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Thermography is a promising breast cancer detection complementary diagnostic tool

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Abstract: From the last Twenty years of complying with the strict standardized thermogram interpretation protocols by proper infrared-trained personnel as documented in the literature, breast thermography has achieved high sensitivity and specificity [1]. An abnormal thermogram is reported as the significant biological risk marker for the existence of or continued development of breast tumors. This paper further discusses the implementation, performance, and environmental requirements in characterizing thermography as being used for breast tumor screening under strict indoor controlled environmental conditions. The essential elements of performance requirements include display temperature color scale, display temperature resolution, emissivity setting, screening temperature range, workable target plane, response time, and selection of critical parameters such as uniformity, minimum detectable temperature difference, detector pixels and drift between auto-adjustment. The imaging procedure in this study was carried out at Warith International Oncology Institute..
Keywords: *Breast cancer, Human body thermal pattern, Infrared radiation, Medical diagnosis, thermography..*

Key Point:

Thermography can be associated with standard modalities of breast cancer diagnosis due to its advantages such as being non-invasive, no-radiation, reachable, accepted cost, easy procedure, and overcoming the limitations of other modalities. Also, the resulting images (thermograms) can help in making the final decision about suspicious cases (biopsy, mastectomy, chemotherapy, or radiotherapy). Where The optimal treatment approach depends on various factors and should be tailored to each patient. Ongoing research and clinical trials continue to explore new diagnostic strategies and improve outcomes for individuals with thermography.

1. Introduction

Digital thermography is utilized in medical oncology because tumors typically exhibit increased angiogenesis and blood flow, in addition to heightened metabolic activity [1], which results in elevated temperature differences from the surrounding average tissue. Finding these gradients and infrared "hotspots" can therefore aid in detecting and diagnosing cancer [2]. The use of infrared thermography in medical diagnosis was accepted by the US Food and Drug Administration (FDA) in 1982 as an additional tool for the finding of breast cancer. However, its application was restricted [3]. by the capacity of previous imaging to resolve temperature technology, the heavy machinery needed to carry out processes, as well as the overall dearth of analytical computing tools [4]. Considering that since significant progress has been achieved in infrared thermal digitally enhanced high-resolution image technique and advanced neural networks based on artificial intelligence analysis of images [5].

The temperature range that could be resolved by infrared emission measurement equipment in the past was limited to 5 to 1°C. Some of the machinery required liquid nitrogen, and some even required

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patient contact, which involved using far less advanced technology that involved placing a special liquid crystal film on the patients' breasts to detect temperature [6].
Modern digital infrared thermography cameras don't need to come into touch with patients to detect temperature changes of.08°C or less [7] [8]. DITI has the potential to have a big influence on medicine now.
In this study, we evaluate the efficacy of a DITI system, the Breast Scan, in identifying breast pathology in a cohort of patients undergoing biopsy in a prospective, double-blinded trial who had suspicious findings on mammography, partial mastectomy, or case study.

1.1. Cancer

A term for situations in which abnormal cells multiply uncontrolled and have the potential to invade neighboring healthy tissues. Before entering into a description of the imaging process, a few terms must be defined. Neoplasia is the process by which a neoplasm, or abnormal and excessive tissue development, develops. When the initial trigger is removed, a neoplasm's development continues abnormally and usually results in a mass, which is referred to as a tumor. Its growth is not synchronized with that of the typical surrounding tissue. Additionally, neoplasms are classified into four types: malignant neoplasms, benign neoplasms, in situ neoplasms, and neoplasms with uncertain or unknown behavior.
The goal category is malignant neoplasms, the primary focus of oncology and

Also known as malignancies Cells typically go through an abnormal developmental pattern, such as metaplasia or dysplasia, before exhibiting abnormal tissue growth, known as neoplasia. However, metaplasia or dysplasia can occur in different conditions and does not always lead to neoplasia.

1.2. Infrared Radiation (IR)

Infrared radiation (IR), sometimes referred to simply as infrared, is a region of the electromagnetic radiation spectrum where wavelengths range from about 0.750 micrometers (μm) to 1000 micrometers (μm) as shown in the figure (1) [9]. Infrared waves are longer than visible light waves but shorter than radio waves. Correspondingly, the frequencies of IR are higher than microwave frequencies but lower than visible light frequencies, ranging from about 300 GHz to 400 THz. Infrared light is invisible to the human eye [10], but heat sensors can detect longer infrared waves. Infrared shares some characteristics with visible light, however. Like visible light, infrared light can be focused, reflected, and polarized [11].

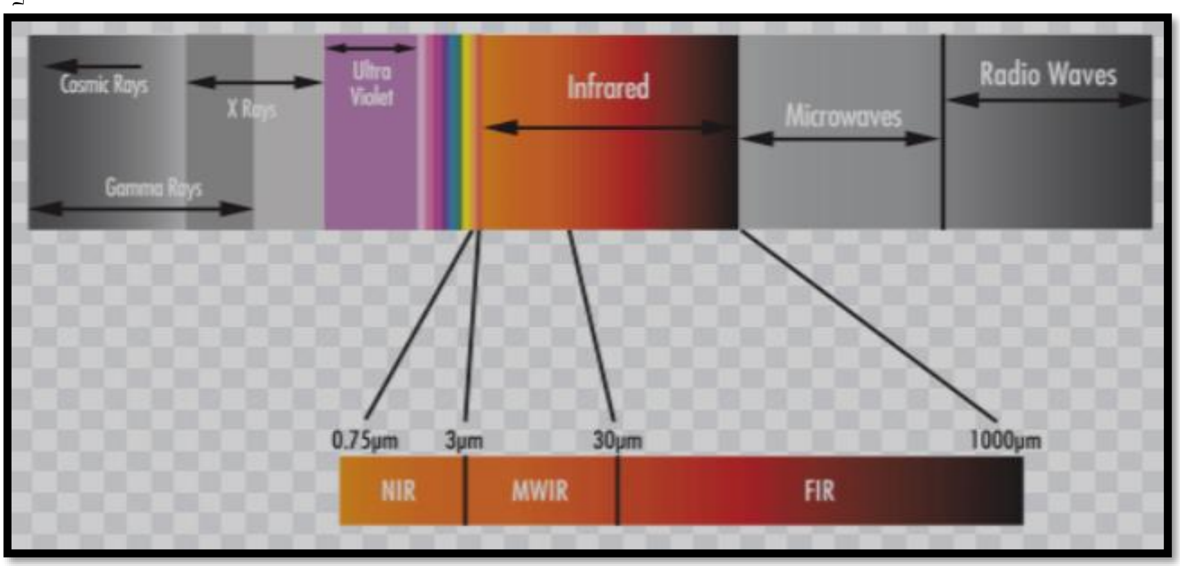

Figure 1.
IR electromagnetic wavelengths spectrum.

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As a result, its wavelengths range from roughly 1000 micrometers (300 GHz) to 0.75 micrometers (430 THz), which is the nominal red edge of the visible spectrum, rendering it invisible to the human eye [12]. Near room temperature, objects mostly produce black-body radiation at infrared wavelengths. It moves forward as energy and momentum, having the properties of a wave and a particle (photon), because it is a form of electromagnetic radiation. So, to make the IR radiation visible to the Human eye vision special equipment must be used (i.e. IR detectors).

1.3. Selection of IR Wavelength Band

The type of IR detector used in this study was uncooled. IR detectors are different from visible light detectors where they cover a small portion of the IR wavelength spectrum (approximately about 20 micrometers are covered only by the single detector) while visible light detectors cover all of the visible light detector (approximately about 370 micrometers from 380 to 570 μm)

Infrared radiation is used for imaging for a variety of reasons, including the fact that the human body is the source of radiation and that no external source of radiation (either ionizing or non-ionizing) is added to the system. There is also no contact between the human body and the detector, it is a non-invasive technique, it is low in cost and easy to obtain, and it produces functional images (thermograms). The human body's IR radiation is (from 2-20 μm) and

According to the mentioned reasons the chosen detector working wavelengths are (from 8-14 μm).

1.5. Breast Anatomy

The female breast consists of three parts: the base, the apex, and the tail. The Base, which normally runs from top to bottom, connects the sternum to the mid-axillary line and the second to sixth ribs [13] (sagittal axis to lateral side). The pectoralis major muscle accounts for two-thirds of the base. The external oblique and serratus anterior muscles positioned inferior laterally, account for one-third. It enters the axilla by a technique known as the axillary tail or axillary process.

The fourth intercostal gap is where the conical-shaped nipple is situated. The areola is a round, dark pink, brownish-colored skin region that surrounds the nipple. The subcutaneous tissues of the areola or nipple contain no fat.

Sweat glands that are not contained have developed into mammary glands. They are buried in subcutaneous adipose tissue and consist of ten to fifteen lobes, each with many lobules. Fibrous threads called Cooper Ligaments connect the deep fascia of the pectoralis major to the epidermis. The lobes and deep fascia are separated by the retro-mammary gap. Where Fibrous stands known as "ligaments of Cooper" and interlobar and interlobular fatty tissue separate the lobes and lobules. Furthermore, they have 15 to 20 lactiferous ducts that escape via the same number of openings on the nipple's peak.

The veins are matched by the lateral thoracic, intercostal, perforating, and mammary branches of the internal thoracic (internal mammary) artery. The circular venous plexus, found around the nipple base, also drains the axillary and internal thoracic veins.

The subclavian lymph trunk is generated when the arteries of the pectoral (anterior), subscapular (posterior), brachial (lateral), central, and apical groups of axillary lymph nodes meet. As shown in Figure 2 below.

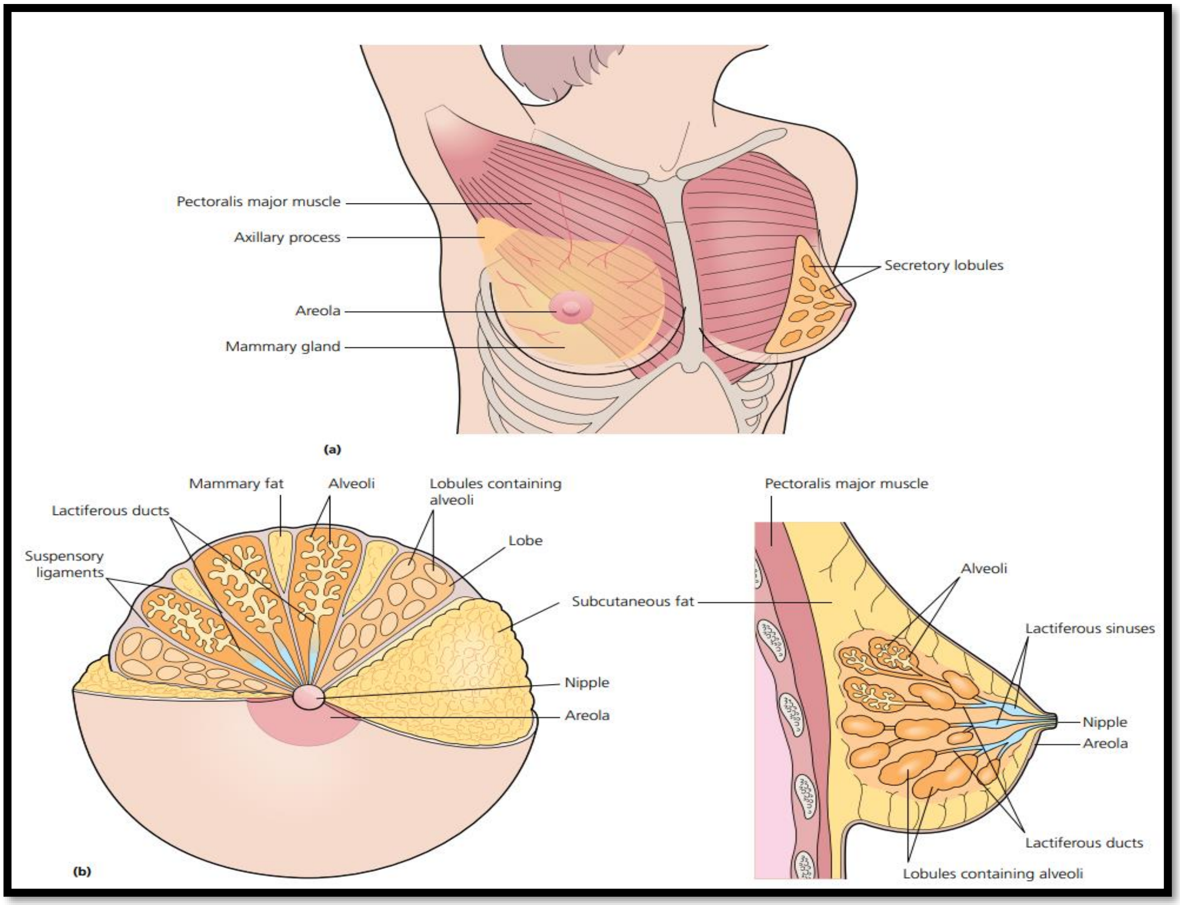


Figure 2.
breast anatomy

2. Materials and Procedure

Before starting imaging, there are several factors must be considered first:

i. IR imaging depends on the interesting band of detection where the IR detector covers the short portion of wavelengths of the IR wavelength range. So the purpose of imaging is to indicate the suitable band. For human body infrared radiation, the suitable band extends from (2 to 20 μm). The used IR detector features are illustrated below:

The type of sensor is an Uncooled infrared focal plane that covers from (8-14 μm) and its resolution is about (256x192) pixels, the pixel size is about (12 μm) and the Noise Equivalent Temperature Difference is about ≤ 50 milli Kelvin at temperature room (i.e. 25 °C), the detector image output (10bit/14 bit), Lens type is thermalized.

ii. Ethics protocol is followed in this study where the patient must understand the thermography procedure and the nature of the IR radiation and after that the patient information was written as shown in the list below:

2.1. Patient Information

Name:
Gender:
Age:
Time from last period:

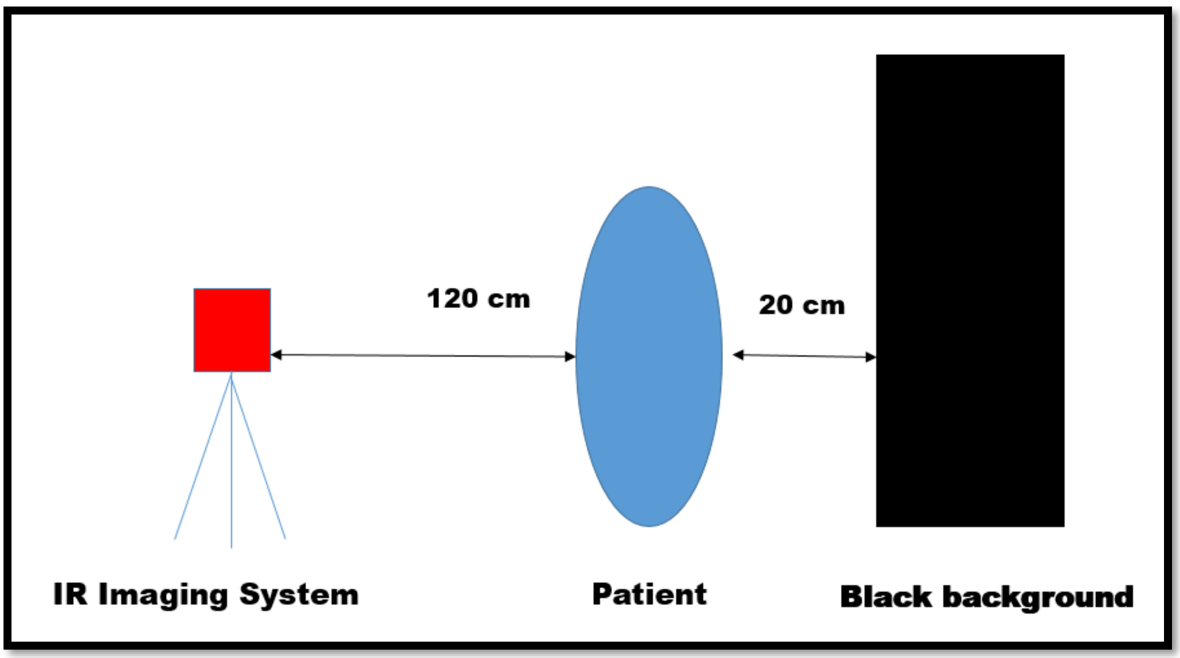
Status:
Number of children:
Breastfeeding:
Nipple Discharge:
Patient code:
Height:
Weight:
Disease condition:
Other modality:
Color of skin:
Family History:

Notes:

2.2. List of Patient Information

iii. Imaging System:

Components of the system includes IR Camera which consist of IR detector with IR transparent filter plus black background as shown below:



(A)

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(B)

Figure 3.
imaging alignment (A) General alignment (B) Investigation room.

iv. The conditions of imaging are very important to get good thermograms where the IR radiation is weak and affected by the environment such as the ambient temperature and humidity and light (sunlight and lamp lights), also the patient must be calm and not exhausted or at a period time.

v. The Imaging process takes about several seconds but the patient must be calm and in disrobing clothes for 5 minutes at least before snapping to reduce the effect of disrobing on the resulting thermograms and it is preferred to be done by a female operator.

3. Results and Discussion

After Imaging several cases the results are shown below:

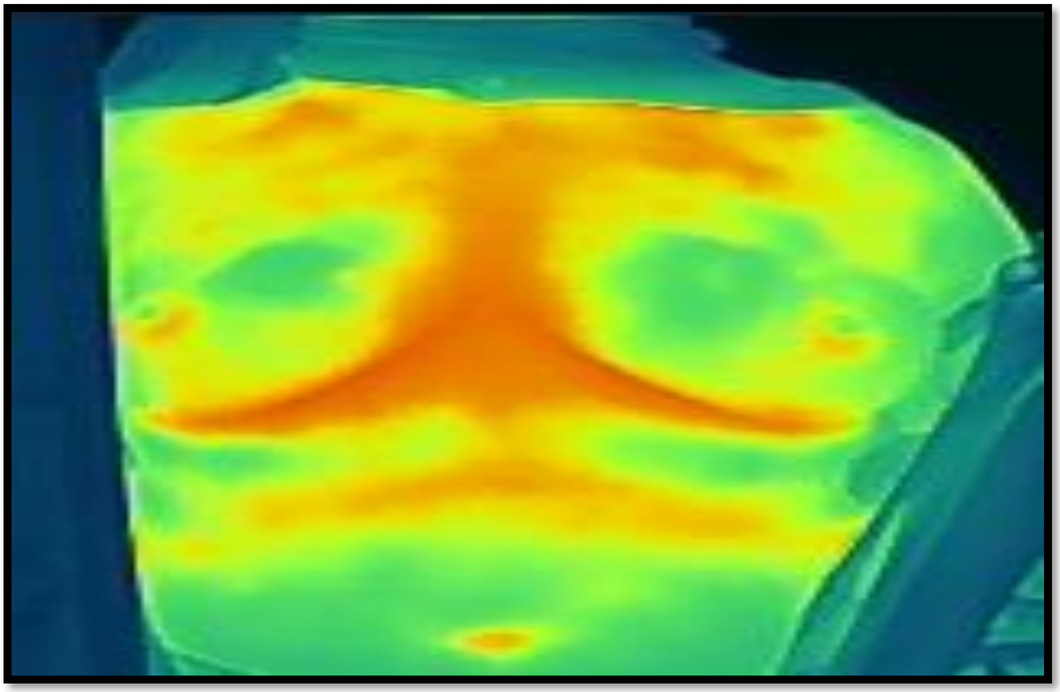

Figure 4.
Result (1) Case study.

For the thermogram shown above rapid imaging (rapid, and partial disrobing) will give a false thermal pattern of the areola region and breast base region plus the symmetry thermal pattern of both breasts shows a normal breast condition and there is nothing suspicious of the case study (1).

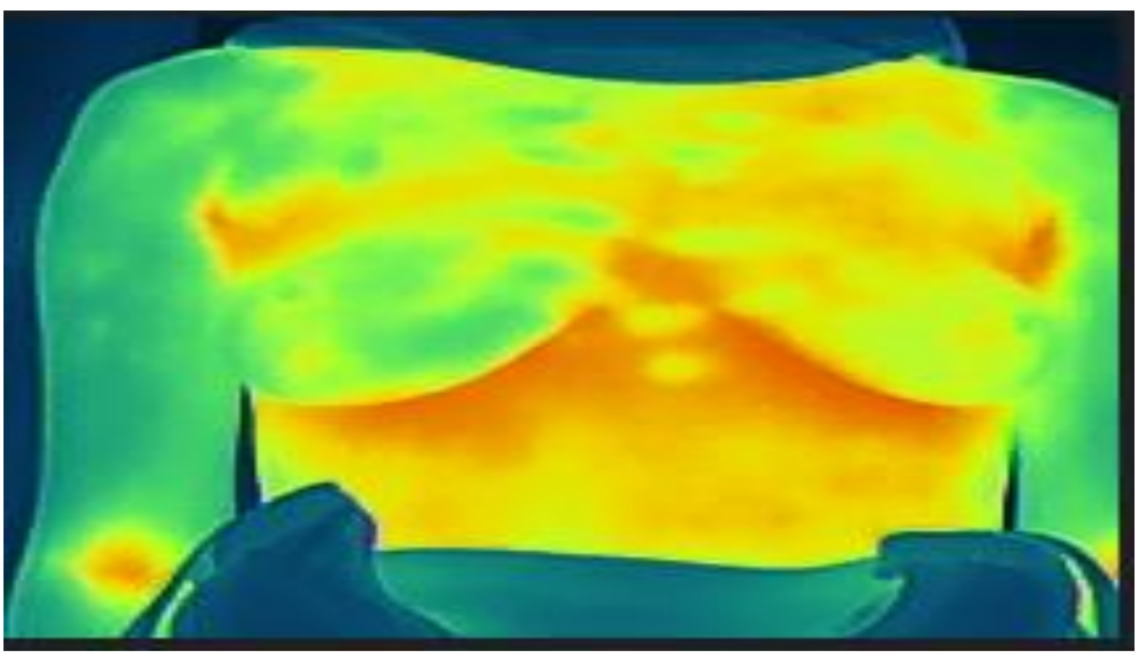

Figure 5.
Result (2) case study.

For the thermogram shown above rapid imaging (rapid, and partial disrobing) will give a false thermal pattern of the areola region and breast base region plus the symmetry thermal pattern of both breasts shows a normal breast condition and there is nothing suspicious of the case study (2).

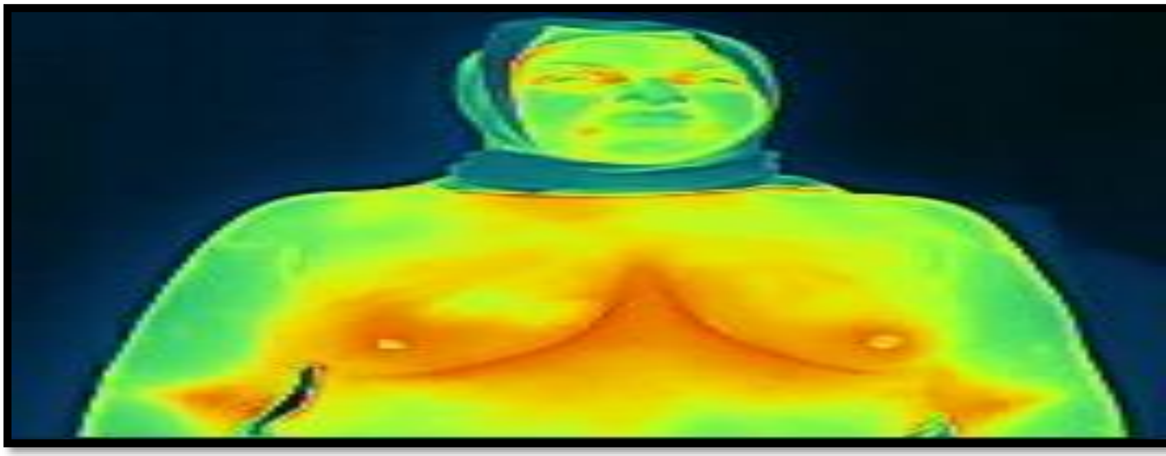

Figure 6.
Result (3).

This thermogram shows cancer in the right breast due to the asymmetric thermal pattern and different sizes of the breasts, which was confirmed via the standard modality (mammography) where a Tumor in the right breast and now the chemotherapy (two doses are taken). She is screened for the follow-up stage.

Figure 7.
Result (4).

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This thermogram shows cancer in the right breast (lateral side) due to the asymmetric thermal pattern and different sizes of the breasts, which was confirmed via the standard modality (mammography) and this thermogram effect by the period. So, it is recommended to carry out any thermography out of the period interval.

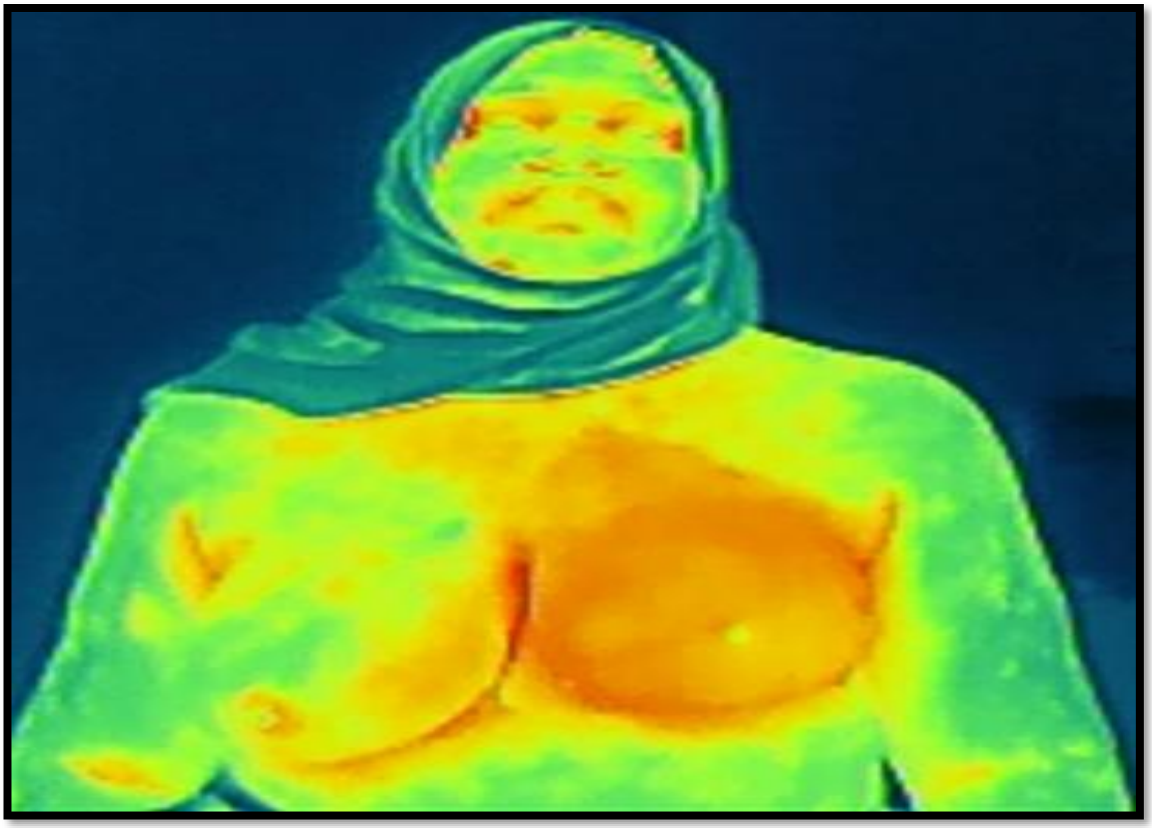

Figure 8.
Result (5).

This thermogram shows a false positive due to the partial mastectomy which leads to the asymmetric thermal pattern and different sizes of the breasts, which was confirmed via the standard modality (mammography). So, thermography has a limited ability in such cases.

4. Conclusion

Thermography is a promising complementary diagnostic tool [14] [15] that can be used for subcutaneous cancers. It can be carried out in oncology as a reliable technique due to many factors such as dense breasts create a useful thermogram, no age limitations (standard breast diagnostic tool (mammography) has age limitations), low cost, non-invasive method, and no radiation included [16] [17]. The utility IR Imaging systems can scan over the bandwidth of wavelengths instead of a single wavelength [18] [19], the accurate analysis of the resulting images instead of colored images only, and the comparison between the Furthermore, it may be utilized to compile a medical history of selected individuals from diagnosis to final treatment [20].

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Funding acquisition: Mohammed Hassoon Alwan.
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Supervision: Auns Qusai Al-Neami, Haydar Hamza Alabedi.
Validation: Mohammed Hassoon Alwan.
Visualization: Haydar Hamza Alabedi.
Writing–original draft: Mohammed Hassoon Alwan.
Writing–review and editing: Mohammed Hassoon Alwan.
Conflicts of interest
The authors declare that they have no competing interests.
Declaration of generative AI and AI-assisted tools in the writing process
During the preparation of this work, the authors utilized ChatGPT—a chatbot developed by OpenAI—to refine grammar points and language style in writing. Subsequently, the authors thoroughly reviewed and edited the content as necessary, assuming full responsibility for the publication's content.

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