	< 0.5	0.5 ± 0.9	> 0.9
4	Axilla	0.9 ± 0.7	0.1 ± 0.5	< 0.6	0.6 ± 1.0	> 1.0
5	Submammary	1.1 ± 0.7	0.0 ± 0.3	< 0.3	0.3 ± 0.6	> 0.6
	Hyperthermia*	2.1 ± 0.7	0.2 ± 0.8	< 1.0	1.0 ± 1.7	> 1.7

(*) The difference between the maximal temperature of one breast and the mean temperature of the contralateral one.

The average relative temperature ranges and their standard deviations were used for establish the limit values of ΔTi for evaluation of the asymmetry levels of five selected ROIs and hyperthermia. It was assumed that differences between the mean temperatures of right and left body sides of less than ΔTi,av + SDi correspond to mild ROI asymmetry, while the differences higher than Ti,av + 2SDi correspond to severe ROI asymmetry. The intermediate values of the differences correspond to the moderate asymmetry. The corresponding ranges for the mild, moderate and severe asymmetry levels are shown in the three last columns of table 2.

Figure 4. Frequency distribution histograms for the mean temperature differences of indicated ROIs and breast hyperthermia for symptom-free and cancerous women.



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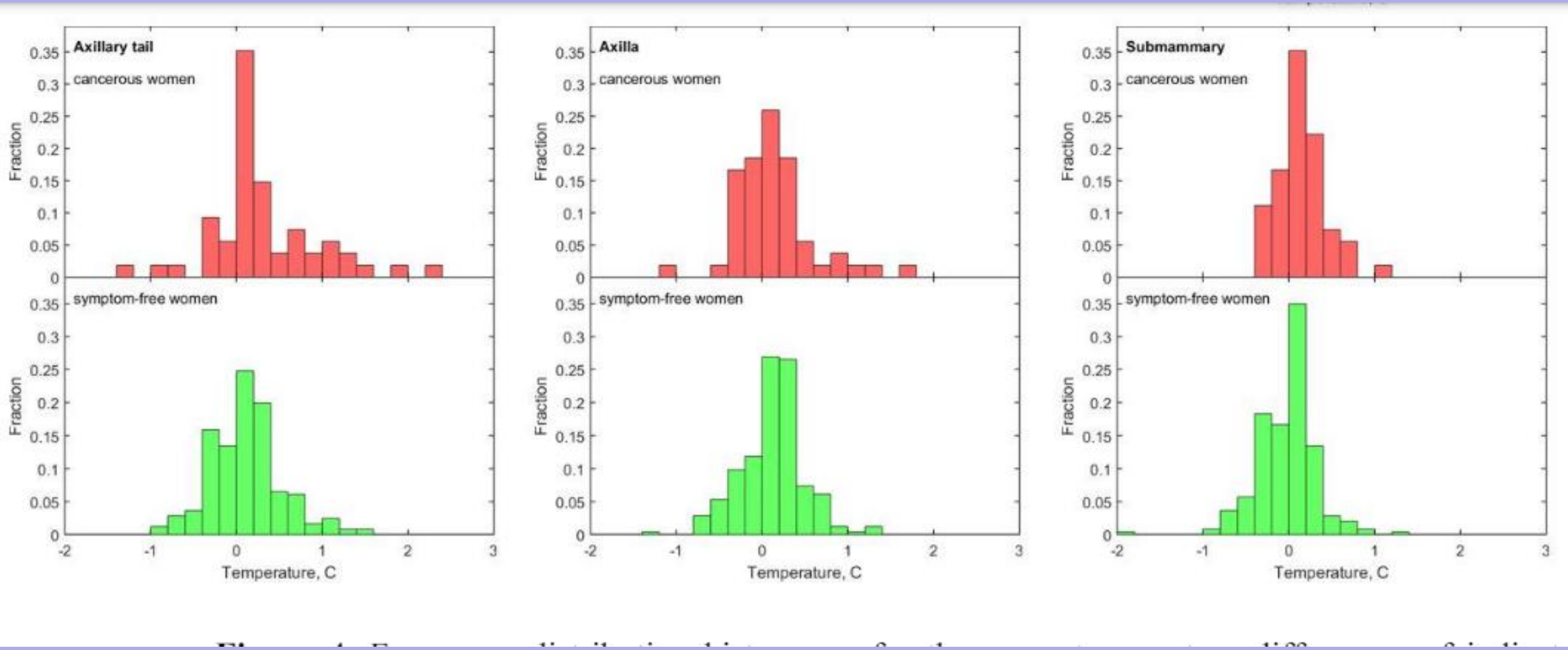


Conclusion

Conclusion

We developed a simple grading scale consisted of three grades, mild, moderate or severe for estimation of an asymmetry level of breast thermograms.

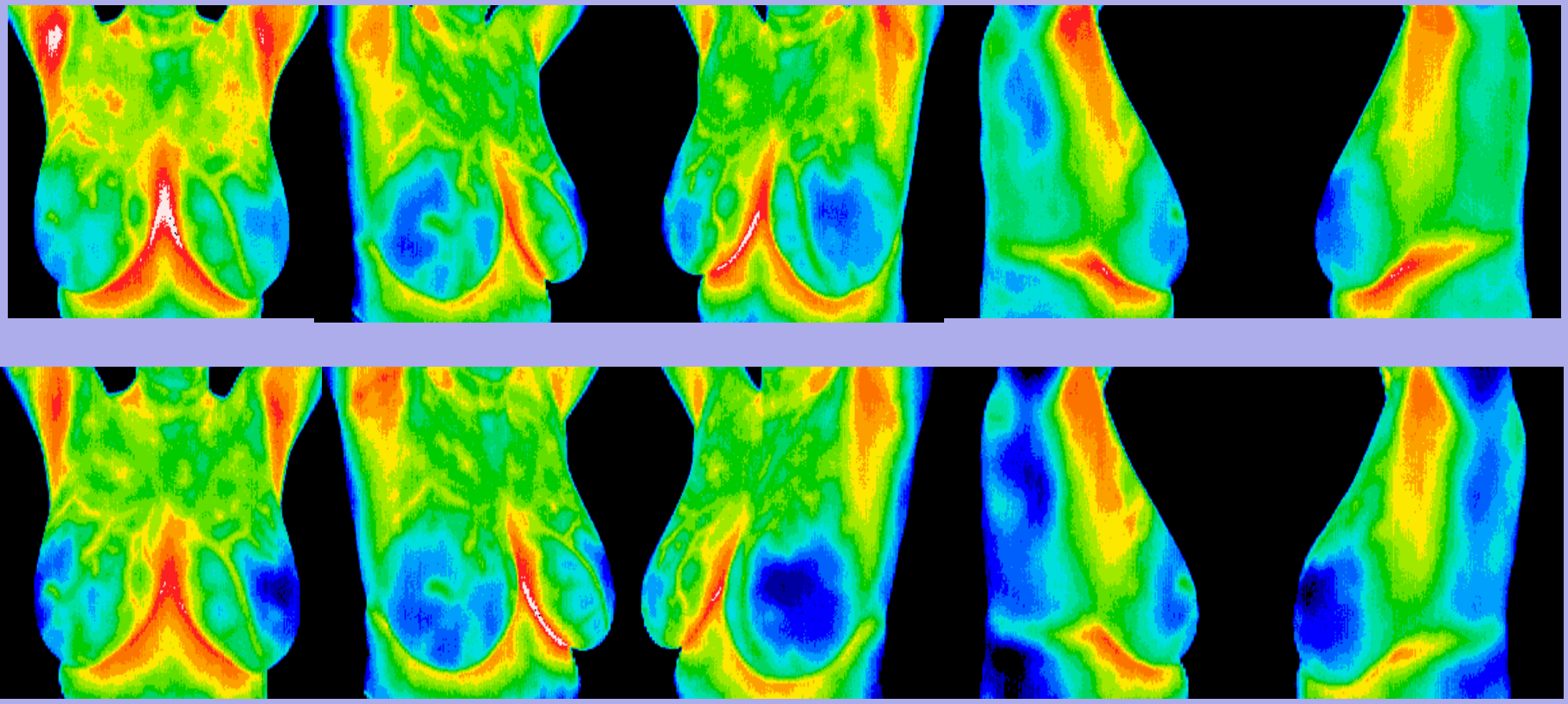
The grading scale could be useful for assessment of the breast cancer risk by using the IR thermography as a complementary first-line component of a multi-imaging strategy for detecting breast cancer.

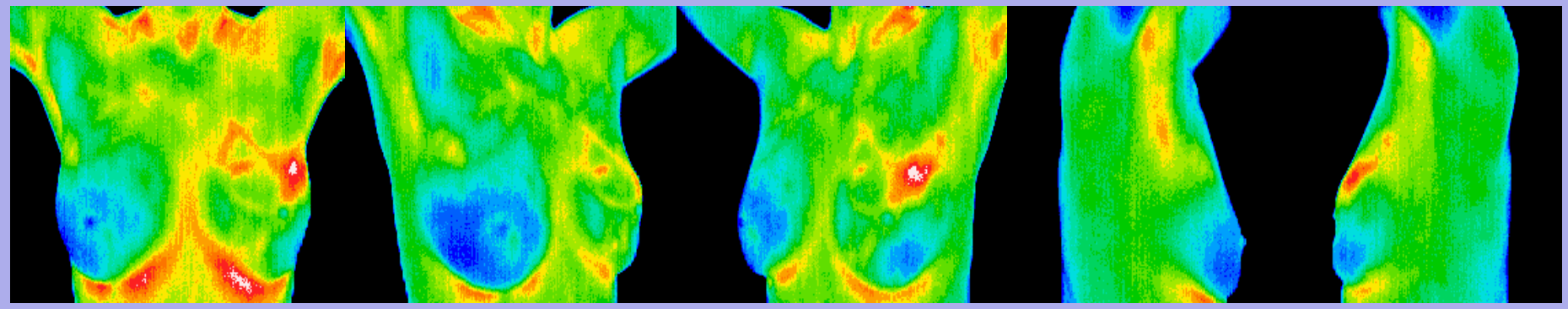
The proposed grading scale could be considered as a simplified and fully objective (independent of the experience of a thermography technician) and should help to distribute test subjects into three groups.

The first group, with mild asymmetry, will be supposed to have no thermographic abnormalities. Persons from the second group, moderate asymmetry, will be asked to receive a second thermography exam within 3 to 6 months. The third group, individuals with severe asymmetry, will be referred to medical doctor and receive the second thermography exam within 2 to 3 months.

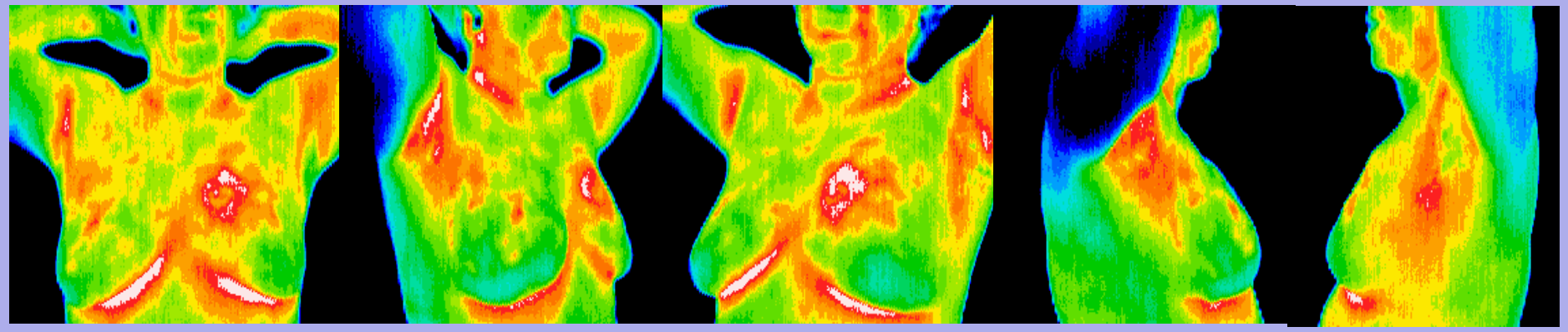
Final remarks

Thermography images corresponding to first thermogram compared with a thermogram one year later. No significative temperature changes are observed.

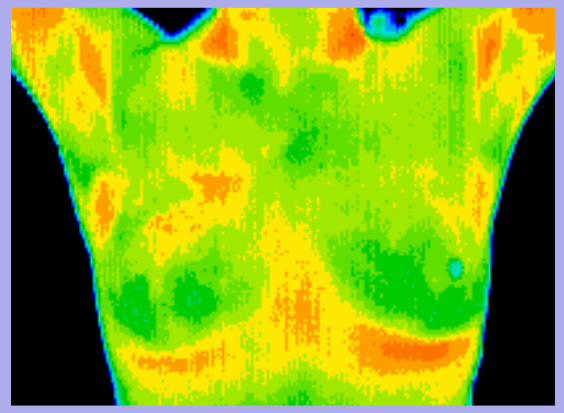




Thermal asymmetries related to a developing DCIS at 1 O’clock in the left breast.

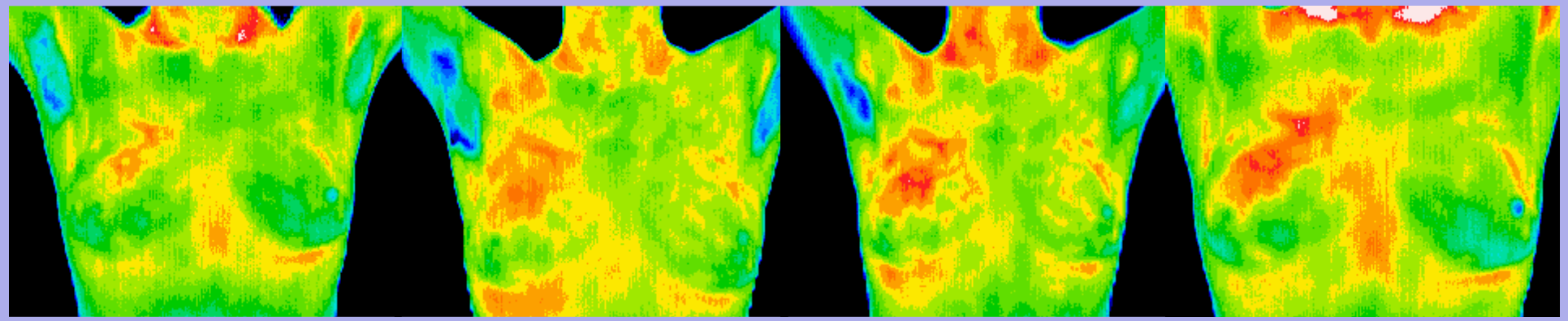


Thermal asymmetries relating to an advanced DCIS (3cm) at 10 O’clock in the left breast.



Baseline

This patient was age 37 when her first baseline thermogram showed a slight hyperthermic asymmetry in the upper right breast. The follow-up study showed the pattern had become more well defined and although clinical correlation did not find anything remarkable it was decided to repeat the exam again in a further 3 months, when again significant changes were seen.



3 months

6 months

9 months

12 months

The NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

Effect of Three Decades of Screening Mammography on Breast-Cancer Incidence

Archie Bleyer, M.D., and H. Gilbert Welch, M.D., M.P.H.

ABSTRACT

BACKGROUND

To reduce mortality, screening must detect life-threatening disease at an earlier, more curable stage. Effective cancer-screening programs therefore both increase the incidence of cancer detected at an early stage and decrease the incidence of cancer presenting at a late stage.

METHODS

We used Surveillance, Epidemiology, and End Results data to examine trends from 1976 through 2008 in the incidence of early-stage breast cancer (ductal carcinoma in situ and localized disease) and late-stage breast cancer (regional and distant disease) among women 40 years of age or older.

From the Quality Department, St. Charles Health System, Central Oregon, and the Department of Radiation Medicine, Oregon Health and Science University, Portland (A.B.); the University of Texas Medical School at Houston, Houston (A.B.); and the Dartmouth Institute for Health Policy and Clinical Practice, Geisel School of Medicine at Dartmouth, Hanover, NH (H.G.W.). Address reprint requests to Dr. Bleyer at 2500 NE Neff Rd., Bend, OR 97701, or at ableyer@gmail.com.

Conclusions. Despite substantial increases in the number of cases of early-stage breast cancer detected, screening mammography has only marginally reduced the rate at which women present with advanced cancer. Although it is not certain which women have been affected, the imbalance suggests that there is substantial overdiagnosis, accounting for nearly a third of all newly diagnosed breast cancers, and that screening is having, at best, only a small effect on the rate of death from breast cancer.

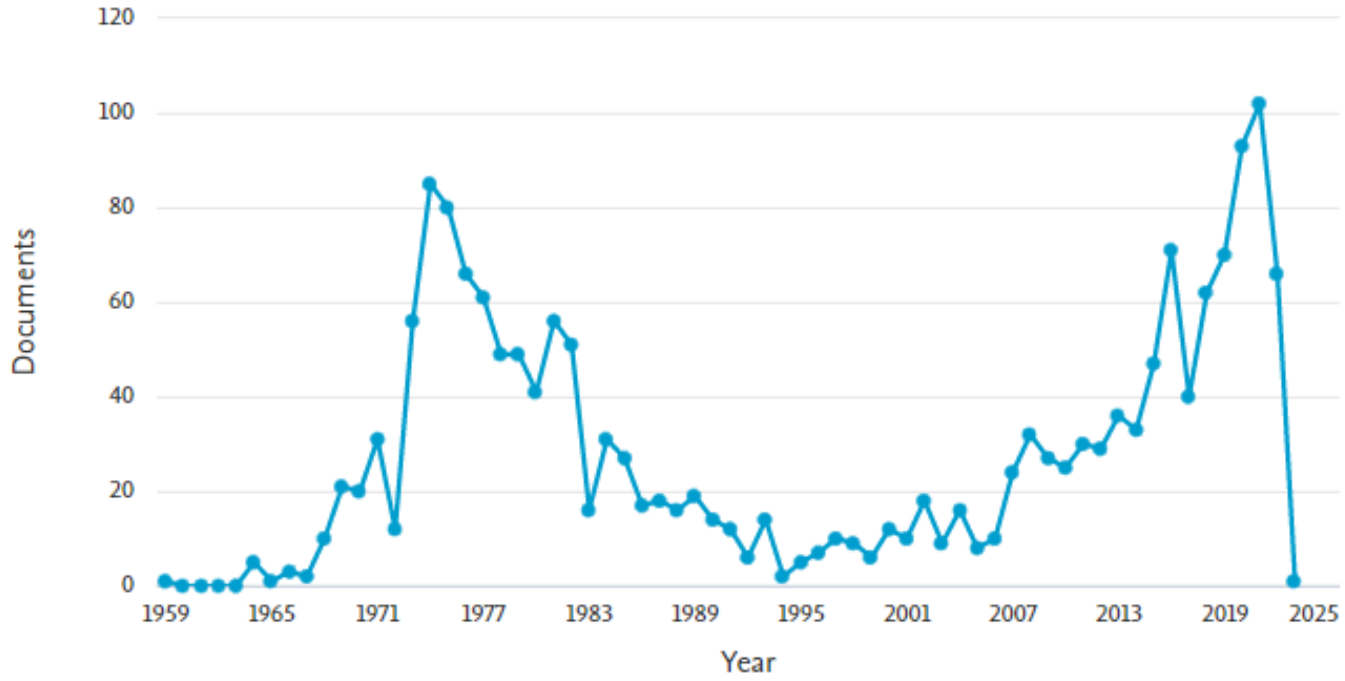
TITLE-ABS-KEY (thermography AND breast AND cancer)

1,800 document results

Select year range to analyze: 1959 to 2023 Analyze

Year	Documents
2023	1
2022	66
2021	102
2020	93
2019	70
2018	62
2017	40
2016	71
2015	47
2014	33

Documents by year



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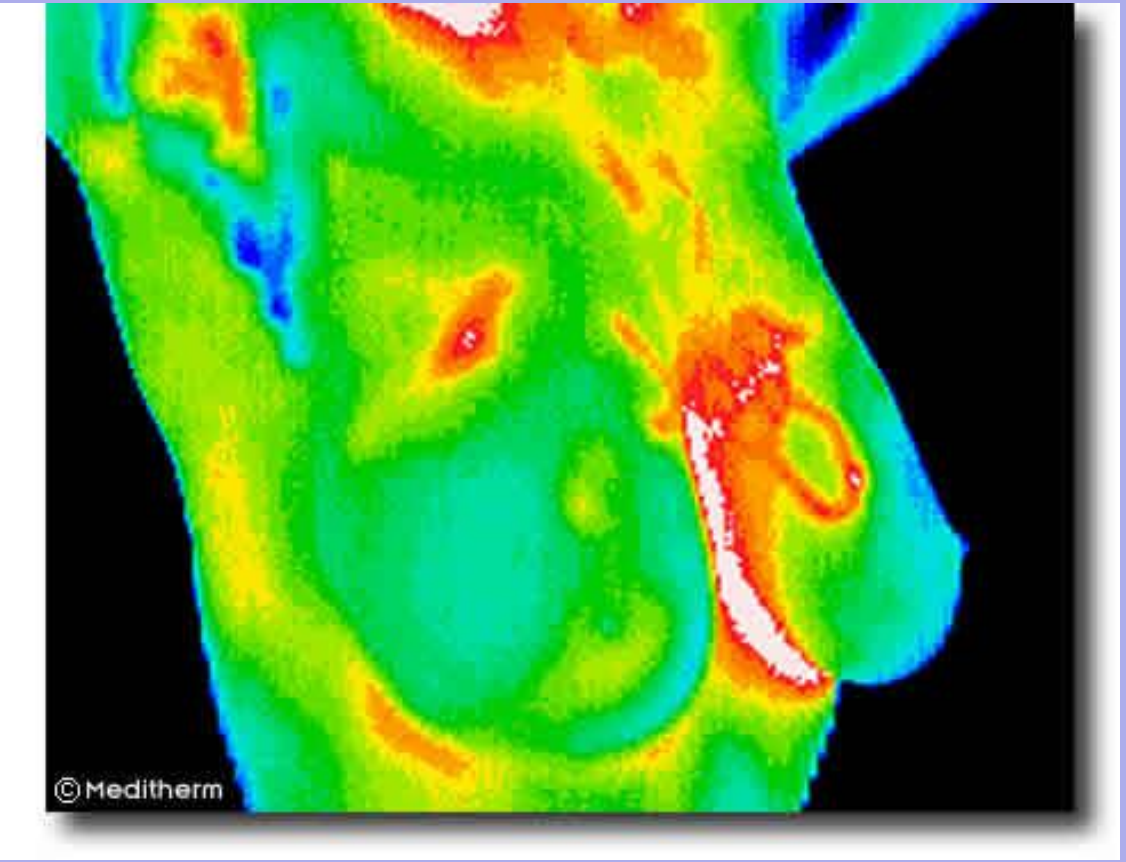
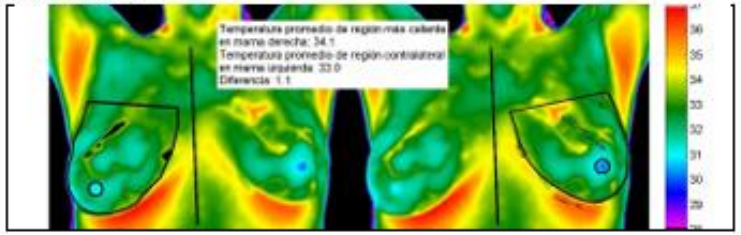


Hipertermia

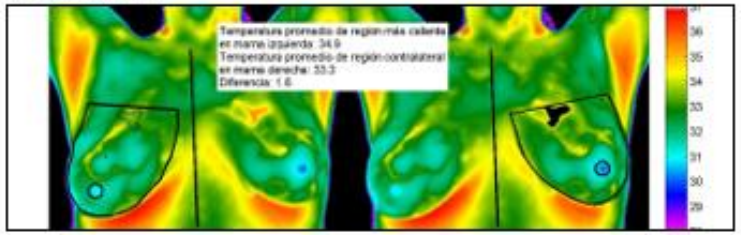
La zona más caliente es un área (área negra) con la temperatura mayor a 2.0 desviaciones estándar que la temperatura promedio de la mama.
El área bordeada de línea negra fina en la mama contralateral es la región simétrico contralateral.
La diferencia es la diferencia entre las temperaturas promedio de la zona más caliente y la región simétrico contralateral.
La asimetría de la zona más caliente se interpreta como: leve (no significante) para $\Delta T < 1.5$ °C, moderada para $1.5\ °C \leq \Delta T < 3.0$ °C y severa para $\Delta T \geq 3.0$ °C.

La mama derecha



La zona más caliente en la mama derecha consiste de más de dos sub áreas con temperatura promedio de 34.1 °C. La diferencia de 1.1 °C indica que la asimetría entre esta zona y la región simétrica contralateral es no significante.

La mama izquierda

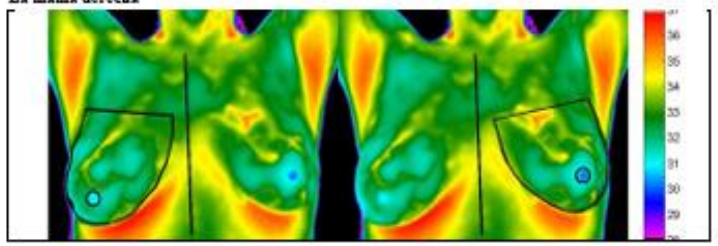


La zona más caliente en la mama izquierda consiste de dos sub áreas con temperatura promedio de 34.9 °C. La diferencia de 1.6 °C indica que la asimetría entre esta zona y la región simétrica contralateral es moderada.

Hipotermia

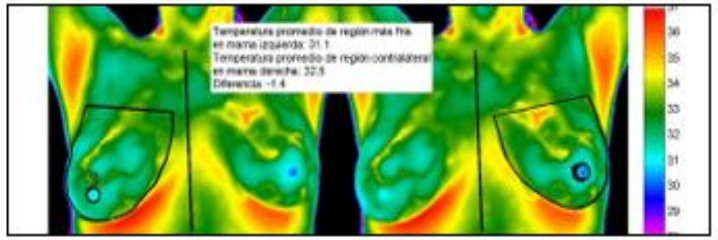
La zona más fría es un área (área negra) con la temperatura menor a 2.0 desviaciones estándar que la temperatura promedio de la mama.
El área bordeada de línea negra fina en la mama contralateral es la región simétrico contralateral.
La diferencia es la diferencia entre las temperaturas promedio de la zona más fría y la región simétrico contralateral.
La asimetría de la zona más fría se interpreta como: leve (no significante) para $(-\Delta T) < 1.5$ °C, moderada para $1.5\ °C \leq (-\Delta T) < 3.0$ °C y severa para $(-\Delta T) \geq 3.0$ °C.

La mama derecha



La mama derecha no exhibe regiones hipotérmicas.

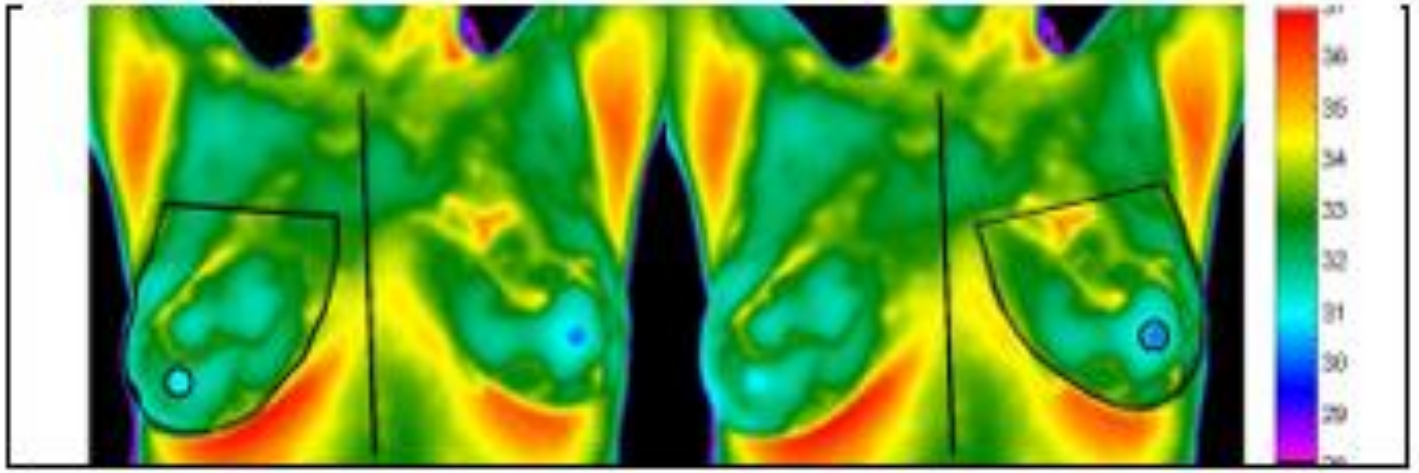
La mama izquierda



La zona más fría en la mama izquierda consiste de un área con temperatura promedio de 31.1 °C. La diferencia de 1.4 °C indica que la asimetría entre esta zona y la región simétrica contralateral es no significante.

La zona más fría es un área (área negra) con la temperatura menor a 2.0 desviaciones estándar que la temperatura promedio de la mama.
El área bordeada de línea negra fina en la mama contralateral es la región simétrico contralateral.
La diferencia es la diferencia entre las temperaturas promedio de la zona más fría y la región simétrico contralateral.
La asimetría de la zona más fría se interpreta como: leve (no significante) para $(-\Delta T) < 1.5$ °C, moderada para $1.5\ °C \leq (-\Delta T) < 3.0$ °C y severa para $(-\Delta T) \geq 3.0$ °C.

La mama derecha



La mama derecha no exhibe regiones hipotérmicas.

La mama izquierda