ORIGINAL ARTICLE

Temperature measurement: Must it be the forehead? A prospective cross-sectional study

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ABSTRACT

Background: The aim of this study was to compare temperature readings measured at the forehead and wrist against the tympanic temperature which is generally accepted as the standard.

Method: This is a cross-sectional study carried out on 325 people from the general population entering a private hospital for consultation or work. Forehead and wrist temperature was taken using the CEFC RoHS K3 model (China) and tympanic temperature using the Braun Thermoscan 7 Thermometer Irt6520 by the same investigator on consenting individuals.

Results: There was no significant difference between the forehead (mean =36.6, standard deviation, SD=0.30) and tympanic (mean=36.6, SD=0.41), Z= -1.609, p=0.108. However, there was significant difference between the wrist (mean=36.4, SD= 0.28) and tympanic (mean=36.6, SD=0.41) temperature values, Z= -8.749, p<0.001, the former being lower. Temperature measured at forehead (mean=36.6, SD=0.30) was also significantly higher than the wrist (mean=36.4, SD=0.28), Z= -9.381, p<0.001. The wrist temperature values were lower than forehead and tympanic.

Conclusion: Forehead temperature values are better representatives of the core temperature (tympanic) and be the preferred site of measurement compared to the wrist.

KEYWORDS:
Temperature, wrist, forehead, tympanic, compare

INTRODUCTION

With the current Covid-19 pandemic has come the need to identify and isolate people who are infected and with symptoms, who are a threat to the public. Many measures have been put in place to ensure public safety as advised by the World Health Organization (WHO). It had become a norm early in the pandemic to measure the temperature of individuals who frequent public places for work, daily needs, or recreation as fever was identified as one of the common symptoms of COVID-19 infection.

Temperature can be measured by various means and at various sites on the body and accuracy of readings is important. Studies have looked at the validity of various sites in terms of accuracy and stability.[1,2] Most commonly used are the non-contact infrared thermometers (NCIT) where infrared rays are used to measure heat generated by the body or an object. Research shows that NCITs are accurate, comfortable, and reliable and most importantly fast.[3] However, handheld infrared thermometers have their limitations too and require individual validation.[4,5] Some, however, question the safety of pointing the thermometers at the forehead suggesting that frequent exposure may lead to some health issues in the future. However, there is no concrete evidence to support this. How often does an individual have their temperature taken in a day prior to this pandemic compared to several times in a day during the pandemic? With the various controversies, the public is fearful and unsure, also fearing risks to the pineal gland from frequent exposure to the NCIT despite reassurance about safety of the use.[6] Others are not comfortable with the pistol-like object aimed at humans' forehead possibly evoking a primal terror no matter how benign the instrument may be.[7] There is research suggesting wrist measurement is more stable than forehead measurement while another suggests otherwise.[1,8]

The goal of this study was to determine the differences in temperature values taken at the forehead and inner wrist, the reference (standard) being the temperature of the ear (tympanic membrane). Forehead and wrist temperatures were taken using the infra-red thermometers, CEFC RoHS K3 model (China), and tympanic temperatures using Braun Thermoscan 7 Thermometer Irt6520, respectively, for the purpose of this study with an acceptable difference of ±0.2°C.

MATERIALS AND METHODS

Data were obtained from the routine screening carried out on all patients and staff, respectively, at the entrance of the Negeri Sembilan Chinese Medical Hospital (NSCMH), a private hospital before entering the premises from February to March 2021. Forehead, inner wrist, and tympanic membrane temperatures were taken using a NCIT after informed consent was obtained from participants. The tympanic temperature reading was taken as the standard against which the temperature from other sites was measured. As this was temperature measurement carried out at the entrance of the hospital premise, we were unable to check the ear canal for patency prior to the measurement. Furthermore, these measurements were conducted during the pandemic and unnecessary contact with individuals was prohibited.

Temperatures measurement

Forehead and wrist temperatures were taken using the CEFC

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RoHS K3 model (China) that had an accuracy of ±0.2°C with a temperature range of 10-40oC. The tympanic temperature was measured using the Braun Thermoscan 7 Thermometer Irt6520 which had features like patented pre-warmed tip that was supposed to help ensure professional accuracy of up to 0.2°C. Tympanic thermometers measure the thermal radiation from the tympanic membrane within the ear canal.

The tympanic measurement was taken with disposable sleeves for the probe provided by the manufacturer. Using disposable sleeves, the probe was gently inserted into the external auditory meatus, holding until a beep was heard, and reading was then recorded.

Forehead temperature was taken by approaching the front of the thermometer and within 5–10cm from the forehead as instructed by manufacturer and wrist measurement was taken by holding up the palmar surface of the wrist in the same manner. The thermometers were ensured to be calibrated and stable before use. Temperature measurement technique advised by the manufactures was adhered to during the process of measurement. Device was used out of the box directly after unpacking and already calibrated by the manufacturer. The irt6520-thermoscan infrared ear thermometer is initially calibrated at the time of manufacture and according to the manual, if this thermometer is used according to the use instructions, periodic re-adjustment will not be required. All measurements on consenting individuals were obtained and recorded by the same personnel.

Statistical analysis

Data were collected over a period of two months and later analysed using the IBM SPSS Statistics for Windows, version 28 (IBM Corp., Armonk, NY, USA). Assuming alpha=0.05, beta=0.1 (power 90%), minimum allowable difference of temperature between ear and forehead or wrist = 0.2 degree, standard deviation (SD)=1, we estimated a sample size of 325 (which includes a 20% higher value to account for dropout and errors) participants. Sample size was calculated by the Study Size 2.0.4. Sweden: Cresostat HB, 2017 Software. A normality test was carried out, and since data was found to be not normally distributed, a Wilcoxan Signed Rank test was performed to compare the temperature values.

Ethical clearance was obtained from the National Malaysian Research Registry (NMRR), Ministry of Health Medical Research Ethics Committee (MREC) ID: NMRR-20-2857-56240.

RESULTS

A total 325 individuals participated in the study, 50 % (n=163) were females and 50 % (n=162) males. The participants' age ranged from 13 to 87 with an average age of 46.

We had compared temperatures between:

1. Forehead and wrist
2. Forehead and tympanic
3. Wrist and tympanic.

Kolmogorov-Smirnov test of normality showed that data were not normally distributed, $p<0.05$ for forehead, wrist, and tympanic temperatures, respectively. Therefore, the null hypothesis was rejected and the non-parametric test, Wilcoxon Signed Rank test was carried out.

Forehead and wrist temperature values.

The results showed a difference in temperature values between forehead (mean=36.6, SD=0.30) and wrist (mean=36.4, SD=0.28). A Wilcoxon signed-rank test showed statistically significant difference in temperature readings between forehead and wrist ($Z= -9.381$, $p<0.001$, Table I).

Forehead and tympanic temperature values.

The results showed no difference in temperature values between forehead (mean=36.6, SD=0.30) and tympanic (mean=36.6, SD=0.41). The Wilcoxon signed-rank test showed no statistically significant difference in temperature readings between forehead and wrist ($Z= -1.609$, $p=0.108$, Table I).

Wrist and tympanic temperature values.

The results showed a significant difference between wrist (mean=36.4, SD=0.28) and tympanic temperature values (mean=36.6, SD=0.41). The Wilcoxon signed-rank test showed a statistically significant difference in temperature readings between wrist and tympanic ($Z= -8.749$, $p<0.001$, Table 1).

DISCUSSION

Common symptoms noted in COVID-19 patients are fever, fatigue, and dry cough. Fever was commonly the first presenting symptom. Therefore, temperature screening became the tool used for the high-risk population as well as the general population for the early identification of COVID-19 infection worldwide to reduce the risk of spread.[9] There is a long-term implication in need for early detection, isolation, and management, in terms of lives, economy, and future. Every small measure towards the safety of lives would make a difference.

Non-contact infrared thermometry involves the assessment of skin surface temperature through the measurement of its emitted radiation in the infrared waveband. The use of forehead skin temperature measurement for detection is because blood vessels distribute only about 0.1 mm beneath the forehead skin, making it easy to detect. Using forehead thermometer can eliminate the discomfort and inconvenience caused by the traditional contact thermometer's insertion into the ear, mouth, or rectum.[10] Most of all there is no contact, which eliminates the risk of infection transmission.

Foster et al in their review state that a screening thermograph or spot measurement for the detection of fever should be measured at the face only, but during these pandemic, alternative anatomical locations have been seen to be used (i.e., the wrist). However, these do not comply with international guidelines and are considered too unreliable.[11] They conclude that skin temperature assessment with non-contact infrared thermometry can sufficiently track core body

Table I: Comparing wrist, forehead, and aural temperatures (n=325)

	Mean	Standard deviation	Z	p value
Forehead	36.6	0.30	-9.381	<0.001
Wrist	36.4	0.28		
Forehead	36.6	0.30	-1.609	0.108
Tympanic	36.6	0.41		
Wrist	36.4	0.28	-8.749	<0.001
Tympanic	36.6	0.41		

temperature, but only with appropriate technology and under standardized conditions. They also state that NCIT assessment of either the forehead or inner eye canthus though have the utility for fever screening, cannot replace conventional methods of internal temperature assessment.[11] However, handheld infrared thermometers have their limitations too and require individual validation.[4,5,12]

We looked to compare the temperature values at three different sites, namely the forehead, wrist, and tympanic (standard) on each individual. For this research, we identified tympanic temperature as the reference as all other more accurate sites for core temperature are more invasive. The tympanic temperature has been found to be close to the core temperature of the body and gives the most accurate representation of the body temperature.[8,13]

There was a significant difference in temperature values between the wrist and forehead, wrist, and tympanic. The wrist temperature values were lower than the forehead and tympanic values. Data in febrile humans indicate that core and skin temperature responses vary between participants, environments, and pathogen. Hand skin temperature is likely to decrease during fever development. Data using NCIT for fever screening in children indicate that facial temperatures (i.e., forehead and inner canthus) can provide a good estimate of a raised core temperature under well-controlled conditions.[11]

A study investigating the impact of infrared sensors on core body temperature monitoring by comparing measurement sites found that the measurement values for wrist temperature showed significant offsets with the tympanic temperature and thus cannot be used to screen fevers.[8] Similarly, our data analysis suggested that the forehead reflected the core temperature better than the wrist, with the wrist temperature being significantly lower than the tympanic temperature. Our results also agree with a previous study on the agreement between the core temperature values and the forehead, tympanic membrane, and axillary values in postoperative adult patients in clinical practice that found that forehead temperature recordings showed a good correlation with the core temperature with accuracy that was comparable to the tympanic temperature.[14]

Research by Chen et al that aimed to compare the accuracy of individuals' wrist and forehead temperatures with their tympanic temperature under different circumstances (means of transportation to the hospital: by foot, by bicycle/electric vehicle, by car, or as a passenger in a car) found the wrist temperature to be more stable than the forehead temperature readings. However, they concluded that both measurements have fever screening abilities for indoor patients.[1]

One research where patients' body temperature was measured by four peripheral methods; oral, axillary, tympanic, and forehead along with a standard central nasopharyngeal measurement, found that the tympanic and forehead measurements had the highest and lowest accuracy for measuring body temperature, thus recommending tympanic temperature measurement for patients in ICU.[15] Notably, all these studies had differences in terms of type of population and environments compared to ours.

One research investigated the sensitivity and specificity of two temperature measurement methods – wrist and forehead and compared with the sublingual or axillary standard methods. Researchers found that the wrist and forehead temperatures measurement were not accurate in detecting fever although forehead measurement though not an ideal method, nevertheless appeared more consistent than wrist measurement.[16]

In a summary of evidence on the reliability of one form of temperature checking over another, the authors note that there is currently no gold standard thermometer type, manufacturer, or route. They reviewed several studies and reported that the thermometers that are compared, and accuracy measured also appears to be inconsistently reported across studies including systematic reviews.[17] A systematic review and meta-analysis accuracy of peripheral thermometers for estimating temperature concluded that peripheral thermometers do not have clinically acceptable accuracy and should not be used when accurate measurement of body temperature is required when making clinical decisions.[18] Evidence suggests that they are not acceptable methods for detecting temperatures outside the normothermic range and do not detect fever accurately.[19]

There have been concerns about the accuracy of non-contact handheld infra-red thermometers for measuring temperature during the pandemic. There has been recommendation for the use of infra-red thermal imaging cameras at entrances as they are more accurate with a wider temperature and avoid missing the potential hottest points of the body surface, such as the inner canthus of the eye. They are argued to be more accurate than the handheld infra-red thermometers.[20] However, at our premise and most public establishments, handheld NCIT were commonly used and often individuals tried to use their wrists as an alternative. Awareness regarding inaccuracy of the wrist as opposed to the forehead need to be increased for public to understand the importance and comply.

CONCLUSION

Accuracy of temperature reading is very important especially during this pandemic where there is a need to identify those at high risk so they can be monitored and medically managed hence reducing the spread to the general population. Our results suggest that the forehead temperature reflects the tympanic temperature better than the wrist and thus suggest that wrist temperature not be used interchangeably with the forehead temperature for fear of missing individuals with fever.

LIMITATION

- All temperature measurements were taken at the entrance of the hospital before individuals could enter the hospital building; hence, environmental temperature, effect of air-conditioned cars, and other external factors could not be standardized.
- Weight, height, and body mass index were not taken due to the challenge and policies of social distancing.
- Ear canal patency prior to measurement of temperature could not be performed due to the social distancing policies

There is no conflict of interest among contributors to the conduct of this study.

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REFERENCES

1. Chen G, Xie J, Dai G, Zheng P, Hu X, Lu HL, et al. Validity of the use of wrist and forehead temperatures in screening the general population for COVID-19: a prospective real-world study. Iran J Public Health 2020; 49(Suppl 1): 57-66.
2. Sullivan SJL, Rinaldi JE, Hariharan P, Casamento JP, Baek S, Seay N, et al. Clinical evaluation of non-contact infrared thermometers. Sci Rep 2021; 11(1): 22079.
3. Teran CG, Torrez-Llanos J, Teran-Miranda TE, Balderrama C, Shah NS, Villarroel P, et al. Clinical accuracy of a non-contact infrared skin thermometer in paediatric practice. Child Care Health Dev 2011; 38(4): 471-6.
4. Ng DK, Chan C, Chan EY, Kwok K, Chow P, Lau WF, et al. A brief report on the normal range of forehead temperature as determined by noncontact, handheld, infrared thermometer. Am J Infection Control 2005; 33(4): 227-9.
5. Chan WP, Kosik RO, Wang CJ. Considerations and a call to action for the use of noncontact forehead infrared handheld thermometers during the COVID-19 pandemic. J Global Health 2021; 11: 03023.
6. Infrared thermometers used for COVID-19 testing do not pose risk to pineal gland. AP NEWS. https://apnews.com/article/archive-fact-checking-9121703294
7. Quito A. Coronavirus: We need to rethink the design of the temperature gun. Quartz 2020 [updated 22 Feb 2020; accessed 03/09/2020]. https://qz.com/1806728/coronavirus- we-need-to-rethink-the-design-of-the-temperature-gun/.
8. Chen HY, Chen A, Chen C. Investigation of the impact of infrared sensors on core body temperature monitoring by comparing measurement sites. Sensors (Basel) 2020; 20(10): 2885.
9. Wang D, Hu B, Hu C, Zhu F, Liu X, Zhang J, et al. Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus–infected pneumonia in Wuhan, China. JAMA 2020; 323(11): 1061-9.
10. Chi YC. Infrared thermometer and method for determining temperature. https://patents.google.com/patent/US20050094705A1/en . [Accessed 03/09/2020].
11. Foster J, Lloyd AB, Havenith G. Non-contact infrared assessment of human body temperature: The journal Temperature toolbox. Temperature (Austin) 2021; 8(4): 306-19.
12. Dzien C, Halder W, Winner H, Lechleitner M. Covid-19 screening: are forehead temperature measurements during cold outdoor temperatures really helpful? Wien Klin Wochenschr 2021; 133(7-8): 331-5
13. Non-Contact Thermometers for Detecting Fever: A Review of Clinical Effectiveness [Internet]. Ottawa (ON): Canadian Agency for Drugs and Technologies in Health; 2014
14. Kameda N. Clinical accuracy of non-contact forehead infrared thermometer and infrared tympanic thermometer in postoperative adult patients: A comparative study. J Perioper Pract. 2022 Jun;32(6):142-148
15. Asadian S, Khatony A, Moradi G, Abdi A, Rezaei M. Accuracy and precision of four common peripheral temperature measurement methods in intensive care patients. Med Devices (Auckl). 2016; 9: 301-8.
16. Malawi I, Alsohabani T, Aleidan M, Al shahrani N, Karairi A, Bandr Mzahim, et al. Wrist and forehead temperature measurement as screening methods during the COVID-19 pandemic. J Med Law Public Health 2021; 1(2): 26-30.
17. National Health Library & Knowledge Services (NHLKS), Ryan P, Leen B, Cole N. Evidence summary: Is there any evidence to suggest that one form of temperature checking is more reliable than another - eg is infra-red thermography more accurate than oral or aural measurements for the purposes of screening? [v1.0]. 2020 May 26. https://www.lenus.ie/handle/10147/627806. [accessed 10 Dec 2021].
18. Niven DJ, Gaudet JE, Laupland KB, Mrklas KJ, Roberts DJ, Stelfox HT. Accuracy of peripheral thermometers for estimating temperature: a systematic review and meta-analysis. Ann Intern Med 2015; 163(10): 768-77.
19. Bolton S, Latimer E, Clark D. Temporal artery and non-contact infra-red thermometers: is there sufficient evidence to support their use in secondary care? Global Clin Eng J. 2020; 2(2): 8-16.
20. Zhang J, Liu S, Zhu B. Fever screening methods in public places during the COVID-19 pandemic. J Hosp Infect 2021; 109: 123-4.