

## Issues in Emerging Health Technologies

### Infrared Thermography for Population Screening and Diagnostic Testing for Breast Cancer

#### Summary

- ✓ **Thermography is a non-invasive diagnostic imaging tool that uses infrared thermal technology to detect variations of temperature on the human skin surface that may be attributed to cancer.**
- ✓ **No randomized controlled trials have been conducted that compare the effectiveness of thermography with mammography for screening in well women, and there is no evidence regarding the cost-effectiveness of thermography used for screening.**
- ✓ **Prospective cohort studies of symptomatic patients or patients with abnormal mammograms or ultrasounds do not provide the type of evidence needed to justify the use of thermography for breast screening. Results indicate that thermography performance is worse than mammography in terms of sensitivity, specificity, and predictive values; however, some of the studies' authors have suggested there may be a role for thermography as an adjunct diagnostic test in some cases.**

#### Background

Breast cancer is the most common cancer among Canadian women. The Canadian Cancer Society estimates that one in nine women is expected to develop breast cancer during her lifetime and one in 29 will die of it.<sup>1</sup>

The purpose of breast cancer screening is to improve prognosis by detecting early malignancies or precancerous conditions when there is greater potential for successful treatment. For more than 40 years, mammography has been the gold standard for breast cancer detection.<sup>2</sup> However, recent concerns over the effectiveness of mammography as a screening tool have been reported in the media and

medical journals.<sup>3-5</sup> One concern relates to mammography's role in reducing breast cancer-related mortality; the extent of its effect is uncertain, with estimates ranging from 15%<sup>6</sup> to 40%.<sup>5</sup> Mammography has been associated with high over-diagnosis and over-treatment rates,<sup>3-5</sup> and high rates of false negatives and false positives.<sup>7</sup> As well, the appropriateness of the use of mammography in younger women<sup>2</sup> and women with dense breasts<sup>8</sup> has also been questioned. These concerns have led to a renewed interest in alternative techniques for screening and diagnosing breast cancer.

Breast thermography is a non-invasive diagnostic imaging technique intended for the detection of breast cancer and precancerous conditions. While thermography may have initially been proposed as an alternative to mammography, it is now largely regarded as a complementary diagnostic tool because of a lack of evidence to support its efficacy.<sup>4</sup>

Thermography was originally developed for military purposes in the 1950s. In the 1970s, it was investigated as a diagnostic tool for breast cancer detection.<sup>9</sup> Interest in the technology as a screening tool declined in 1977, after a report found its sensitivity to be less favourable than ultrasound and mammography.<sup>2</sup>

Improvements in the accuracy of thermographic infrared camera technology and the use of more sophisticated computer software have led to a resurgence in interest in thermography as a potential diagnostic tool for breast cancer detection.<sup>8,9</sup>

#### The Technology

Thermography is a non-invasive imaging technique that is intended to detect and record the temperature variation on the surface of the skin and provide a visual representation of the infrared emission of body tissue. Thermography is also known as thermal or infrared imaging.

The underlying principle of breast thermography is that the metabolic activity and blood circulation of abnormal breast tissue is higher than that of normal breast tissue and could be an indicator of disease or

infection. The procedure involves the use of an infrared high-resolution camera that takes images of each breast. The data collected from the images are then analyzed by computer algorithms that compare infrared patterns. The procedure takes approximately 15 to 20 minutes.

Breast thermography does not involve the compression of the breast or exposure to radiation.<sup>2</sup> While thermography can localize an abnormal area, it is unable to pinpoint the actual depth, location, and size of a tumour.<sup>2</sup>

## Regulatory Status

Breast thermography is not licensed in Canada, nor is it recommended by Health Canada as a breast cancer screening technique. Health Canada states: *“New technologies, such as thermal scanning (thermography), are being evaluated to see if they are safe and effective. Claims that thermography is useful in diagnosing breast cancer have not been proven, and thermography equipment has not been licensed for breast cancer screening in Canada.”*<sup>10</sup>

Private clinics across Canada use thermography for imaging various conditions, including breast cancer.<sup>11</sup> Some of these clinics advertise that thermography should be used as an adjunct to mammography.

The United States Food and Drug Administration (FDA) registered thermography as an adjunct for the detection of breast cancer,<sup>12</sup> as a Class II medical device.

In June 2011, the FDA issued an alert to the public that thermography is not a replacement for screening mammography and should not be used by itself to diagnose breast cancer.<sup>13</sup> This alert was issued in response to concerns that some practitioners promote thermography as an alternative to mammography, rather than a complementary tool.

## Patient Population

In Canada, 80% of newly diagnosed cases of breast cancer occur in women over the age of 50 years.<sup>14</sup> Eligibility for population-based breast screening programs across Canada depends on age and risk factors. Currently, all jurisdictions provide screening mammography for women aged between 50 and 69 years. Eligibility for screening in British

Columbia is available for women up until the age of 79 years. Prince Edward Island and Saskatchewan provide screening for women up until the age of 75 years. And Manitoba and Ontario provide screening for women up until the age of 74 years.

For women aged 40 to 49, screening programs are offered in British Columbia, Alberta, Prince Edward Island, Nova Scotia, the Northwest Territories, and Yukon. In Ontario and Quebec, women aged 40 to 49 require a health care provider’s referral. For women outside of the eligible age, either a doctor’s referral or a self-referral is required depending on the jurisdiction. Currently, the Maritime provinces, Saskatchewan, the North West Territories, and Yukon accept self-referral.<sup>15</sup>

## Current Practice

The most commonly recommended breast cancer screening detection tool is mammography.<sup>16,17</sup> Other screening methods, such as magnetic resonance imaging (MRI), ultrasound, and positron emission tomography (PET), play complementary roles.

New evidence-based recommendations from the Canadian Task Force on Preventive Health Care (CTFPHC) in 2011 advise women at average risk of breast cancer to begin mammogram screening at age 50 and to continue every two to three years to age 74. The recommendations advise average-risk women between the ages of 40 and 49 years to not routinely screen with mammography, and encourages women to discuss the benefits and harm of screening with their doctor.<sup>14</sup> The Task Force recommendations have been endorsed by the College of Family Physicians of Canada and the Canadian Cancer Society,<sup>18</sup> and are similar to those recommended by the United States Preventive Task Force, which advise women against routine screening before the age of 50.<sup>14</sup>

## Methods

### *Literature Search Strategy*

A peer-reviewed literature search was conducted using the following bibliographic databases: MEDLINE, PubMed, The Cochrane Library (2011, Issue 11), and the University of York Centre for Reviews and Dissemination (CRD) databases. Grey literature was identified by searching relevant sections of the Grey Matters checklist.<sup>19</sup> No methodological filters were applied. The search was limited to English-language documents published

between January 1, 2007, and November 3, 2011. Regular alerts were established on MEDLINE and PubMed and information retrieved via alerts was current to January 3, 2012.

### *Selection Criteria*

Eligible studies for inclusion in the “The Evidence” section of this report included all study designs that compared the effectiveness of infrared thermography with mammography in terms of sensitivity and specificity. Abstracts, editorials, letters, and literature reviews were excluded.

## The Evidence

Four studies were found — Wishart,<sup>8</sup> Kontos,<sup>9</sup> Arora,<sup>12</sup> and Wang<sup>20</sup> — that assessed the performance characteristics of infrared thermography with mammography and/or ultrasound in patients with suspicious breast masses. The Wishart and Kontos studies were conducted in the United Kingdom,<sup>8,9</sup> the Arora study was conducted in the United States,<sup>12</sup> and the Wang study was conducted in Taiwan.<sup>20</sup> No randomized controlled trials were found that reported the sensitivity and specificity of thermography. None of the studies reported adverse events. The Wang study was funded by industry.<sup>20</sup> A co-author of the Wishart study was also a co-founder of the thermographic device tested in the study.<sup>8</sup> The generalizability of the results of the studies was limited, as each study’s population consisted of symptomatic patients. Findings from these studies do not provide information on the potential usefulness of thermography in healthy populations or populations in whom mammography has a lower sensitivity. No cost-effectiveness studies that have compared thermography with alternative screening tests were identified.

Kontos’ prospective cohort study of 63 patients assessed digital thermography for the detection of breast cancer.<sup>9</sup> Patients were selected for this study based on a complaint of unilateral symptoms and a consultation with a breast surgeon. Breast masses were evaluated with digital thermography prior to biopsy and compared with ultrasound and mammography. The study reported sensitivity, specificity, a positive predictive value (PPV), and a negative predictive value (NPV) of 25%, 85%, 24%, and 86%, respectively, for thermography. Sensitivity, specificity, PPV, and NPV for ultrasound were reported as 88%, 91%, 79%, and

95%, respectively. For mammography, the values were 84%, 97%, 89%, and 96%, respectively.

Wang used thermography to assess 276 patients for breast cancer diagnosis following a suspicious mammography or ultrasound finding.<sup>20</sup> The thermography test was performed prior to biopsy. A radiological technician and a radiologist marked the location and size of the suspicious masses based on imaging via mammography and/or ultrasound. Two additional radiologists interpreted the thermographic images based on information provided by conventional imaging modalities. The sizes of the masses were graded using the Ville Marie Infrared grading scale. The authors assessed the relationship between diagnostic infrared signs and the disease status confirmed during surgery using univariate and multivariate logistic regression models. Based on the authors’ analysis, the higher infrared scores were positively associated with the presence of breast cancer. The sensitivity and specificity varied according to the multiple cut-off values used by the author. For the overall study population, when the cut-off value was 0.3, the study reported sensitivity, specificity, and a PPV and NPV of 72.4%, 76.6%, and 81.3% and 66.4%, respectively,

Wishart’s prospective study used digital thermography to assess 100 symptomatic patients for breast cancer.<sup>8</sup> Patients eligible for this study were those scheduled for a biopsy following a suspicious finding from mammography, ultrasound, or MRI. Patients excluded from the study were those who had been previously treated for breast cancer, those with loss of one or both nipples, those weighing over 113 kg, and those with acute breast inflammation. The results of the thermography scans were analyzed in four ways: screening reports after digital thermography, neural network analysis (a clinical decision support tool that analyzes large amounts of data), expert manual review, and the use of artificial intelligence software (used to analyze small changes in heat patterns of the breast). Of the 106 biopsies performed, 65 were malignant and 41 were benign. Sensitivity for screening reports was 55%, sensitivity for neural network analysis was 48%, sensitivity for expert manual review was 78%, and sensitivity for artificial intelligence software was 70%. For women aged less than 50, the sensitivity value using the artificial intelligence software was 78% and specificity was 75%. Sensitivity for expert manual review may have been higher because the expert thermographer was informed of the biopsy site and analyzed the specific area.

Arora's prospective cohort study assessed 92 patients with digital thermography for the detection of breast cancer.<sup>12</sup> The patients had previously been recommended for breast biopsy following suspicious mammography or ultrasound results.

Due to technical limitations, patients were excluded from the study if they were morbidly obese, had a bra size greater than DD, or had had prior contralateral mastectomy. Three scores were generated: an overall risk score, a clinical score, and

an evaluation of artificial neural network. Of the 94 biopsies performed, 60 were malignant and 34 were benign. Digital thermography identified 58 of the 60 malignancies. The study reported sensitivity, specificity, and an NPV of 97%, 44%, and 82%, respectively, depending on the mode used. The sensitivity, specificity, PPV, and NPV reported in studies by Kontos, Wishart, Arora, and Wang are presented in Table 1.

**Table 1. Sensitivity, Specificity, and PPVs/NPVs of Studies Relating to Infrared Thermography for Breast Cancer in Women with Abnormal Mammography/Ultrasound Results, or Suspicious Masses**

Study	Sensitivity	Specificity	PPV	NPV
Kontos et al. 2011 <sup>9</sup>	25%	85%	24%	86%
Wishart et al. 2010 <sup>8</sup>	SS: 53% SNN: 48% EMR: 78% NT: 70%	SS: 41% SNN: 74% EMR: 48% NT: 48%	SS: 59% SNN: 73% EMR: 69% NT: 67%	SS: 36% SNN: 48% EMR: 59% NT: 51%
Arora et al. 2008 <sup>12</sup>	97%	44%	N/R	82%
Wang* et al. 2010 <sup>20</sup>	72.4%	76.6%	81.3%	66.4%

\* For the overall study population, when the cut-off value was 0.3  
EMR = expert manual review; NPV = negative predictive value; N/R = not reported; NT = no touch; PPV = positive predictive value; SNN = sentinel neural network; SS = sentinel screening.

## Adverse Effects

Thermography is a non-invasive and non-contact imaging tool. No evidence was found that reported risks associated with this technology. The potential harms of thermography, when used for breast cancer detection, arise from the number of false-positive and false-negative diagnoses.

## Cost

According to the information provided by Meditherm, the cost of purchasing a full thermographic system is approximately US\$30,000. The average cost of an exam is US\$150 for a regional study, US\$250 for a half-body exam, and US\$350 for a full-body exam. According to the manufacturer, there are no consumables or operating costs with thermography.

The cost advertised for a breast thermography exam at a private Canadian clinic is \$250.<sup>21</sup> The average cost of a mammography exam is \$80.<sup>22</sup>

Commercial thermography systems include the CRT 2000 Thermographic System (Eidam Diagnostics Corporation, Richmond, British Columbia), BSC 2100 (Computerized Thermal

Imaging, Ogden, Utah), Sentinel BreastScan (Stony Brook, New York), and med2000 (Meditherm, Summerland Key, Florida).

## Concurrent Developments

Mammography is the most common technique for breast cancer screening and diagnosis.<sup>23</sup> Other common cancer screening detection methods that are used to complement mammography in Canada include breast self-examination, clinical breast examination, ultrasound, and MRI.<sup>24</sup> The new Task Force recommendations suggest that screening average-risk women using breast self-examination, clinical breast examination, or MRI does not reduce the risk of mortality from breast cancer.<sup>14</sup>

Planar and single-photon emission computed tomography (SPECT) and PET are other techniques used to detect the presence of breast cancer, but are not used specifically for screening.<sup>23</sup>

New and experimental breast imaging techniques currently in development include molecular breast imaging, electric impedance scanning, optical imaging, breast computed tomography, digital breast tomosynthesis, and biomarker imaging.<sup>23-25</sup>

## Rate of Technology Diffusion

The adoption of thermography in conventional medicine will likely depend on the availability of evidence from well-designed studies on the accuracy and clinical effectiveness of screening techniques, and cost-effectiveness studies. The availability of accredited staff with expertise in conducting and interpreting the test, regulations and standards to provide accurate and consistent results, and interest in this diagnostic procedure by health care providers are other factors that may affect its rate of diffusion.

## Implementation Issues

Considering that the accuracy of thermography depends on skin surface temperature, numerous protocols must be implemented to ensure the accuracy of results is maintained. Patients should be advised not to engage in activities that raise skin surface temperature prior to examination. These activities include sunbathing; using lotions, creams, makeup, deodorant, or antiperspirants near the imaging area; exercise; physical therapy or stimulation of the breasts; and smoking and alcohol intake. Menstruation, pregnancy, and hormone replacement therapy can also change breast surface temperature.<sup>26</sup> Environmental conditions influence skin surface temperature and can affect image quality. The thermal imaging device should be used in an environment where ambient temperature, humidity, and electrical sources can be controlled.<sup>26</sup> The accuracy of the thermal imaging device also depends on the skill and expertise of the operator and the strict adherence to standardized procedural protocols.<sup>26</sup>

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