

Infrared Imaging: Making Progress in Fulfilling Its Medical Promise

Past, Present, and Future Applications of Infrared Imaging in Medicine

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Infrared imaging in medicine has been around since the early 1970s, but its utility for any medical application has not been clearly demonstrated. Therefore, infrared technology is not widely accepted in medicine. Over the past ten years improvements in infrared systems (including staring array sensors, true digital output, sophisticated image processing, and analysis using target recognition software) have allowed objective analysis of digital radiometric information for a variety of medical applications.

Current medical applications that have supporting documentation in the peer-reviewed medical literature include breast cancer risk assessment and prognosis, analysis of burn trauma, and battlefield application of a helmet-mounted infrared imager for use by medics. Other promising areas for medical application of infrared imaging in medicine include coronary artery bypass surgery, diabetes, deep vein thrombosis, and areas involving angiogenesis (wound healing and microsurgery). However, some classic uses of infrared imaging that have achieved some amount of widespread use, such as pain management, probably will not survive rigorous scientific scrutiny. This article looks at where current applications of medical imaging started and promising future uses as the technology improves.

Applications Breast Cancer

Initial studies of the application of infrared imaging to breast cancer concentrated on trying to use breast infrared imaging (contact or telethermography) as a stand-alone technology for the detection of breast cancer in a screening environment. The early Breast Cancer Detection

and Demonstration Projects (BCDDP), which were done between 1973 and 1981 by the American Cancer Society and National Cancer Institute of the United States, clearly demonstrated the shortcomings of both mammography and infrared imaging of the breast but also showed that mammography was a superior stand-alone detection technology, if only because it localized a lesion that could be then surgically resected and examined by the pathologist to determine if the patient had breast cancer. In other words, even if infrared imaging was able to tell the surgeon that the patient was very likely to have breast cancer, its inability to tell the surgeon where the lesion was, because it is a physiological measurement and not a physical view as in mammography, made it unacceptable as a stand-alone detection device.

The ability of infrared imaging to be used in a multimodality-screening environment has not received the attention that it deserves. Although physical exam and ultrasound examination are widely accepted as techniques that complement mammography and are routinely used in the differential detection/diagnosis of breast cancer, this has not happened with breast infrared imaging. This is despite support for this concept by physicians who routinely use infrared technology. Recently Keyserlingk et al. [1] have shown that in their hands infrared imaging can help confirm the diagnosis of breast cancer, but larger studies are needed to determine if the false positive rate of 66 to 80% in the present clinical setting (physical exam, mammography and/or ultrasound) [2] can be reduced by integrating routine infrared imaging into breast cancer screening programs.

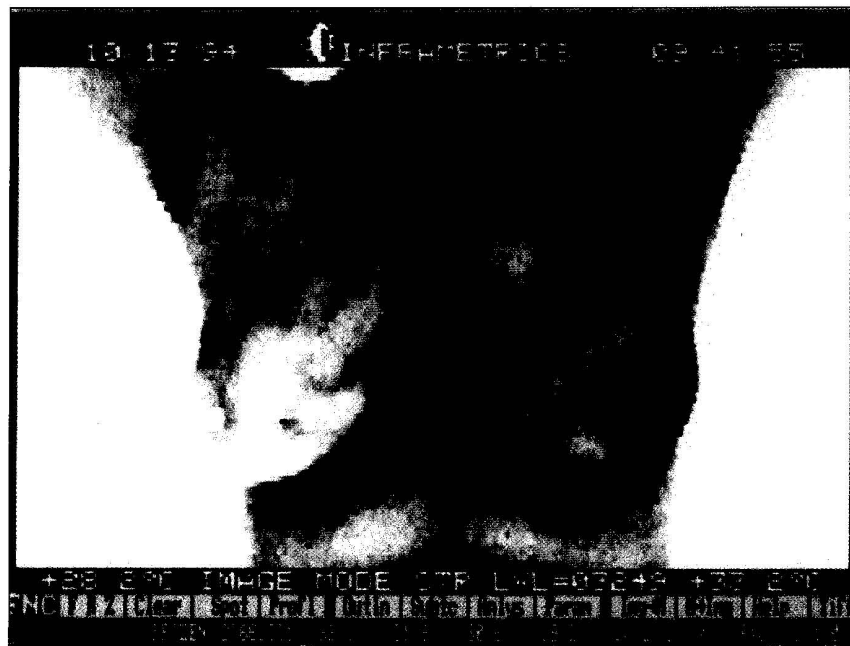
An application of infrared imaging in breast cancer that has been extensively studied with very positive results is the use of breast infrared imaging in risk assessment (determining whether a female is at average or high risk of getting breast cancer during her lifetime). Other imaging technologies (such as mammography, breast ultrasound, magnetic resonance imaging (MRI), and positron emission tomography (PET) scans) have not been found to be useful for predicting whether a woman will develop breast cancer in her lifetime. In addition, infrared imaging was not studied during the Breast Cancer Detection and Demonstration Projects to determine its ability to define a subgroup of women at increased risk of developing breast cancer, as this was not considered important. However, in more recent times intervention or prevention trials have become a reality, specifically the use of the anti-estrogen tamoxifen in patients who have not been diagnosed with breast cancer but are believed to be at a higher than normal risk of getting breast cancer due to their genetic makeup and/or environmental factors. Presently, the Gail Model is used to determine if a woman is at increased risk of getting breast cancer. This model uses age, age at first menstrual period, number of first-degree relatives who have had breast cancer, whether the woman had a previous breast biopsy (number and presence of atypical hyperplasia), and race to determine the risk of getting breast cancer for a woman who has received regular clinical breast exams and screening mammography. This risk assessment model does not apply to genetically predisposed women or women who have previously had a biopsy that contained DCIS (ductal carcinoma in situ) or LCIS (lobular carcinoma in situ). However, even by combining all these factors, less than half of the women at risk of getting breast cancer can be identified, and the women at increased risk only have about a two- to four-fold increase.

Several studies have shown that infrared imaging is a good, and perhaps the best, method for risk assessment in breast cancer. Gautherie and Gros [3] demonstrated in a prospective study of 58,000 women being screened for breast cancer that there were 784 patients that had an abnormal asymmetric infrared image of their breasts with normal physical exams, mammograms, and ultrasounds, and that 298 (38%) of these 784 patients were diagnosed with breast cancer within four years.

This is in contrast to expecting only 1-2% of women from the general population being diagnosed with breast cancer in a four-year period, and thus the presence of an abnormal asymmetric infrared heat pattern of the breasts probably increases a woman's risk of getting breast cancer at least ten-fold. In a second study Stark [4] followed 11,249 women who were being screened for breast cancer and found that 1,499, or about 15%, of the women had abnormal asymmetric heat patterns of their breasts. Stark further found that in the next ten years 346, or 23%, of the women with abnormal asymmetric infrared images of their breasts were diagnosed with breast cancer. Stark further found that only 8.1% of women who had not had any children and 8.6% of women with one or two first-degree relatives who had breast cancer (family history) developed breast cancer during the same period of time. Therefore, two of the major criteria used to

enroll patients in the tamoxifen prevention trial were poorer risk assessment tools than the presence of an abnormal asymmetric breast infrared image. The presence of atypical hyperplasia in a biopsy sample was found by Stark to result in 30 to 50% of these patients being diagnosed with breast cancer, but only 34 women had this risk marker, and this is too small a proportion of the overall population to be a significant risk assessment tool. In our own studies [5]-[10], we have found that approximately 28% of women have abnormal asymmetric breast infrared patterns (Figure 1) and are therefore at increased risk of getting breast cancer, and this is supported by the fact that a much higher proportion (65%) of breast cancer patients at presentation have an abnormal asymmetric breast infrared pattern (Table 1).

Although these studies support the use of breast infrared imaging in breast cancer risk assessment, it will be necessary for the



1. A patient with an abnormal asymmetric breast infrared image.

| Infrared Results | Patients | | |
|------------------|-----------|-----------|------------|
| | Normal | Cancer | Deceased |
| Normal | 72 72% | 35 35% | 15 12% |
| Abnormal | 28 28% | 65 65% | 111 88% |

p < 0.0001, chi-square analysis for independence

