USEFULNESS OF FOREHEAD INFRARED THERMOMETERS TO SCREEN PATIENTS FOR FEVER DURING COVID-19 PANDEMIC

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ABSTRACT

Objective: To determine accuracy of infrared thermometer for detection of fever as compared to mercury thermometer.

Study Design: Cross sectional study.

Place and Duration of Study: Department of Medicine, Combined Military Hospital Peshawar, from May to Jun 2020.

Methodology: All willing adult patients reporting to the fever desk were selected by consecutive sampling. Exclusion criteria included any dermatological condition affecting forehead and unwillingness. Forehead temperature was first checked twice using Kinlee FT3010 infrared thermometer. Axillary temperature was then recorded using a standard clinical mercury thermometer.

Results: There were 538 patients, including 251 (46.65%) males and 287 (53.35%) females, aged 46.76 ± 12.44 years. Median temperatures recorded with infrared and mercury thermometers were 97.00°F (interquartile range: 95.10- 97.80°F) and 98.30°F (interquartile range: 98.00- 98.90°F) respectively (p<0.001). Intra-class correlation was 0.143 (95% CI -0.052, 0.323). There was a weak to moderate correlation (R: 0.366; p<0.001) between temperatures recorded by the two techniques. ROC curve analysis for temperatures recorded by infrared thermometer revealed an area under curve of 0.725 at a threshold of 98.6°F and 0.746 at a threshold of 100.4°F defined by mercury thermometer. Infrared thermometer had sensitivity, specificity, positive predictive value and negative predictive value of 13.61% and 9.38%, 97.95% and 99.80%, 71.43% and 75.00%, and 75.10% and 95.57% for thresholds of 98.6°F and 100.4°F respectively.

Conclusion: Infrared thermometer underestimates temperatures recorded by mercury thermometer. Limits of agreement are too broad, indicating inconsistency in measurements. A significantly lower threshold is required to improve the sensitivity of Infrared thermometer in picking up fever.

Keywords: Agreement, infrared thermometry, Skin temperature, Temperature measurement, Thermometry.

INTRODUCTION

COVID-19 pandemic, originating from Wuhan (China) in December 2019, has taken the world by storm. The first case in Pakistan was reported on 26 February 2020[1]. Since then, the disease has continued to spread like wild fire. Four months on, there are 198,883 confirmed cases and 4,035 deaths in our country[2]. For obvious reasons, healthcare setups are most likely to be congested with infected patients. Infection control practices to limit spread of this viral disease should focus on targeting patients/ visitors right at the point of entry into hospitals. Considerable time can lapse during physician encounter and subsequent period waiting for results of investigations. Spread of infection to others during this period is very likely. Outside of hospitals, body temperature is not an effective COVID-19 screening tool for multiple reasons[3]. However, recording body temperature would provide the quickest way to separate suspected infectious patients from others in the emergency departments. This is important because patients are known to avoid self- reporting fever during pandemics[4].

Body temperature is one of the fundamental signs recorded during every physical examination. There are different ways to do so, both invasive and non-invasive. This could also be

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done on different sites, such as the skin, tympanic membranes and rectum etc. The inherent advantages/disadvantages of all these different methods as well as the variations between them are already very well known. As has happened during infectious disease epidemics in the past, screening every patient/visitor for fever has become a routine practice at hospitals these days.

Concerns regarding hazard to individuals and environment from mercury leaking from broken thermometers are valid[5]. Still, mercury-in-glass thermometers are widely used in our setup. Given the need for infection control practices during the current pandemic, non-contact techniques have become more important and are now universally employed at hospital entry points and fever desks. Infrared thermometers (IRT) have the added advantage of being quick and thus reduce burden on healthcare workers as well[6]. Unfortunately, the accuracy of these thermometers is questionable and needs to be validated in our setups in comparison to other well-established methods[7].

This study was therefore planned to document our experience with IRT to pick up febrile patients at a busy accident and emergency department during the COVID-19 pandemic. The objectives were to compare the temperatures obtained by IRT and mercury thermometer as well as to determine the diagnostic accuracy of IRT using mercury thermometer as the gold standard.

METHODOLOGY

This comparative cross- sectional study was carried out at Combined Military Hospital Peshawar from May to June 2020. The protocol was approved by the local Ethics Review Committee vide serial no 30. We included all willing adult patients reporting to the fever desk established at Accident & Emergency Department to screen patients for COVID-19. Patients were selected by consecutive sampling and verbal consent was obtained. Exclusion criteria included any dermatological condition affecting the forehead and unwillingness expressed by the patients. Patient confidentiality was maintained by recording minimum identifying information (only names and age). All data was kept secure and was accessible to only three of the authors during collection phase. A minimum sample size of 101 patients was required to achieve 80% power at 5% two-sided level of significance to detect a mean difference of 0.33°F, assuming the standard deviation of differences to be 1.17°F, based on figures reported by Sener *et al*[8].

For this study, we used Kinlee FT3010 non-contact electronic forehead infrared thermometer (Zhongshan Jinli Electronic Weighing Equiptment Co Ltd, China). It works well under environmental temperature range of 16- 40°C and has a maximum laboratory error of 0.3°C. Age and gender of all patients were recorded. Forehead temperature was first checked twice using the infrared thermometer. For this purpose, patients were made to sit under a shade for at least three minutes and the device was placed at a distance of 5-15 cm from the forehead, in midline, as per manufacturer's instructions. Patients with visible sweating on forehead were asked to wipe off the sweat. Two measurements were recorded successively, with no restriction on minimum time gap in-between. Average of these values was recorded. Axillary temperature was then recorded using a standard clinical mercury thermometer, kept in place for a minimum of 3 minutes. This was done by another nurse, who was blinded to the results obtained using infrared thermometer. Mercury thermometer was appropriately disinfected after each use.

Data analysis was carried out using IBM SPSS Statistics for Windows, Version 20.0 (IBM Corp, Armonk, NY) and MedCalc Statistical Software version 19.3.1 (MedCalc Software Ltd, Ostend, Belgium). Shapiro-Wilk test was used to check normality of data. Quantitative variables with non-parametric distribution were described as median and interquartile range. Median temperatures recorded with two thermometers were compared using Wilcoxon Signed Ranks Test. Estimates for intra-class correlation and 95% confidence intervals were calculated using absolute agreement, 2-way mixed-effects model. Correlation between the measurements by IR and mercury thermometers was determined by linear regression. ROC curve analysis was carried out to plot sensitivity against (1-specificity) for varying values of temperature recorded by IRT, against cut-offs of 98.6°F and 100.6°F measured by mercury thermometer. Proportions of patients with normal and higher temperatures as recorded by the two devices were cross tabulated to determine different parameters of diagnostic accuracy. For this, two different thresholds were used: >98.6°F and >100.4°F.

RESULTS

A total of 538 patients, including 251 (46.65%) males and 287 (53.35%) females, aged 46.76 ± 12.44 years were included in this study. Temperatures recorded by IRT and mercury thermometer had non-parametric distribution (*p*<0.001 for both). Median temperatures recorded were 97.00°F (interquartile range: 95.10 - 97.80°F) and 98.30°F (interquartile range: 98.00-98.90°F) with each of these devices respectively. This difference was statistically significant, with *p*<0.001 (table-I). Intra-class correlation between the two techniques was 0.143 (95% CI-0.052, 0.323), indicating poor reliability. Linear regression analysis showed a weak to moderate, statistically significant correlation (R: 0.366; *p*<0.001) between temperatures recorded by the two techniques (fig-1). This relationship is further depicted in Bland-Altman plot, which highlights the bias and number of outliers (fig-2). ROC curve analysis for temperatures recorded by IRT revealed an area under curve of 0.725 (95% CI: 0.676-0.773) at a threshold of 98.6°F and 0.746 (95% CI: 0.635-0.857) at a threshold of 100.4°F defined by mercury thermometer (fig-3).

A total of 147 patients had temperature >98.6°F on mercury thermometer, indicating fever, out of whom only 20 had fever detected by IRT. IRT did not record fever in 383 out of the 391 patients labelled afebrileon mercury thermometer. Using a threshold of 100.4°F by mercury thermometer, 32 patients had fever, but IRT detected fever in only 3 of them. IRT did not record fever in 505 out of the 506 truly afebrile patients. Various measures of diagnostic performance for IRT using these two cut-offs thus obtained are shown in table-II.

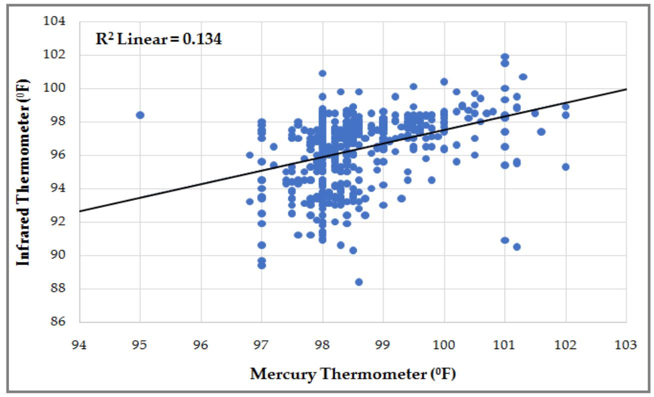

Figure-1: Correlation between temperatures recorded by mercury and infrared thermometers.

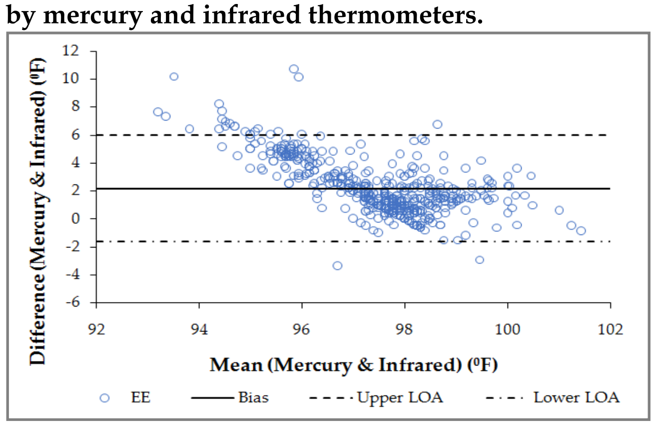

Figure-2: Bland–Altman plot comparing means and differences between temperatures recorded by infrared and mercury thermometers.

LOA: Limit of Agreement

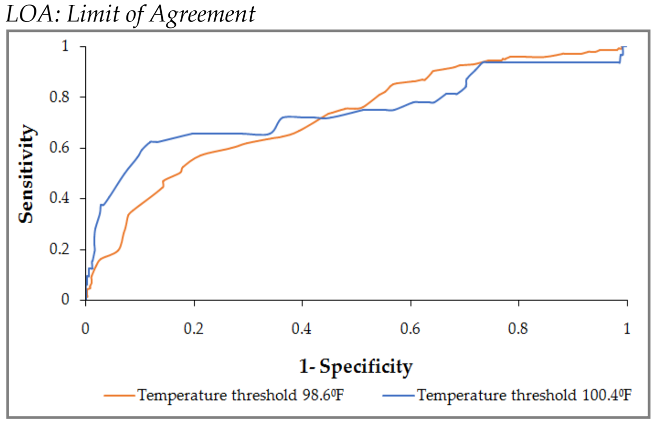

Figure-3: Receiver operating characteristics curves to predict fever with infrared thermometer, with reference to different thresholds for mercury thermometer.

DISCUSSION

The results of this study have shown that the IRT significantly under estimates skin temperature and has only a weak correlation with values obtained by mercury thermometer. It is poor in picking up fever but very effective in excluding fever in afebrile individuals. These characteristics become more prominent with higher cut- off values to define fever. IRT is thus not a good substitute for mercury thermometer, but offers the advantage of limiting cross-infection during current scenario. Environmental temperature and incorrect placement of thermometers in axilla can produce flawed results[9]. Still, we used axillary temperatures as the reference in this study because of the ease of axillary access, extensive experience of our nurses with this technique and the fact that this does not expose patients to infectious agents as much as the oral route.

Though the visitors to the hospital during this study period were screened for fever at main entrance, we included only the patients presenting to accident and emergency department. Still, a vast majority of the study population was afebrile. The figures are similar to those reported from outdoor clinics working during other infectious disease epidemics in the past. As an example, Hewlett *et al* documented fever (temperature ≥100.4°F) in 43 (7.6%) out of 566 patients during 2009/10 H1N1 epidemic in America[10].

During pandemics such as COVID-19, temperature recording devices should ideally have a low false-negative rate for them be to a useful screening tool. This property could enable wide spread use at community level. In contrast, use in hospital settings demands them to have a high true-positive rate, so that cases are not easily missed. With specificity around 86-90% and sensitivity of 9-14% depending upon the threshold to define fever, IRT used in this study has failed to impress. The results suggest considering a different cut-off value to detect fever by IRTs. Careful evaluation of the coordinates of ROC curve reveals that the sensitivity could be enhanced to 85% and specificity changed to 43% by using a cut- off of 96.15°F by IRT to detect temperatures greater than 98.6°F as recorded by mercury thermometers. This would make it more useful as a screening tool in A&E clinic.

Accuracy of IRT can be gauged by the distribution of differences between temperatures by the two devices as shown in the Bland-Altman plot. The range of deviation was very broad, with standard deviation of 1.94°F. Almost 4.1% of the values were outside the 95% confidence interval limits, negatively affecting the clinical utility of IRT. Another interesting finding is the lesser bias at higher body temperatures, where values are more tightly scattered around the mean body temperature. Same finding was also documented

Table-I: Wilcoxon Signed Ranks test to compare temperatures recorded by mercury and infrared thermometers.

	Mercury thermometer	Infrared thermometer	*p*-value
Temperature (°F)	98.30 (98.00 - 98.90)	97.00 (95.10 - 97.80)	<0.001

Table-II: Diagnostic performance of infrared thermometer for detection of fever.

Parameter	Fever: Temperature >98.6°F		Fever: Temperature >100.4°F	
	Value	95% Confidence Interval	Value	95% Confidence Interval
Sensitivity	13.61%	8.51 - 20.23%	9.375%	1.98 - 25.02%
Specificity	97.95%	96.01 - 99.11%	99.80%	98.90 - 100%
Positive likelihood ratio	6.65	2.99 - 14.77	47.44	5.08 - 443.3
Negative likelihood ratio	0.88	0.83 - 0.94	0.91	0.81 - 1.02
Frequency of fever	27.32%	23.60 - 31.3%	5.95%	4.10 - 8.29%
Positive predictive value	71.43%	52.96% - 84.74%	75.000%	24.30 - 96.56%
Negative predictive value	75.10%	73.85 - 76.31%	94.57%	93.97 - 95.11%
Accuracy	74.91%	71.02 - 78.52%	94.42%	92.14 - 96.21%

by Ng *et al* while measuring tympanic membrane temperature in pediatric patients[11]. Though we have no plausible explanation for this phenomenon, it is definitely important from the perspective of minimizing false negatives amongst febrile patients.

Previous data on utility of IRTs is conflicting. Most of the available data focuses on children. Olasinde *et al* proved that axillary mercury thermometers and forehead IRT could be used interchangeably in view of the good correlation and narrow limits of agreement[12]. Chiappini *et al* and Teran *et al* documented excellent accuracy of IRTs as compared to axillary and rectal temperatures respectively in children and recommended their routine use in clinical practice[13,14]. Contrary to these observations, Sethi *et al* found a broad limit of agreement and higher mean difference between axillary and IRT measurement in neonates[15].

Our results may not be directly comparable with other studies considering differences in sample populations as well as the settings. Moreover, most of the available data has been collected in indoor environments with well controlled temperatures. This study is different because it has been done in a large public sector hospital in a developing country. Considering enormous burden on limited resources, fever clinic has been established as a make shift arrangement next to A&E department. Ambient temperature at the time this study was carried out was quite high, with a wide diurnal variation. This could have impacted the results.

The positive aspect of our methodology is employing only a single person to use IRT for all the patients in this study, thereby excluding inter-observer bias related to procedural skills. Both nurses were blinded to measurements recorded by the two types of thermometers. However, this study has a few limitations. Outliers are known to affect linear regression analysis[16,17]. The correlation between IR and mercury thermometers should be interpreted in context of significant outliers towards the lower end for IRT readings and the higher end for measurements by mercury thermometer in this data set. We did not repeat axillary temperature measurement due to time constraints and thus cannot comment on precision of this technique. Ng *et al* have previously reported significant variations in surface temperatures (up to 3.6°F) recorded by different brands of IRT[18]. They suggest ensuring internal validation of each instrument before use in clinical practice, so as to avoid misleading results. We used only a single brand of commercially available IRT to ensure consistency in results. The findings of this study may not be generalizable to other brands/makes of IRTs.

CONCLUSION

IR thermometer readings are not representative of true body temperature as recorded by mercury thermometer. The limits of agreement are too broad, highlighting inconsistency in measurements. A significantly lower threshold is required to improve the sensitivity of IRT in picking up fever.

CONFLICT OF INTEREST

This study has no conflict of interest to be declared by any author.

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