Canadian Agency for Drugs and Technologies in Health

RAPID RESPONSE REPORT: SUMMARY WITH CRITICAL APPRAISAL

TITLE: **Mass Thermography Screening for Infection and Prevention: A Review of the Clinical Effectiveness**

DATE: 19 November 2014

CONTEXT AND POLICY ISSUES

Thermography involves the quantification of emitted radiation to measure temperature, and provides a quick non-invasive means to measure body temperature.[1] Infrared thermography (IRT) can be implemented at international airports in order to detect febrile passengers and prevent the introduction and spread of infectious diseases to other countries.[2] Border control strategies were enacted as a response to the emergence of Severe Acute Respiratory Syndrome (SARS) in 2003, which included the introduction of non-contact infrared thermal scanners at international airports and bus or railway stations for mass screening of individuals.[2] IRT has also been used as a measure to detect and prevent influenza outbreaks and transmission of dengue fever across borders.[2]

IRT may be influenced by several confounding factors including age and outdoor temperature.[3] In addition, results from studies looking at IRT as a tool to detect fever tend to have small positive predictive values due to the small prevalence of febrile passengers.[3] However, advantages of using IRT include its ability to screen mass numbers of individuals and reduce close contacts with infected individuals.[2] Recently, the 2014 Ebola epidemic in West Africa has renewed concerns of disease transmission across borders and increased vigilance to identify individuals entering the country who may harbour infection.[4]

The purpose of this review is to examine the effectiveness of screening for fever at border crossings to reduce the risk of infectious disease outbreaks.

RESEARCH QUESTION

What is the effectiveness of screening for fever at border crossings to reduce the risk of outbreaks?

KEY FINDINGS

One prospective study found that infrared thermography readings correlated moderately well with temperature readings taken using a conventional method (oral, aural, or axillary). One prospective study and four retrospective studies found that fever screening using a combination of infrared thermography, health declaration forms, and a conventional method at international airports had low sensitivity for detecting influenza viruses and dengue fever. There were no studies that assessed how border control strategies would mitigate the risk of disease outbreaks.

METHODS

Literature Search Strategy

A limited literature search was conducted on key resources including PubMed, The Cochrane Library (2014, Issue 10), University of York Centre for Reviews and Dissemination (CRD) databases, Canadian and major international health technology agencies, as well as a focused Internet search. No filters were applied to limit the retrieval by study type. Where possible, retrieval was limited to the human population. The search was also limited to English language documents published between January 1, 2004 and October 15, 2014.

Selection Criteria and Methods

One reviewer screened citations and a second reviewer selected studies based on full-text review. In the first level of screening, titles and abstracts were reviewed and potentially relevant articles were retrieved and assessed for inclusion. The final selection of full-text articles was based on the inclusion criteria presented in Table 1.

Table 1: Selection Criteria	
Population	Any traveller
Intervention	Mass screening with infrared thermography (IRT)
Comparator	None
Outcomes	Effectiveness for detecting fever and/or infection, accuracy, outbreak prevention, reduction of infection spread
Study Designs	Health technology assessments, systematic reviews, meta-analyses, randomized controlled trials, non-randomized studies

Exclusion Criteria

Studies were excluded if they did not satisfy the selection criteria, if they were duplicate publications, or were published prior to 2004.

Critical Appraisal of Individual Studies

The quality of included non-randomized studies were evaluated using the Downs and Black instrument.[5] A numeric score was not calculated for each study. Instead, strengths and limitations of each study were summarized and described.

SUMMARY OF EVIDENCE

Quantity of Research Available

A total of 399 citations were identified in the literature search. Following screening of titles and abstracts, 389 citations were excluded and 10 potentially relevant reports from the electronic search were retrieved for full-text review. No potentially relevant publications were retrieved from the grey literature search. Of these potentially relevant articles, three publications were excluded due to irrelevant outcomes, while seven publications met the inclusion criteria and were included in this report. Appendix 1 describes the PRISMA flowchart of the study selection.

Summary of Study Characteristics

Details on study characteristics can be found in Appendix 2.

Study design and country of origin

Five retrospective studies[3,6-9] and two prospective studies[10,11] were included. One retrospective study from Korea[6] and one prospective study from Hong Kong[6] considered the use of IRT for the detection of fever. Two retrospective studies from Australia[7] and Japan[3] and one prospective study from New Zealand[11] investigated the use of IRT for the identification of travellers with influenza. Two retrospective studies from Taiwan[8,9] investigated the use of IRT for the detection of dengue fever. The prospective study from Hong Kong was conducted in a controlled setting,[10] while all other included studies were conducted at international airports.

Participants

The prospective study from Hong Kong recruited participants from the accident and emergency department of a hospital.[10] All of the other studies performed screenings of inbound passengers at international airports. One retrospective study screened patients at an international airport in Korea between January 1, 2012 and December 31, 2012.[6] One retrospective study screened patients at the Sydney airport between April 28, 2009 and June 18, 2009 to detect H1N1-2009.[7] One retrospective study screened patients at the Narita international airport in Japan between April 28, 2009 and June 18, 2009, and between September 2009 and January 2010 to detect H1N1-2009 and influenza cases.[3] One prospective study screened patients at the Christchurch international airport in New Zealand between August 21, 2008 and September 12, 2008 to detect influenza.[11] Two retrospective studies screened patients at the Taoyuan and Kaohsiung international airports in Taiwan for dengue fever; one analyzed data between the years of 2007 to 2010, and the other between July 2003 and June 2004.[8,9]

Interventions

The prospective study from Hong Kong compared temperature measurements from IRT to core temperatures measured by conventional oral thermometry or aural temperature.[10] The prospective study from New Zealand measured temperature using IRT and compared it to a tympanic temperature reading.[11] The retrospective study from Korea analyzed IRT measurements, tympanic temperature measurements, and health declaration forms.[6] The retrospective study from Australia analyzed IRT measurements, health declaration forms, and clinical assessments that included a nose and throat swab.[7] The retrospective study from Japan analyzed IRT measurements, axillary temperature measurements, and self-reports and reports by relatives and friends.[3] Both retrospective studies from Taiwan analyzed IRT measurements, tympanic temperature measurements, and confirmation of dengue fever diagnoses via reverse transcription polymerase chain reaction (RT-PCR) and other laboratory tests.[8,9]

Outcomes measured

The prospective study from Hong Kong assessed the correlation between IRT readings and core temperature readings (oral or aural), and defined fever as having a core temperature of at least 38^{o}C.[10] The prospective study from New Zealand assessed the accuracy of IRT in predicting tympanic temperature, and defined fever as having a tympanic temperature of at least 37.8^{o}C.[11] The retrospective study from Korea assessed the prevalence of febrile arrivals (defined as a tympanic temperature above 37.8^{o}C) and the association between IRT readings and tympanic temperature readings.[6] The retrospective study from Australia determined the sensitivity, specificity, and positive predictive value of airport fever screening at detecting H1N1-2009 using the total number of overseas-acquired cases in the study period.[7] The retrospective study from Japan assessed the sensitivity and specificity of IRT at detecting febrile individuals, and the correlation between IRT and axillary temperature.[3] One retrospective study from Taiwan assessed the sensitivity, specificity, positive predictive value, and negative predictive value of IRT at detecting dengue fever cases using the total number of imported dengue cases as detected by passive and active surveillance, and defined fever as having an ear temperature of greater than 38^{o}C.[8] One retrospective study from Taiwan determined the proportion of dengue cases identified by active surveillance.[9]

Summary of Critical Appraisal

Details of the critical appraisal can be found in Appendix 3.

All of the included studies enrolled large numbers of participants or had access to large datasets of travellers. All participants had both IRT readings and temperature readings using a conventional method (gold standard) in the majority of included studies.[3,6,8-11] No conventional temperature reading was performed in the retrospective study from Australia.[7]

One prospective study recruited patients from a Hong Kong hospital, which may not be representative of the general population that would be screened at border crossings.[10] The other included studies analyzed datasets or screened participants at international airports, which represented a real-world setting in which IRT would be applied. However, the studies that screened passengers in an airport setting were screening for specific infections that included H1N1-2009 and influenza strains,[3,7,11] dengue fever,[8,9] or general febrile arrivals,[6] and may not be generalizable to screening for other infectious diseases.

The prospective study from Hong Kong performed temperature readings using both IRT and a conventional method on the entire sample of patients, even those that were not necessarily febrile.[7] The other studies that performed temperature readings using both IRT and a conventional method generally only did so on patients suspected of having a fever via initial IRT screening, and so these samples were enriched with symptomatic travellers.[3,6,8,9,11] In addition, this would not allow for the analysis of the number of travellers who were febrile but were not detected by IRT. The retrospective study from Australia assumed that 45 people with overseas-acquired H1N1-2009 would have passed through the airport during the time of the study, but it was not clear how this number was obtained.[7]

Summary of Findings

What is the effectiveness of screening for fever at border crossings to reduce the risk of outbreaks?

Febrile Detection

The prospective study from Hong Kong found that the correlation coefficients between IRT and conventional temperature measurements (oral or aural) ranged from 0.361 when IRT readings were targeted at the forehead to 0.440 when using the IRT readings of the maximum lateral temperature.[10] Higher correlations between IRT readings and conventional temperature readings were found in febrile participants (≥ 38°C; range 0.224 to 0.328) compared to non-febrile participants (< 38°C; range 0.241 to 0.273). The prospective study also found that the IRT readings would decrease on average by 0.3°C per meter increase in distance from the camera. The Area Under the Receiver Operating Characteristic Curve (AUROC) for distinguishing between febrile and non-febrile participants using a cut-off of 38°C ranged from 0.780 (95% CI 0.723 to 0.837) when IRT readings were targeted at the forehead to 0.815 (95% CI 0.763 to 0.867) when IRT readings were targeted at the maximum lateral temperature.

The retrospective study conducted at an international airport in Korea between January 1, 2012 and December 2, 2012 found that fever screening using IRT (set at 36°C), tympanic temperature readings, and health declaration forms, identified six febrile arrivals of 355,887 total arrivals and 608 self-declared symptomatic arrivals as defined by a tympanic temperature above 37.8°C.[6] This study found that there was no statistically significant difference between IRT readings and tympanic temperature readings (average temperature 36.83°C versus 38.14°C, respectively).

H1N1-2009 and Influenza

The retrospective study from Australia identified 5845 symptomatic or febrile passengers of 625,147 arrivals at the Sydney airport between April 28, 2009 and June 18, 2009 using health declaration cards and IRT set at 38°C ± 2°C.[7] Of the 5845 symptomatic or febrile passengers, 1296 were identified as requiring further assessment and 3 were confirmed to have H1N1-2009. Of the 1296 passengers identified as requiring further assessment, 1144 (88.27%) were detected through health declaration cards and 11 (0.85%) were detected by IRT. The study assumed that 45 people with overseas-acquired H1N1-2009 would have passed through the airport during the study duration, giving a sensitivity of 6.67% (95% CI 1.40 to 18.27) and PPV of 0.05% (95% CI 0.02 to 0.15) for the airport screening program.

The retrospective study from Japan screened 9,140,435 passengers through the Narita airport between September 1, 2009 and January 31, 2010 and identified 1049 passengers who had axillary temperatures measured based on self-reported symptoms, symptoms reported by relatives or friends, or temperature detected by IRT (set at 35.4°C).[3] The correlation coefficient between IRT readings and axillary temperature readings was 0.44. Using the cut-off levels of

37.5°C, 38.0°C and 38.5°C, the sensitivities were estimated to be 58.3%, 50.8% and 70.4%, respectively; the PPV ranged from 37.3% to 68.0%; the AUROC ranged from 74.0% to 75.9%. The same study also used a dataset of passengers traveling through the Narita airport between April 28, 2009 and June 18, 2009 to determine the sensitivity of fever for detecting influenza. Of 441,041 passengers screened during this period, 16 passengers were confirmed to have influenza using RT-PCR (9 H1N1-2009, 7 influenza A). Using a cut-off level of 37.5°C or 38.0°C axillary temperature, the sensitivities of fever for detecting influenza was 22.2% (95% CI 0 to 56.0) for H1N1 and 42.9% (95% CI 14.3 to 85.7) for other influenza viruses.

The prospective study from New Zealand screened 5274 passengers who returned a screening questionnaire using IRT.[11] Of these passengers, 1275 passengers had IRT measurements, tympanic temperature measurements and respiratory sampling performed and were included in the analyses. The AUROC for distinguishing between febrile and non-febrile participants using a cut-off tympanic temperature of 37.8°C was 0.86 (95% CI 0.75 to 0.97) when IRT readings were targeted at the front of the face and 0.76 (95% CI 0.54 to 0.97) when IRT readings were targeted at the side of the face. This study also analyzed fever as a predictor of influenza infection, and found that of the 30 respiratory samples that tested positive for influenza (3 type A, 27 type B), 27 of the passengers were symptomatic, but none had a measured tympanic temperature of ≥ 37.8°C.

Dengue Fever

Both retrospective studies that assessed the effectiveness of fever screening at detecting dengue fever were conducted using data from the Taoyuan and Kaohsiung international airports in Taiwan.[8,9] Dengue fever is not endemic in Taiwan and domestic cases are the result of travellers arriving from dengue-endemic countries. One study analyzed passengers through the airports from 2007 to 2010 and found that 44.9% (95% CI 35.73 to 54.13) of the confirmed imported dengue cases with apparent symptoms were detected by the thermal screening program, giving a PPV of 2.36% (95% CI 0.96 to 3.75).[8] The IRT was set at 37.5°C and fever was defined as having a tympanic temperature of greater than 38°C. The other study analyzed over 8 million inbound passengers that passed through the airports between July 2003 and June 2004 and found that approximately 22,000 passengers were identified as fever patients by IRT (set at 37°C) and tympanic temperature readings (fever defined as > 37.5°C).[9] This study found that airport fever screening identified 83.3% (40 of 48) of all imported dengue fever cases identified by the active surveillance system.

Limitations

None of the included studies employed a negative control in which passengers were not screened using IRT. Infrared thermometry readings vary depending on location of the body that the reading is targeting and the ambient temperature of the surroundings; these data were not presented in every study, making it difficult to generalize results to other settings. The majority of included studies included a conventional method of measuring temperature (e.g., oral, tympanic, axillary). The sensitivity and positive predictive values varied greatly, even within studies, depending on temperature cut-offs. This variation was compounded by the very low numbers of febrile patients in studies, but that is reflective of a real-world setting. No studies were conducted in a Canadian setting, but it is possible that the volume of travelers going through Canadian airports may be less than those going through the major international hubs the included studies were conducted at such as Narita, giving a lower number of febrile travelers. The definition of fever differed between studies, making it difficult to compare results across studies. There were no studies looking at how border screening using IRT would reduce the risk of outbreaks of infectious disease. There were no studies conducted at other border crossings other than international airports (e.g., bus or train terminals).

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.

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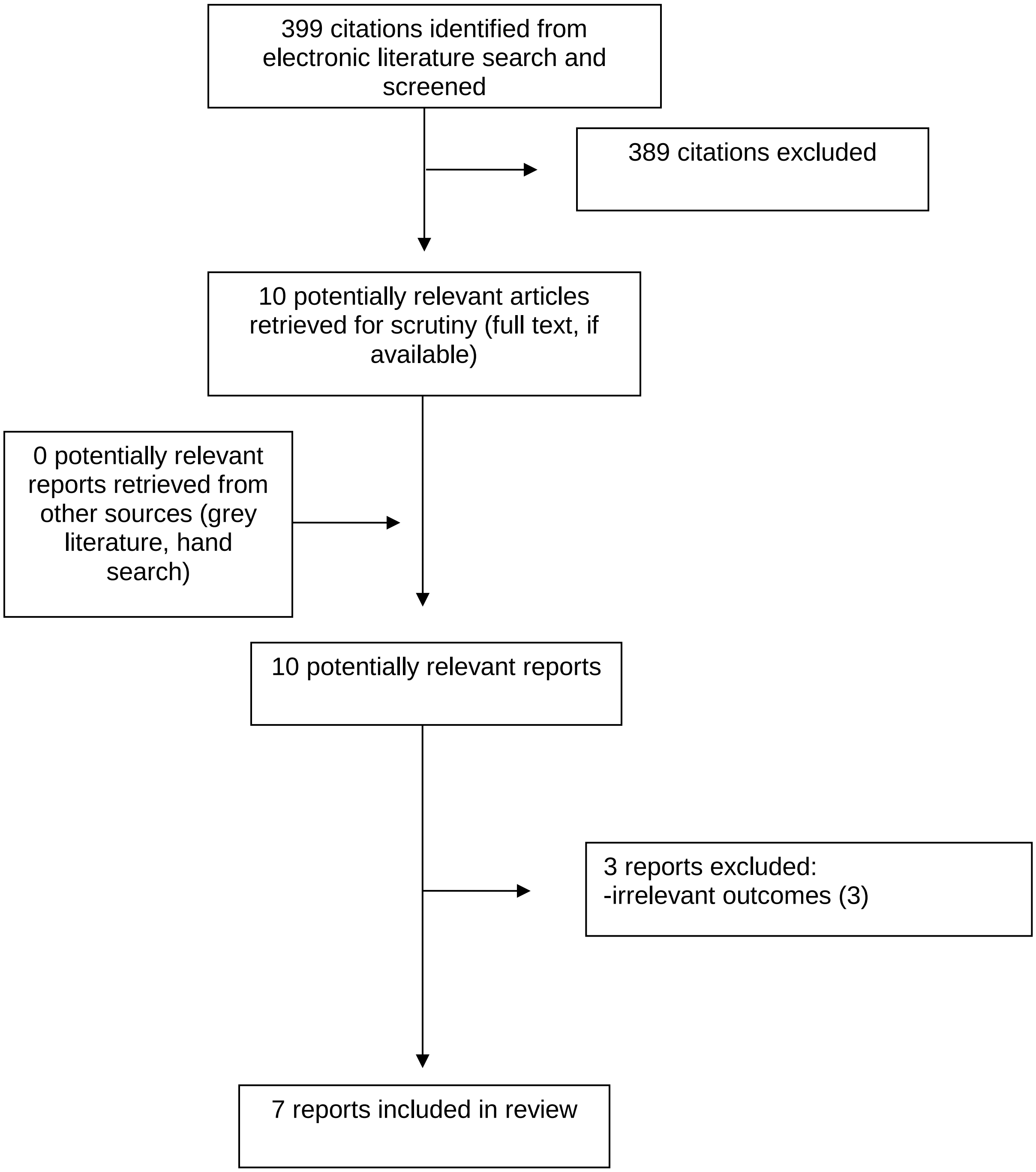
APPENDIX 1: Selection of Included Studies



APPENDIX 2: Characteristics of Included Studies

First Author, Publication Year, Country	Study Design, Location, Length	Participants	Intervention(s)	Outcomes Measured
Febrile Detection				
Cho[6] 2014 Korea	Retrospective study using health declaration forms and interview records International airport Jan 1-Dec 31, 2012	584,323 arrivals 355,887 (60.9%) from quarantinable countries 608 subjects reporting at least one health-related symptom	Fever screening to detect febrile arrivals (thermal camera set for 36°C, tympanic temperature scanner, health declaration forms) Brands of thermoscanner: Thermovision A20M, FLIR; Thermo Tracer TH7800; ThermoGraphy R300	Prevalence of febrile arrivals (defined as tympanic temperature above 37.8°C), association between fever measurements and thermal camera temperature
Chan[10] 2013 Hong Kong	Prospective study Hospital Oct 2005-Jul 2006	1517 participants (770 women) recruited from the accident and emergency department of a hospital	Infrared thermography (forehead, temples, nose, mouth cheeks, ear, neck) versus core temperatures measured by conventional oral thermometry or aural temperature (higher measurement) to detect fever (core temperature ≥38°C)	Correlation between IRT and core temperatures
H1N1 and Influenza				
Gunaratnam[7] 2014 Australia	Retrospective study Sydney Airport Apr 28-Jun 18, 2009	625,147 arrivals 5845 symptomatic or febrile 1296 identified as requiring further assessment 3 confirmed with H1N1-2009	Thermal imaging scanners (set point 38°C ± 2°C), health declaration form, clinical assessment, nose and throat swab	Detection rate, sensitivity, specificity, PPV
Nishiura[3] 2011 Japan	Retrospective study using 2 different datasets (dataset 1: confirmed H1N1 or influenza cases; dataset 2: suspected passengers detected by infrared thermoscanner) Narita international airport Dataset 1: Apr 28-Jun 18, 2009	Dataset 1: 441,041 passengers and 30,692 airline crew members 805 passengers underwent rapid diagnostic testing 18 confirmed cases of influenza (10 H1N1, 7 influenza type A, 1 influenza type B)	Fever screening using infrared thermoscanner (TVS-500, NEC/AVIO Infrared Technologies Co. Ltd.) set at 35.4°C threshold, axillary temperature measurement, self-report or reports by relatives/friends to detect H1N1-2009 or influenza	Sensitivity and specificity of IRT in detecting hyperthermia, positive predictive value, correlation between IRT and axillary temperature

First Author, Publication Year, Country	Study Design, Location, Length	Participants	Intervention(s)	Outcomes Measured
	Dataset 2: Sept 2009-Jan 2010	Dataset 2: 9,140,435 passengers screened 1,049 selected and suspected passengers (self-reported symptom, reported by relatives or friends, detected by IRT) had axillary temperature measured		
Priest[11] 2011 New Zealand	Prospective study Christchurch international airport Aug 21-Sept 12, 2008	5274 travellers returned a questionnaire 823 were symptomatic 1275 airline travellers had IRT screening, tympanic temperature measurement and respiratory sampling	Influenza border screening: Infrared image thermal scanner (ThermaCAM E45, FLIR Systems), tympanic temperature – threshold 37.8°C (ThermaScan PRO 4000, Braun), swab for respiratory sampling, screening questionnaire	Accuracy of IRT in predicting tympanic temperature
Dengue Fever				
Kuan[8] 2012 Taiwan	Retrospective study Taoyuan (4 entry gates) and Kaohsiung (1 entry gate) international airports 2007-2010	Inbound passengers 2007: 12,508,621 2008: 12,202,392 2009: 12,499,365 2010: 14,837,391 Confirmed febrile passengers (%) 2007: 11,118 (0.09) 2008: 12,158 (0.10) 2009: 12,286 (0.10) 2010: 12,553 (0.08) Dengue importations detected in airport fever screening 2007: 72 2008: 100 2009: 108 2010: 126	Active surveillance Infrared thermal camera at each entry gate set at 37.5°C, ear thermometer (fever defined as temperature > 38°C), Dengue NS1 Rapid Test Kit and central laboratory used to confirm diagnosis Passive surveillance Hospital-based reporting system for the notification of either imported or domestic dengue cases.	Sensitivity, Specificity, PPV, NPV
Shu[9] 2005 Taiwan	Retrospective study Taoyuan (4 entry gates) and Kaohsiung (1 entry gate) international airports	>8,000,000 inbound passengers ~22,000 passengers identified as fever patients by infrared thermal camera and rechecked by ear	Active surveillance Infrared thermal camera at each entry gate set at 37°C, ear thermometer (fever defined as temperature > 37.5°C), RT-PCR	Proportion of dengue cases identified by active surveillance

First Author, Publication Year, Country	Study Design, Location, Length	Participants	Intervention(s)	Outcomes Measured
	Jul 2003-Jun 2004	temperature 3011 serum samples sent for laboratory diagnosis 40 serum samples confirmed to be positive based on RT-PCR	and ELISA to confirm dengue fever diagnosis. <u>Passive surveillance</u> Hospital-based reporting system for the notification of either imported or domestic dengue cases.	

IRT = infrared thermoscanner; NPV = negative predictive value; PPV = positive predictive value; SARS = severe acute respiratory syndrome

APPENDIX 3: Summary of Critical Appraisal

First Author, Publication Year, Country	Strengths	Limitations
Febrile Detection		
Cho[6] 2014 Korea	• Large population screened • All participants were measured with both thermal scanner and tympanic temperature scanner • No participants lost to follow-up • Duplicate retrieval of data	• Small number of febrile arrivals • Sample was enriched with suspected fraction of patients • Arrivals detected as having fever by thermal camera but asymptomatic not included
Chan[10] 2013 Hong Kong	• Large population enrolled • All participants were measured with both infrared thermography and a conventional method	• Study was performed in a controlled setting and not in a real-world setting • Participants were recruited from a Hong Kong hospital, which may not be representative of the general population • It was unclear whether there was a time gap between both temperature measurements
H1N1 and Influenza		
Gunaratnam[7] 2014 Australia	• Large population screened • Screening practices reflected real-world conditions	• No gold standard for temperature measurement employed • Study was specifically detecting H1N1-2009 and influenza, and may not be generalizable to other diseases
Nishiura[3] 2011 Japan	• Large population screened • All participants had both IRT and axillary temperature measurements	• A retrospective non-random sample was used, representing a suspected fraction of patients that may not be representative of the general population • Study was specifically detecting H1N1-2009 and influenza, and may not be generalizable to other diseases
Priest[11] 2011 New Zealand	• Large population screened • Screening practices reflected real-world conditions • All participants had both IRT and tympanic temperature measurements	• Included sample was enriched with symptomatic travellers, which may not be representative of general population • Study was specifically detecting influenza, and may not be generalizable to other diseases
Dengue Fever		
Kuan[8] 2012 Taiwan	• Large population screened • Screening practices reflected real-world conditions • All participants were measured with both infrared thermography and a conventional method	• Study was specifically detecting dengue, and may not be generalizable to other diseases
Shu[9] 2005 Taiwan	• Large population screened • Screening practices reflected real-world conditions • All participants were measured with both infrared thermography and a conventional method	• Study was specifically detecting dengue, and may not be generalizable to other diseases

APPENDIX 4: Summary of Findings

First Author, Publication Year, Country	Main Study Findings	Authors' Conclusions
Febrile Detection		
Cho[6] 2014 Korea	Fever screening identified 6 febrile arrivals based on a tympanic temperature above 37.8°C - Fever prevalence 0.002% (6/355,887) - 1% of 608 symptomatic arrivals had fever - There was no statistically significant difference between thermal camera scanning (average temperature 36.83°C) and tympanic temperatures (38.14°C) of the febrile arrivals	"This study also finds no significant difference between thermal camera temperature and ear temperature. Therefore, an array of the procedures employed by quarantine stations in Korea-health declaration form, thermal camera scanning, and subsequently tympanic temperature measurement-could service as useful complements to one another in detecting febrile arrivals as accurately as possible." (p. 5)
Chan[10] 2013 Hong Kong	<u>Correlation coefficients between infrared thermography and conventional temperature measurements (n=1517)</u> AREAMAX (maximum frontal temperature): 0.434 FOREHEAD (forehead temperature): 0.361 LATMAX (maximum lateral temperature): 0.440 Febrile subjects: range 0.224 to 0.328 Non-febrile subjects: 0.241 to 0.273 <u>AUROC (95% CI)</u> AREAMAX: 0.812 (0.761 to 0.863) FOREHEAD: 0.780 (0.723 to 0.837) LATMAX: 0.815 (0.763 to 0.867) <u>Effects of distance on infrared thermography temperature reading recorded (n=31)</u> IRT temperature decreased on average by 0.3°C per meter increase in distance from the camera.	"Infrared thermographic temperature correlates only moderately with core temperature, but performs better in children, men, and among febrile subjects. The IRT temperature is inversely proportional to the distance from the camera. Although the study results suggested better test performances using either the maximum lateral or frontal temperature, their sensitivity might still not be high enough and the high number/proportion of false positives would be overwhelming. This property renders IRT unsuitable as a routine screening tool for febrile conditions, especially at border crossings with huge numbers of passengers. A single IRT measurement of the forehead from a distance should be replaced by a method with greater sensitivity and specificity." (p. 114)
H1N1 and Influenza		
Gunaratnam[7] 2014 Australia	Of the 1296 passengers identified as requiring further assessment: - 1144 (88.27%) were detected through health declaration cards - 11 (0.85%) were detected by thermal scanners - 35 (2.70%) identification method unknown or other 5845 passengers were identified as symptomatic or febrile, and 3 were subsequently confirmed as having H1N1-2009. There were 45 people with overseas-acquired H1N1-2009 that would have probably passed through the airport during this time. Sensitivity: 6.67% (95% CI 1.40 to 18.27) Specificity: 99.10% (95% CI 99.00 to 100.00) PPV: 0.05% (95% CI 0.02 to 0.15)	"Our analysis shows that airport screening in NSW during pandemic (H1N1) 2009 influenza had low sensitivity, detecting far fewer cases during the DELAY and CONTAIN phases compared with emergency departments or general practitioners…The small number of passengers detected by thermal scanners is also consistent with published estimates of the sensitivity of non-contact infrared thermal image scanners, and the high proportion of influenza infections that are likely to be asymptomatic." (p. 2014)
Nishiura[3] 2011	<u>Dataset 1</u>	"Among the confirmed H1N1-2009 cases (n = 9), the sensitivity of fever for detecting

First Author, Publication Year, Country	Main Study Findings	Authors' Conclusions
Japan	Of the 16 confirmed cases of influenza: - 9 were male - 13 were under medication upon arrival Using a cut-off level of 37.5°C or 38.0°C, the sensitivities of hyperthermia for detecting influenza was 22.2% (95% CI, 0 to 56.0) for H1N1 and 42.9% (95% CI, 14.3 to 85.7) for other influenza viruses. Using a cut-off level of 38.5°C, the sensitivities of hyperthermia for detecting influenza was 11.1% (95% CI, 0 to 33.3) for H1N1 and 28.6% (95% CI, 0 to 57.1) for other influenza viruses. Age, gender, and medications were not associated with hyperthermia. The proportion of hyperthermia cases was smaller among those with medications for both cut-off levels of 37.5°C and 38.0°C Dataset 2 1049 screened passengers had axillary temperature readings. Mean axillary temperature: 37.6°C ± 1°C Mean IRT temperature: 36.3°C ± 0.9°C Correlation coefficient between IRT and axillary temperature readings: 0.44 ($p < 0.01$) The surface temperatures as measured by IRTs were statistically significantly higher among those defined as having hyperthermia ($p < 0.01$). Using the cut-off levels of 37.5°C, 38.0°C and 38.5°C, the sensitivities were estimated to be 58.3%, 50.8% and 70.4% and the specificities were estimated to be 70.5%, 81.7% and 63.6%, respectively. The PPV ranged from 37.3% to 68.0% and NPV ranged from 61.1% to 87.5%. The AUROC ranged from 74.0% to 75.9%.	influenza upon arrival appeared to be as low as 22.2%, and 5 of the 9 cases (55.6%) were under antipyretic medications. The PPV or the infrared thermoscanners for detecting fever among the suspected fraction of passengers (n = 1,049) was shown to be insufficient to actively detect febrile influenza cases among passengers. Given the additional presence of confounding factors and unrestricted medications among passengers, the reliance on fever alone is unlikely to be feasible as an entry screening measure against influenza." (p. 10)
Priest[11] 2011 New Zealand	7 travellers had a tympanic temperature of ≥ 37.8°C (5 symptomatic) IRT as a predictor of tympanic temperature (n = 1275) using a definition of fever of ≥ 37.8°C tympanic temperature **IRT of front of face** AUROC (95% CI): 0.86 (0.75 to 0.97) Sensitivity: 86% Specificity: 71% Estimated PPV: 1.5%	"In this study, during a seasonal epidemic of predominantly influenza type B, influenza-infected arriving travellers had a very low prevalence of fever. Consequently, IT IS would not have identified influenza-infected travellers even though it performed moderately well at detecting febrile travellers. Some aspects of this study may not generalise to a pandemic of Influenza A. 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

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	IRT of side of face AUROC (95% CI): 0.76 (0.54 to 0.97) Sensitivity: 86% Specificity: 51% Estimated PPV: 0.9% **Temperature as a predictor of influenza infection** 30 samples were positive for influenza (3 Type A, 27 Type B) - 27 were symptomatic - 0 had a measured tympanic temperature of ≥ 37.8°C	entry screening of travellers to detect influenza infection with the intension of preventing entry of the virus into a country." (p. e14490)
Dengue Fever		
Kuan[8] 2012 Taiwan	Overall, 44.9% (95% CI 35.73 to 54.13) of the confirmed imported dengue cases with apparent symptoms were detected by the thermal screening program. PPV: 2.36% (95%CI 0.96 to 3.75) NPV: >99.99% Specificity: 99.97% (95% CI 99.96 to 99.97) Percentage of imported symptomatic dengue cases detected at entry 2007: 40.2 (72/179) 2008: 44.3 (100/226) 2009: 52.9 (108/204) 2010: 41.5 (126/304)	"A moderate sensitivity of 44.93% and a PPV that ranged from 1.28-3.22% were obtained for airport fever screening in this study. Our findings indicated some limitations of the airport fever screening programs for preventing the introduction of dengue. However, these procedures might help to target some symptomatic dengue importations for an immediate self-quarantine that might mitigate some local dengue transmissions." (p. 9)
Shu[9] 2005 Taiwan	Airport fever screening identified 40 of 48 (83.3%) of all imported cases identified by the active surveillance system. Percentage of imported symptomatic dengue cases detected at entry: 65.8 (48/73)	"Our results demonstrated that fever screening at airports is an effective means of identifying imported dengue cases, whereas the health statements of inbound passengers, which have been required for years, are ineffective." (p. 461)