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PERSPECTIVES

Why Temperature Screening for Coronavirus Disease 2019 With Noncontact Infrared Thermometers Does Not Work

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Coronavirus disease 2019 screening can evaluate large numbers of patients while reducing healthcare exposures and limiting further spread of the virus. Temperature screening has been a focal point of case detection during the pandemic because it is one of the earliest and most frequently reported manifestations of the illness. We describe important factors to consider of screened individuals as well as the measurement process and current outcomes. Optimal temperature-based screening involves both individual and environmental factors as well as reconsideration of the current fever threshold.

Keywords. clinical thermometry; COVID-19; fever; SARS-CoV-2; screening.

With millions of cases and hundreds of thousands of deaths due to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infections in the United States, screening Americans for SARS-CoV-2, the virus responsible for coronavirus diseases 2019 (COVID-19), has become a national priority. In that fever is one of the earliest and most frequent manifestations of the illness, temperature screening has been a focal point of case detection during the pandemic [1–3]. In partnership with the White House Coronavirus Task Force, the US Department of Health and Human Services and the Centers for Disease Control and Prevention (CDC) released a website and app (www.apple.com/covid19) in late March 2020 that guides Americans through a series of questions to determine whether they should seek further evaluation for symptoms suggestive of infection with SARS-CoV-2. According to the guidelines, persons in nonhealthcare settings having a temperature of 100.4°F (38.0°C) or higher on at least 2 occasions should practice social distancing with self-quarantine for 14 days [1]. In healthcare settings, the CDC defines fever as a forehead temperature greater than or equal to 100.0°F (37.8°C) [1]. In screening persons for infections requiring quarantine in the nonhealthcare setting, the CDC defines fever as a forehead temperature ≥100.4°F (≥38.0°C) [4] obtained with a noncontact infrared thermometer (NCIT) [5]. Unfortunately, temperature screening programs intended to identify SARS-CoV-2-infected persons are, at best, marginally effective, because approximately half of infected persons never develop a fever [6].

Temperature screening for SARS-CoV-2 is also an integral component of containment efforts globally. Although on the surface the screening process appears straightforward, several basic questions arise on closer examination. How, for example, did fever happen to be defined as a temperature of ≥100.4°F (≥38.0°C) in nonhealthcare settings and ≥100.0°F (≥37.8°C) for healthcare settings, and are these cutoff temperatures adequately sensitive and specific for cases of the infection? And where should the temperature be measured (oral, tympanic membrane, or forehead skin surface) using what kind of thermometer?

The origin of ≥100.4°F (≥38.0°C) as the definition of a fever is generally traced to a magnum opus, *Das Verhalten der Eigenwärme in Krakheiten* (*The Course of Temperature in Diseases*) published by Carl Reinhold August Wunderlich in 1868. Although Wunderlich's definition was based on axillary temperatures measured with a thermometer calibrated some 3.6°F (2.0°C) higher than contemporary thermometers, his concept of the lower limit of the febrile range has persisted to this day [7].

In one of the earliest descriptions of the clinical manifestations of SARS-CoV-2 infection, Chen et al [8] reported that approximately 60% of 534 immunocompetent patients examined had temperatures less than 100.4°F (38.0°C). When the cases were stratified by temperature thresholds, 38% had a temperature <37.3°C (99.1°F), 19% 37.3–38.0°C (99.1–100.4°F), 34% 38.1–39.0°C (100.6–102.2°F), and 9% >39.0°C (>102.2°F). Because patients' temperatures were taken in the axilla using a mercury-in-glass thermometer (written personal

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communication), the relevance of these observations for SARS-CoV-2 screening strategies in the United States, which rely primarily on NCITs, is uncertain.

Because temperature varies throughout the body by anatomic site, the term "body temperature" is meaningless. There is an axillary temperature, an oral temperature, a rectal temperature, and so on, all of which differ one from another. In general, axillary temperatures are slightly lower than simultaneously obtained oral temperatures, which are lower than rectal temperatures. In the face of such variability, there is no body temperature, only the temperatures of individual body parts. "Core temperature"—generally defined as the temperature of blood in the pulmonary vein—is as close as one can get to a body temperature, in that it is the temperature of the internal environment of the body, and it is influenced less by the environmental temperatures than surface temperatures such as those of the axilla, mouth, or skin. However, measuring the core temperature requires catheterization of the pulmonary artery, which is neither safe nor practical as a screening test [9]. Instead, surrogate temperatures obtained at various sites (eg, mouth, rectum, axilla), which correlate approximately with the core temperature, are monitored clinically. Various types of thermometers have been used for this purpose, including mercury-in-glass, alcohol-in-glass, digital, and infrared (IR) devices. Of these, IR thermometers inserted into the external ear canal to measure tympanic membrane temperatures are some of the most frequently used thermometers in clinical settings in the United States. Unfortunately, measurements with these thermometers involve direct contact with patients. With the advent of the SARS-CoV-2 pandemic, NCIR-based thermometers have become the preferred instruments for mass screening of potentially infected persons, in that they avoid direct contact with screened individuals, emit no harmful radiation, and require neither sterilization nor disposables.

Handheld NCITs are now being used to screen persons for possible SARS-CoV-2 infection in a variety of settings, of which airports are of particular interest [10]. As of February 23, 2020, more than 46 000 travelers were screened with such devices in selected US airports. Only a single person infected with SARS-CoV-2 was identified [10]. As of April 21, 2020, CDC staff members and US Customs and Border Protection officers had screened approximately 268 000 travelers, among whom only 14 were shown to be infected with SARS-CoV-2 [11].

Readings obtained with NCITs, which measure surface temperature (generally of the mid-forehead), are influenced by numerous human, environmental and equipment variables, all of which can affect their accuracy, reproducibility, and relationship with core temperature. These include the subject's age and gender and medications (especially antipyretic drugs) being taken [7]. Women have slightly higher temperatures than men, and African Americans have slightly higher temperatures than whites [12]. In addition, temperature varies in a circadian fashion, with early morning (oral) temperatures lower on average by 1.0°F (0.56°C) than evening temperatures. Then there is the "emissivity" (the capacity to emit heat by radiation) of the surface being examined, which is influenced by a person's complexion, the wearing of makeup, and sweat. Environmental factors, such as subject-to-sensor distance and ambient temperature, and humidity, also affect readings obtained with NCITs [13].

Finally, the phases of fever itself are potentially important factors determining the results obtained with NCITs. During the ascending phase of fever, a rise in core temperature occurs because of cutaneous vasoconstriction that reduces the release of heat from the body. During devervescence, cutaneous vasodilation produces the opposite effect. Because NCITs measure heat being emitted from the skin surface, both cutaneous responses can limit their capacity to detect the presence of fever [14].

The reliability of NCIT devices is largely unknown. We are aware of only 1 study comparing readings obtained with such devices and an electronic thermometer, one reported by Ng et al [15], in which the surface temperature of water baths heated from 32.0 to 42.0°C (98.6–107.6°F) were examined. The investigation recorded differences of 1.0–2.12°C (1.8–3.82°F) between readings obtained with 3 NCITs and those obtained with an electronic thermometer. Such differences increased "pari passu" with increases in the temperature of the water bath. Based on 1000 NCIT temperatures obtained in healthy adults, Ng et al [15] determined the normal forehead temperature to be 31.0–35.6°C (87.8–96.1°F).

CONCLUSIONS

These are some of the reasons why mass screening programs for SARS-CoV-2 infections that rely on NCITs are ineffective. To develop better programs for distinguishing infected from noninfected persons, the myriad of factors adversely affecting thermal screening with NCITs enumerated above will have to be addressed. Given the low number of COVID-19 cases detected using a thermal cutoff of 100.4°F (38°C), consideration should be given to lowering the cutoff temperature used to identify symptomatic infected persons, especially when screening frail elderly and certain immunocompromised persons. The results of the investigation by Ng et al [15] cited above suggest that a cutoff temperature of >96.1°F (>35.6°C) should be used in screening persons for symptomatic SARS-CoV-2 infections. Unfortunately, because 40%–45% of persons with SARS-CoV-2 infections are asymptomatic [6], any effort to identify such persons short of testing them for the virus itself would likely fail. Because mass screening for the virus is constrained by our current capacity to do so and the cost of such a program should it become available, innovative tactics for public health surveillance, such as those involving group testing

[16], crowdsourcing of digital wearable data, geolocated fever measurements from "smart thermometers" (ie, thermometers paired to mobile devices) [17], and monitoring sewage sludge for SARS-CoV-2 [6] are worth considering. These ideas, like the question of how far the cutoff temperature defining a fever can be lowered without increasing the number of false-positive cases of symptomatic SARS-CoV-2 infection to an unacceptable level, will have to be determined by carefully designed future investigations.

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