

Infrared thermal imaging in health and care settings for the prevention of COVID-19 transmission

Rapid literature review

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Contents

Aim	4
Objectives	4
Search strategy	5
Results	6
Conclusions	10
References	12

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Aim

Infrared thermal imaging (ITI) of the skin is currently utilised in airports for mass temperature screening to detect febrile patients for the prevention of infectious disease transmission. The benefits of ITI over conventional temperature measurement include contactless application, and rapid on the spot testing which is ideal for high volume crowds transiting in airports.

To date, this technology has not been applied in UK health and care settings for prevention of infectious disease transmission. Conventional temperature assessment measures oral or tympanic temperature at close range. With the ongoing COVID-19 pandemic, rapid identification of potentially infectious patients, staff and visitors presenting to health and care settings is essential. ITI is an attractive option as it is rapid and provides the ability to measure temperature without breaching social distancing measures.

This aim of this review is to assess the available evidence to determine if ITI is feasible for the detection of COVID-19 cases in health and care settings.

Objectives

The following research question was addressed:

What is the efficacy of infrared thermal imaging for fever screening for the identification of COVID-19 cases in health and care settings?

Search strategy

The following search strategy was developed and search terms entered to Medline and Embase databases on 18 May 2020.

1. Thermal imag*
2. Thermography
3. Thermal scanning
4. Thermal video
5. Infrared
6. Infrared imag*
7. 1 or 2 or 3 or 4 or 5 or 6
8. Fever screen*
9. 7 and 8
10. Deduplicate, English only, human only (36 studies)

As this was a rapid review, evidence was critiqued but not formally graded with the use of an appraisal tool.

Results

Assessment of infrared thermography typically measures the sensitivity and specificity to determine the accuracy of the device. Sensitivity is the ability of a test to correctly identify those individuals with true fever (true positives). Specificity is the ability of the test to correctly identify those individuals without fever (true negatives). Positive and negative predictive values are also measured, however these are directly related to the prevalence of the disease (or fever) in the population, therefore arguably do not provide as clear an estimation of accuracy of a device as sensitivity and specificity. It is preferable to have false-positive cases rather than false-negative cases to prevent the spread of infection. Thermography devices therefore must show high specificity i.e. should have a very low proportion of false-negative cases.

Twenty-two articles were included for assessment in this rapid review; 12 of these were excluded.

Five studies assessed use of ITI in airports therefore these studies were excluded.¹⁻⁵

Five studies tested handheld devices that required close contact (~10cm) to the individual, therefore these studies were excluded.⁶⁻¹⁰ Handheld devices are less accurate than other infrared thermal systems for temperature measurement and fever detection; performance is also operator-dependent as it is aimed at the temple or forehead and distance between may affect its accuracy.^{6, 11}

One study tested a bundled intervention therefore was excluded.¹² One study was conducted outside in a tropical environment, which is not representative of UK settings therefore was also excluded.¹¹

Two systematic evidence appraisals were included.^{13, 14} The Canadian Coordinating Office for Health Technology Assessment (CCOHTA) conducted an evidence appraisal in 2003 and concluded that there was no high quality, published evidence available (at the time) on which to base a full assessment of the use of thermal imaging devices in screening for fever.¹⁴ The Emergency Care Research Institute (ECRI), a US company that evaluates medical devices, conducted a review (updated in April 2020) that assessed the accuracy of external infrared temperature screening devices with or without questionnaires for visitors and staff entering healthcare facilities to identify those who may have potentially infectious disease.¹³ This report concluded that thermography for fever screening used alone or with a questionnaire for mass screening is ineffective for detecting infected persons. The inclusion of airport studies as

evidence in the ECRI report may be a limitation; the small relative number of true fever cases in a mass airport population compared to a pandemic healthcare setting, as well as the difference in environmental factors between these settings are possible limitations. The ECRI report assessed 11 hospital screening studies, all of which were assessed for relevance for this rapid review.

Two studies were identified that assessed variation in the accuracy of measurements depending on the area of the head that is scanned.^{15, 16}

Six studies were identified that test efficacy of various thermal imaging devices within hospital settings at detecting febrile individuals;¹⁷⁻²² these are discussed in greater detail below. Only two of these studies assessed disease detection as an outcome measure. All six studies were observational and uncontrolled therefore of low quality and prone to bias from confounding factors. There was heterogeneity between studies in terms of the study population, type of device used, and study design. Not all studies assessed use of antipyretic medication. Notably, only one of these studies used a device that was capable of mass screening of moving crowds;²² the majority required people to pause in front of the device.

Chan et al tested the efficacy of a FLIR Systems ThermaCAM S40 infrared camera (image taken at 1-5 metre distance) at detecting fever ($\geq 38^{\circ}\text{C}$) in patients ($n=1,517$) presenting to the A&E department of a hospital in Hong Kong, and found the device to be unreliable.¹⁷ Even at a low cut-off temperature of 35.0°C , the maximum sensitivity was only 0.87 which means that 13% of subjects with core temperature above 38.0°C would be missed. Furthermore, the proportion of individuals testing positive would be $>50\%$ (these would then require confirmatory temperature measurements), which was much higher than the actual proportion of 7.4% febrile subjects.

Hewlett et al tested the efficacy of a ThermoScreen Infrared Fever Screening System (OptoTherm) (image taken at 6 foot distance) at detecting fever ($>101.5^{\circ}\text{F}$ ($>38.61^{\circ}\text{C}$)) in patients presenting to the emergency department (ED) at the University of Nebraska Medical Center (UNMC), a 624-bed acute care facility.¹⁸ The ED was experiencing a higher than normal patient volume (a 10%-20% increase compared with the previous year) before and during the study period because of a large number of patients with influenza-like illness presenting to the ED for evaluation during the H1N1 influenza pandemic. Sensitivity was low in this study (0.58); this suggests that the ability of the Thermoscreen to identify those with true fever was poor – 42% of possible fever patients would be missed (false-negatives).

Three different thermal imaging devices were tested on a total of 1032 subjects at a medical centre in Taiwan.²¹ The ear drum IRT, thermoguard and DITI screening station was set up away from the entrance of the hospital at distances of 0 m, 5 m, and 10 m. Temperature data at different distances and ambient temperatures were collected on 3 different days.

Sensitivity in this study for all thermal imaging devices at all distances (0, 5, 10 metres) was poor.

Three different devices were tested at three hospitals in the US; each camera was positioned 2–3 metres from the patient and captured the face and the neck.¹⁹ Cameras were calibrated daily to reduce error. Men accounted for 52.7% of the 2,873 participants; the mean age was 42 years (range 18–92 years). Confirmed fever was defined as an oral temperature of

$\geq 100^{\circ}\text{F}$ ($\geq 37.8^{\circ}\text{C}$), the three devices had calibrated cut-offs. In total, 64 (2.2%) patients had confirmed fever, including 48 (10.1%) of 476 patients that self-reported fever. Antipyretic or analgesic drug use within 8 hours was reported by 1,121 (39.0%) patients, including 39 (60.9%) who had confirmed fever. This study demonstrated that the sensitivity and specificity of screening by using thermography sensors is determined by the selected fever temperature cut-off, which tends to be 2–3 degrees lower than the standard fever threshold because of differences between skin and core temperatures. For example, lowering

OptoTherm's threshold from the optimal 95.7°F (35.38°C), to 94.5°F (34.72°C) would achieve almost 100% sensitivity but would reduce specificity to 63.6% and increase the false-positive rate to 36.4%. These possible false-positives would require further screening, using conventional temperature measurement, which might be unfeasible depending on the size of the hospital and staffing.

Bardou demonstrated that calibration of thermography devices is essential to obtaining accurate results.²⁰ After calibration testing was carried out, 625 temperature measurements (246 in-patients and out-patients, 379 HCWs) were taken; subjects had to stay for a few seconds in front of the camera. The cut-off was set at $\geq 38.5^{\circ}\text{C}$. Conventional tympanic measurements were taken as reference. Of these 625 individuals, 14 cases (2.24%) of true fever were identified; 5 febrile cases detected by both the tympanic thermometer and infrared thermal camera had an upper respiratory infection. Thirteen febrile cases were detected both with the tympanic thermometer and infrared thermal camera (true positive). Two cases were detected only by the infrared thermal camera, which were confirmed to be false-positive cases. One febrile case was not detected with the infrared thermal camera (false-negative). From this, the sensitivity of the infrared thermal camera in detecting febrile cases was identified as 0.9286 (95% CI: 0.6613–

0.9982); and the specificity of the infrared thermal camera in detecting febrile cases was identified as 0.9967 (95% CI: 0.9882–0.9996). The high values for sensitivity, specificity, positive and negative predictive values in this study may be explained by the thermal sensitivity of the infrared cameras which had been calibrated by considering variations in ambient temperature before clinical application.

Thermal imaging was used in combination with a thorough screening policy to identify SARS cases entering a hospital in Taiwan.²² During the period from April 13 to May 12 2003, 72,327 outpatients and visitors were mass screened using a digital infrared thermal imaging (DITI) system (Telesis Spectrum 9000 MB); the DITI system has two components: a sensor head and a PC imaging workstation. The system conducts mass screening of persons walking into the frame. The cut-off was $\geq 37.5^{\circ}\text{C}$. A total of 305 febrile patients (0.42%) were detected by the DITI system to have a fever higher than 37.5°C . These patients then went through a fever workup protocol to determine if they had true fever and/or SARS. From these 305 patients, 145 were found to have a true fever (tympanic measurement of $>38^{\circ}\text{C}$); three of these patients had SARS. Of the 145 false-positives, none were found to have SARS. A major limitation of this study is that the protocol used was not able to identify potential false-negatives, as tympanic measurements were only taken from individuals that were identified by the DITI system as febrile. From a correlation analysis, the sensitivity was 75% and specificity was 99.6%. This is quite a low sensitivity; indicating that 25% of possible cases may have been missed. The authors argue that at this very busy hospital (~3,000 outpatients per week), this protocol identified 3 probably SARS patients, which otherwise would have gone undetected. Screening such a huge number of outpatients using conventional temperature measurements would have been unfeasible.

From these six hospital-based studies, there was wide variation in the sensitivity of the various devices (0.13 to 0.92), demonstrating variation in efficacy to detect febrile patients.

There are a number of reasons for poor efficacy of thermal imaging devices. These include poor device quality and inadequate calibration to the setting, poor correlation between core body temperature and infrared images of skin areas, and overreliance on fever as a constant determinant of disease. Two International Standards exist in relation to fever screening; International Electrochemical Commission (IEC) 80601-2-59:2017 provides the general requirements, including equipment standards, for a screening thermograph for non-invasive febrile temperature screening of individuals under indoor environmental conditions to prevent the spread of infection.²³ It provides many performance and calibration requirements for devices used in this application. ISO/TR 13154:2017(n) provides guidance on the

implementation of IEC 80601-2-59, including the deployment, implementation and operation of a screening thermograph.²⁴ Calibration of the device is essential to ensure accuracy; the two studies that demonstrated the highest sensitivity (0.91, 0.92) both ensured that calibration was undertaken to improve accuracy.^{19, 20} A number of studies have demonstrated variation in the accuracy of measurements depending on the area of the head that is scanned. Compared to the forehead, measurements taken from the ear area (particularly the ear region at close range) and the side view of the face are the most reliable and precise.^{15, 16} The forehead continues to be favoured in mass screening programmes (i.e. at airport) for feasibility reasons;⁵ the ear and side view of the face are more difficult to capture by cameras that are set up to capture people walking face forward towards the camera. Infrared thermal scanning devices should be calibrated specifically to the setting in line with international standards and should first be piloted in the setting in which it is to be used to ensure high specificity.

The success of fever screening to detect possible COVID-19 cases is critically dependent on all cases displaying fever at the time of screening. However, fever is not a constant symptom during an infectious episode, and many COVID-19 cases do not experience fever at any time during infection.²⁵ Antipyretic drugs can also reduce the ability of thermal imaging to detect fever as they lower the core body temperature. Use of antipyretic medication can be as high as 39% in people presenting to A&E and as high as 60% in patients with confirmed fever.¹⁹

Conclusions

Only six studies were identified that assessed the efficacy of infrared thermal devices at detecting fever in health and care settings. Only two of these studies assessed disease detection as an outcome measure however COVID-19 was not included. All six studies were observational and uncontrolled therefore of low quality and prone to bias from confounding factors. There was heterogeneity between studies in terms of the study population, type of device used, and study design. Not all studies assessed use of antipyretic medication. Notably, only one study used a device that was capable of mass screening of moving crowds; the majority required people to pause in front of the device. There was wide variation in the sensitivity of the various devices.

The limited evidence highlights multiple limitations of ITI for the detection of febrile patients in health and care settings. There is not enough evidence to recommend the use of ITI for the prevention of COVID-19 transmission in health and care settings.

Studies demonstrated that to achieve a high sensitivity (to prevent false-negatives) may require lowering the cut-off for fever detection in the infrared device. This may be desirable during stages of a pandemic where the infection rate in the population is high, when true positive cases outnumber false-negatives. However, lowering the cut-off will also lower the specificity and result in a high number of false-positives; these individuals will require isolation/cohorting and further triage to establish not only if they have a true fever but also if they are positive for COVID-19. This would significantly increase the workload for health and care staff and resource may not be available to provide a second triage of possible false-positives.

Patients presenting with atypical COVID-19 symptoms (i.e. no fever) and those in which fever has passed but are still infectious, will not be identified by fever screening. This, combined with the issues regarding sensitivity, and the impact of antipyretic medication on sensitivity, indicate that health and care settings should not implement infrared thermal imaging as a means of detecting COVID-19 patients.

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