Bioimages 20 : 1-7, 2012

REVIEW

Infrared thermography to quantify the risk of breast cancer

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Summary

From the last decades, infrared thermography is quite often associated with things other than clinical medicine. For example, the chemical, automobile, aeronautic industries and civil engineering. However, thermography is where infrared images of the breast are analyzed by board certified thermographers and an abnormal thermogram is reported as the significant risk for the existence of breast tumor (Ng, 2009). Thermography is a painless, noninvasive, no radiation, as well as being cheaper and faster, easier access. The aim of this review was to identify the views of clinicians on the use of thermography for quantifying the risk of breast cancer. We used articles published recently in a reliable database. Thermography has been convicted over the years; it has been labeled by subjective interpretation. Most of the reviewed articles agree that mammography is currently the main examination chosen by doctors for the screening of breast cancer (Acharya et al., 2010; Kennedy et al., 2009). However, several studies have reported promising results for the technique (Wang et al., 2010). Additionally, some authors suggest that thermography is complementary to other diagnostic methods, and that the best strategy for the early detection of breast cancer would be to use them together (Kennedy et al., 2009; Hersh, 2004). The combination of thermal imaging with other tests would increase accuracy, sensitivity and specificity of the evaluation and allow a better quantification of the risk of breast cancer.

Keywords

infrared thermography, breast cancer, thermograms, quantification of the risk

Introduction

The use of thermal tests on health is not something new. The first use of thermography was in 1957. Lawson found that the temperature of the skin over the breast cancer was higher than normal tissue. The relationship between skin temperature and breast cancer was also studied by Gautherie and Gros (1980) in 1975 and Acharya et al. (2010), who detected differences in skin temperature of healthy and cancerous breasts. However, until the late '70s, few documents showed that the thermographic images had a direct relationship both with the clinical findings and diagnosis and with breast pathologies. The lack of proper training, understanding the equipment, and the absence of protocols, led to inappropriate uses of the method and to errors of interpretation of thermograms. These drawbacks made thermography get discredited by many medical professionals (Brioschi et al., 2010).

Fortunately, the computational development allowed the evolution of electronic thermography examination. The technique, which had low resolution and subjective results in the 80's, has been replaced by modern computer systems and sensors for high resolution and thermal sensitivity in the late 90's. The equipment has become more compact and has been provided with specific software. The sensitivity of modern infrared cameras to detect differences in skin temperature is 0.025°C (Kennedy et al., 2009).

This evolution radically changed the opinion of the medical professionals about the exam and brought more respect and attention to this technology that resurfaces with works of great scientific value (Bezerra, 2007).

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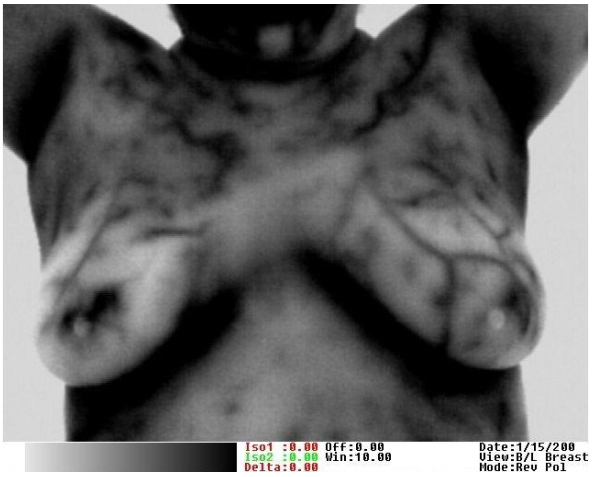

Fig. 1. The darker areas are higher in temperature, suggesting increased risk of breast cancer

Development

Thermography uses infrared radiation emitted by bodies to observe different patterns in temperature distribution. It detects the subtle physiologic changes that accompany breast pathology, whether it is cancer, fibrocystic disease, an infection or a vascular disease (American College of Clinical Thermology, 2010). Changes detected by thermograms are related to metabolic changes, and those detected by mammograms are related to anatomical structures. Also, its usage in medical procedures was feasible because it is painless, non-invasive, and it does not use ionizing radiation (American College of Clinical Thermology, 2010).

Among its applications in medical practice, we can mention studies of inflammatory processes, determination of some circulatory changes, physiotherapy treatment, sports injuries, and the detection of several types of cancers, including breast cancer (Bezerra, 2007).

The mammary tumor requires a steady flow of nutrients to develop. For this, new blood vessels are created around the tumor (angiogenesis), which ultimately increases the local temperature. This temperature rise can be detected on the surface of breast cancer through the examination of the thermography. A study done in Japan with 48 women who would undergo surgery for resection of the breast, had thermographic images collected from the suspected area and from the underlying tissues, in addition to measuring the local temperature using a thermometer inserted in breast tissue. The temperature was found higher on the diseased tissue, which coincided with the images of the thermograms. Thermograms were found abnormal in 43 of the 48 women (Yahara et al., 2003).

Fig. 1 shows the temperature difference between the right breast and the left indicating the inflammatory process, which may be early cancer.

Considering that the cure for breast cancer is possible in many cases when detected early, it is important to consider thermography as an indispensable tool in screening programs for breast cancer. It should be emphasized that the technique should be used mainly to quantify the risk of breast cancer or as a complement to other methods to increase its diagnostic sensitivity. The intent of thermography is not to replace other existing methods, but to collaborate for the early detection of breast cancer. Table 1 summarizes the advantages and disadvantages of diagnostic methods for breast cancer.

Early detection of breast cancer

Early detection of breast cancer has obvious importance. The delay in obtaining a diagnosis can establish the limits of survival of the patient. The only way to reduce mortality from breast cancer is to detect the disease before they notice the first symptoms (Unzu, 2001).

The thermographic examination involves using special infrared cameras to produce high quality images, detecting changes in temperature. Due to the sensitivity of the infrared image, the first signs of breast cancer can be observed in the spectrum. The image can also suggest a pre-cancerous activity through the variation of the normal blood flow. Xie et al. (2004) conducted an experiment with rats, consisting of the evaluation of thermography after injecting the animals with tumor cells. They observed changes in skin temperature, which indicates that any change in surface temperature points to a poor prognosis. The use of infrared imaging for the early detection of breast cancer is based on the principle that metabolic activity and vascular proliferation in the tumor tissue and surrounding areas are more pronounced than in normal breast tissue (Acharya et al., 2010; Fok et al., 2002). A study by Gautherie and Gros (1980) included 1527 patients considered healthy by conventional tests, such as breast physical examination, mammography and ultrasound, but with abnormal thermograms. They were followed by a period of 12 years. 44% of the patients developed cancer in the first five years. The researchers concluded that "an abnormal thermogram is the most important marker for future high risk of developing breast cancer" (Gautherie and Gros (1980).

In 1995, a case study demonstrated that a 50 years-old woman with nodules in the left breast had a tumor which was not revealed by mammography. Subsequently, the medical team opted for an examination through thermography, which revealed a hyperthermic pattern

Table 1. Advantages and disadvantages of diagnostic methods of breast cancer

EXAM	ADVANTAGES	DISADVANTAGES
MAMMOGRAPHY	Reduction in mortality from breast cancer Relative and absolute risk reduction Increased survival time from diagnosis Reduced need for mastectomy (Jorgensen et al., 2007; Youk & Kim, 2010)	Low sensitivity for dense breasts High cost Patient's exposure to radiation Little accuracy when the tumor is located deep Some patients report discomfort during the exam (Foster, 1998)
ULTRASOUND	Low cost Does not require use of contrast Well tolerated by patients More accessible than complex exams like magnetic resonance (Youk & Kim, 2010)	Obsolete tools Lack of skilled operators Inability to detect microcalcifications Higher rates of false positives than mammography (Youk & Kim, 2010)
CLINICAL EXAMINATION	Helps detect breast cancer Easily applied (Kennedy, Lee & Seely, 2009)	Low sensitivity Does not reduce the mortality rate Low adherence Increases the number of biopsies (Brodersen, Jorgensen & Gotzsche, 2010; Kennedy et al., 2009; Sadler et al., 2007)
MAGNETIC RESONANCE	Locates precisely the tumor It has high sensitivity, even in dense breasts Determines the size of the malignant lesion known (Alvares & Michell, 2003; Hlawatsch et al., 2002)	High cost Difficult access to most of the population Low specificity (Alvares & Michell, 2003)
BIÓPSY	Lower inadequate and suspicious rates, allowing easier grade assessment and ancillary testings (hormome receptors, HER2) in cases of cancer (Tse & Tan, 2010)	One can confidently diagnose papillary lesion, although there is still significant false positive and false negative rates, even with immunohistochemistry (Tse & Tan, 2010)
INFRARED THERMOGRAPHY	Noninvasive Painless Low cost Not radiate Portability Easy access to the population (Ng, 2009; Tang et al., 2008)	Not able to locate precisely the tumor in order to lead to surgical excision Depends on optimal conditions to maintain the accuracy of the method (Kennedy et al., 2009)

in the mammary region and led to the biopsy, confirming a tumor 0.8 cm in diameter.

Thermography as an early detection method of breast cancer

In order to analyze the opinion of the authors in scientific literature regarding the use of infrared thermography as a quantifier of the risk for breast cancer, the following questions were considered:

1) Did they compare infrared thermography with other diagnostic methods?

We have found many experiments comparing thermography and other diagnostic techniques, encouraging its use as a complement to screening programs for breast cancer. Most of the reviewed articles agree that mammography is currently the main examination chosen by doctors for the screening of breast cancer (Acharya et al., 2010; Kennedy et al., 2009).

Only a review study done in New Zealand in 2004, did not recommend the use of infrared thermography (Kerr, 2004) because, in that country at that moment, there were not enough consistent studies to demonstrate the effectiveness of the method.

Table 2. Articles that obtained positive results using thermography

ARTICLE	AUTHORS	YEAR OF PUBLICATION
Thermography Based Breast Cancer Detection Using Texture Features and Support Vector Machine	Acharya UR, Ng EY, Tan JH, Sree SV	2010
Uso de imagens termográficas em tumores mamários para validação de simulação computacional	Bezerra LA	2007
Early detection and visualization of breast tumor with thermogram and neural network	Fok SC, Ng EYK, Tai K	2002
Thermography based breast cancer analysis using statistical features and fuzzy classification	Schaefer G, Zavisek M, Nakashima T	2009
Effectiveness of a noninvasive digital infrared thermal imaging system in the detection of breast cancer	Arora N, Martins D, Ruggerio D, Tousimis E, Swistel AJ	2008
Use of digital infrared imaging in enhanced breast cancer detection and monitoring of the clinical response to treatment	Arena F, Barone C, DiCicco T	2008
Evaluation of the ability of digital infrared imaging to detect vascular changes in experimental animal tumours	Xie W. McCahon P, Jakobsen K, Parish C	2004
Functional infrared imaging of the breast - Historical perspectives, current applications, and future considerations	Keyserlingk JR, Ahlgren PD, Yu E, Belliveau N, Yassa M	2000
The accuracy of digital infrared imaging for breast cancer detection in women undergoing breast biopsy	Wishart GC, Campisi M, Boswell M, Chapman D, Shackleton V, Iddles S	2010
Evaluation of the diagnostic performance of infrared imaging of the breast: a preliminary study	Wang J, Chang K-J, Chen C-Y, Chien K-L, Tsai Y-S, Wu Y-M, Teng YC, Shih TTF	2010
A review of thermography as promising non-invasive detection modality for breast tumor	Ng EYK	2009
Morphological measurement of localized temperature increase amplitudes in breast infrared thermograms and its clinical application	Tang XW, Ding HS, Yuan YE, Wang Q	2008
Thermographic detection of Brast Cancer	Foster KR	1998
The important role of the infrared images in breast cancer	Head JF, Wan F, Lipari CA, Elliott RL	2000

2) Did the researchers obtain positive results using thermography?

Most of the articles reached positive results when thermography was used. Table 2 identifies those articles.

The accuracy of infrared thermography depends on different factors, such as symmetry of body temperature, physiological state and the menstrual cycle. Ng et al. (2009), investigated the cyclical variation in skin temperature and breast vascularization in thermograms made under a controlled environment. The authors analyzed more than 800 thermograms of 50 Asian women and obtained the optimal conditions for carrying out the examination and analysis.

Different international associations have published the standard conditions to perform a valid thermogram (Ring, 1983). Such works have made thermography a

popular tool for the early prevention of various diseases.

In breast cancer studies, the room temperature for the acquisition of thermographic images should be between 18ºC and 25ºC which variations below 1ºC (Kennedy, Lee and Seely, 2009). The humidity of the environment must be monitored, as well as any other factors that may interfere with the local temperature, such as air flow, the presence of sunlight or heat from the computer, or any other external source.

The patient should be asked to remove all clothing that covers the area that is to be analyzed and to wear a disposable gown. The patient should adapt to the ambient conditions for 10 minutes without touching the area to be examined in order to stabilize the skin temperature during the procedure (Yahara, 2003).The monitoring of these factors, as well as any others related with the psychological aspect of the patient, ensures the perfect collection of thermographic images.

Some authors have supplemented the technique with modern software that helped on the analysis of thermograms. This is the case of Fok, Ng and Tai (2002) who used the neural network to assist in the detection, analysis and visualization of tumors, and Wang et al. (2010), who interpreted the images through a specific system.

3) Do the authors advocate the use of infrared thermography?

Thermography has been convicted over the years; it has been labeled by subjective interpretation. However, several studies have reported promising results for the technique (Wang et al., 2010). Acharya et al. (2010) conducted a study that used the texture extracted from the thermograms, making the test more objective and the diagnosis, more accurate. In this study, the authors analyzed 50 thermograms (25 normal and 25 with breast cancer) and by extraction of textures, achieved an 88.1% accuracy, 85.71% sensitivity and a specificity of 90.48%.

Other important studies demonstrate the sensitivity and specificity guaranteed by thermography. One of them, done in 2009, analyzed the differences between the right and left breasts of 150 women (29 malignant cases and 117 benign) and reached a sensitivity and a specificity close to 80% by combining the evaluation of thermograms to a computer system for fuzzy classification (Schaefer, Zavisek and Nakashima, 2009). In 2008, a prospective trial with 92 patients who were referred for biopsy after mammography or ultrasound, showed that thermography performed before biopsy detected 58 of 60 malignant tumors identified on biopsy, indicating 97% sensitivity and 44% specificity (Arora et al., 22008).

Additionally, some authors suggest that thermography is complementary to other diagnostic methods, and that the best strategy for the early detection of breast cancer would be to use them together (Kennedy, Lee and Seely, 2009; Hersh, 2004).The combination of thermal imaging with other tests would increase accuracy, sensitivity and specificity of the evaluation and allow a better quantification of the risk of breast cancer.

Keyserlingk et al. (2008) reported that, in 100 cases of cancer, infrared images had a 83% sensitivity, compared to the 66% achieved by a mammogram when done alone. Combining mammography with clinical examination, the sensitivity rises to 83% and using these two tests in conjunction with thermography, the sensitivity obtained is 98% (Keyserlingk et al., 2008).

Arena, Barone and Dicicco (2003) made a thermographic assessment of 517 women who were divided into three groups: 343 were healthy (presumably without cancer), 110 were newly diagnosed with breast cancer and 63 were already receiving treatment. Additionally to the 110 newly diagnosed cases, three more patients from the healthy group, screened by mammography or ultrasound, were discovered by the infrared thermography. Through further analysis performed in this study, we observed the high sensitivity of thermographic examination, especially when combined with other diagnostic techniques. These results are important not only for radiologists, but especially for oncologists and patients (Arena, Barone and Dicicco, 2003).

4) Was thermography considered an effective method for quantifying the risk of cancer in dense breasts?

Almost 80% of the reviewed articles considered thermography to be an effective method for quantifying the risk of cancer in dense breasts. The other 20% did not report results on this issue because dense breast was not considered on the discussion.

Conclusion

There is not still a tool that, used alone, has 100% sensitivity for the detection of breast cancer. The single definitive method for diagnosis is biopsy. Many studies have shown that the use of two or more features can increase accuracy, sensitivity and specificity to nearly 100%. Since infrared thermography is a low-cost, painless, and noninvasive survey, that does not emit radiation, and which is accessible to the general population, we must consider the inclusion of this exam as a complement to the early detection of breast cancer.

Received March 6, 2012; Revised version received June 2, 2012, Accepted June 5, 2012

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