Thermal Imaging for Detecting Potential SARS Infection

R. James Seffrin, Director
Infraspection Institute
Burlington, NJ

Presented at:

National Conference on Thermal Imagers for Fever Screening - Selection, Usage and Testing

30 May 2003

Sheraton Towers Singapore

Abstract

Recent efforts to control the spread of Severe Acute Respiratory Syndrome (SARS) have prompted public health officials to develop a rapid screening process to detect air travelers who are experiencing an elevated body temperature. Because high fever is a symptom of SARS, many have proposed using thermal imaging cameras as a means to rapidly identify potential SARS carriers as they pass through airports. Although the use of infrared instruments to measure body surface temperatures has many advantages, there are human, environmental, and equipment variables that can affect the accuracy of collected data. This paper discusses the application and limitation of infrared devices to measure body temperature.

Introduction

Severe Acute Respiratory Syndrome (SARS) is a newly discovered and potentially fatal infectious disease in human beings. Since its initial recognition in February 2003, over 8200 cases have been reported worldwide resulting in 735 deaths. According to the World Health Organization, current analyses place estimated case fatality rate at approximately 15%; however, this rate can exceed 50% in persons over age 65. The rapid spread of the disease has prompted the World Health Organization to label SARS as "the first severe infectious disease to emerge in the twenty-first century."

SARS has shown to be readily spread through international air travel. Since its initial discovery in Hanoi, Vietnam, SARS has spread globally along international air travel routes and has now been reported on six continents. While much about SARS is still unknown, it is believed to be caused by a previously unknown member of the Corononaviradae Family of viruses. Presently, there is no vaccine or treatment for SARS; the most effective response is isolation, infection control and contact tracing.

According to the Centers for Disease Control and Prevention, the primary way that SARS appears to spread is by close person-to-person contact. Most cases of SARS have involved people who cared for or lived with someone with SARS, or had direct contact with infectious material (for example, respiratory secretions) from a person who has SARS. Potential ways in which SARS can be spread include touching the skin of other people or objects that are contaminated with infectious droplets and then touching your eyes, nose, or mouth. This can happen when someone who is sick with SARS coughs or sneezes droplets onto themselves, other people, or nearby surfaces. It also is possible that SARS can be spread more broadly through the air or by other ways that are currently not known.

Because SARS appears to be readily transmitted, isolation of infected persons is the most effective means in preventing and reducing the spread of the disease. To this end, it is imperative that infected persons be identified and isolated as quickly as possible.

The CDC advises that SARS begins with a fever greater than 38°C (100.4°F). Other symptoms may include headache, an overall feeling of discomfort, and body aches. Some people also experience mild respiratory symptoms. After 2 to 7 days, SARS patients may develop a dry cough and have trouble breathing.

In an effort to identify persons potentially infected with SARS, health care officials in several locations worldwide have employed thermal imaging cameras to measure the skin temperature of airline passengers as they pass through airport checkpoints located within SARS-affected regions. Persons exhibiting elevated skin temperatures are then isolated for further evaluation to determine the cause.

Although thermal imaging cameras offer several distinct advantages for this type of application, there are several variables that can affect the accuracy of collected data. These variables are capable of producing both false positive and false negative readings without any outward indication that the data are flawed.

Thermal Imaging and Temperature Measurement

The idea of thermal imaging is simple. All objects above Absolute Zero (0 Kelvin) emit infrared radiation. While infrared radiation is invisible to the human eye, it can be detected and displayed by special cameras called thermal imagers. These cameras detect the invisible infrared radiation emitted by an object and convert it into a monochrome or multi-colored image on a monitor screen wherein the various shades or colors represent the thermal patterns across the surface of the object.

Once used primarily for military and surveillance applications, thermal imagers are now widely available for commercial and industrial applications. Many commercially available models of thermal imagers are capable of measuring surface temperature. These instruments are called imaging radiometers. Another category of infrared devices which provide only temperature measurement are called point radiometers or infrared thermometers. Accurate application of any infrared device requires a clear line of sight to the subject target. Infrared test equipment is unable to see through most objects including clothing.

Currently, there are many commercially available infrared devices that have ability to measure surface temperature. These include both imaging radiometers, non-contact radiometers, and contact infrared thermometers such as those that are used to measure temperature within a patient's ear canal. With any equipment that measures temperatures across the surface of the body, there are several factors that can adversely affect observed temperature values.

Understanding how radiometers work and the variables that affect the accuracy of observed temperatures is critical to understanding the potential error sources associated with the use of non-contact infrared temperature measurement.

Thermal Imaging and Medical Applications

Thermal imaging is in use worldwide by medical professionals to help detect evidence of disease such as breast cancer, circulatory problems, and soft tissue injury. Thermal imaging is also used as a diagnostic tool in sports medicine for both animals and humans.

As a diagnostic technology, thermography offers several distinct advantages for clinical use. Among them are:

- Test equipment is completely passive and emits no harmful radiation.
- Thermal imaging is non-invasive.
- Humans radiate infrared energy very efficiently. The emittance value of human skin is nearly 1.0.
- Test equipment does not require the use of tracer dyes or chemicals.
- Information is provided in real time and can be analyzed instantly.
- Data can be recorded to photographic media, videotape or to a computer.
- Equipment is highly portable and fully self-contained.
- Equipment can be easily transported and set up within minutes.

With thermal imaging physicians can detect, display and record thermal differences as little as 0.1°C on the surface of a patient's body. Evaluating thermal data relies on detecting inexplicable thermal asymmetry across the body or by detecting changes in thermal patterns exhibited by a patient over a period of time.

Because small temperature differentials can be indicative of a serious medical condition, preparation of the subject is critical to making an accurate diagnosis. This requires that patients refrain from any activity that might impact their body temperature for several hours prior to testing. Immediately prior to imaging, patients are asked to expose the skin of the subject area(s) and wait in a temperature stabilized room for several minutes. Upon completion of imaging, a qualified physician will analyze the observed thermal patterns recorded across the patient's body. It should be noted that physicians rely on observed thermal patterns for their diagnosis rather than specific temperature values.

Error Sources for Non-contact Infrared Temperature Measurement

Although non-contact infrared temperature measurement offers several advantages for data collection, there are many variables that can significantly affect accuracy of observed skin surface temperatures of humans. Listed below are the most significant potential error sources associated with non-contact infrared temperature measurement.

Human Body: Several common conditions can produce significant but unpredictable changes in body temperature. Circulatory problems, previous injuries, the use of certain drugs, and alcohol consumption can reduce body surface temperature. Perspiration or surface moisture can also result in decreased body surface temperature.

Recent stress, physical activity, and the use of stimulants including caffeine and nicotine are all capable of increasing body surface temperature. Inflammation caused by trauma or even sunburn can cause skin temperature to increase as well.

Environment: Ambient air temperature can cause significant temperature changes across the human body. Additionally, hot or cold air currents can cause significant temperature changes as well. Lastly, point sources of heat or cold can also raise or lower the surface temperature of the body.

Test Equipment: As imaging radiometers have evolved, they have become more user friendly while offering more features and capabilities with each successive generation of new equipment. Unfortunately, these instruments are not self-diagnostic and cannot advise an operator when the system is being used improperly. Additionally, due to a lack of standardization among equipment manufacturers, there can be wide performance variations between different makes and models of equipment.

As with any diagnostic tool, it is imperative to understand that each make and model of infrared equipment has specifications that can affect the accuracy of observed temperatures. The following are some of the most important criteria for affecting temperature measurement accuracy.

Spot measurement size is the area from which temperature data are derived. Unfortunately, most infrared equipment manufacturers do not provide data regarding spot size for their instruments; others provide data that is incomplete or inaccurate. To ensure accuracy, a radiometer's spot measurement size must always be smaller than the target being measured.

Some imaging radiometers require several frames of data in order to process temperature data accurately. Obtaining accurate temperature with such systems requires that a target remain stationary for up to several seconds while data are collected.

All imaging radiometers have accuracy limitations for temperature measurement. Typical accuracy specifications for temperature measurement are ± 2% of target temperature or 2°C, whichever is greater. With this in mind, a person with a normal body temperature of 37°C could be reported as high as 39°C (fever) while a person with a fever of 38°C could be reported as low as 36°C (below normal temperature).

Lastly, some imaging radiometers built with microbolometer detectors are subject to significant drift over very short periods of time. Some models can drift by as much as 3°C every 5 minutes. Temperature measurement error caused by such drift can lead to both false positives and false negatives.

Applying Non Contact Temperature Measurements to the Human Body

Obtaining meaningful temperatures for the human body requires identifying a body site that will provide reliable and repeatable data across a large cross-section of the population. While some have offered that the medial corner of the eye usually exhibits the highest surface temperature across the human face, no empirical data have been developed to correlate facial surface temperatures with internal body temperatures. Currently, there is no standard that recognizes a specific body surface site for accurate body temperature measurement.

It is important to understand that skin temperature does not directly correlate to body-core temperature. It is possible to encounter cool skin temperatures even when a fever is present.

In order to use body surface temperatures as a diagnostic tool, research is necessary to identify the optimal location for non-contact temperature measurement. Should such a site be identified, it is likely that imaging radiometers will afford the best measurement solution since they generally have smaller spot sizes and can be aimed more accurately than non-imaging radiometers.

It is further possible that specific thermal patterns may be associated with various diseases. Once again, research is necessary to identify whether such patterns exist and the characteristics of their signature.

Regardless of the diagnostic criteria, accurate interpretation of thermal data will be largely dependent upon an experienced, knowledgeable operator who understands infrared theory and heat transfer concepts, basic anatomy and physiology, and infrared equipment operation and limitations.

Summary

The use of infrared thermography holds promise as a mass screening tool for the detection of persons with an elevated body temperature due to fever. Unless unique thermal patterns can be identified as indicators of a specific disease, the detection of elevated body temperature alone cannot be used to identify a specific type of infection including SARS.

Accurate detection of fever by non-contact radiometry will require the identification of a body surface site that correlates to accurate representation of body-core temperature. Should such a site be identified, it will be imperative to use infrared equipment capable of accurately measuring body surface temperatures under environmental conditions that ensure the collection of accurate, repeatable data.

In order to ensure accurate collection of data, specific test procedures and the physical requirements of test sites will need to be standardized. Improper use of infrared test equipment, improper preparation of subjects and improper collection of data can cause erroneous readings resulting in both false positive and false negative diagnoses. Until standards are developed, traditional methods of body temperature measurements should continue to be used in preference to non-contact temperature measurement.

It should be understood that temperature measurement is one diagnostic tool in determining the presence of disease. Further examination and testing by a qualified medical professional are required to provide an accurate diagnosis.

At present, the use of infrared test equipment designed for commercial use could lead to inaccurate data collection resulting in both false positive and false negative diagnoses. All test equipment should be carefully selected with attention given to the suitability of the instrumentation for use in accurately measuring body temperature. When designing and setting up an infrared imaging system, working with an independent, experienced infrared professional can help to avoid making costly mistakes.

While thermography holds promise for large-scale screening of potentially feverish persons, the technology must be applied with caution. The political pressure to find a quick solution should not take precedence over appropriate and accurate application of technology. Misapplication of technology will not only waste resources but can endanger public safety by allowing infected persons to slip through the screening process, potentially causing further spread of the disease and fatalities.

References

1. Revision of International Health Regulations, Severe Acute Respiratory Syndrome, 56th World Health Assembly, Copyright 17 May 2003 by the World Health Organization

2. World Health Organization website www.who.int. Copyright 29 May 2003 by the World Health Organization

3. Centers for Disease Control and Prevention website www.cdc.gov/ncidod/sars/factsheet.htm. Copyright May 8, 2003, 2:30 PM ET by Centers for Disease Control and Prevention.

4. Fever website http://nic.sav.sk/logos/books/scientific/node44.html#SECTION00500000000000000000. Copyright 1993, 1994, Nikos Drakos, Computer Based Learning Unit, University of Leeds.

5. Results of Tests Conducted by SPRING Singapore on Thermometers and Thermal Imagers. SPRING Singapore website www.spring.gov.sg/portal/newsroom/news/speeches/03_05_20_results.html Copyright 20 May 2003 by Standards, Productivity and Innovation Board

About the Author

R. James Seffrin is a Level III Infraspection Institute Certified Infrared Thermographer with over 20 years experience in the application of thermal imaging and infrared temperature measurement for commercial, industrial, residential and medical applications. During his career Mr. Seffrin has been a Director and officer in the corporation of Jersey Infrared Consultants, an infrared consulting firm headquartered in Burlington, NJ.

Mr. Seffrin has worked as an infrared consultant to some of the largest industrial firms in the world. He has co-authored standards and specifications, published numerous articles and technical papers, and has served internationally as an Expert Witness in thermography. Mr. Seffrin's expertise has been sought by industry professionals for the design and development of infrared test equipment, infrared software, and the development of new applications.

Since 1995 he has acted as curriculum developer and instructor for Infraspection Institute training hundreds of thermographers from around the world. In the year 2000, he was appointed Director of Infraspection Institute located in Burlington, NJ. He is also Publisher of the content-based website, IRINFO.ORG and co-author of Exception™ infrared data management and report writing software.

Mr. Seffrin holds a Bachelor of Science degree in Biology from Fairleigh Dickinson University. He has been certified as an Emergency Medical Technician in the State of New Jersey, and is a member of the Endeavor Emergency Squad. He is also a member of the American Society for Testing and Materials, the American Society for Nondestructive Testing, and has worked with the International Organization for Standardization.