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Review

Infrared imaging technology for breast cancer detection – Current status, protocols and new directions

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ABSTRACT

Early and accurate detection of breast cancer is a critical part of the strategy to reduce the morbidity and mortality associated with this common disease. While current guidelines recommend mammography for screening, the sensitivity and specificity of mammograms remains less than optimal, especially for patients with dense breast tissue. Thermography has been explored in the past as an alternative to mammography. Advances in IR cameras that are used to obtain thermal images of the breast as well as computational tools used to accurately model heat transfer within the breast have significantly increased the accuracy of thermography. The current work reviews the progress that has been made in using thermal imaging to detect breast cancer over the past three decades and identifies aspects that need further refinement for it to become a reliable tool to diagnose breast cancer. Recent advances and suggestions for future work in the field including using advanced simulation methods, inverse modeling, imaging protocols, and using artificial neural networks to better predict the location of the tumor are also presented.

Contents

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1. Introduction

The term cancer is used to describe a group of disorders associated with dysregulated cell growth leading to tumor formation, invasion into surrounding tissues and spread to other parts of the body. Some of the most common types of cancer originate in the breast, prostate, lung, skin and pancreas. The exact reasons for developing cancer have not been determined [1,2]. However researchers agree that factors such as genetic predisposition, age, smoking tobacco, exposure to ultraviolet radiation, unhealthy lifestyle, and exposure to carcinogenic agents can significantly increase the odds of a person being affected by cancer. Between 2008 and 2010, the average annual cost of healthcare for a newly diagnosed cancer patient in the US was $ 21,222 [3]. The economic impact due to loss in productivity by cancer in the US was estimated to be $130 billion in 2009 alone [4]. By 2020 the cost of cancer treatment is expected to reach $158 billion just in the US [5]. Over the past few decades a large amount of research has emphasized on improving diagnostic techniques used to detect cancer at an early stage when treatment can be less expensive and more effective.

Breast cancer is the most frequently diagnosed form of cancer among women and has the second highest mortality rate after skin cancer. It is estimated that the lifetime probability of being diagnosed with invasive breast cancer among women is 12.3% with 246,660 women expected to be diagnosed with breast cancer in the United States in 2016 [6]. A healthy breast consists of glands that are connected to the surface of the skin by ducts. The glands and ducts are surrounded by connective tissue embedded in which are blood vessels, lymph nodes, lymph channels and nerves. Breast cancer can originate in any part of the breast with more than 20 types of cancer having been identified. The most common types of breast cancer are ductal carcinoma, which originates in the ductal epithelium; and lobular carcinoma, which develops in the glands.

Sensitivity of a diagnostic technique is a measure of the rate at which a tumor is detected by the technique. Specificity of a technique refers to the accuracy of a positive diagnosis. Higher the sensitivity, greater is the likelihood of a tumor in a patient being detected, and higher the specificity, greater is the probability of a positive diagnosis of being true. A variety of imaging modalities aimed at improving the sensitivity and specificity for breast cancer detection have been developed. Mammography however remains the mainstay of screening for breast cancer. Supplemental screening and diagnostic techniques for breast cancer detection include ultrasound, Magnetic Resonance Imaging (MRI), and tomosynthesis. No single imaging modality is capable of identifying and characterizing all breast abnormalities and a combined modality approach is still necessary.

Mammography it the most common screening technique which detects the presence of a tumor using low energy X-rays to image the internal anatomy of the breast. Mammography detects masses in the breast and calcifications, which may indicate the presence of a tumor. A randomized trial with 134,867 women aged between 40 and 74 showed that regular screening resulted in a 31% reduction in mortality from breast cancer [7]. However, the rate of false positives using mammograms is high with a 10 year study showing that the likelihood of a false positive diagnosis for women after getting a mammogram every year for 10 years to be 49.1% [8]. Mammography is also known to be less sensitive for women with dense breast tissue, since the cancer can be obscured or masked by the normal surrounding fibroglandular tissue; the greater the ratio of fibroglandular tissue to fat in the breast, the greater the density of the breast. Approximately 50% of women undergoing screening mammography have dense breasts. The proportion of the glandular tissue is higher for younger women and fat content in the breast increases as women get older. Kerlikowske et al. [9] studied the effect of breast density and age on the sensitivity of mammography and found that the technique has the high sensitivity for women 50 years or older due to increased fatty tissue content while the sensitivity was relatively lower for women under 50 due the denser breast tissue.

MRI uses a strong magnetic field along with pulsing radio waves to get a high resolution image of the breast at different cross-sections. A contrast agent is added to help better image the breast. This procedure is used to screen women who are at a high risk of developing breast cancer or to better image tumors found in other tests [10]. This procedure is very expensive and time consuming and hence is only used as an adjunct to mammography for high risk asymptomatic and symptomatic women. Screening breast MRI has been found to be more sensitive but less specific than mammography for the detection of invasive breast cancers in high-risk women in both retrospective and prospective studies [11,12].

Ultrasound or sonography detects the presence of tumors by bouncing sound waves of the surface of the tissue. A transducer is used to interpret the reflected sound waves in order to determine the boundaries of different types of tissue. This technique is normally used to further investigate suspicious areas of the breast found in the mammogram or during a breast exam. It can help distinguish between cysts (non-tumorous sacks filled with fluid) and solid masses. It is also used for supplemental screening in subsets of patients with dense breasts. When used as a supplement to mammography, ultrasound can improve sensitivity of screening at the expense of decreased specificity and increased biopsy rate [13]. Ultrasound is an attractive supplement to mammography because it is widely available, relatively inexpensive and does not inconvenience the patients.

Digital breast tomosynthesis, also known as 3D mammography, provides three-dimensional images using a moving X-ray source and digital detector. Tomosynthesis has been approved in the United States for breast cancer screening, when used in combination with mammography. Tomosynthesis, when used in combination with mammography have been shown to modestly increase the