

Use of noncontact infrared thermography to measure temperature in children in a triage room

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Abstract

We compared the accuracy and utility of 3 infrared (IFR) thermographs fitted with axillary digital thermometers used to measure temperature in febrile and afebrile children admitted to an emergency triage room.

A total of 184 febrile and 135 afebrile children presenting to a triage room were consecutively evaluated. Axillary temperature was recorded using a digital electronic thermometer. Simultaneously, IFR skin scans were performed on the forehead, the neck (over the carotid artery), and the nape by the same nurse. Fever was defined as an axillary temperature $\geq 37.5^{\circ}\text{C}$. The temperature readings at the 4 sites were compared.

For all subjects, the median axillary temperature was $37.7 \pm 1.5^{\circ}\text{C}$, the IFR forehead temperature was $37 \pm 1.1^{\circ}\text{C}$, the IFR neck temperature was $37.6 \pm 1.5^{\circ}\text{C}$, and the IFR nape temperature was $37 \pm 1.2^{\circ}\text{C}$. A Bland–Altman plot of the differences suggested that all agreements between IFR and axillary measures were poor (the latter measure was considered the standard). The forehead measurements had a sensitivity of 88.6% and a specificity of 60% in patients with temperatures $\geq 36.75^{\circ}\text{C}$. The sensitivities of the neck measurement at cut-offs of $\geq 37.35^{\circ}\text{C}$ and ≥ 36.95 were 95.5% and 78.8% for those aged 2 to 6 years. Thus, 11.4% of febrile subjects were missed when forehead measurements were performed.

An IFR scan over the lateral side of neck is a reliable, comfortable, rapid, and noninvasive method for fever screening, particularly in children aged 2 to 6 years, in busy settings such as pediatric triage rooms.

Abbreviations: AD = axillary digital, IFR = infrared, ROC = receiver-operating characteristics.

Keywords: child, infrared thermography, pediatric emergency, temperature measurement

1. Introduction

It is essential to evaluate fever status in children admitted to pediatric triage rooms. Accurate, rapid, and safe measurement of core body temperature is very important. The gold standard is rectal temperature; however, taking this temperature is invasive, impractical, and time-consuming in triage rooms with high patient flows and is associated with the possibility of perforation.^[1–3] Axillary thermometry is noninvasive and safe, and the results correlate well with rectal temperature.^[4] However, axillary thermometers are also impractical and measurements are time-consuming in crowded hospital settings. Indeed, glass mercury thermometers are no longer used in Turkey because of the risk of metal toxicity.

Another popular alternative is tympanic thermometers. Although infrared (IFR) tympanic thermometers are considered ideal, being both practical to use and yielding core temperatures,

ear wax, and conditions such as otitis media may compromise the readings.^[5] In our hospital, body temperature measurements are performed by triage nurses. We do not use tympanic devices before physical examination of patients admitted to the triage room.

The 2013 National Institute for Health and Clinical Excellence guidelines recommended that temperature should be measured using an electronic or chemical dot axillary thermometer in children <5 years of age, or that an IFR tympanic thermometer should be employed in children aged 4 weeks to 5 years.^[6] The Canadian Pediatric Society recommended the use of electronic axillary thermometers in children ≤ 5 years of age.^[7] Noncontact IFR skin thermometers measure temperature rapidly and noninvasively, without an infection risk.

However, the cited guidelines do not address the use of IFR thermometers. Some small studies conducted in hospital inpatient and emergency departments have found that IFR thermometers afford high sensitivity and specificity when used to detect fever; electronic thermometers were less satisfactory.^[8,9]

In the present study, we measured axillary digital (AD) and IFR temperatures (at the forehead, neck, and nape) in children admitted to pediatric emergency triage. We compared the accuracy of the methods in the context of fever screening in a triage room.

2. Materials and methods

2.1. Ethics and patient selection

This study was conducted at Dr Behçet uz Children Teaching Hospital, Turkey, between July and September 2014 prospectively. Patients including children >1 month of age, presenting with or without fever to the emergency triage room during the day time were evaluated for inclusion in the study. The average number of the patients admitted to our emergency service

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including emergency outpatient clinic is about 117,000 per year; the population from which the study sample was derived was 869 during daytime for 2 months at emergency triage room. Body temperature measurement is routine in our emergency triage room except only for whom temperature measurements were not appropriate (patients with sepsis, trauma, critically ill patients, and those having a seizure). Those patients were not enrolled in the study. The number of such patients was 369. Patients who were unwilling to be enrolled in the study, those having perspiration during temperature measurement, those with inappropriate temperature readings, and patients whose axillary temperature readings could not be measured at 1 time due to the incompatibility of their family were further excluded from the study. The number of such patients was 181.

The study was approved by the Ethical Committee of İzmir Katip Çelebi University (no: 2017/2325). Because body temperature measurement is routinely obtained by using IFR or AD thermometer in our emergency triage room, parents and children were informed verbally and the study was carried out on the patients who accepted the participate and signed the written informed consent.

2.2. Method of measurement and instruments

Before the study, 2 dedicated nurses were trained on how to use the IFR and AD thermometers. Patients who fulfilled the study criteria had their axilla and 3 different site of IFR thermometers simultaneously conducted by the same nurse to avoid personal and physiological variations. Measurements were collected consecutively at single time point with time interval to collect all readings of ≤ 3 minutes. Temperature readings in every patient were collected at 1 time point, every patient was only included once, and readings were only performed once in every child. The same nurse would read and document readings from 3 sites of IFR thermometer. Immediately, another nurse would then read and document AD thermometer, blinded from the results of the other nurse. The study periods were chosen to provide 2 months of hot weather (July and August; mean: 28°C) to avoid an extraneous factor that affect skin temperature readings. The ambient temperature was recorded in every study day. An IFR thermoscope (model DT-8806) was used to measure forehead, neck, and nape temperature in each child; a Beurer FT09 digital thermometer was used to measure AD temperature. Axillary temperature was taken after wiping underarm with dry towel and the tip of the device was placed under the arm then the reading was recorded after the beep sound. The temperature was read 3 minutes after placement on the patients's axilla. The IFR thermometer was held 0.5 cm distant from the mid-forehead, neck, and nape. This thermometer measures body temperature within 2 seconds without any contact with the patients. Calibration of each thermometer was checked before every study day. For axillary temperature, the generally used cut-off point for fever is 37.5°C. Therefore, we defined fever as an AD temperature $\geq 37.5^\circ\text{C}$. We also recorded sex, age, the ability of the child to sit, parental declarations of fever, body weight, and ambient temperature.

2.3. Statistical analysis

All analyses were performed with the aid of SPSS version 17 statistical software. Normality distribution was evaluated using the Kolmogorov–Smirnov test. Categorical variables are described as frequencies with percentages, and numerical variables are presented as medians with interquartile ranges. Agreements

among different temperature measurements were investigated by constructing Bland–Altman Plots. The significance of relationships between 2 categorical variables was explored using the χ^2 test. The Mann–Whitney test was employed to compare independent medians. The Friedman test, followed by Dunn's post-hoc test, was used to compare dependent medians. Receiver-operating characteristic (ROC) curves were drawn to explore the predictive ability of temperature measurements. Cut-off values were calculated with the aid of the Youden Index. A P value $< .05$ was considered to reflect a statistically significant difference.

3. Results

3.1. Demographic and clinical data

In total, 319 children (176 males, 143 females) with a median age of 30 (SD: 50) months (range: 1 month to 18 years) were included. We divided the patients into 3 age groups (< 2 , 2–6, and > 6 years of age). The median body weight was 13 (SD: 9.5) kg. Patient characteristics and median temperature readings are shown in Table 1.

3.2. Evaluation of IFR thermometers and AD

The Bland–Altman plots revealed concordance between the AD and all 3 IFR measurements, but the latter measures were not in good agreement with the AD readings (considered the standards) (Fig. 1A–C). Table 2 compares the median values of all measurements in febrile and afebrile children of all 3 age groups. Figure 2A–D shows the ROC curves associated with detection of a temperature $\geq 37.5^\circ\text{C}$. The areas under the ROCs were 0.791, 0.815, and 0.810 for the IFR measurements on the forehead, neck, and nape ($P < .001$) (Fig. 2A). The sensitivities, specificities, and cut-offs for all IFR measurements are shown in Table 3.

4. Discussion

Body temperature is very important when making triage decisions for children. We admit about 117,000 patients to

Table 1
Patient characteristics.

Age, years (n, %)	
≤ 2	146 (45.8)
2–6	110 (34.5)
> 6	63 (19.7)
Sex (n, %)	
Male	176 (55.2)
Female	143 (44.8)
Body weight (median, IQR)	13 (9.5)
Ambient temperature* (median, IQR)	24.4 (2.9)
Baby seating (n, %)	
No	264 (82.8)
Yes	55 (17.2)
Fever (parent's declaration) (n, %)	
Absent	72 (22.6)
Present	247 (77.4)
Axilla temp* (median, IQR)	37.7 (1.5)
Forehead temp* (median, IQR)	37 (1.1)
Under neck temp* (median, IQR)	37.6 (1.5)
Nape and body temp* (median, IQR)	37 (1.2)
Fever (n, %)	
Afebrile	135 (42.3)
Febrile	184 (57.7)

*°C.

IQR = interquartile range, n = frequency.

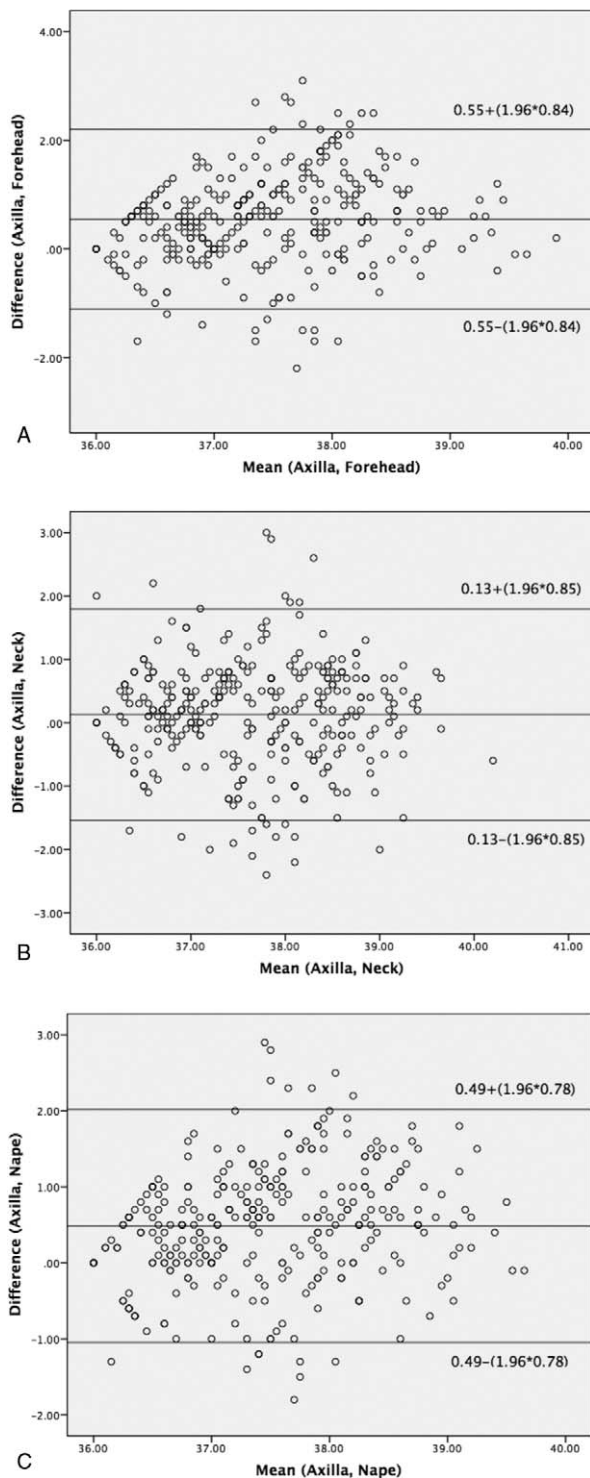


Figure 1. (A) Bland–Altman plot of differences comparing IFR forehead and axillary temperatures with a mean difference was 0.55°C and 95% limits of agreement. (B) Bland–Altman plot of differences comparing IFR neck and axillary temperatures with a mean difference was 0.13°C and 95% limits of agreement. (C) Bland–Altman plot of differences comparing IFR nape and axillary temperatures with a mean difference was 0.49°C and 95% limits of agreement. IFR=infrared.

our pediatric emergency triage room annually; safe, rapid, noninvasive, and accurate temperature measurement is essential. IFR thermometry is safe, simple, comfortable, and rapid; thus, it is an attractive alternative to rectal and axillary measurements.

Table 2
Comparison of measurement in different classes of ages.

Age, years (n)	Axilla, °C	Forehead, °C	Under neck, °C	Nape and body, °C	P value
Febrile					
≤2 (n=87)	38.4 (1.2)	37.1 (1.2)	38.0 (1.5)	37.2 (1.1)	<.001 ^{*,†,‡,§,¶}
2–6 (n=66)	38.4 (0.8)	37.5 (1.4)	38.2 (1.1)	37.7 (1.2)	<.001 ^{*,†,‡,§,¶}
>6 (n=31)	38.4 (1.3)	37.6 (0.9)	38.1 (1.6)	37.8 (1.2)	<.001 ^{*,†,‡}
Afebrile					
≤2 (n=59)	37.0 (0.5)	36.7 (0.8)	36.8 (0.8)	36.7 (0.6)	.005 [§]
2–6 (n=44)	36.8 (0.5)	36.5 (0.7)	36.8 (0.9)	36.6 (0.7)	<.001 ^{*,§,¶}
>6 (n=32)	36.8 (0.8)	36.55 (1.0)	36.7 (0.8)	36.6 (0.9)	.082

* Axilla vs forehead.
 † Axilla vs under neck.
 ‡ Axilla vs nape and body.
 § Forehead vs under neck.
 ¶ Under neck vs nape and body.

However, are IFR measurements reliable? Only a few studies have compared IFR thermometers with axillary devices in children, and the results have been inconsistent.^[9–13]

Our principal finding was that the correlations between axillary and IFR measurements were weak, as revealed by Bland–Altman plots. Our data support those of a study performed on 90 children (inpatients and outpatients).^[11] The cited work found weak correlations between IFR temperatures and tympanic, temporal artery, and AD temperatures. Sethi et al^[12] reported that the temperatures measured by an axillary and an IFR method were in poor agreement in neonates. IFR forehead temperatures were less accurate than AD temperatures. By contrast, a moderate correlation between axillary and IFR temperature ($r=0.66$, $P=.001$) was observed in another study.^[9] Chiappini et al^[10] found a strong correlation between IFR measurements and axillary temperatures in 251 children ($r=0.84$). However; a mercury-in-glass thermometer was used for axillary measurements. The differences noted may be attributable to the use of an AD rather than a mercury-in-glass thermometer; we thus did not use the gold-standard measure of body temperature. Many studies have found that agreement between rectal and IFR temperatures is low.^[13–17] De Curtis et al^[13] reported that an IFR instrument reliably measured body temperature in neonates. One study on 434 children aged 1 to 48 months found a strong correlation between IFR and rectal temperatures.^[18] In those studies, consecutive readings were made using either thermometer. We did not take multiple IFR temperatures; the fact that we performed only single measurements at 3 sites.

Many factors may contribute to the differences evident among the various studies. These may include differences in age, body weights, measurement settings, and methodological standards.

We compared measurements by sex, age group, parental declaration of fever, whether the child could sit, and confirmed fever. The axillary recordings were consistently significantly higher than the forehead and nape. Interestingly, the axillary temperatures were rather similar to the neck IFR readings regardless of age, sex, parental declaration of fever, and whether the child could sit; however, statistical significance was not attained. Not only were the neck IFR results the most similar to the AD data, but the former readings were higher than the forehead IFR readings in all age groups ($P=.001$) except for children aged >6 years of age with confirmed fever. In this age group, all 3 IFR readings were similar and lower than the axillary readings. On the other hand, in afebrile children of the same age group, the readings of all 4 methods did not differ significantly. The reliability of forehead IFR readings is lower than that of neck

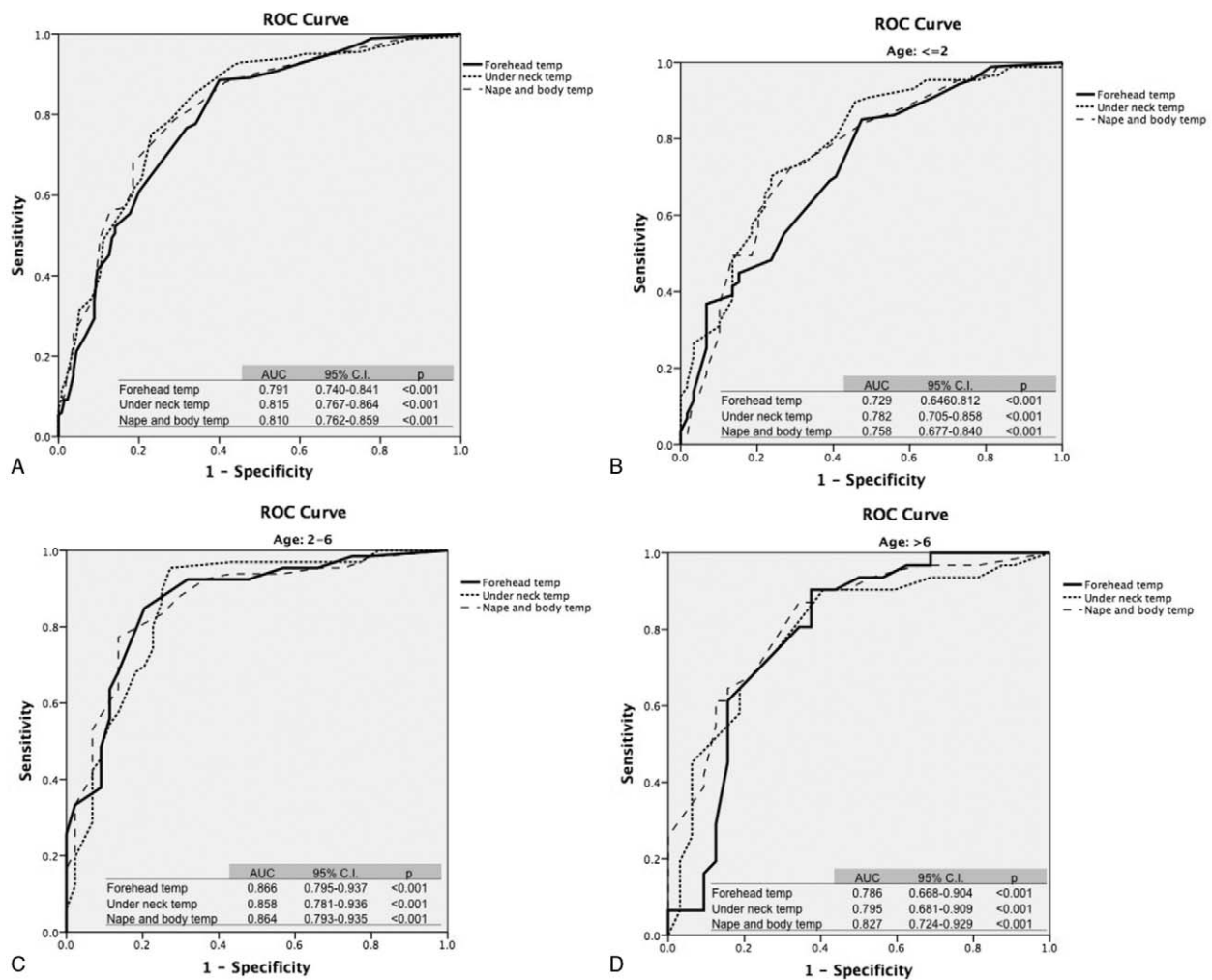


Figure 2. (A) ROC curve of IFR measurements. (B) ROC curve of IFR measurements for age ≤ 2 . (C) ROC curve of IFR measurements for age 2 to 6 years. (D) ROC curve of IFR measurements for age > 6 years. IFR=infra-red, ROC=receiver-operating characteristics.

readings principally because the blood supply to the forehead may be limited by vasoconstriction, and the forehead may perspire, as in adults.^[19] Most prior studies measured forehead IFR temperatures; to the best of our knowledge, the neck and nape temperatures were not examined. Only neck IFR temperature was evaluated in 1 study in the English-language literature.^[20]

Despite the statistically significant difference between the median AD and median IFR temperatures, both the nape and neck IFR measurements were good predictors of (axillary) fever in all patients. However, the predictive ability of forehead IFR data was reduced in children < 6 years of age. Overall, the use of forehead IFR data would mean that about 11.4% of febrile children would be missed. When neck IFR temperatures were evaluated in children aged 2 to 6 years, the proportion of febrile children missed was 4.5%. In children aged > 6 years, the febrile proportion missed using any IFR measure was 9.7%. Thus, neck IFR measures may be more accurate in children aged 2 to 6 years. The temperature is measured on the lateral side of neck, which lies closer to large arteries (carotid artery) than do the temporal arteries of the forehead region. Thus, neck IFR measures closely reflect axillary temperatures. This is in line with data from the first study comparing rectal and neck IFR temperatures in

children aged 2 to 6 years during anesthesia. This was the first study to compare neck IFR and rectal temperatures.^[20] IFR measures on the lateral side of neck the most reliable in children aged 2 to 6 years. However, the study methodology differed from ours; the cited authors used logistic regression analyses to evaluate multivariable data.

No IFR measure may be adequately reliable when used to detect fever in children < 2 years of age. IFR measures afford a sensitivity of 95.5% and a specificity of 72.7% in children aged 2 to 6 years. Such measures are rapid and comfortable. Neck IFR is reliable when used to screen for fever in pediatric triage settings with high patient flows.

One of the limitations of the present study is the use of axillary temperature as a measurement of core temperature. A second limitation of this study is that it is a single-center experience and we performed 1 temperature readings for every method.

5. Conclusion

We found that forehead IFR thermometry did not reliably predict axillary temperature. However, as an alternative to axillary measurements, particularly in children aged 2 to 6 years, IFR measurements performed on the lateral side of neck are reliable,

Table 3**Cut-off values of temperature measurements for different age groups.**

	Temperature, °C	Febrile	Afebrile	OR (95% CI)	% Sensitivity	% Specificity
Total	Forehead					
	≥36.75	163	54	11.6 (6.6–20.6)	88.6	60.0
	<36.75	21	81			
	Neck					
	≥37.35	138	31	10.1 (6.0–17.0)	75.0	77.0
	<37.35	46	104			
Nape						
≥36.95	145	39	9.2 (5.5–15.3)	78.8	71.1	
<36.95	39	96				
Age ≤2 years	Forehead					
	≥36.75	74	28	6.3 (2.9–13.7)	85.1	52.5
	<36.75	13	31			
	Neck					
	≥37.35	61	14	7.5 (3.5–16.0)	70.1	76.3
	<37.35	26	45			
Nape						
≥36.95	63	17	6.5 (3.1–13.5)	72.4	71.2	
<36.95	24	42				
Age 2–6 years	Forehead					
	≥36.95	56	9	21.8 (8.1–58.9)	84.8	79.5
	<36.95	10	35			
	Neck					
	≥37.05	63	12	56 (14.7–212.8)	95.5	72.7
	<37.05	3	32			
Nape						
≥37.05	51	6	21.5 (7.6–60.7)	77.3	86.4	
<37.05	15	38				
Age >6 years	Forehead					
	≥36.75	28	12	15.6 (3.9–62.4)	90.3	62.5
	<36.75	3	20			
	Neck					
	≥36.90	28	13	13.6 (3.4–54.4)	90.3	59.4
	<36.90	3	19			
Nape						
≥36.75	28	12	15.6 (3.9–62.4)	90.3	62.5	
<36.75	3	20				

CI=confidence interval, OR=odds ratio.

comfortable, rapid, and noninvasive. Such measurements should be used to screen for fever in busy settings such as pediatric triage rooms.

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