**Literature search: Clinical efficacy of having routine temperature checks at entrances like airports. The devices are either thermal detection, or with a infra-red thermometer.**

Search strategy (Pubmed): ("Non-Contact" AND (thermometer\* OR "thermal detection" OR thermograph\* OR "fever detect\*") AND (comparison OR effectiveness OR accuracy) AND (english[Filter])) OR (((("infrared" OR "infra-red") AND (temperature OR thermometer)) OR "thermal detection" OR "temperature monitor\*" OR "temperature check\*" OR "thermomet\*" OR thermograph\*) AND (pandemic\* OR epidemic\* OR coronavirus OR sars OR mers OR covid\*) AND (english[Filter]))

Contents

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[Sun, G., et al. (2013). "Development of an infection screening system for entry inspection at airport quarantine stations using ear temperature, heart and respiration rates." Conf Proc IEEE Eng Med Biol Soc **2013**: 6716-6719. 9](#_Toc38626127)

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[Yao, Y., et al. (2016). "Multiple Vital-Sign-Based Infection Screening Outperforms Thermography Independent of the Classification Algorithm." IEEE Trans Biomed Eng **63**(5): 1025-1033. 10](#_Toc38626129)

# (2014). CADTH Rapid Response Reports. Mass Thermography Screening for Infection and Prevention: A Review of the Clinical Effectiveness. Ottawa (ON), Canadian Agency for Drugs and Technologies in Health

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Full text: <https://www.ncbi.nlm.nih.gov/books/n/rc0609/pdf/>

CONCLUSIONS AND IMPLICATIONS FOR DECISION OR POLICY MAKING

Fever screening was implemented at border crossings after the global outbreak of SARS, which prompted countries to set up border control strategies.2 According to the included studies, fever screening at international airports was generally not effective at detecting H1N1-2009 and other influenza viruses, or dengue fever. One study performed in a controlled setting assessed how well IRT readings correlated with conventional methods and found only moderate correlation. The study concluded that IRT would not be suitable as a routine screening tool due to the high number of false positives. Relatively low sensitivity and positive predictive values were also seen in studies looking at fever as a predictor of influenza or dengue fever. The reason for these results may be due to the delayed appearance of febrile symptoms for these infectious diseases. Infection associated with the influenza virus begins a few hours before the onset of symptoms, and the viremia of dengue begins one day before the onset of febrile symptoms, making it difficult to detect cases via fever screening.8 The Ebola epidemic in West Africa was declared a public health emergency of international concern by the World Health Organization on August 8, 2014.4 The Ebola virus has an average 8 to 10 day incubation period (range 2 to 21 days) during which the traveller would experience no symptoms.4 This would make it difficult to detect travellers who have been recently infected with the virus at border screenings. Fever screening in the included studies consisted of a combination of health declaration forms, IRT, a conventional temperature measurement and laboratory testing to confirm diagnosis. Despite using all of these methods, results showed that fever screening was not a very effective strategy at detecting infected individuals. A limitation of this review was the lack of studies that assessed how border control strategies would mitigate the risk of disease outbreaks.

# (2014). CADTH Rapid Response Reports. Non-Contact Thermometers for Detecting Fever: A Review of Clinical Effectiveness. Ottawa (ON), Canadian Agency for Drugs and Technologies in Health

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Full text: <https://www.ncbi.nlm.nih.gov/books/NBK263237/pdf/Bookshelf_NBK263237.pdf>

CONCLUSIONS AND IMPLICATIONS FOR DECISION OR POLICY MAKING

Most of the non-randomized studies included in this review had a similar prospective observationnal design with non-blinded measurements taken in a single group. Two SRs were deemed of average quality and two had many limitations. A majority of studies used rectal, oral, axillary, tympanic, or pulmonary artery catheter as a reference for body temperature. Seven out of twenty publications were specifically investigating pediatric patients, while only one enrolled geriatric patients. Three studies were conducted at a border crossing; others were in hospitals. The most commonly reported outcomes were sensitivity, specificity, PPV, NPV, positive/negative likelihood ratios, corelation coefficient and AUROC.

The conclusions of six non-randomized studies and two SRs supported the utilization of tympanic thermometry. The conclusions from one study and one SR were not in favor of its accuracy. The evidence is then in favor of the accuracy of tympanic thermometers. The accuracy of handheld infrared skin thermometers were favored by three studies but also unfavored by three studies. Four studies expressed conclusions in favor of the utilization of thermal scanners for fever detection, whereas one study stated that this type of device is unsuitable for this purpose. The conclusions of a SR, although of low quality, highlighted the poor scientific evidence available for the utilization of infrared skin thermometers and thermal scanners for mass screening. Evidence for the accuracy of infrared skin thermometers is equivocal whereas it is somehow in favor of the accuracy of thermal scanners.

Many issues raise doubts about the generalizability of the included studies. It is not clear if the people who refused to participate in these studies biased the results and the percentage of enrollment among eligible participants was not reported in most of the studies. The retrieved studies have mentioned potential confounders for measure of temperature such as sweat, gender, age, the range of temperature, the rater, physical activity, the use of antipyretic drugs and emotional state. These factors are even more susceptible to vary in a real world conditions than in a clinical study setting. Moreover, the different brand/model/mode of devices used make it difficult to draw general conclusions on a class of thermometers. Also, a fair number of pediatric studies were included in the present review, limiting the extrapolation of their results to a general population.

Depending on the context of utilization (hospital vs border), the volume of measurements to be done and the age of the person to be measured, it might be imperative to use infrared thermometers over more accurate and/or more invasive thermometers. Therefore, tympanic thermometers and thermal scanners might be the only effective and accurate tools to detect fever under certain circumstances. However, one has to keep in mind that screening for fever and screening for a virus are two different issues.

In conclusion, evidence retrieved from sixteen non-randomized studies and four systematic reviews is in favor of accuracy of tympanic thermometers and, more cautiously, of thermal scanners. Evidence for the accuracy of infrared skin thermometers is equivocal and requires more research. The generalizability of the evidence found is nevertheless uncertain.

# Aw, J. (2020). "The non-contact handheld cutaneous infra-red thermometer for fever screening during the COVID-19 global emergency." J Hosp Infect **104**(4): 451.

Full text: <https://www.journalofhospitalinfection.com/action/showPdf?pii=S0195-6701%2820%2930058-X>

# Basak, T., et al. (2013). "Comparison of three different thermometers in evaluating the body temperature of healthy young adult individuals." Int J Nurs Pract **19**(5): 471-478.

Full text: 

The aim of this study was to compare the measurement values obtained with a non-contact infrared thermometer, a tympanic thermometer and a chemical dot thermometer. The research population was composed of students studying in two departments of a university in Ankara. A total of 452 students who fit the inclusion criteria of the study and volunteered to participate were included in the sample. Body temperature measurements with different thermometers were performed by the same researcher at the same room temperature. Data were analyzed in a computerized environment by SPSS 15.0 statistical program pack and Bland-Altman graph. Mean age of healthy young adults participating in the study was 19.66 ± 0.94, and 55.1% of them were female. The agreement limits for non-contact infrared and chemical dot was between -1.30 and 0.32°C; for non-contact infrared and tympanic was between -1.26 and 0.13°C; and for chemical dot and tympanic -0.89 and 0.74°C. It was determined that, although the measurement values of the tympanic membrane and chemical dot thermometers conformed with each other, the conformity of the non-contact infrared thermometer was weak.

# Bitar, D., et al. (2009). "International travels and fever screening during epidemics: a literature review on the effectiveness and potential use of non-contact infrared thermometers." Euro Surveill **14**(6).

Full text: <https://www.eurosurveillance.org/docserver/fulltext/eurosurveillance/14/6/art19115-en.pdf?expires=1587728203&id=id&accname=guest&checksum=D16A022A6D6D023EE8995BAFA2F156F3>

Several countries plan to introduce non-contact infrared thermometers (NCIT) at international airports in order to detect febrile passengers, thus to delay the introduction of a novel influenza strain. We reviewed the existing studies on fever screening by NCIT to estimate their efficacy under the hypothesis of pandemic influenza. Three Severe Acute Respiratory Syndrome (SARS) or dengue fever interventions in airports were excluded because of insufficient information. Six fever screening studies in other gathering areas, mainly hospitals, were included (N= 176 to 72,327 persons; fever prevalence= 1.2% to 16.9%). Sensitivity varied from 4.0% to 89.6%, specificity from 75.4% to 99.6%, positive predictive value (PPV) from 0.9% to 76.0% and negative predictive value (NPV) from 86.1% to 99.7%. When we fixed fever prevalence at 1% in all studies to allow comparisons, the derived PPV varied from 3.5% to 65.4% and NPV was >or=99%. The low PPV suggests limited efficacy of NCIT to detect symptomatic passengers at the early stages of a pandemic influenza, when fever prevalence among passengers would be =or<1%. External factors can also impair the screening strategy: passengers can hide their symptoms or cross borders before symptoms occur. These limits should be considered when setting up border control measures to delay the pandemic progression.

# Bordonaro, S. F., et al. (2016). "Human temperatures for syndromic surveillance in the emergency department: data from the autumn wave of the 2009 swine flu (H1N1) pandemic and a seasonal influenza outbreak." BMC Emerg Med **16**: 16.

Full text: <https://bmcemergmed.biomedcentral.com/track/pdf/10.1186/s12873-016-0080-7>

BACKGROUND: The emergency department (ED) increasingly acts as a gateway to the evaluation and treatment of acute illnesses. Consequently, it has also become a key testing ground for systems that monitor and identify outbreaks of disease. Here, we describe a new technology that automatically collects body temperatures during triage. The technology was tested in an ED as an approach to monitoring diseases that cause fever, such as seasonal flu and some pandemics. METHODS: Temporal artery thermometers that log temperature measurements were placed in a Boston ED and used for initial triage vital signs. Time-stamped measurements were collected from the thermometers to investigate the performance a real-time system would offer. The data were summarized in terms of rates of fever (temperatures ≥100.4 °F [≥38.0 °C]) and were qualitatively compared with regional disease surveillance programs in Massachusetts. RESULTS: From September 2009 through August 2011, 71,865 body temperatures were collected and included in our analysis, 2073 (2.6 %) of which were fevers. The period of study included the autumn-winter wave of the 2009-2010 H1N1 (swine flu) pandemic, during which the weekly incidence of fever reached a maximum of 5.6 %, as well as the 2010-2011 seasonal flu outbreak, during which the maximum weekly incidence of fever was 6.6 %. The periods of peak fever rates corresponded with the periods of regionally elevated flu activity. CONCLUSIONS: Temperature measurements were monitored at triage in the ED over a period of 2 years. The resulting data showed promise as a potential surveillance tool for febrile disease that could complement current disease surveillance systems. Because temperature can easily be measured by non-experts, it might also be suitable for monitoring febrile disease activity in schools, workplaces, and transportation hubs, where many traditional syndromic indicators are impractical. However, the system's validity and generalizability should be evaluated in additional years and settings.

# Chiang, M. F., et al. (2008). "Mass screening of suspected febrile patients with remote-sensing infrared thermography: alarm temperature and optimal distance." J Formos Med Assoc **107**(12): 937-944.

Full text: <https://www.sciencedirect.com/science/article/pii/S0929664609600176>

BACKGROUND/PURPOSE: Detection of fever has become an essential step in identifying patients who may have severe acute respiratory syndrome (SARS) or avian influenza. This study evaluated infrared thermography (IRT) and compared the influence of different imagers, ambient temperature discrepancy, and the distance between the subject and imager. METHODS: IRT-digital infrared thermal imaging (IRT-DITI), thermoguard, and ear drum IRT were used for visitors to Municipal Wang Fang Hospital, Taipei, Taiwan. The McNemar and Chi-squared test, standard Pearson correlation, ANOVA, intraclass correlation coefficient (ICC), and receiver operating characteristic curve (ROC) analysis were used to calculate the alarm temperature for each imager. RESULTS: A total of 1032 subjects were recruited. Different distances and ambient temperature discrepancy had a significant influence on thermoguard, and lateral and frontal view DITI. By ICC analysis, a significant difference was found at 10 m distance between ear drum IRT and thermoguard (r = 0.45), lateral view DITI (r = 0.37), and frontal view DITI (r = 0.44). With ROC analysis, the optimal preset cut-off temperatures for the different imagers were: 36.05 degrees C for thermoguard (area under the curve [AUC], 0.716), 36.25 degrees C for lateral view DITI (AUC, 0.801), and 36.25 degrees C for frontal view DITI (AUC, 0.812). CONCLUSION: The temperature readings obtained by IRT may be used as a proxy for core temperature. An effective IRT system with a strict operating protocol can be rapidly implemented at the entrance of a hospital during SARS or avian influenza epidemics.

# Fletcher, T., et al. (2018). "Comparison of non-contact infrared skin thermometers." J Med Eng Technol **42**(2): 65-71.

Full text: 

Non-contact infra-red skin thermometers (NCITs) are becoming more prevalent for use in medical diagnostics. Not only are they used as an alternative means of estimating core body temperature but also to assess the diabetic foot for signs of inflammation prior to ulceration. Previous investigations have compared the performance of NCITs in a clinical setting against other gold standard methods. However, there have been no previous investigations comparing the performance of NCITs in assessing temperature measurement capability traceable to the International Temperature Scale of 1990 (ITS-90). A metrological assessment of nine common NCITs was carried out over the temperature range of 15-45 °C using the National Physical Laboratory's blackbody reference sources to identify their accuracy, repeatability, size-of-source and distance effects. The results are concerning in that five of the NCITs fell far outside the accuracy range stated by their manufacturers as well as the medical standard to which the NCITs are supposed to adhere. Furthermore, a 6 °C step change in measurement error over the temperature range of interest for the diabetic foot was found for one NCIT. These results have implications for all clinicians using NCITs for temperature measurement and demonstrate the need for traceable calibration to ITS-90.

# Ghassemi, P., et al. (2018). "Best practices for standardized performance testing of infrared thermographs intended for fever screening." PLoS One **13**(9): e0203302.

Full text: <https://doi.org/10.1371/journal.pone.0203302>

Infrared (IR) modalities represent the only currently viable mass fever screening approaches for outbreaks of infectious disease pandemics such as Ebola virus disease and severe acute respiratory syndrome. Non-contact IR thermometers (NCITs) and IR thermographs (IRTs) have been used for fever screening in public areas such as airports. While NCITs remain a more popular choice than IRTs, there has been increasing evidences in the literature that IRTs can provide great accuracy in estimating body temperature if qualified systems are used and appropriate procedures are consistently applied. In this study, we addressed the issue of IRT qualification by implementing and evaluating a battery of test methods for objective, quantitative assessment of IRT performance based on a recent international standard (IEC 80601-2-59). We tested two commercial IRTs to evaluate their stability and drift, image uniformity, minimum resolvable temperature difference, and radiometric temperature laboratory accuracy. Based on these tests, we illustrated how experimental and data processing procedures could affect results, and suggested methods for clarifying and optimizing test methods. Overall, the insights into thermograph standardization and acquisition methods provided by this study may improve the utility of IR thermography and aid in comparing IRT performance, thus improving the potential for producing high quality disease pandemic countermeasures.

# Hewlett, A. L., et al. (2011). "Evaluation of an infrared thermal detection system for fever recognition during the H1N1 influenza pandemic." Infect Control Hosp Epidemiol **32**(5): 504-506.

Full text: 

Infrared thermal detection systems (ITDSs) have been utilized in several countries to screen for fever in travelers. Since fever screening with an ITDS is rapid and noninvasive, this technology may be useful as an infection control measure in clinical settings during a pandemic.

# Ng, E. Y. and R. U. Acharya (2009). "Remote-sensing infrared thermography." IEEE Eng Med Biol Mag **28**(1): 76-83.

Full text: 

The outbreak of the severe acute respiratory syndrome (SARS) in 2003 has ignited studies and research (and even the general public interest) in the field of infrared (IR) imaging systems for blind mass human fever screening to control the spread of the pandemic. The ideal device for blind mass fever screening should be speedy, noninvasive, and able to accurately detect people with fever. IR thermography has been used to detect inflammatory abnormalities and has the potential to serve as a tool for mass screening of fever. This article reviews the IR fever-screening systems and suggests the performance and environmental requirements for characterizing thermography for possible fever screening, during the onset of a pandemic, under indoor controlled-environmental conditions.

# Nishiura, H. and K. Kamiya (2011). "Fever screening during the influenza (H1N1-2009) pandemic at Narita International Airport, Japan." BMC Infect Dis **11**: 111.

Full text: <https://link.springer.com/article/10.1186/1471-2334-11-111>

BACKGROUND: Entry screening tends to start with a search for febrile international passengers, and infrared thermoscanners have been employed for fever screening in Japan. We aimed to retrospectively assess the feasibility of detecting influenza cases based on fever screening as a sole measure. METHODS: Two datasets were collected at Narita International Airport during the 2009 pandemic. The first contained confirmed influenza cases (n = 16) whose diagnosis took place at the airport during the early stages of the pandemic, and the second contained a selected and suspected fraction of passengers (self-reported or detected by an infrared thermoscanner; n = 1,049) screened from September 2009 to January 2010. The sensitivity of fever (38.0 °C) for detecting H1N1-2009 was estimated, and the diagnostic performances of the infrared thermoscanners in detecting hyperthermia at cut-off levels of 37.5 °C, 38.0 °C and 38.5 °C were also estimated. RESULTS: The sensitivity of fever for detecting H1N1-2009 cases upon arrival was estimated to be 22.2% (95% confidence interval: 0, 55.6) among nine confirmed H1N1-2009 cases, and 55.6% of the H1N1-2009 cases were under antipyretic medications upon arrival. The sensitivity and specificity of the infrared thermoscanners in detecting hyperthermia ranged from 50.8-70.4% and 63.6-81.7%, respectively. The positive predictive value appeared to be as low as 37.3-68.0%. CONCLUSIONS: The sensitivity of entry screening is a product of the sensitivity of fever for detecting influenza cases and the sensitivity of the infrared thermoscanners in detecting fever. Given the additional presence of confounding factors and unrestricted medications among passengers, reliance on fever alone is unlikely to be feasible as an entry screening measure.

# Normile, D. (2020). Airport screening is largely futile, research shows. Science. United States. **367:** 1177-1178.

Full text: 

# Priest, P. C., et al. (2011). "Thermal image scanning for influenza border screening: results of an airport screening study." PLoS One **6**(1): e14490.

Full text: <https://doi.org/10.1371/journal.pone.0014490>

BACKGROUND: Infrared thermal image scanners (ITIS) appear an attractive option for the mass screening of travellers for influenza, but there are no published data on their performance in airports. METHODS: ITIS was used to measure cutaneous temperature in 1275 airline travellers who had agreed to tympanic temperature measurement and respiratory sampling. The prediction by ITIS of tympanic temperature (37.8°C and 37.5°C) and of influenza infection was assessed using Receiver Operating Characteristic (ROC) curves and estimated sensitivity, specificity and positive predictive value (PPV). FINDINGS: Using front of face ITIS for prediction of tympanic temperature ≥37.8°C, the area under the ROC curve was 0.86 (95%CI 0.75-0.97) and setting sensitivity at 86% gave specificity of 71%. The PPV in this population of travellers, of whom 0.5% were febrile using this definition, was 1.5%. We identified influenza virus infection in 30 travellers (3 Type A and 27 Type B). For ITIS prediction of influenza infection the area under the ROC curve was 0.66 (0.56-0.75), a sensitivity of 87% gave specificity of 39%, and PPV of 2.8%. None of the 30 influenza-positive travellers had tympanic temperature ≥37.8°C at screening (95%CI 0% to 12%); three had no influenza symptoms. CONCLUSION: ITIS performed moderately well in detecting fever but in this study, during a seasonal epidemic of predominantly influenza type B, the proportion of influenza-infected travellers who were febrile was low and ITIS were not much better than chance at identifying travellers likely to be influenza-infected. Although febrile illness is more common in influenza A infections than influenza B infections, many influenza A infections are afebrile. Our findings therefore suggest that ITIS is unlikely to be effective for entry screening of travellers to detect influenza infection with the intention of preventing entry of the virus into a country.

# Sun, G., et al. (2013). "Development of an infection screening system for entry inspection at airport quarantine stations using ear temperature, heart and respiration rates." Conf Proc IEEE Eng Med Biol Soc **2013**: 6716-6719.

Full text: <https://ieeexplore.ieee.org/abstract/document/6611097>

After the outbreak of severe acute respiratory syndrome (SARS) in 2003, many international airport quarantine stations conducted fever-based screening to identify infected passengers using infrared thermography for preventing global pandemics. Due to environmental factors affecting measurement of facial skin temperature with thermography, some previous studies revealed the limits of authenticity in detecting infectious symptoms. In order to implement more strict entry screening in the epidemic seasons of emerging infectious diseases, we developed an infection screening system for airport quarantines using multi-parameter vital signs. This system can automatically detect infected individuals within several tens of seconds by a neural-network-based discriminant function using measured vital signs, i.e., heart rate obtained by a reflective photo sensor, respiration rate determined by a 10-GHz non-contact respiration radar, and the ear temperature monitored by a thermography. In this paper, to reduce the environmental effects on thermography measurement, we adopted the ear temperature as a new screening indicator instead of facial skin. We tested the system on 13 influenza patients and 33 normal subjects. The sensitivity of the infection screening system in detecting influenza were 92.3%, which was higher than the sensitivity reported in our previous paper (88.0%) with average facial skin temperature.

# Teran, C. G., et al. (2012). "Clinical accuracy of a non-contact infrared skin thermometer in paediatric practice." Child Care Health Dev **38**(4): 471-476.

Full text: 

BACKGROUND: Rectal thermometry is considered the most reliable method for measuring the temperature in the paediatric population. Recently, a new non-contact skin infrared thermometer for children was introduced in the market with excellent acceptance by parents. METHODS: A prospective, analytical, cross-sectional study was designed in order to assess the effectiveness of the infrared non-contact thermometer (Thermofocus) in comparison with two other known methods used to measure body temperature. Children aged 1 to 48 months were included from the emergency room and inpatient unit. All patients selected were assessed with three different thermometers: (1) non-contact infrared thermometer (Thermofocus); (2) temporal artery thermometer (Exergen); and (3) rectal glass mercury thermometer. RESULTS: Four hundred and thirty-four patients were eligible to complete the study. One hundred and sixty-seven were identified with fever. The mean age of the patients studied was 14.6 ± 10.7 months. Both devices were strongly correlated with the rectal temperature: r = 0.950 for Exergen and r = 0.952 for Thermofocus. The mean difference in temperature between the rectal temperature and the non-contact thermometer was 0.029 ± 0.01 °C (P < 0.001), while the mean difference between the temporal artery thermometer and the rectal temperature was -0.20 ± 0.27 °C (P < 0.001). The sensitivity and specificity for the non-contact thermometer is 97%. The negative predictive value is 99%, which is especially important to rule out fever and avoid unnecessary laboratory work-up. CONCLUSIONS: The non-contact infrared thermometer is a reliable, comfortable and accurate option for measurement of temperature and is very useful for the screening of fever in the paediatric population. More studies are recommended to support the evidence found in this study and compare its accuracy with more complex devices.

# Yao, Y., et al. (2016). "Multiple Vital-Sign-Based Infection Screening Outperforms Thermography Independent of the Classification Algorithm." IEEE Trans Biomed Eng **63**(5): 1025-1033.

Full text: <https://ieeexplore.ieee.org/abstract/document/7271021>

GOAL: Thermography-based infection screening at international airports plays an important role in the prevention of pandemics. However, studies show that thermography suffers from low sensitivity and specificity. To achieve higher screening accuracy, we developed a screening system based on the acquisition of multiple vital-signs. This multimodal approach increases accuracy, but introduces the need for sophisticated classification methods. This paper presents a comprehensive analysis of the multimodal approach to infection screening from a machine learning perspective. METHODS: We conduct an empirical study applying six classification algorithms to measurements from the multimodal screening system and comparing their performance among each other, as well as to the performance of thermography. In addition, we provide an information theoretic view on the use of multiple vital-signs for infection screening. The classification methods are tested using the same clinical data, which has been analyzed in our previous study using linear discriminant analysis. A total of 92 subjects were recruited for influenza screening using the system, consisting of 57 inpatients diagnosed to have seasonal influenza and 35 healthy controls. RESULTS: Our study revealed that the multimodal screening system reduces the misclassification rate by more than 50% compared to thermography. At the same time, none of the multimodal classifiers needed more than 6 ms for classification, which is negligible for practical purposes. CONCLUSION: Among the tested classifiers k-nearest neighbors, support vector machine and quadratic discriminant analysis achieved the highest cross-validated sensitivity score of 93%. SIGNIFICANCE: Multimodal infection screening might be able to address the shortcomings of thermography.