DETERMINATION OF MEAN TEMPERATURES OF NORMAL WHOLE BREAST AND BREAST QUADRANTS BY INFRARED IMAGING AND IMAGE ANALYSIS

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Abstract-**In clinical testing it is standard to determine the normal range, and then to determine if a test can differentiate normal from diseased patients. Now with the advent of uncooled staring array digital infrared imaging systems (Prism 2000; Bioyear Group, Houston, TX) and image analysis, numerical results (mean temperatures of the whole breast and quadrants of the breast) can be used to determine the normal range and cutoff temperatures for risk assessment and detection of breast cancer. In this study we determined mean temperatures of whole breast and breast quadrants of women being screened for breast cancer. The mean temperatures for the right breast, left breast, right upper outer quadrant (UOQ), Left UOQ, right upper inner quadrant (UIQ), left UIQ, right lower outer quadrant (LOQ), left LOQ, right lower inner quadrant (LIQ), and left LIQ were 32.79, 32.65, 32.60, 32.46, 32.91, 32.69, 32.28 32.12, 33.29,and 33.00°C, respectively. Temperature differences were calculated between the right and left breasts and quadrants, and temperature differences greater than 0.5°C for whole breasts and 1.00°C for breast quadrants were considered asymmetric and abnormal. This resulted in 4 (17%) patients with differences in whole breast temperatures and 3 (13%) patients with quadrant differences from the 23 screened patients. These results are consistent with our previous results with both objective image analysis and subjective visual analysis (15% of screened patients have asymmetric breast infrared patterns). Further objective infrared measurements in breast cancer patients are needed to determine the sensitivity and specificity of this objective method for risk assessment and detection of breast cancer.**

Keywords - **Breast cancer, infrared imaging, cancer detection, risk assessment, image analysis**

I. INTRODUCTION

Infrared imaging in breast cancer has been around since the early 1970s, but was not widely accepted because of the lack of large clinical trials to prove its utility. In recent years the availability to the civilian sector of infrared systems with high thermal sensitivity, focal plane staring arrays, and digital output, that can be exported to a personal computer for image analysis, has caused many investigators to re-evaluate infrared imaging in breast cancer. This renaissance of infrared imaging in breast cancer has again focused on the ability of infrared imaging to contribute to breast cancer detection [1] but other areas such as risk assessment [2-7], breast cancer prognosis [8-10] and the monitoring of antihormone and chemotherapy have also been investigated.

The ability to export data as a two dimensional array of radiometric temperatures, that represent numerically the information that is displayed in the pictorial images, combined with the ability to designate areas within the arrays, has allowed computer assisted image analysis. Thus medical researches, often working with algorithms developed in the military for target recognition, are able to develop and test a wide variety of methods for their applicability to medical problems and specifically breast cancer.

Although much research has already been done to determine what an abnormal asymmetric infrared image of the breast means in terms of breast cancer risk assessment, detection, prognosis and therapeutic response, there has not been adequate determination of what is a normal breast infrared image. This is true for individual breasts or when two breasts are compared to each other for asymmetry. Therefore this study was undertaken to determine what are the temperature parameters of the breasts of normal women and this was done by using a group of women being screened for breast cancer who did not have breast cancer.

II. METHODOLOGY

Twenty-three women being screened for breast cancer by infrared imaging, physical exam, mammography and ultrasound (when appropriate) were included in this study. Three infrared images of each patient's breasts were taken with a Prism 2000 infrared imaging system (Bioyear Group, Houston, TX). The three black and white views of both breasts with black being hot included front, right oblique and left oblique views. The front view was also rendered in a colorized isotherm for improved viewing and size determination of breast areas with asymmetric increased heat.

The digital infrared images and the associated temperatures were exported for additional analysis. Proprietary software was used to access the radiometric information that is included with each image. For each patient the mean, standard deviation, minimum, median and maximum temperatures were determined for each breast and these quantitative parameters were compared between the two breasts in order to find temperature asymmetry. Then each breast was divided into quadrants (upper outer, upper inner, lower outer and lower inner) by drawing a line from each nipple to the chin, lines horizontally left and right from the nipple to the edge of the breast, and a line from the nipple to the lowest contour of the breast. Quantitative temperature parameters (mean, standard

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Abstract

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TABLE 1
TEMPERATURES OF BREAST AREAS

BREAST AREA	BREAST AREA MEAN TEMPERATURE (^{o}C)		DIFFERENCE IN TEMPERATURE BETWEEN TWO BREAST AREAS
	RIGHT	LEFT	
WHOLE BREAST	32.79	32.65	+0.14
UPPER OUTER QUADRANT	32.60	32.46	+0.14
UPPER INNER QUADRANT	32.91	32.69	+0.22
LOWER OUTER QUADRANT	32.28	32.12	+0.16
LOWER INNER QUADRANT	33.29	33.00	+0.29

deviation, minimum, median, maximum temperatures) were determined for each quadrant of both the right and left breasts. Then temperature comparisons were made between the quadrants of the right and left breasts, and among the quadrants of each individual breast.

III. RESULTS

The mean temperatures of the two breasts (see Table 1) in this population of women being screened for breast cancer were 32.79^{o}C for the right breast and 32.65^{o}C for the left breast, and the two breasts were not significantly different by Student's t-test. Also there was no significant difference between the mean quadrant temperatures between the right and left breasts. There seems to be a trend toward higher temperatures on the right side (See Table 1) with the whole breast and all four quadrants of the breast having slightly higher temperatures for the right breast. However the difference for the whole breasts is less that 0.25^{o}C, and for the breast quadrants is less than 0.50^{o}C.

We then decided to use a 0.50^{o}C difference between the right and left whole breasts in mean temperatures as the cutoff for asymmetry of the breast temperature, and therefore patients with greater than a 0.50^{o}C difference between breasts would be at increased risk of having or getting breast cancer. For the quadrants we used a cutoff of 1.00^{o}C difference to put the women being screened for breast cancer at increased risk. Using these cutoffs we found that 4 (17%) of the patients had asymmetric whole breast temperatures and 3 (13%) had asymmetric quadrant breast temperatures.

IV. DISCUSSION

Infrared imaging in medicine has failed to reach its full potential due to a variety of reasons, but two of the most important reasons are the lack of sensitivity of the infrared imagers and the lack of objective analysis of the temperature data present in the images. Within the past five years state of the art focal plane staring array infrared imaging systems with true digital output have become available for medical applications. This has allowed the medical research community the opportunity to process the digital radiometric information from the infrared images [11-13] and to develop and test algorithms based on objective measurements obtained from image analysis of the digital data.

One of advantages of using objective numerical criteria to describe asymmetric abnormalities is that it allows the determination of what is normal by the same objective numerical criteria. Thus if a breast infrared image is analyzed by several readers at different locations the results will be the same, and this is not true of subjective visual analysis. An additional advantage of the easy export of the digital radiometric information is that test sets can be developed and easily analyzed by any available algorithm that can use digital numerical information. Therefore civilian medical researchers can develop and apply new algorithms, while many of the algorithms already developed by the military for target recognition can also be tested.

In the present study we have used a previously developed analysis method [14,15] to determine several numerical parameters of the whole breast and quadrants of the breast, and further to compare the numerical results (temperatures) from the right and left breasts. The mean whole breast temperatures from a group of 23 control women (normal without diagnosed breast cancer) did not significantly differ between the right (32.79^{o}C) and left (32.65^{o}C) breasts. There also was no significant difference between the comparable quadrants of the right and left breasts (See Table 1). However the right breast whole temperature and four quadrant temperatures (range 32.28^{o}C to 33.29^{o}C) were all slightly greater (range 0.14^{o}C to 0.29^{o}C) than those found for the left breast (range 32.12^{o}C to 33.00^{o}C). The lower inner quadrants had the highest temperatures of all the quadrants (33.29^{o}C right and 33.00^{o}C left), and this is probably due to heat from the heart.

Several conclusions can be drawn from this study when viewed in the context of our preliminary data on screened patients with and

without breast cancer. Our previous studies [14,15] have looked at numerical breast infrared data from very small groups of women and suggested that increases of 0.50^{o}C for whole breast would be the best cutoff to distinguish asymmetry that would best differentiate normal from breast cancer. In the present study on a different data set of only noncancer patients we again found that the differences between the right and left whole breasts and all four quadrants are less than 0.50^{o}C and therefore differences greater than this would be associated with high risk, breast cancer and poor prognosis of breast cancer patients. Due to the higher differences (0.14 to 0.29^{o}C for quadrants compared to 0.14^{o}C for whole breast) we chose to use a 1.00^{o}C cutoff for quadrants. This again reflects well on our previously reported cutoffs, but the cutoffs presented here will be more useful in clinical practice as they are simpler than the ones used in our previous algorithms.

When using the objective cutoffs, that are similar to the cutoffs previously found to both improve sensitivity and specificity over subjective visual infrared image analysis by lowering both the false positive and false negative rate [16], in this study, we were able to define a subgroup of women with asymmetric breast heat patterns. This resulted in 17% (4 of 23) of the women, who were screened by infrared imaging for breast cancer, being found to have abnormal asymmetric whole breast mean temperatures, and 13% (3 of 23) of these women being found to have abnormal asymmetric quadrant mean temperatures. This suggests that these cutoffs may function well to distinguish in an objective manner the women at increased risk of getting breast cancer or who already have breast cancer, from women at reduced or normal risk of getting or having breast cancer.

V. CONCLUSION

The use of infrared imaging with state of the art focal plane staring array infrared systems, that can export digital images for computer assisted analysis of radiometric information, has only recently become available for medical application. The application of these new state of the art infrared imaging systems to breast cancer risk assessment, detection, prognosis and monitoring of therapy must be further investigated and developed before it will become widely accepted in clinical practice. The future promises the development of objective parameters, based on numerical analysis, which will eliminate the very subjective visual analysis presently done by physicians. This could possibly remove the long learning curve for medical infrared interpretation as well as diminish the inherently variable results from subjective visual analysis.

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