PROTECTIVE ASPECTS IN CONTACTLESS INFRARED THERMOGRAPHY FEVER SCREENING

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Abstract

Main symptoms found in patients with same diseases as for example COVID-19 is febrile. The infrared thermography (IRT) represents a fast measurement in case of screening in public places. One of the limitations of IRT is the resolution of sensor, which has close connection with the distance between camera and ROI. To maximize the effectivity of resolution of the camera is to reduce the distance from the object. The aim of presented study showed the possibility how to protect the camera or medical staff that operates the device against potential infection or contamination from the person with infection. Two protective foils of different thickness (40 μm; 9 μm) were tested as a barrier between the IRT and the ROI (black body model and human face). Even though the results have shown that the transparent foils decrease linearly the measured value of the temperature, it can be used as a protective barrier between IRT and the object if an appropriate recalculation is done during analysis of IRT images. Results are acceptable in the case of 9μm foil especially. The authors see this possibility as a minor concession from IRT standards but as a great help in health protection. The transparent foil can be used as protective barrier of the infrared camera.

Keywords

febrile screening, infrared thermography, protective foil

Introduction

Infrared thermography (IRT) is a non-invasive, contactless method for the measurement of surface temperature. Low operational costs, speed of the examination and no radiation hazard for both the patient and medical staff are its main advantages. Because of these benefits, IRT can be applied in various medical fields including neurology [1, 2], rheumatology [3], dermatology [4, 5], sports medicine [6–8], dentistry [9, 10] and diabetology [11–13], especially in wound healing monitoring [14–16].

The most common area of IRT medical application is fever screening, e.g. in connection with COVID-19 disease monitoring activities now. IRT was used as a tool for fever screening in human population in virus outbreaks in the past, during SARS outbreaks in particular [17]. This use of IRT was not so ubiquitous and it was applied as a local precaution measure in cited outbreaks. IRT fever screening devices were installed in places with a large concentration of people, typically in airports. Literary sources addressing this topic contain different, often conflicting, conclusions [18–20]. Same authors even state that forehead infrared thermography readings from a distance should be abandoned for fever screening [21]. Ambiguity regarding the appropriateness of this diagnostic method for febrile symptoms may be the result of lack of defined measurement methodology in the past. The measurement methodology and the possible impact of poor procedure in the application of IRT are repeatedly discussed by the authors associated in the European Association of Thermology [22, 23]. The authors plead all users to perform measurements with rigorous standards [24]. The selection of suitable temperature measurement area on human body as well as technical parameters of the used IRT device and its positioning relative to the person being measured play an important role in correct measurement of temperature of the human body.

Threatened by the possibility of infection, people generally adopt a typical and specific behavior. This includes self-separation and spacing when the threat of a communicable disease is anticipated in their environment. Such behavior is even recommended and required as we have witnessed at the time of the coronavirus pandemic. Increasing the distance between the studied object and the IRT device with its operator reduces the active area from which it is possible to read the temperature (ROI). Many measurements in public places (e.g., entrance areas of medical facilities, airports, and transport terminals) are incorrectly per-

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formed from a distance of many meters and as a consequence of this fact the monitored person's faces occupy only a few percent of the total area of the IRT image. The World IEC Fever Screening Standards Explained recommends maximize the number of pixels in the face image, which should be a minimum of 240 by 180 for example [25]. To overcome this barrier, we looked for an alternative simple way to protect the IRT staff operator and the IRT device from infection and contact with potential danger. Would it be possible to use stretched transparent thin plastic foils (plastic wrap, also known as cling film, food wrap) as barriers? Would this go against the required measurement standards and will it result in significant measurement errors?

Materials and methods

The sterile protective cover foil Panep Steriset of 40 µm thickness (PANEP Ltd., Rosice, Czech Republic) was tested – foil1. This foil is routinely used in tertiary hospitals for protection of medical equipment, for example endoscopes and endocameras. The foil is commercially made of polyethylene Bralen FB 3-33. The standard food wrap foil of 9 µm thickness made of polyethylene (Clarima, Brno, Czech Republic) was tested as the second – foil2. The used stretch foil is supplied in rolls with a width of 60 cm.

The IRT images were recorded with infrared camera WIC 640 (Workswell, Prague, Czech Republic) equipped with Flir focal plane array microbolometer thermal detector, 640×512 IR resolution, and spectral range from 7.5 µm to 13 µm. The absolute accuracy of the measurement is declared at ± 2 °C or ± 2% of reading and thermal sensitivity of device is 0.03 °C, according to the technical data list provided by the manufacturer. The thermoimages are presented in the so-called rainbow palette.

The calibrated model of a black body (Pyrotherm CS 120, Dias Infrared GmbH, Dresden, Germany) was used as an observed object with defined temperature and defined emissivity (0.98).

The IRT measurement was performed at room temperature condition (22 °C) without external heaters. The IRT images of model of black body were taken from distance of 50 cm. The temperature of black body model was set in rage 32–42 °C by step of 1 °C. IRT measurements were performed without the foil and with 40 µm and 9 µm foil for each temperature setting. The foils were inserted between IRT camera objective and model of black body at the distance of 10 cm from camera´s objective. The foils were positioned and fastened by a frame holder (simulation of protective barriers separating monitored persons from medical staff and equipment operator at the monitoring workplace). As is demonstrated at Fig. 1, the IRT images of human face without the inserted foil and with the foils were obtained from distance of 50 cm under the same experimental setting.

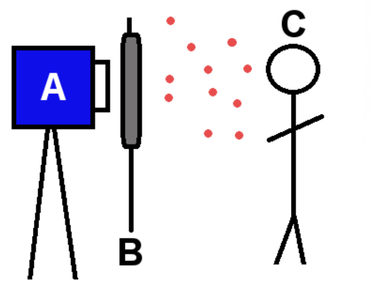

Fig. 1: The experimental setting; A IRT device, B foil, C monitored person.

The obtained IRT images were processed by FLIR QuickReport 1.2 (Flir System, Danderyl, Sweden) and CorePlayer (Workswell, Prague, Czech) software. The obtained data were processed by Excel (Microsoft Corporation, Redmond, Washington) software.

The analysis of black body temperature model was performed by using a mean value (obtained approx. from square area ROI of 100×100 pixels).

Results

The object with defined emissivity and various temperatures was monitored by the IRT camera (black body model). IRT images were taken without the use of the foil ("without foil" data) and through the foils ("foil1" and "foil2" data) and thus obtained mean temperature values from ROIs were compared.

Table 1: Table of measured temperatures for experiment with foils and black body.

Temperature °C					
black body	without foil	foil1	foil2	Δfoil1	Δfoil2
32.0	32.8	32.2	32.6	0.6	0.2
33.0	33.9	33.0	33.8	0.9	0.1
34.0	34.9	33.9	34.5	1.0	0.4
35.0	35.7	34.7	35.5	1.0	0.2
36.0	36.5	35.1	36.1	1.4	0.4
37.0	37.6	36.4	37.2	1.2	0.4
38.0	38.9	37.4	38.2	1.5	0.7
39.0	39.8	38.1	39.0	1.7	0.8
40.0	40.6	38.8	39.8	1.8	0.8
41.0	41.1	39.4	40.4	1.7	0.7
42.0	42.4	40.3	41.4	2.1	1.0

Temperature set to black body; temperature measured on black body – without foil, foil1, foil2; temperature differences (without foil - foil1 or foil2).

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We observed different measured temperature values of the black body model when using different thickness foils as is presented in Table 1. Nonlinear shift between measurements without foil and with foil is evident in the graph in Fig. 2. All data groups (without foil, foil1 and foil2) show the clearly linear dependence but with different slopes. As it is seen, normal measurement without foil also contains a value shift error even though an IRT device with a calibration certificate was used. However, the observed deviation is within the tolerance limits stated by the certificate. The existence of a linear course of all functions is important.

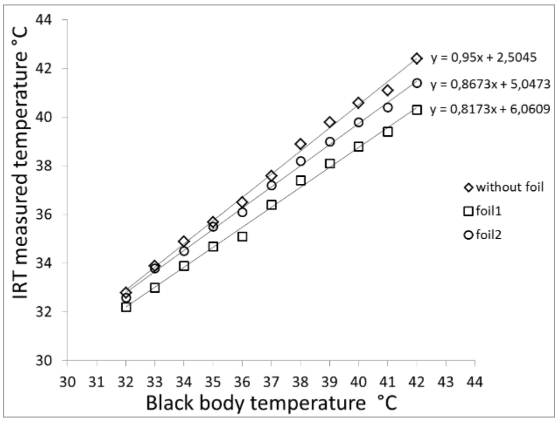

Fig. 2: The graphs of IRT measured temperature in depends on black body temperature; rhombus symbol without foil, square foil1 and circle foil2.

Temperature differences between temperature values obtained from IRT when the foil was used and temperature values obtained from IRT when the foil was not used in dependence on real temperature of the black body model is shown in Fig. 3. The increasing linear dependence with local deviations caused by detector sensitivity is evident for both used foil types. The calculated average deviation of the actually measured temperature from the idealized linear function

$$y = 0.1327x - 3.5564 \qquad (1)$$

for foil1 and function

$$y = 0.0827x - 2.5427 \qquad (2)$$

for foil2 is 0.09 °C, maximal deviation was found as 0.18 °C from all measurements.

The images of the real biological object are seen in Fig. 4. The identical human face in identical position in very short time interval was monitored. The maximal temperature value was determined from inner canthus of the eye by using ROI square selection tool with reading of maximum.

Maximal temperature values of inner canthus of eye are shown in Table 2. It is evident that both temperature values obtained by using foil are lower compared to native temperature value obtained without foil. The difference was 1.2 °C in case of foil with thickness 40 μm (Δfoil1) and 0.4 °C in case of foil with thickness 9 μm (Δfoil2). Note, not quite unrelated to the topic, that the temperature difference in left and right inner canthus of eye is 0.3 °C; it is almost comparable to the value Δfoil2 (Table 2).

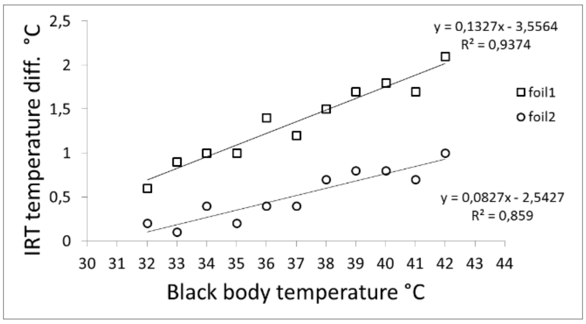

Fig. 3: The graphic representation of IRT measured temperature differences in depends on black body temperature for foil1 and foil2; square symbol represents foil1 and circle foil2.

Fig. 4: IRT images of real human face; without foil, measuring through foil1 and foil2; square represent position of maximal measured temperature.

Table 2: Table of measured temperatures for experiment with foils and real human body.

Temperature °C				
without foil	foil1	foil2	Δfoil1	Δfoil2
36.3	35.1	35.9	1.2	0.4

Temperature measured on real human body—without foil, foil1, foil2; temperature differences (without foil - foil1 or foil2).

Discussion

Correct measuring of temperature is not as easy as it might seem at first glance. This is even more obvious when measuring living systems. Rapid information about the temperature of a person is desirable in the context of fever screening. The use of IRT for this purpose is a topic of ongoing discussion, but there is much positive scientific evidence [26] favoring its use. IRT is increasingly used as a mean of valid fever screening [27]. Thanks to its contactless principle and speed of detection, it is a suitable tool during epidemic or pandemic of viral or bacterial diseases for the detection of infected people. A really widespread use is currently seen due to the existing COVID-19 pandemic. It is necessary to follow strict measurement

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rules to obtain valid data, due to the relatively complex process of temperature detection by IRT. The methodology of fever screening was developed and there are some general recommendations accepted worldwide [24, 25, 28, 29]. It is advisable to follow these general instructions, but this is not always fully possible. An example is the situation of recent days, when it was necessary to introduce a screening of patients and not enough suitable IRT devices were available in medical facilities. The authors witnessed many inappropriate procedures, especially in terms of the distance of the monitored person from the IRT device and the place of measurement on the body. One of the factors is also that people do not want to come into close contact with another person, and in the case of manual IRTs, this reduction in distance is necessary for a valid measurement. Shorter distance of monitored person from IRT device assures more pixels for IRT analysis in selected ROI and eliminates possible external sources of background radiation. One option is to use a mechanical barrier, serving as a sterile barrier to prevent the transmission of the infection to the staff and surface of the IRT device. However, this is technically difficult and not in agreement with the existing theoretical recommenddation. The World IEC Fever Screening Standards Explained recommends maximize the number of pixels in the face image, which should be at least 240 by 180; the minimum display of the workable target plane shall be 320 image pixels by 240 image pixels [25]. Appropriate number of pixels in the face image can only be achieved by a decreasing distance between the person being measured and IRT device in case of use of IRT device with a low resolution. The current pandemic situation has shown that many workplaces have only such an IRT device available.

Our recent study tested the idea of using thin foil as a protective material protecting against biological contamination. It is necessary to evaluate whether the data obtained in this way are subject to a large error or not. There are other important factors besides the presence of the foil affecting results of measurement: the sensitivity and stability of the IRT device, ambient temperature, cooperation of the monitored person, etc. However, these factors will affect any others method of the IRT measurement in any case.

The thickness of used foil plays an important role as it is evident from obtained results. Increased thickness increases the deviation from the actual temperature, which is a logical effect. Our study shows results from a 40 µm and 9 µm foil. The 9 µm foil was found to be superior, because the measurement results were found to be closer to the situation, when temperature measurement was performed without foil. The really measured temperature shift compared to the standard is 0.2–1 °C in temperature interval 36–42 °C. According to the interleaved linear dependency function, this shift is 0.1–0.9 °C for the same temperature interval 36–42 °C. This is de facto a measurement error caused by the use of the foil. Much (according to some authors even the total) of this error interval is comparable in value to the variability interval of thermal symmetry of skin human temperature, where up to 1 °C symmetry difference is mentioned [30, 31]. But this is again a topic for discussion, because it is recommended to measure the temperature in the inner canthus of eye, where the temperature is closer to the temperature of the human body core [18]. But even the inner canthus of the eye can show temperature asymmetry, which can be seen in the presented IRT image (Fig. 4) with a difference of 0.3 °C. The discussed measurement error when using the foil does not have to be considered insurmountable with respect to the above; although it is clear that it increases the measurement inaccuracy, especially if the errors add up.

Another more suitable procedure how to deal with the value shift is the recalibration of the obtained data which is possible due to the linearity of the function (Fig. 3). As it can be imagined, it could be done simply by shifting the border value of temperature alarm in the IRT device. The advantage is that often only information about exceeding the threshold temperature is sufficient during fever screening. For example: if we want to set the detection alarm at the value 38 °C, it is necessary to set the value 38 °C based on the calculated parameters of the function

$$y = 0.8673x + 5.0473 \qquad (3)$$

for foil2 and 37.1 °C based on the calculated parameters of the function

$$y = 0.8173x + 6.0609 \qquad (4)$$

for foil1. This will be unique for each individual IRT device. Calculated values included calibration correction of used IRT (see „without foil“ line in Fig. 2).

Given by personal experience, it can be assumed that long-distance measurement without foil by IRT device with lower resolution sensor will be probably burdened with a comparable or even larger error (because the size of ROI will be in dimension units of pixels, maybe not even that) than the presented foil measurement including value correction.

Conclusion

As the development of events in the first months of the year 2020 shows, measuring temperature has become very important. Many institutions are trying to implement fever screening by IRT due to a viral pandemic. Fever screening is subject to strict rules. Very often, however, insufficient equipment or concern for one's own safety and health becomes an obstacle of correct measurements and subsequent actions. It is very important to measure the temperature from a reasonable distance. If the distance between the object and the IRT device is large, the quality of the IRT image analysis decreases because of the decreasing area of

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ROI in the image. The presented analysis shows the potential usability and level of errors in case of the use of a thin plastic foil as a protective barrier. The results show the shift in measured values as expected. The subsequent discussion argues that it is possible to deal with this error and introduce the use of thin plastic foil for this type of temperature measurement. This statement is valid under the assumption of willingness to accept some uncertainty in accuracy of such measurement, but in the presented case it is shown that this is comparable to the natural signal noise of IRT (which can be identified with as a deviation from best fit line "without foil" in Fig. 2).

Notice

The authors are familiar with the recommendations for contactless measuring of fever by using IRT [23]. The authors know that there are strict rules that clearly define the conditions under which the measurement is to be performed and that in some respects they are not followed in the presented study. This was done in a targeted way due to the study of specific conditions and measurement procedure. Authors recommend performing IRT measurements optimally according to the IEC and ISO standards "IEC 80601-2-59:2017 Medical electrical equipment: Particular requirements for the basic safety and essential performance of screening thermographs for human febrile temperature screening, ISO/TR 13154:2017 Medical electrical equipment - Deployment, implementation and operational guidelines for identifying febrile humans using a screening thermograph and ISO 80601-2-56:2017 Medical electrical equipment: Particular requirements for basic safety and essential performance of clinical thermometers for body temperature measurement" and wherever possible.

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