Mid Infrared Imaging to Predict Response to Neoadjuvant Therapy in Early-Stage Breast Cancer

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Abstract

Motivation

Breast cancer is the most common non-dermatological malignancy in women with an estimated 276,480 new breast cancer cases and 42,170 cancer deaths projected in 2020 in the United States[1]. Radiographically, MRI is commonly used to assess baseline and end of treatment responses, but more frequent interval imaging with MRI or ultrasound is limited due to the high cost and limited availability. Rather, serial physical exams are used to determine continued responses prior to surgery[2]. However, this is subject to individual error and evaluates only for changes in size of the tumor[2].

Methods

Our group has shown in preliminary studies that a Mid Infrared (MidIR) imaging (8-12μm spectral range) can detect functional changes in the tumor vicinity at the very early stages of treatment sessions (possibly even at the first/second sessions). The MidIR map captures energy changes that are related to changes in glucose uptake of the tumor affected by the chemotherapy agents. MidIR imaging is performed with a very small camera (less than the size of the palm) and has a low cost.

Results

Testing has been done on four thermal cameras with various heated objects to verify functionality, and programs have constructed through MATLAB to simplify the image capturing process. Currently, a breast phantom is currently being developed with CAD software to study heat transfer across various tissue.

Introduction

Breast cancer is a heterogeneous disease comprising of several molecular subtypes, which are commonly extrapolated into clinical subtypes based on receptor status, such as hormone or human epidermal growth factor 2-neu (HER2) receptors. Patients with hormone receptor and HER2-negative tumors are triple negative breast cancer (TNBC) and tend to have aggressive phenotype.

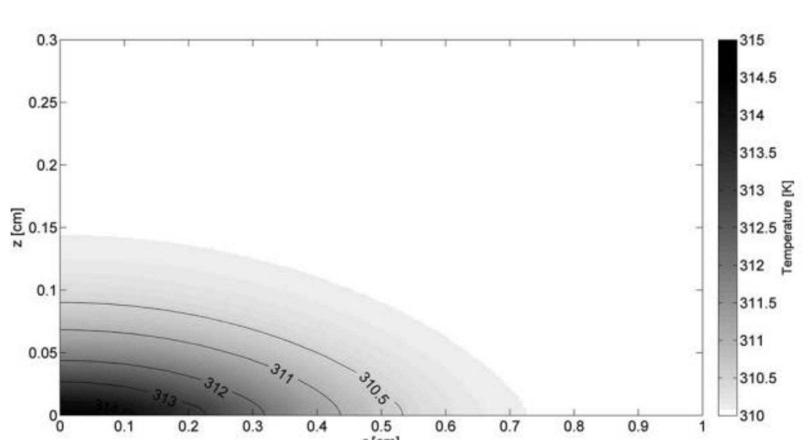


Figure 1: COMSOL simulation of heat distribution on skin tissue

In treatment, the response to neoadjuvant chemotherapy leads to both functional changes and structural changes to the breast tumor, but functional changes occur much earlier than structural changes. Functional changes can present as early as hours or days after the beginning of therapy and may predict ultimate response to therapy. We have previously used PET imaging to evaluate response to neoadjuvant chemotherapy in patients and demonstrated that reductions in SUV within days of initial treatment are predictive of response. PET scans, however, are clinically difficult to integrate due to radiation exposure, expense, and limited availability.

Studies have shown that increased blood flow due to the vascular proliferation that results from angiogenesis is associated with tumors, which can be detected through infrared imaging and allows for functional information during the course of tumor development or treatment. We hypothesize that changes in features observed in the MidIR images in the first few sessions will correlate with pCR to neoadjuvant therapy in early stage breast cancer.

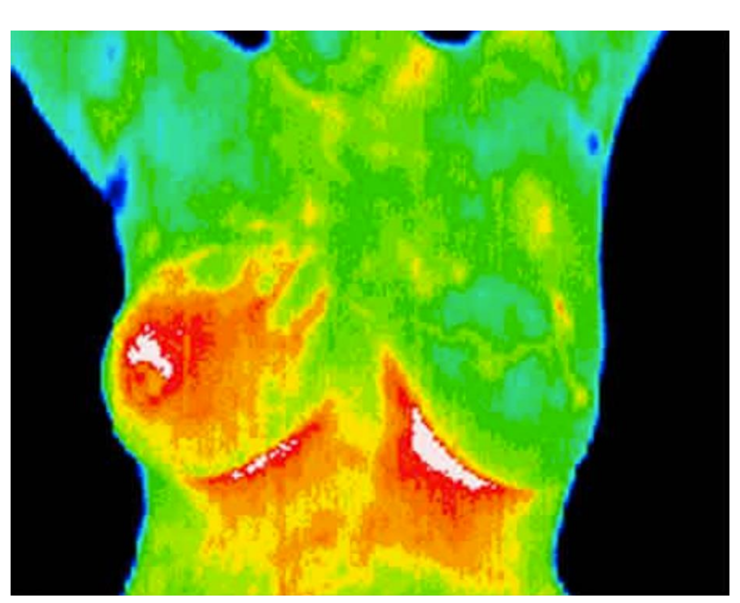
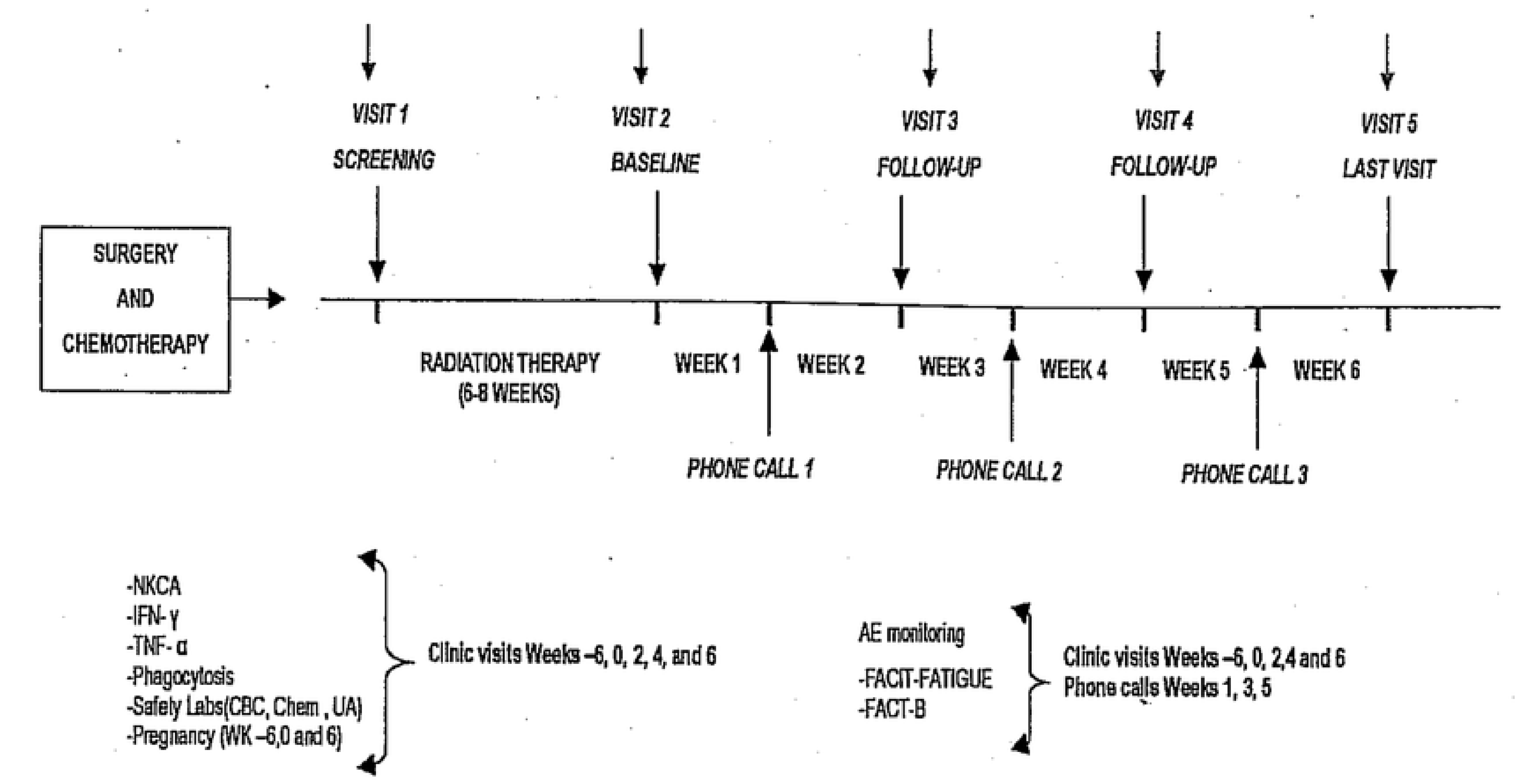


Figure 2: Thermal Image of Breast, with cancerous tissue on the right breast

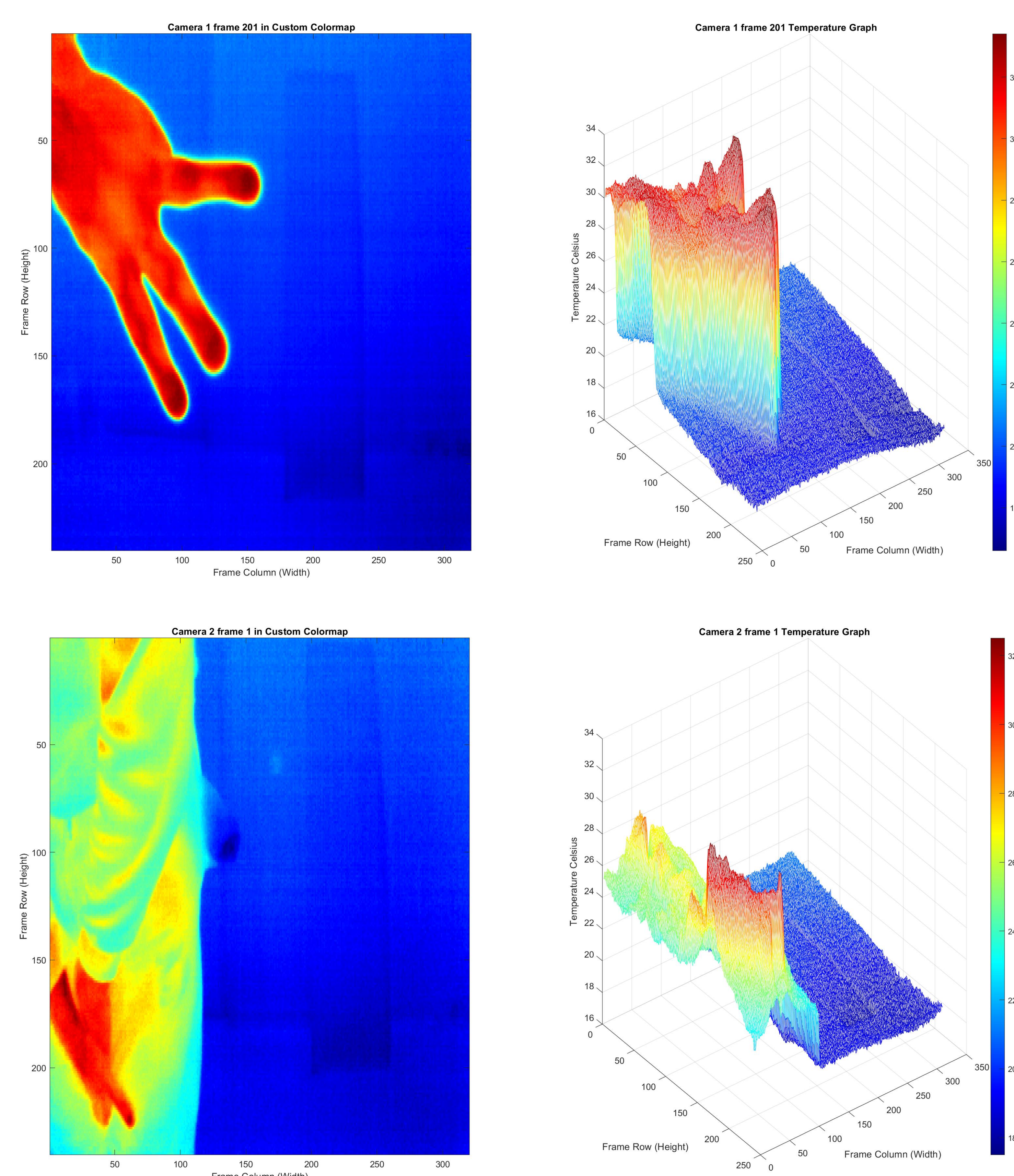
Process of Thermography for Treatment

The use of thermography in diagnosing breast cancer alleviates the complicated process a patient would usually undergo for treatment (shown to the right). However, there are certain protocols and best practices to consider when performing thermography. Before examination, patients should be cooled so abnormal hotspots are highlighted, and their breasts should not come into contact with objects that could alter their temperature. Tight clothes and physical exertion before imaging should be avoided. The exam room should be temperature and humidity controlled and should not have incandescent lighting, which produces radiation that may interfere with imaging. Furthermore, the patient should sit at rest for 10-12 minutes before imaging to achieve thermal equilibrium. Studies have suggested that the patient's menstruation cycle must also be considered when performing thermography, as the 20th day of the menstruation cycle has been associated with unstable body temperatures and false-positive breast thermogram results.



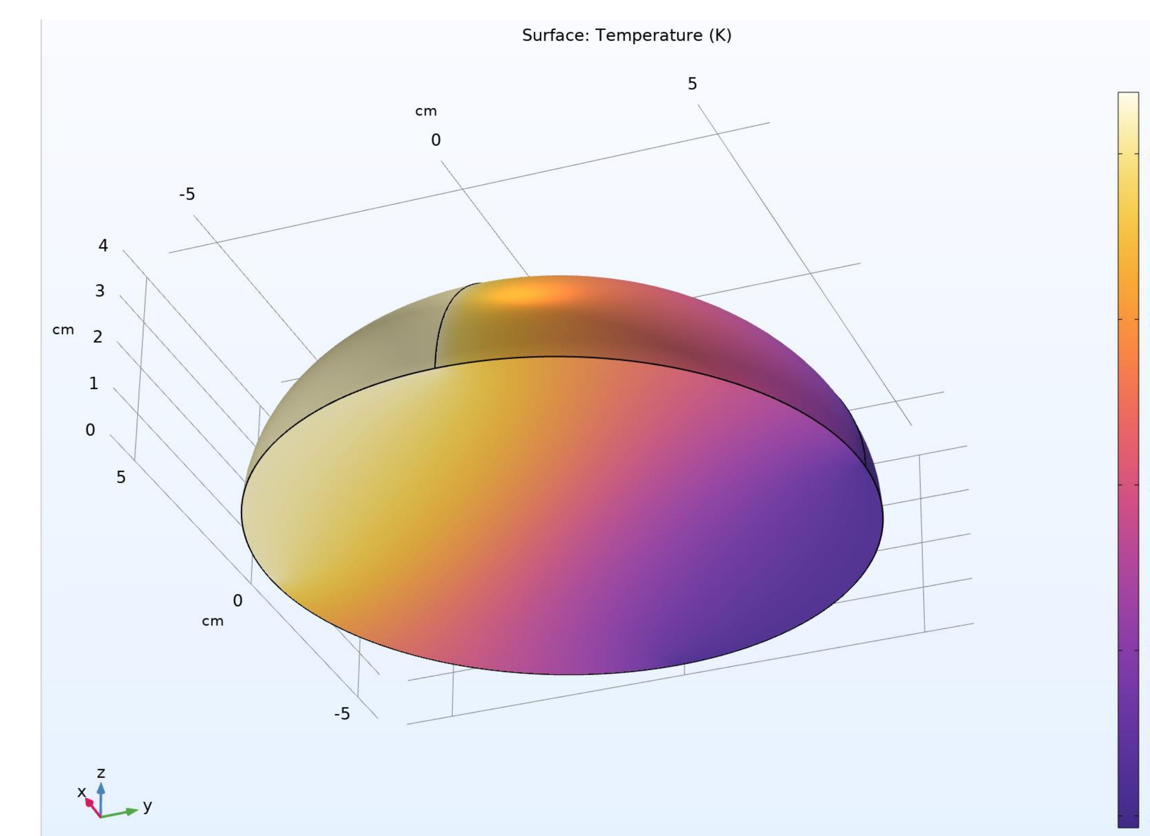
Thermal Images Captured By Camera

These images are the results of testing done using Seek Thermal infrared cameras. Raw data was collected through the software provided by Seek, which was transformed into a thermal image through image processing techniques done in MATLAB. Two figures are displayed, one of the thermal image and a heatmap of each pixel.



COMSOL Phantom Construction

We are currently working on building a phantom of the breast with the cancerous tissue to simulate its heat distribution properties in the presence of a heat source. So far, a rudimentary model has been made with a hemisphere, but continuous improvements are being made to the model.



Conclusions

When performed correctly with fidelity, breast thermography can be a beneficial tool for assessing the tumor status of breast cancer patients at various stages along the care continuum. Our project aims to eliminate the redundancy of the treatment process and provide an affordable and harmless way to detect functional changes without the need for chemotherapy.

References

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