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Comment: Home monitoring of foot temperature for risk reduction of diabetes-related foot ulcer.

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Breast Thermal Imaging: Does it have a role in the diagnosis of breast disease?

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SUMMARY

Breast cancer is the most common cancer in women worldwide. Thermal imaging is being increasingly used internationally for the diagnosis of breast pathology. However, there is little evidence to support its use due to the lack of clinical and methodological standardisation in the imaging, analysis and reporting process of thermography research. This pilot study presents a model of research designed to test the capability of modern digital infra-red thermal imaging (DITI) in a UK breast clinic.

A FLIR T650 IR thermal camera (640x480) was used to image the breasts of 28 symptomatic women within a temperature-controlled environment. A single gate diagnostic test accuracy study was performed, independently double-read and agreed by two experienced thermographers. Results were compared to the index test of triple assessment by physical breast examination, mammography, ultrasound, and biopsy if appropriate, confirmed with the reference standard of pathology. Image analysis was based on an 8-point assessment model: left and right whole breast, nipple, areolar, and axilla; upper lateral, upper medial, lower lateral, lower medial breast quadrants; areolar four point 'compass' measurement; visual assessment for obvious hot or cold spots. Referral was recommended for contra-lateral symmetry differences of >1°C in any of the assessment zones.

Sensitivity 100% (CI:63-100), Specificity 75% (CI:51-99), Accuracy 82% (CI:63-94%). 15 normal cases were correctly identified. There were no false negatives. Based on the 8-point model, 13 patients, which included 5 false positives, would have been referred for further clinical imaging. ICC=0.914 to 0.996 for all ROIs confirmed excellent inter-operator reliability in blinded assessment between the two readers.

Triple assessment in a hospital breast clinic needs to be timely, although is a limited resource. All 28 of the patients in this study were referred from their general practitioner with symptoms of breast cancer, yet 15 were correctly identified as negative using thermography alone. The false positive rate of 18% is comparable with the 20% of mammography screening. It appears that thermography, if done to a high standard, can potentially provide a useful function, particularly in primary care at the point of first presentation, reducing patient stress, and optimising the use of hospital facilities. A larger study is required to substantiate these findings; however, this pilot study has provided the underpinning evidence for further research and a training database for the education of clinical thermographers in analysis technique.

KEYWORDS: Thermography, infra-red, DITI, thermal imaging, breast

SPIELT DIE BRUSTTHERMOGRAFIE EINE ROLLE BEI DER DIAGNOSE VON BRUSTERKRANKUNGEN?

Brustkrebs ist die häufigste Krebsart bei Frauen weltweit. Die Infrarotthermografie wird international zunehmend zur Diagnose der Brustpathologie eingesetzt. Aufgrund der fehlenden klinischen und methodischen Standardisierung im Bild- gebungs-, Analyse- und Berichtsprozess der Thermografie gibt es jedoch wenig Evidenz für ihre Verwendung. Diese Pilotstudie präsentiert ein Forschungsmodell, das entwickelt wurde, um die Fähigkeit der modernen digitalen Infrarot-Thermografie (DITI) in einer britischen Brustklinik zu testen.

Eine FLIR T650 IR-Wärmebildkamera (640x480) wurde verwendet, um die Brüste von 28 symptomatischen Frauen in einer temperaturkontrollierten Umgebung abzubilden. Es wurde eine Single Gate-Testgenauigkeitsstudie durchgeführt, die von zwei erfahrenen Thermographen voneinander unabhängig doppelt gelesen und abgestimmt wurde. Die Ergebnisse wurden mit dem Indextest der dreifachen Beurteilung durch körperliche Brustuntersuchung, Mammographie, Ultraschall und Biopsie verglichen und, gegebenenfalls mit dem Referenzstandard der Pathologie bestätigt. Die Bildanalyse basierte auf einem 8-Punkte-Bewertungsmodell: linke und rechte ganze Brust, Brustwarze, Areola und Axilla; obere laterale, obere mediale, untere laterale, untere mediale Brustquadranten; areolare Vierpunkt-"Kompass"-Messung; Visuelle Beurteilung für offensichtliche heiße oder kalte Stellen. Eine Überweisung wurde für kontralaterale Symmetrieunterschiede von >1OC in einer der Bewertungszonen empfohlen.

Sensitivität 100% (CI:63-100), Spezifität 75% (CI:51-99), Genauigkeit 82% (CI:63-94%). 15 Normalfälle wurden korrekt identifiziert. Es gab keine falschen negative Fälle. Basierend auf dem 8-Punkte-Modell wären 13 Patienten, darunter 5 falsch positive Ergebnisse, zur weiteren klinischen Bildgebung überwiesen worden. ICC=0,914 bis 0,996 für alle ROIs bestätigten eine ausgezeichnete Inter-Operator-Zuverlässigkeit bei der verblindeten Bewertung zwischen den beiden Auswerter.

Die dreifache Beurteilung in einer Brustklinik eines Krankenhauses muss rechtzeitig erfolgen, obwohl dies eine begrenzte Ressource ist. Alle 28 der Patienten in dieser Studie wurden von ihrem Hausarzt mit Symptomen von Brustkrebs überwiesen, aber 15 wurden allein durch Thermografie korrekt als negativ identifiziert. Die Falsch-Positiv-Rate von 18% ist vergleichbar mit den 20% des Mammographie-Screenings. Es scheint, dass die Thermografie, wenn sie zu einem hohen

Standard durchgeführt wird, möglicherweise eine nützliche Funktion bieten kann, insbesondere in der Primärversorgung zum Zeitpunkt der ersten Präsentation, wodurch der Stress der Patienten verringert und die Nutzung von Krankenhauseinrichtungen optimiert wird. Eine größere Studie ist erforderlich, um diese Ergebnisse zu untermauern. Diese Pilotstudie hat jedoch die Grundlage für weitere Forschungen und eine Trainingsdatenbank für die Ausbildung klinischer Thermografen in der Analysetechnik geliefert.

SCHLÜSSELWÖRTER: Thermografie, Infrarot, DITI, Wärmebildgebung, Brust

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Introduction

With nearly 1.7 million new cases diagnosed annually, breast cancer is the most common cancer in women worldwide, representing about 25 per cent of all cancers in women. One in eight women will develop breast cancer at some stage in their lifetime. About 85% of breast cancers occur in women who have no familial history (1).

Mammography screening is routinely offered to women aged 50 to 71 in the UK; however, this has a minor effect on mortality (2). A similar service is offered in many countries of the world. The technique has a false positive rate of around 20% (3) leading to a high volume of unnecessary referrals to specialist breast clinics where patients undergo the "triple-test" ('index test'). This test is a combination of physical examination, mammography, and ultrasound; including biopsy if justified (4, 5). Symptomatic patients can be referred directly to the specialist breast clinic regardless of age; however, the use of mammography needs justification, considering the risk of using ionising radiation. The 'reference standard' which defines if cancer is present, is pathology. Due to the natural progression of the diagnostic process for breast cancer, it is rare that the reference standard will be performed prior to the index test, particularly if the reference standard includes surgical intervention. Ultrasound, MRI, and potentially thermal imaging offer non-ionising alternatives. Additionally, thermography is non-invasive and does not require the breast compression that women find so uncomfortable with mammography. In principle it could be repeated at regular intervals to enable monitoring throughout the whole adult life.

LIST OF ABBREVIATIONS

DITI - Digital infra-red thermal imaging

NETD - Noise equivalent temperature difference

ROI - Region of interest

STARD - STAndards for Reporting Diagnostic accuracy studies

TAMB - Ambient temperature

TREF - Reflected temperature

STDEV - Standard deviation

SEM - Standard error of measurement

ICC - Inter-class correlation

LLQ - Lower lateral quadrant

ULQ - Upper lateral quadrant

LMQ - Lower medial quadrant

UMQ - Upper medial quadrant

DCIS - Ductal carcinoma in situ

Early use of thermography as a tool for breast cancer detection demonstrated low sensitivity (39%) (6), however technology has improved considerably, in principle offering improved clinical performance. Concerns regarding the highly variable sensitivity and specificity mean that thermography is still not adopted by the Royal College of Radiologists (RCR) as a diagnostic imaging modality or used in the UK National Health Service (NHS); however, thermography is widely available in the private health sector.

The imaging, analysis and reporting process of thermography research demonstrates a distinct lack of clinical and methodological standardisation. Studies utilised a vast array of infra-red imaging devices to capture the thermogram, including novel prototype designs and artificial intelligence (AI) systems. Unique methods of classifying benign/normal tissue from malignant lesions are common. The expertise of the clinician analysing the thermogram is often poorly defined, with many clearly learning as part of their study. Expert and novice analysis will be clearly different, thus impacting the results. Most studies adopted a single gate design whereby all patients pass through a single set of criteria for study admission, typically defined by the clinical presentation (7). Others adopted a two-gate design using healthy controls. Blinding of the results from both the index test and reference standard is essential to reduce review bias. Inadequate blinding in diagnostic accuracy studies can over-estimate the performance of the index test (8) and studies that do not report double blinding portray an increased odds ratio 17% higher on average than studies that do (9).

The literature reveals a wide range of bespoke developmental software as part the research process. In time some of these might become viable commercial solutions, however for the short/medium term, the ability to use universally available software is advantageous, as this allows for rapid dissemination within healthcare organisations. Analysis must be time efficient and operator independent to have clinical utility. A pilot study to evaluate the method and estimation of inter-operator reliability are essential precursors to trials in clinical practice.

Aim and objectives of proposed investigation

Working towards the overall aim of identifying better and more accurate ways to detect and diagnose breast cancer, using digital infra-red thermography (DITI) our study proposed to:

1) Assess the accuracy, particularly sensitivity, of DITI in women with symptoms suggestive of breast cancer in an NHS breast care unit.

2) Establish a library of adjudicated DITI images to support future training and benchmarking.

Methods

Study Design

A single gate diagnostic test accuracy study performed to meet the 'standards for reporting diagnostic accuracy studies' (STARD) reporting criteria [10]. Measuring sensitivity and specificity, independently double-read and agreed by two experienced thermographers, relative to the index test of triple assessment by physical breast examination, mammography (if <40 years of age), ultrasound, and biopsy if appropriate, confirmed with the reference standard of pathology. The study was performed in the UK NHS in a well-established, highly experienced clinic for the investigation of women with suspicion of breast cancer e.g., breast lump, breast pain, nipple discharge, or nipple retraction. The study was prospectively conducted according to a pre-specified approved protocol.

Sample

Twenty-eight females were recruited by referral from their general practitioner to hospital's symptomatic breast clinic. Patients ages ranged from 16 to 90 (mean 52.6; STDEV 16.1). All participants were provided with an information leaflet and allowed a minimum of 24 hours before being asked for written consent. Ethical approval was gained from the hospitals research committee and the Integrated Research Application System (IRAS) for studies to be conducted in the UK NHS (R&D 2010041), and the research carried out in accordance with the Declaration of Helsinki.

Skin Temperature Assessment

The thermal images were recorded with an FLIR T650SC infrared camera (FLIR® Company, Wilsonville, Oregon, USA) uncooled microbolometer, 14 bit, with a high-resolution focal plane array sensor size of 640x480, noise equivalent temperature di?erence (NETD) of <20mK, accuracy of $\pm$1% across the overall temperature range (calibration certificate #DN17370), and a 25° lens. Emissivity was set to 0.98.

All imaging took place within a temperature (21-26°C) and humidity-controlled room with no windows. Ambient temperature and humidity were measured using a UMI digital monitor. Consistent with the guidelines for standardisation of thermal imaging in medicine, participants were advised not to smoke, avoid caffeinated drinks, exercise, and the use of deodorant or anti-perspirant or talc, prior to the examination [11]. Upon arrival, participants were escorted to the private examination room, where they removed clothing above the waist and if necessary, tied their hair back. After a 15-minute acclimatisation period, they then sat on a stool positioned in front of a black background, facing the camera, with arms raised and hands placed on their head. The camera was placed on a tripod 2m from the patient. After the frontal projection was acquired, the patient was then turned approximately

Figure 1
8-point breast analysis model

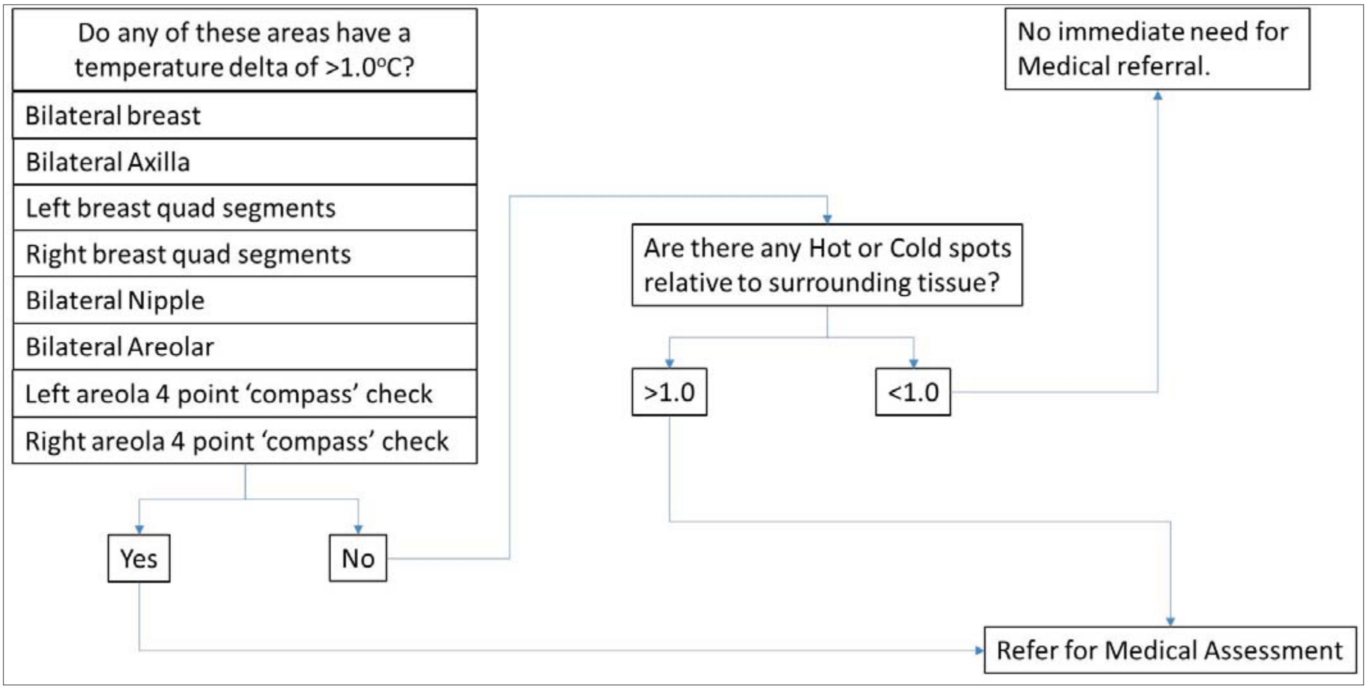
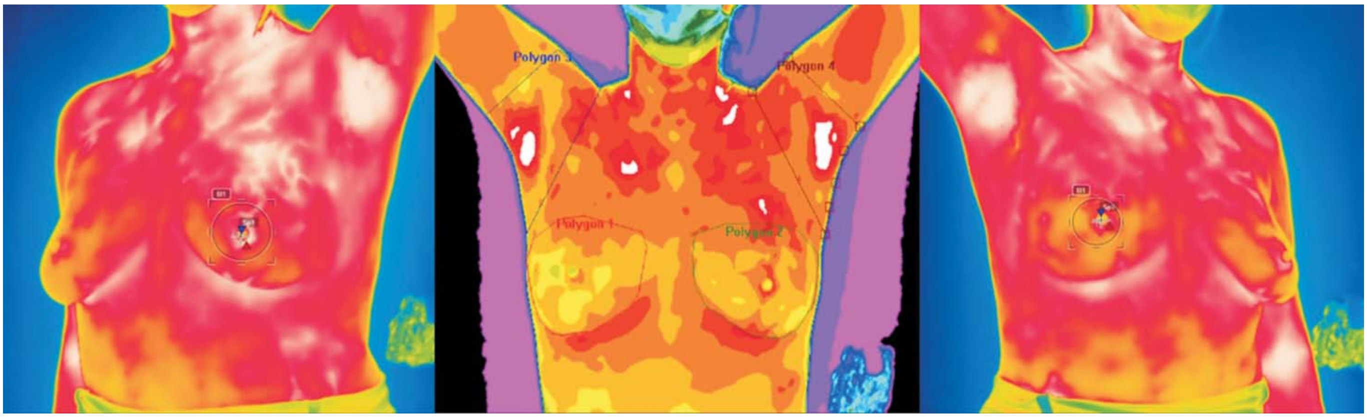


Figure 2
Regional assessment of breasts, areolar and nipples



45° to either side to capture oblique images with the nipple and areolar pointing directly at the camera. The back screen carries a reflector from which reflected temperature (TREF) can be assessed in the first stage of analysis. Ambient temperatures (TAMB) were recorded using an independent digital thermometer.

Images were downloaded by fire-wire to the data-compiler using FLIR Researcher IR. They were then blind reported by two independent experienced readers using an 8-point check model devised as part of this research (see figure 1). In the event of disagreement in diagnosis, the readers should discuss to reach consensus.

The first analysis included the temperature measurement of left and right whole breasts and axilla from the frontal image, and nipples and areolar, from the oblique images (see figure 2).

Using the frontal images, each breast was then segmented into four quadrants (upper lateral, upper medial, lower lateral, lower medial). Drawing one horizontal guideline around the level of the nipples and two vertical lines in the region of the mid-clavicular lines, provides a useful template to aid consistency (See figure 3)

Four 'compass' measurements (North, South, East, West) were taken from the oblique projections of each breast areolar. (See figure 4)

Finally, a visual assessment was made for obvious hot or cold spots, with quantitative analysis of each relative to both surrounding and contra-lateral bilateral tissue (see figure 5)

Prescribing each ROI is a potential source of error, however this an inherent limitation of breast thermography, because the exact location of the areolar can be challenging to identify, as are the size and margins of the areolar. The use of mixed mode (photograph and thermogram) available in FLIR TOOLS is a useful aid to visualise the exact location of the areolar margins before changing to thermal mode for final assessment.

The choice of display colour palette is a matter of personal preference. Although there are inherent limitations, a Rainbow palette is still widely used in thermography practice

Figure 3
Segmentation of the frontal breast image to form quadrants

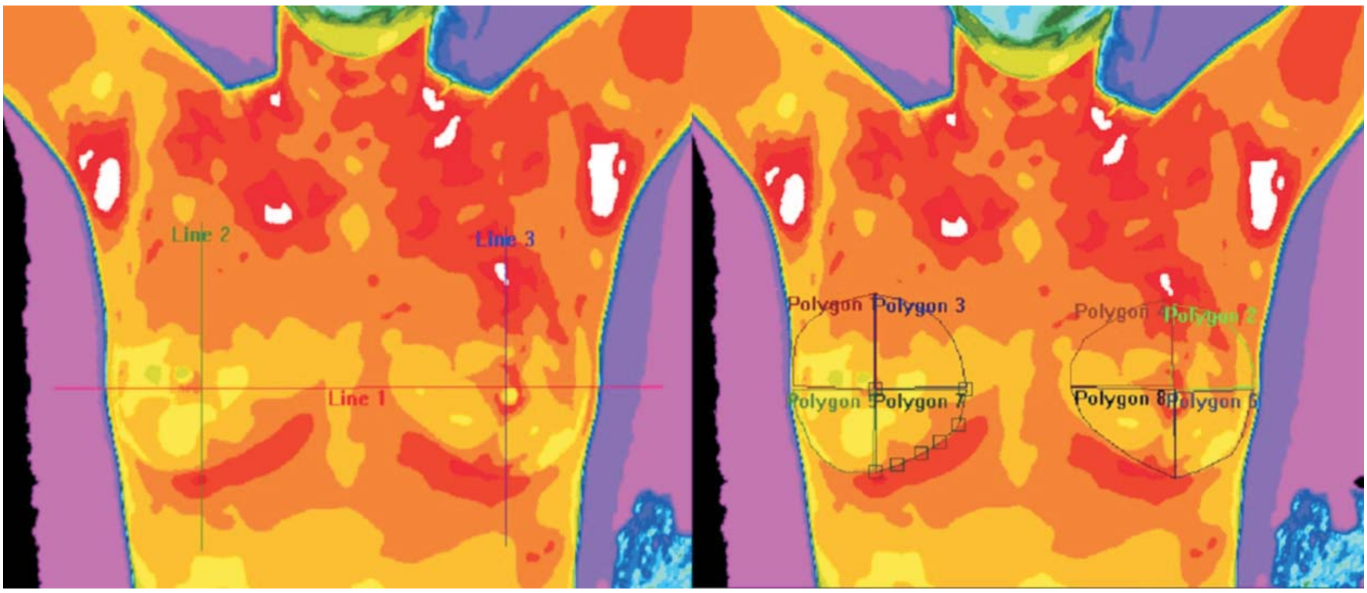


Figure 4
Compass point assessment of areola

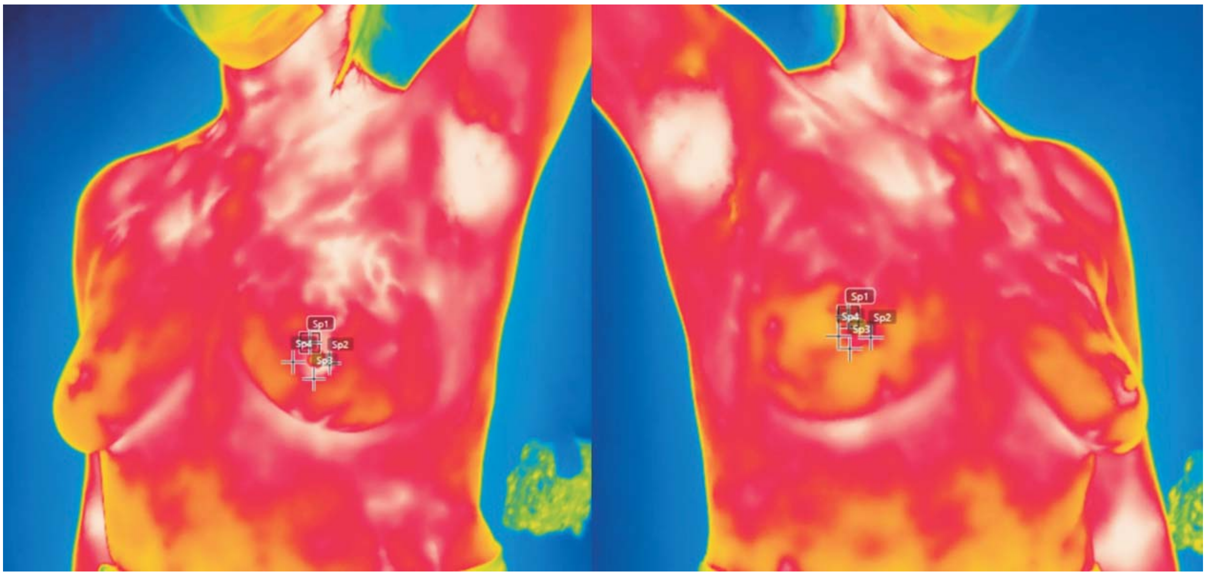
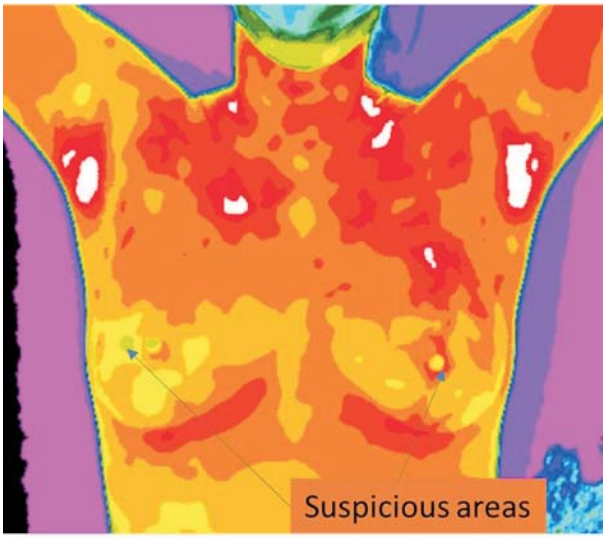


Figure 5
Suspicious areas



[12]. This study used a 'Rainbow 20' colour palette for routine image display which in some cases, made the margins of the breasts difficult to define, even with manipulation of level and span. The 'Grayscale' palette for the measurement phase, overall, enabled better visualisation of breast margins and nipples (See figure 6)

Minimum, maximum, and mean temperatures were recorded for all measurements.

Statistical analyses were performed using IBM SPSS v26 statistical software package.

All statistical tests used a 95% level of significance.

Results

There were no cases of unequivocal referral decision between the readers.

Figure 6
Frontal breast image with Grayscale and Rainbow 20 colour palettes

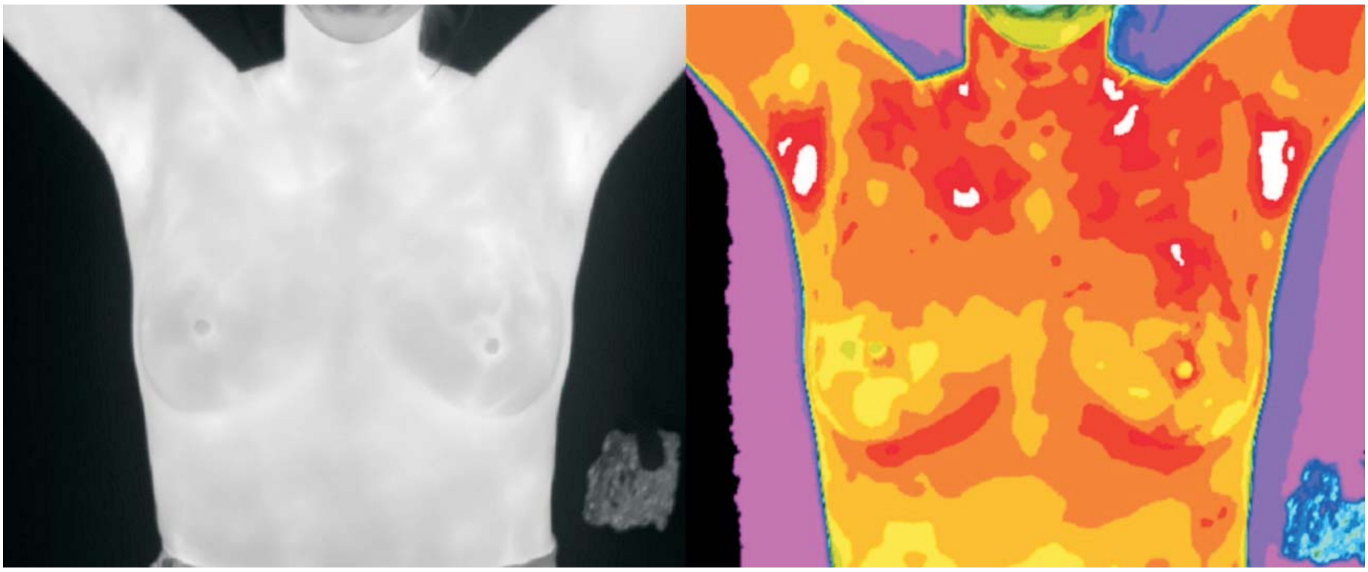


Table 1
Mean temperatures

	Mean Temperature (°C)															
	Left								Right							
	Breast	Nipple	Areolar	Axilla	ULQ	UMQ	LLQ	LMQ	Breast	Nipple	Areolar	Axilla	ULQ	UMQ	LLQ	LMQ
Min	30.8	30.2	30.1	31.9	30.2	31.2	30.1	31.5	31.1	30.2	31.4	33.0	30.7	30.6	31.0	31.2
Max	34.8	34.5	35.2	35.3	34.6	35.0	34.8	35.5	34.8	34.2	34.9	35.1	34.6	34.9	34.8	35.3
Mean	33.4	32.9	33.3	33.9	33.2	33.4	33.3	33.8	33.4	32.7	33.3	33.9	33.2	33.3	33.2	33.7
STD Dev	1.0	1.0	1.1	0.9	1.1	1.0	1.1	1.1	1.1	1.1	0.9	0.8	1.1	1.1	1.0	1.1
SE	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
95%UCL	33.8	33.3	33.7	34.2	33.6	33.8	33.7	34.2	33.8	33.1	33.6	34.2	33.6	33.8	33.6	34.1
95%LCL	33.0	32.5	32.9	33.6	32.7	33.0	32.8	33.4	33.4	32.2	32.9	33.6	32.8	32.9	32.8	33.3

The first analysis focussed on whole breasts, areolar, nipple, axilla, and the four breast quadrants (see table 1).

The temperature measurements from each patient were assessed relative to a bilateral delta of >1°C (See Table 2).

Table 2
8-point breast analysis model check list

Bilateral breast D>1.0?	YES/NO
Bilateral Axilla D>1.0?	YES/NO
Left breast quad segments D>1.0?	YES/NO
Right breast quad segments D>1.0?	YES/NO
Bilateral Nipple D>1.0?	YES/NO
alphaBilateral Areolar D>1.0?	YES/NO
Left areola 4 point ´compass´ check D>1.0?	YES/NO
Right areola 4 point ´compass´ check D>1.0?	YES/NO
Hot or Cold spots>1.0 relative to surrounding tissue?	YES/NO

Table 3
Assessment of the Diagnostic Tests

		95% confidence interval (CI)
True positives (TP)	8	
True negatives (TN)	5	
False positives (FP)	15	
False negatives (FN)	0	
Sensitivity	100%	63% - 100%
Specificity	75%	51% - 91%
Accuracy	82%	63% - 94%
Positive predictive value (PPV)	62%	43% - 77%
Negative predictive value (NPV)	100%	Not calculable
Positive likelihood ratio (LR+)	4	2 - 9
Negative likelihood ratio (LR-)	0	Not calculable

The decision to refer was based on the 8-point check. There were no equivocal cases (see Table 3).

The confirmed diagnosis of abnormal cases was: -

Ductal carcinoma in situ (DCIS)	n=3 (38%)
Malignant Melanoma	n=1 (13%)
Phyllodes Tumour	n=1 (13%)
Fibroadenoma	n=2 (25%)
Lipoma	n=1 (13%)

Reliability Assessment

The final phase of the analysis considers the inter-operator agreement via the inter-class correlation coefficient (ICC). Each of the two readers independently drew their own ROIs based on their interpretation of the breast anatomy. The ICC is independent of the problem of a linear relationship being erroneously considered as agreement, however, is still dependent on the range of measurements. It is not related to the units of measurement or to their size [13]. A two-way mixed-effects, absolute agreement, average measures model was used. In order that the ICC was not considered in isolation, the standard error of measurement (SEM) was also calculated (SEM=STDEVxSQRT(1 - ICC), and provides an indication of the errors that would be expected on retesting (see table 4).

Discussion

Whilst all 28 patients had clinical symptoms of breast cancer, only 8 (29%) proved positive through triple assessment and biopsy or required treatment. In 20 (71%) of cases, the lumps were defined as cystic in nature.

Not all the confirmed abnormal cases were breast cancer, however, they did warrant referral and treatment. The most

Table 4:
ICC and SEM

Side	ROI	Average Measures ICC	Lower 95% CI	Upper 95% CI	SEM
Left	Breast	0.959	0.981	0.909	0.215
	Nipple	0.944	0.876	0.975	0.229
	Areolar	0.986	0.970	0.994	0.127
	Axilla	0.990	0.977	0.995	0.055
	ULQ	0.989	0.975	0.995	0.119
	UMQ	0.988	0.970	0.995	0.113
	LLQ	0.996	0.992	0.998	0.071
	LMQ	0.985	0.966	0.993	0.130
Right	Breast	0.996	0.989	0.998	0.065
	Nipple	0.973	0.941	0.988	0.184
	Areolar	0.984	0.964	0.993	0.115
	Axilla	0.986	0.969	0.994	0.096
	ULQ	0.940	0.866	0.973	0.258
	UMQ	0.959	0.909	0.981	0.228
	LLQ	0.914	0.809	0.961	0.306
	LMQ	0.964	0.919	0.984	0.209

common breast cancer was DCIS (n=3: 38%), highlighting the required focus within the 8-point check on the nipple and areola areas, to ensure close scrutiny.

Referral based on thermography alone was recommended for 13 of the patients, on the basis that one or more of the 8-point check regions had a bilateral temperature difference of >1OC. This included the 8 positive cases, as well as 5 false positive cases. Critically though, no abnormal cases were missed. Logistically, this means that 15 of the 28 patients would not have been referred to the breast clinic, which has implications for the NHS and of course the patient.

Closer examination of the images and data reveal that the cystic breast is challenging to interpret and was responsible for all the false positive errors. In some cases, temperature differences are evident and in others, not. The phase of the menstrual cycle, particularly in younger women could be a key factor in explanation. This study has highlighted that breast lumps can present in females as young as 16, and where familial history of breast cancer is evident, proactive investigation with non-ionising imaging modalities is desirable. The '8 point check' devised for this study aims to provide a robust breast assessment without any contact or information about the patient. ICC between readers was consistently high (0.914-0.996), suggesting that the approach to analysis is robust. The standard error of measurement (SEM) was very small, indicating that the errors that would be expected on retesting would also be very small, and well within the camera NETD of ±1%.

Compared to previous studies from the last decade, whose results are difficult to compare due the non STARD methodologies often adopted, this study had a sensitivity (and NPV) of 100% versus 82% - 98% (median 88.5%). This evidence suggests that thermography can clearly differentiate the normal cases. Deciding if a case is abnormal is more challenging and airing on the side of caution, means that some false positives are inevitable. This study had a specificity of 75% and PPV of 62%, comparable with previous studies ranging from 58-99% (median 74%). It is important to appreciate that the role of thermography is not to provide a specific diagnosis, but simply to determine if the breasts are normal or suspicious of disease.

With further research to refine the 8-point model, and greater experience of the readers, it might be possible to reduce the number of false positives, however, for thermography to have clinical utility, it is critical that the 100% negative predictive value (NPV) is maintained. The cases from this study have been used to create a library of images that form a training package to enable the development of image analysis and interpretation skills of future readers and will be available via www.radbench.org.

Mammography screening, routinely offered to women aged 50 to 71 in the UK, has a false positive rate of around 20%, and a minor effect on mortality. The use of ionizing radiation makes the technique unsuitable for regular screening of all age groups. Many patients find the breast compression required for good image quality, painful and undesirable. Thermography, however, with a false positive rate of 18% in this study, is potentially ideally suited to mass screening of women of all ages. Regular thermological assessment, initially monthly and then quarterly, would enable the normal temperature rhythm to be defined, and potentially identify women who routinely produce cysts as part of their normal cycle. The development of reliable artificial intelligence software would have a major impact.

The 'triple-test', combining physical examination, mammography, and ultrasound; including biopsy if justified, is likely to remain the 'index text' for patients referred to the specialist breast clinics for the foreseeable future, potentially including the addition of thermography or MRI as preferred, however, with reliable thermological assessment in primary care, the volume of patients presenting would be significantly reduced. This could have significant financial and logistical impact on hospitals, and greatly improve patient care. A patient who thinks they have breast cancer is under enormous emotional stress, and so the faster they can get a definitive diagnosis, the better.

Conclusion

If done to this high standard, thermography can potentially provide a useful function, particularly at the point of first presentation of breast cancer symptoms, reducing patient stress, and optimising the use of hospital facilities. A larger study is required to substantiate these findings; however, this pilot study has provided the underpinning evidence for further research and a training database for the education of clinical thermographers in analysis technique. The pilot has clearly indicated that there is a potential role for thermography in a breast screening environment. Ease of use, and comparable sensitivity together with cost benefits will appeal to clinicians and hospitals alike. Developing technology and advances in AI will enhance the modality, and hence these benefits.

Declarations

a) Ethics approval and consent to participate

Ethical approval was gained from the hospitals research committee and the Integrated Research Application System (IRAS) for studies to be conducted in the UK NHS (R&D 2010041), and the research carried out in accordance with the Declaration of Helsinki.

b) Consent for publication

After reading the participant information form supported by further verbal explanation, all participants gave written consent to take part, which included the provision for their anonymised images to be used in teaching, research, and publication.

c) Availability of data and material

Please contact author for data requests.

d) Competing interests

The authors declare that they have no competing interests

e) Funding

The project was funded by the Royal Devon & Exeter NHS Trust

f) Authors' contributions

CW and JM developed the 8-point analysis model, read the images, performed the statistical analysis, and drafted the manuscript. BK created the patient centred materials and coordinated approvals, consent, and data mining to preserve blinding. DF consented the patients and led the clinical team. All authors were involved in the reading and editing of drafts and approved the final manuscript.

g) Acknowledgements

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Comment: Home monitoring of foot temperature for risk reduction of diabetes-related foot ulcer

Review of the article by Golledge, J. et al. Diabetes Metab Res Rev 2022; e3549

Adérito Seixas

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Board Member, European Association of Thermology, Austria

Summary

Background

Foot ulcers in diabetic patients are one of the leading causes of disability, hospital admissions and healthcare costs [1]. Ulcers are often developed because of cumulative effects of high plantar pressure and daily activity in the presence of peripheral neuropathy [2]. Increased skin temperature at a site on one foot compared to the homologous site on the contralateral foot can be an alert of cumulative stress in the soles of feet and may indicate the presence of inflammation and predict the development of foot ulcers [3]. The aim of the systematic review and meta-analysis was to test the efficacy of at-home foot temperature monitoring and reduction of ambulatory activity in response to hotspots on reducing the risk of developing a diabetes-related foot ulcer.

Methods

The authors conducted a systematic review and meta-analysis searching four databases (MEDLINE, Pubmed, Web of Science and Cochrane Library), using no language or date restrictions. The authors included randomised controlled trials testing at-home foot temperature monitoring and reduction of ambulatory activity in response to hot- spots with a control group not receiving at-home foot temperature monitoring but otherwise receiving similar care, and that reported the incidence of foot ulcers during the follow-up period. The primary outcome was the development of any diabetes-related foot ulcer during the study period and the secondary outcomes were minor and major amputations. When outcomes (primary and secondary) were present in at least three trials, meta-analysis were performed using Mantel-Haenszel's statistical method and random effect models. Statistical heterogeneity was assessed using the I^2 statistic, and sensitivity and publication bias analyses were performed. All statistical tests were two-sided and p-values <0.05 were considered significant.

Results

Five trials - one with low, one with moderate and three with high risk-of-bias - involving 772 participants meeting the inclusion criteria were included. Participants in the experimental group (at-home foot temperature monitoring and activity reduction) had a reduced risk of developing foot ulcers (RR = 0.51, 95% CI 0.31-0.84) compared to controls. Findings were consistent according to the sensitivity and sub-analysis. GRADE assessment suggested a low degree of certainty in findingis.

Conclusons

At-home foot temperature monitoring and ambulatory activity reduction in response to hotspots reduce the risk of developing diabetes-related foot ulcers in moderate or high-risk people, with a low level of certainty.

Commentary

I welcome this opportunity to comment on the article published by Golledge and colleagues [4] as the burden of diabetes-related foot ulcers is well known and considering the trend for diabetes in the world, it is expected to increase. Therefore, research that helps clinicians to deal with this problem, systematizing the existing evidence, is much welcomed.

The article is well structured and written, easy to understand, and followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) [5] recommendations.

The introduction presented the rationale for the review, stating the reasons for the need of another systematic review and meta-analysis on the topic when two recent reviews were recently published [6, 7], and the aim of the study was clearly stated.

The methodology of the study (PROSPERO registration number: 235955) is in line with the study aims. Four reference databases (MEDLINE, Pubmed, Web of Science and Cochrane Library) were searched with no language or date restrictions. The eligibility criteria were clearly presented. The studies had to include patients with diabetes at risk of developing diabetes-related foot ulcers, monitoring foot skin temperature using an objective temperature monitoring device at home. Risk was classified according to the International Working Group on the Diabetic Foot (IWGDF) - patients should be in risk categories 2 and 3 - and diabetes-related foot ulcer was defined as a full thickness wound on the foot of a person with diabetes [8, 9]. These criteria and definitions are in line with current best clinical practice; however, some aspects of the implemented methodology must be discussed.

Although MEDLINE and Pubmed are well established databases, considering that Pubmed is an interface used to search MEDLINE and additional biomedical content, to avoid result overlapping, the authors could have opted to use Scopus or another reference database. This would increase the range of the search. Moreover, although reference lists of the studies identified were also searched, nothing is stated regarding the reference lists of relevant systematic reviews and no efforts were made to identify relevant grey literature. The Cochrane Handbook for Systematic Reviews of Interventions [10] states that the search strategy should be as extensive as possible to reduce the risk of publication bias and to identify as much relevant evidence as possible. It is highly desirable to search relevant grey literature sources such as reports, dissertations, theses and conference abstracts. Google Scholar may be a good source of information and authors should focus on the first 200 to 300 results of the search [11]. Nonetheless, it must be noted that Google Scholar should not be used alone for systematic review searches, but it is a powerful addition to other traditional search methods.

Another aspect worth mentioning in the search strategy were the search strings used in the included databases (table 1).

Table 1: Defined search strings for each of the searched databases.

Database	Search string
MEDLINE	exp "diabetic foot" OR exp "diabetic neuropathies" AND randomised controlled trials
Pubmed	"diabetic foot" [MeSH Terms] OR "peripheral neuropathies" [MeSH Terms] AND "temperature" filtered by randomised controlled trials
Cochrane Library	"diabetic foot syndrome" OR "diabetic foot ulcer" filtered by "trials"
Web of Science	"diabetic foot" searched within by "randomized controlled trials"

The PICO strategy - that is Patient (or Participant or Population or Problem), Intervention, Comparison and Outcomes - could have been used to structure the search string and the same search terms could have been used in the different databases. For instance, the use of "diabetic neuropathies" in MEDLINE, "peripheral neuropathies" (as a MESH term) in Pubmed and the absence of such terms in Cochrane Library and Web of Science can raise some questions by the readers. Ulcers, which were a main outcome of the study could have been represented in the search strings as a term that should be combined with the other terms with the Boolean operator AND.

Although the number of reviewers extracting data from the studies was reported, the number of reviewers that searched and screened each record was not stated. The risk of bias of included studies was assessed independently by two authors (from a pool of three) using the 2nd version of the Cochrane risk-of-bias tool [12] and the certainty of the evidence was assessed according to the Grading of Recommendations Assessment, Development and Evaluation (GRADE) to evaluate the risk of bias, inconsistency, indirectness, and imprecision of the combined trial evidence [13]. Moreover, the authors assessed the potential impact of the risk-of-bias in individual studies on the results of the meta-analysis and when interpreting and discussing the results. These methodological options are a strength of the review.

Outcomes were reported accurately, as relative risk (RR) and 95% confidence intervals (CI), and when outcomes (primary and secondary) were present in at least three tria ls meta-analysis were performed using Mantel-Haenszlsel's statistical method and random effect models, and assuming that participants lost to follow-up did not have outcome events. Often, the choice of random or fixed effects models are based on statistical heterogeneity, which is not adequate. However, in this study, the option to use random effect models was correct, as the authors anticipated heterogeneity (clinical and methodological) of the included studies.

Regarding publication bias the authors conducted an assessment by funnel plots comparing the summary estimate of each study and its precision. According to the Cochrane handbook for systematic reviews of interventions [10]: "As a rule of thumb, tests for funnel plot asymmetry should be used only when there are at least 10 studies included in the meta-analysis, because when there are fewer studies the power of the tests is too low to distinguish chance from real asymmetry". Five studies were included in the meta-analysis, which questions the use of the analysis.

It is interesting to note that all the included trials used the TempTouch infrared thermometer (Xilas Medical, San Antonio, TX) to measure foot temperature. Thermal imaging as been researched as a potential assessment tool that could provide information regarding the thermal map of the foot sole. However, no randomized controlled trial has been conducted using this technology for at-home foot temperature assessment. A previous study with two case reports has been published [14] but several limitations were identified, namely the need to use a smartphone, or other expensive alternatives, and the need to develop automatic detector of high-risk thermographic findings helping patients to identify problematic foot areas.

After careful assessment of the risk-of-bias and certainty of the included literature, the authors concluded that the meta-analysis provides promising but low-certainty evidence that daily at-home foot temperature monitoring and reduction of activity in response to hotspots is effective at reducing the risk of a diabetes-related foot ulcer in at-risk diabetic patients.

A critical appraisal of the current systematic review and meta-analysis, using the AMSTAR-2 tool, allowed to identify 5 potentially problematic items (items 3, 4, 5, 7 and 10) related to the explanation for the selection of the included study designs, the search strategy, study selection, study exclusion and sources of funding for the studies included in the review. Two of the items (items 4 and 7) are considered critical domains [15], however, item 4 (Did the review authors use a comprehensive literature search strategy?) and item 7 (Did the review authors provide a list of excluded studies and justify the exclusions?) were not considered critical in this assessment. Item 4 was not considered critical because it was assessed as partially satisfied and item 7 was not considered critical because the meta-analysis was used to summarise a well-known literature base. Therefore, considering that the systematic review has more than one weakness but no critical flaws, it provides an accurate summary of the included studies [15] and the overall confidence in the results of the review and meta-analysis is classified as moderate.

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News in Thermology

SOLATHERM - Latin American Society of Thermology and Thermography in Health - founded

Formed by medical doctors, veterinarians, physiotherapists and Physical Education professionals, this society aims to promote the rationale and scientific use of thermography in Latin America. The society is located in Brazil and will soon welcoming members from Central and South America. Scientific director is Prof Danilo Gomez Moreira, Federal Institute of Education, Science and Technology in Minas Gerais, Brazil. Other members of the scientific board are Drs. Ana Paula Senos Mendes (Physical Medicine & Rehabilitation), Danielli Melo (Physical Education), Jose Jamacy de Almeida (Physiotherapy) and Juan Carlos Bouzas Marins (Physical Education). Director of international Relations is Thomas Miliou, CEO of Poliscan Brazil Medical Technologies.

There are established co-operations between Prof Manuel Sillero Quintana and Danilo Gomez Moreira [1, 2, 3], Juan Carlos Bouzas Marins [2,4,5] and Jose Jamacy de Almeida and [3] resulting in several mutual articles in the past. Thomas Miliou [6] and Danielli Melo [7,8] presented papers at the EAT2021 Online conference.

SOLTHERM agreed to use "Thermology international" as their official publication organ.

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Soft, bioresorbable coolers for reversible conduction block of peripheral nerves designed

Scientists from the United States, China and South Korea developed in a mutual research project implantable devices capable of cooling peripheral nerves and thereby blocking their signal conduction. Lowering the neural tissue's temperature represents an attractive means to reduce electrical nerve activity in pain conducting nerve fibres, but traditional technologies are limited by rigid bulky form factors, imprecise cooling, and requirements for extraction surgeries. The research team designed soft, bioresorbable, microfluidic devices that enable delivery of focused, minimally invasive cooling power at arbitrary depths in living tissues with real-time temperature feedback control.

The potential field of applications are postoperative acute pain signals in peripheral nerves where (i) aberrant neural signals are well defined in selected anatomical regions (ii)nerves carrying aberrant neural signals are already isolated and (iii) a need for opioid therapy exists after operation. Pain management after amputations, nerve grafts or spinal decompression surgeries represent examples. Implantation of a bioresorbable cooler around the nerve that innervates damaged tissues enables reversible elimination of neural activity. Construction from water-soluble materials leads naturally to dissolution of the cooling system after the completion of the healing process and obviates the need for an extraction surgery.

The designed device consists of a hybrid microfluidic and electronic system for cooling and simultaneously measuring the temperature of the peripheral nerve. The elastomeric nature of the microfluidic system and the serpentine shapes of the electrical interconnects yield soft, stretchable mechanics at the device label with effective moduli not substantially higher than those of peripheral nerves. Both systems terminate in a cuff structure with a diameter matched to the rat sciatic nerve to provide an intimate mechanical and thermal interface to the nerve. An essential defining characteristic of this system is that it is constructed entirely with water-soluble constituent materials that controllably dissolve to biocompatible end products in the biofluids that are contained in subcutaneous tissues. An in vitro accelerated aging test showed that the materials largely dissolved within 20 days.

A bioresorbable elastomer, poly-octanediol citrate (POC), forms the microfluidic system. It includes transcutaneous colinear interconnects that deliver liquid coolant perfluoropentane (PFP) and dry N2 to a serpentine evaporation chamber in a completely sealed system that provides fluidic access at the ends. The simultaneous initiation of PFP and N2 flows into the structure prompts evaporation of PFP at the microfluidic junction between PFP and N2 channels and along the serpentine chamber. The mass flow of the liquid coolant and the geometry of the evaporation chamber govern the magnitude and localisation of the cooling effect. The phase change prompts the temperature of a device in a planar configuration to drop to -20°C within 2 min after initializing flow in ambient, room-temperature conditions. A serpentine magnesium trace provides temperature feedback through the temperature coefficient of resistance of Mg.

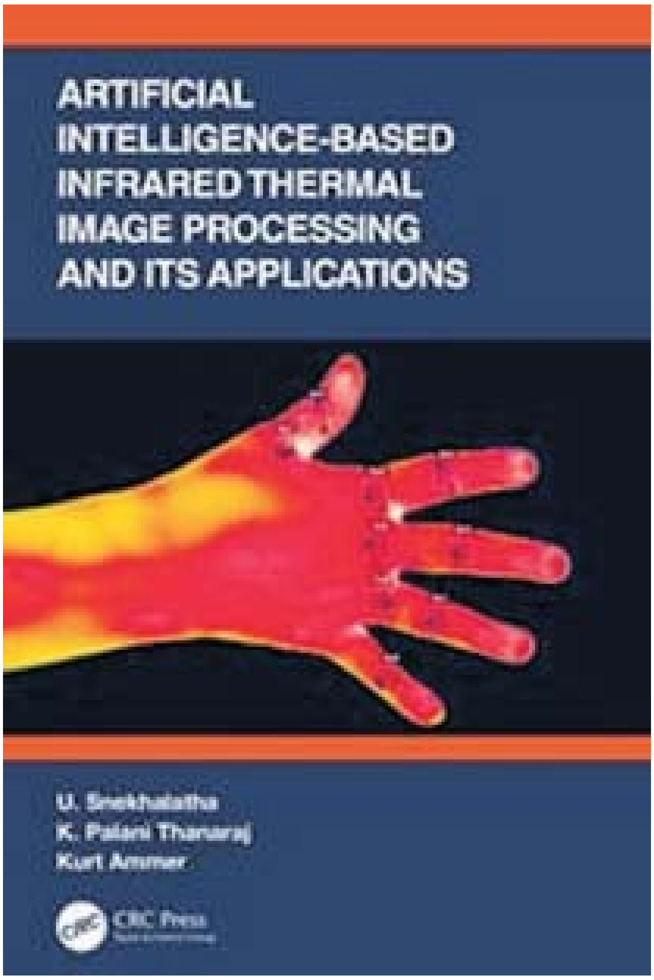
The efficacy of nerve cooling was proven in phantom nerve structure with integrated thermocouple inside a 37°C hydrogel tissue mimic. Phantom-nerve temperature depends on PFP and N2 flow rates. Initiation of a 300 µm/min flow of PFP results in nerve cooling rates greater than 3°C/s. Systematic reduction in PFP flow rate from 300 µm/min enables controlled rewarming of the nerve over a 20 min period. POC microfluidics provides precise and stable nerve cooling for more than 15 minutes. The system´s performance is stable for 21 days in vitro.

Finally, the efficacy of the micro-cooler was investigated in a rat model of neuropathic pain. Cooling the nerve lesion from 37°C to 10°C for 3 weeks lead to a sevenfold increase in the mechanical sensitivity threshold consistent with a significant cooling-induced analgesic effect. Histologic analyses supported biocompatibility and bioresorption of the device.

In summary, this work shows the advances of current bioengineering and bioelectronics in controlling thermodynamics in temperature modifying devices that can be applied to neural structures in living animals.

Reference

Reeder JT, Xie Z, Yang Q, Seo M-H, Yan Y,Deng Y et al. Soft, bioresorbable coolers für reversible conduction block of peripheral nerves. Science 2022, 377(6601)109-115



CRC Press announced the following book by the end of September 2022

Artificial Intelligence-Based Infrared Thermal Image Processing and Its Applications

By U. Snekhalatha, K. Palani Thanaraj, Kurt Ammer

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Subjects Engineering & Technology, Medicine, Dentistry, Nursing & Allied Health, Physical Sciences

Book description

Infrared thermography is a fast and non-invasive technology that provides a map of the temperature distribution on the body's surface. This book provides a description of designing and developing a computer-assisted diagnosis

(CAD) system based on thermography for diagnosing such common ailments as rheumatoid arthritis (RA), diabetes complications, and fever. It also introduces applications of machine-learning and deep-learning methods in the development of CAD systems.

Key Features:

- Covers applications of various image processing techniques in thermal imaging applications for the diagnosis of different medical conditions
- Describes the development of a computer diagnostics system (CAD) based on thermographic data
- Discusses deep-learning models for accurate diagnosis of various diseases
- Includes new aspects in rheumatoid arthritis and diabetes research using advanced analytical tools
- Reviews application of feature fusion algorithms and feature reduction algorithms for accurate classification of images

This book is aimed at researchers and graduate students in biomedical engineering, medicine, image processing, and CA

Table of Contents

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Dr. U. Snekhalatha is currently working as an Professor in the Department of Biomedical Engineering, SRM Institute of Science and Technology (SRMIST), Kattankulathur, India. She pursued her Doctorate in Biomedical Engineering at SRMIST (2015). Her areas of interest include biomedical signal processing, medical image processing, biomedical instrumentation, and machine learning and deep learning techniques. She has published 88 research articles in reputed peer-reviewed international journals and international conferences. She has filed four Indian patents of which, all are in published stage. She obtained the Best Researcher Award for her publications in Nature indexed journal during the Research Day function held on March 1, 2021 at SRMIST. She received Gandhian Young Technological Innovation Award for paper titled "Design of Acetone Breath Gas Analyzer in the Evaluation of Diabetes Mellitus," Appreciation 2020, Society for Research and Initiatives for Sustainable Technologies and Institutions, November 5, 2020. She has obtained best paper award and gold medals for some research paper publications. She is a life member of various professional societies such as the Biomedical Society of India, IEI, IEANG, IRED, ISTE, and ISCA. She is currently serving as a reviewer and guest editor for various reputed peer-reviewed international journals.

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Prof Dr. med. Kurt Ammer was certified as a general medical practitioner in 1978, a consultant for physical medicine and rehabilitation in 1989, and a consultant for physical medicine and rehabilitation (rheumatology) in 1994. He was senior researcher at the Ludwig Boltzmann Research Unit for Physical Diagnostics, Austria, between 1988 and 2004. From 1985 until his retirement in early 2013, he was Vice Director of the Institute of Physical Medicine and Rehabilitation at the Hanusch Hospital in Vienna, Austria. He got involved in medical thermography in 1988, and was appointed as secretary and treasurer of the European Association of Thermology (EAT) in 1990, and currently serves as the EAT treasurer. Since 2002, he has been appointed as external professor at the Medical Imaging Research Unit, University of South Wales, Pontypridd, UK. His research interests focus on rehabilitation medicine and the application and standardization of thermal imaging in medicine.

2022

22nd September 2022, Singapore
MICCAI AIIIMA Workshop

Description

There have been many advances in the use infrared imaging for medical applications in recent years. Infrared imaging comprises near-infrared, mid-wave infrared and long wave infrared spectrum. In the first ever AIIIMA workshop, more focus is given for long wave infrared imaging, in other words, thermal imaging. In the last two decades, infrared thermal imaging hardware devices have improved in thermal sensitivity by orders of magnitude (0.8 to 0.02 deg C) and recent research explorations have unearthed multiple clinical use cases and medical applications for thermal imaging. This non-contact, non-invasive radiation-free low-cost portable modality offers several advantages over other imaging modalities to patient monitoring applications in general. Furthermore, since thermal images have some unique imaging characteristics with inbuilt anonymity and opportunity to analyze in both thermal and imaging feature space, it has sparked considerable interest in several research communities. A simple pubmed search with the combination of words 'Thermal imaging ' and 'Medical' results in over 5000 articles just in the last decade. This surge of applications is 10 times higher when compared to the publications on thermal imaging during 2000-2010. We are also starting to see innovative startups creating breakthrough solutions leveraging this emerging trend of advanced medical infrared thermology and use of novel machine learning algorithms over the captured thermal images. We believe it is time to create a forum to discuss this specific sub-topic at MICCAI and promote this novel area of research among the research community that has the potential to hugely impact our society.

Some specific clinical applications of Infrared Imaging are seen in screening, diagnosis and treatment of cancer, such as breast cancer, skin cancer, oral cancer and others. Utility in evaluating skeletomuscular issues such as rheumatoid arthritis, vascular complications such as detecting early onset of diabetic foot and river blindness (parasites under the skin) or even respiratory abnormalities such as pneumonia and COVID-19. The patient monitoring applications include treatment monitoring during neoadjuvant chemotherapy, acupuncture, cryotherapy and pain management. A focused discussion on the topic of machine analysis of medical Infrared Imaging can help create new radiomic biomarkers that can help in several such clinical use cases.

Call for Papers

The research topics include but are not limited to novel machine learning and thermal image analysis algorithms for :

1.AIIIMA for cancer screening and diagnosis

2.AIIIMA for Treatment Monitoring

3.AIIIMA for health monitoring in public places

4.AIIIMA for patient monitoring with respiratory issues

5.AIIIMA for COVID screening

6.AIIIMA for pain management

7.AIIIMA for veterinary medicine

8.AIIIMA for biomarkers prediction

9.Thermal Surface Reconstruction / registration

10.Thermal Image Segmentation

11.3D modeling

12.Image segmentation and cross-modality registration

13.And others

Submission Guidelines

Submitted manuscripts must be in pdf format following formats available at Lecture Notes in Computer Science . Manuscripts should be at most 8 pages (content) + 2 pages (references and acknowledgements)

All accepted papers will be published as part of the MICCAI Satellite Events joint LNCS proceedings to be published by Springer Nature.

How to Submit?

The manuscripts should be submitted through our CMT paper submission site

Important Dates

- 25 June 2022 Paper submissions due
- 16 July 2022 Notification of paper decisions
- 30 July 2022 Camera ready papers due
- 6 August 2022 Workshop proceedings due
- 22 September 2022 AIIIMA conference date

Preliminary Program

The conference will select the papers for oral and lightning talks. Each oral presentation duration would be 25 minutes (20 mins presentation + 5 minute QA) and lightning talk presentation would be 5 minutes. Along with the presentations, a one hour keynote session from eminent speakers will be conducted. This workshop will be planned for a half-day.

Tentative Schedule

- 8:00 - 8:15 Welcome note
- 8:15 - 9:15 Keynote session
- 9:15 - 10:30 3 oral presentations (20 mins presentation + 5 minute QA)
- 10:30 - 10:45 Break
- 10:45 - 11:35 2 oral presentations (20 mins presentation + 5 minute QA)
- 11:35-12:00 5 lightning presentation (5 mins each)
- 12:00 - 12:30: Open Discussion

List of Open Source Thermal Datasets Available Online

- Onchocerciasis Thermal Imaging Dataset from Niramai: [Dataset] [paper]
- COVID-19 Thermal Screening NTIC Dataset from Niramai: [Dataset] [paper]
- Breast Thermal Imaging Dataset from Visual Lab: [Dataset]
- Thyroid Thermal Image Dataset from Visual Lab: [Dataset]
- Plantar Thermogram Database For The Study Of Diabetic Foot Complications from INAOE [Dataset]
- Chronic Wounds Multimodal Image Database [Dataset]

*The above datasets are listed for experimentation purposes only and we do not endorse the validity or veracity of the above datasets.

Registration

Find more details about registration in MICCAI'22 conference website.

The 25th International Conference on Medical Image Computing and Computer Assisted Intervention, MICCAI 2022, will be held from September 18th to 22nd 2022 in Resort World Convention Centre Singapore. This will be the first MICCAI conference hosted in Southeast Asia.

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Questions?

Contact: aiiima.miccai@gmail.com for any queries about the MICCAI AIII Workshop

8th-9th October, Greenville, SC, USA
AAT 2022 Annual Scientific Session

The 2022 Annual Scientific Session will be a Virtual Meeting consisting of both recorded presentations and live sessions. Those who register for the full meeting with next year's membership will be given 60 days post-meeting access to the recorded presentations.

Separate registration is required for the Pre-Meeting Physician's Thermography Interpretation Course (use the "Registration" link above). The course is on line, at your own pace, with a Virtual Live question and Answer session conducted between 9:00am and 12:00pm (Eastern Time) on Friday, October 7th, 2022.

Program:

2022 Conference Schedule

- Day 1

Pre-Meeting Physician Member Interpretation Course (separate registration required): Friday, October 7th, 2022

9:00 am - 12:00 pm

Virtual Live Physician Interpretation Q & A Session
By Robert Schwartz, MD AAT COB, Greenville, SC

2:00 pm- 5.00pm

Virtual Live"Getting Started in Medical Thermology" Round Table

By Jan Crawford, RN;BSN AAT Board ,Scaly Mt.NC
Robert Kane, DC, AAT Member, San Francisco,CA
Robert Schwartz, MD AAT COB, Greenville, SC

- Day 2

General Sessions: Saturday, October 8th, 2022

- 8:00 am
  Virtual Log In Opens
- 8:15 am - 10:30 am
  Inspirational Advances for Medical Thermology

8:15 am - 8:30 am
The AAT Infrared Imaging Report Resource
By Robert Schwartz, MD AAT COB, Greenville, SC

8:30 am - 8:45 am
Thermofy Platform: Visionfy
By Mayco Moreira, CTO AAT/ABRATERM Member

8:45 am - 9:00 am
Niramai Platform: Thermalytx
By Geetha Manjunath, PhD Bengaluru, India

9:00 am - 9:15 am
PACS For Medical Thermology: PACS-IR
By Javier Gonzalez PhD AAT Member, Orlando Florida

9:15 am - 9:30 am
AI & Deep Learning For Beginners
By Geetha Manjunath, PhD Bengaluru, India

9:30 am - 10:00 am
Robot Assisted Medical Thermography: First Applications
By Marcos Brioschi, MD, PhD Sao Paulo University, Brazil. AAT Member, ABRATERM President.

- 10:00 am - 10:30 pm
  Expert Panel 1 - Q & A

- 10:30 am - 12:15 pm
  Clinician's Corner: Breast Thermography

10:30 am - 10:50 am
Critical Areas of Research Needed to Validate Breast Thermology
By Robert Kane, DC AAT Member, San Francisco, CA

10:50 am - 11:10 am
The Significance Of Alcohol Consumption And Thermal Mottling Patterns
By Christine Horner, MD AAT Board, San Diego, CA

11:10 am - 11:30 am
Patient Education On The Role Of Breast Thermal Findings
By Jan Crawford, RN, BSN AAT Board, Scaly Mt, NC

11:30 am - 11:50 am
An Integrative Approach For Breast Health Using Medical Thermology
By Kenneth Hoffman, LAC Brookfield, CT

- 11:50 am - 12:15 pm
  Expert Panel 2 - Q & A

- 12:15 pm - 1:00 pm
  Lunch

- "1:00 pm - 3:30 pm
  Clinician's Corner:
  Neuro-Musculoskeletal Thermography

1:00 pm - 1:40 pm
A Review Of Medical Thermology And Pain Medicine
By Behnum Habibi, MD AAT Board, Philadelphia, PA

1:40 pm - 2:20 pm
Medical Thermology Applied To Regenerative Medicine
By Robert Schwartz, MD AAT COB, Greenville, SC

2:20 pm - 3:00 pm
Use Of Medical Thermography In Fibromyalgia Care
By Matthew Terzella, MD AAT Board, Greenville, SC

- 3:00 pm - 3:30 pm
  Expert Panel 3 - Q & A

- 3:30 pm - 5:00 pm
  Oral Systemic Presentations

3:30 pm - 3:55 pm
Superficial Venous Disorders
By Ariel Soffer, MD AAT Member

3:55 pm - 4:20 pm
AAT Atlas of Abnormals: Case Presentations
By Charitha Gangadharan,PhD Bengaluru,India

4:20 pm - 4:40 pm
Thermography of the Eye and Orbit
By James Campbell, MD AAT Board, Clemmons, NC

4:40 pm - 5:00 pm
Update on Forensic Applications Of Thermal Imaging
By Brian Bennett Columbia, SC

- 5:00 pm - 5:30 pm Expert Panel 4 - Q & A
- 5:30 pm Saturday Session Ends
- "5:30 pm - 6:00 pm
  Virtual Meet and Mingle Reception

Day 3
General Sessions and Annual Business Meeting:
Sunday, October 9th, 2022

- 8:00 am Virtual Log In
- 8:00 am - 11:00 am
  AAT UPDATES & OUTREACH EFFORTS

8:00 am - 8:15 am
Updates On The AAT Oral Systemic Guidelines
By Robert Schwartz, MD AAT COB, Greenville, SC

8:15 am - 8:30 am
AIRR Approved Protocols
By Robert Schwartz, MD AAT COB, Greenville, SC

8:30 am - 8:45 am
The Introduction of IR Imaging Into Chiropractic
By Jaime Browning, DC AAT Member, Spartanburg, SC

8:45 am - 9:00 am
Experts In Thermology Series: Show And Tell
By Robert Kane, DC AAT Member, San Francisco, CA

- 9:00 am - 9:30 am
  Expert Panel 5 - Q & A
- 9:30 am - 11:00 am
  Veterinary Session: Thermology Presentations

9:30 am - 9:45 am
Update on the AAT Vet Guidelines
By Ken Marcella, DVM AAT Member, Canton, GA

9:45 am - 10:00 am
Clinical Implications of Asymmetrical Hypothermia
By John Godbold, Jr., DVM AAT Member, Jackson, TN, Ronald Riegel, DVM AAT Member, Marysville, OH

10:00 am - 10:30 am
Veterinarian Thermal Imaging
By Natanya Nieman, DVM Versailles, KY

- 10:30 am - 11:00 am Expert Panel 6 - Q & A
- 11:00 am General Session Ends
- 11:00 am - 1:00 pm
  Board of Directors Meeting
  Board Members Only)