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Original Article

Comparison of infrared tympanic, non-contact infrared skin, and axillary thermometer to rectal temperature measurements in a pediatric emergency observation unit

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Abstract: We measured the skin temperature over the forehead, jugular notch, and neck and compared all three infrared skin temperature sites, axillary digital, and infrared tympanic readings with the rectal temperature in children in a pediatric emergency observation unit. This study enrolled 139 patients ranging in age from 1 month to 4 years seen in the pediatric emergency observation room. The temperatures in the rectum and axilla were measured with a digital thermometer, and a non-contact infrared thermometer was used to measure the temperature of the skin over the lateral side of neck, jugular notch, forehead and the tympanic temperature. During the examination of each child, 17 temperatures were measured within 10 minutes, including six (three for each ear) tympanic and three infrared skin temperatures at each of the three sites, one axilla, and one rectal reading. Fever was defined as a rectal temperature ≥ 38°C, and 56 patients fulfilled this definition. All measurements were compared with the rectal measurement using Bland-Altman plot analysis. The ability of each method to predict a rectal fever was calculated using receiver operating curve (ROC) analysis. The rectal readings were slightly and significantly ($p<0.01$) higher than all other measurements overall. The Bland-Altman plots revealed correlations between the rectal temperatures and the axillary, left and right tympanic, and all infrared skin temperatures, but the latter measurements were not in good agreement with standard readings. The highest areas under the curve (AUCs) were 0.942, 0.882, 0.857, and 0.806 for the axillary, right and left tympanic and infrared-neck thermometers, respectively. Tympanic thermometry is a practical method for measuring temperature in children 1 month to 4 years of age in a busy emergency observation room instead of axillary thermometry, which is more accurate but time-consuming.

Keywords: Emergency, infrared thermometer, pediatric, temperature measurement

Introduction

Body temperature is an important measure for detecting the presence of fever in children in emergency observation units. Medical decisions, investigations, and the management of children in the emergency observation unit are partially based on body temperature. Therefore, body temperature measurements in the pediatric emergency observation unit should be accurate, safe, and practical. However, measuring the core temperature by the rectal route is invasive, time-consuming, and poorly tolerated, especially in older children and adolescents, and has a risk of perforation [1-3]. Despite the many disadvantages and the recommendations of the National Institute for Clinical Excellence (NICE) guidelines [http://wwww.nice.org.uk/guidance/CG160], rectal measurement is still considered the gold standard for temperature measurement in many healthcare systems, as in Turkey, but its use is still questioned. An axillary digital thermometer (ADT) can measure body temperature peripherally with readings close to the core temperature [4]. Although recommended by the American Academy of Pediatrics, National Association of Neonatal Nurses [5], and NICE guidelines [http://wwww.nice.org.uk/guidance/CG160] as a non-invasive technique, it is not practical and is time-consuming, especially in crowded hospital settings. Infrared tympanic thermometers are thought to reflect the core temperature directly because the tympanic

Table 1. Patient characteristics and temperatures measured with rectal, axillar, tympanic, infrared forehead, neck, and jugular (providing Mann-Whitney U values for medians)

	Total (n=139)	Febrile (n=56)	Afebrile (n=83)	p
Sex (n, %)				
Male	90 (64.7)	38 (67.9)	52 (62.7)	0.589
Female	49 (35.3)	18 (32.1)	31 (37.3)	
Age (Median, IQR)	10 (21)	8 (10)	18 (26)	0.001
Weight (Median, IQR)	8.3 (5.1)	8 (4.7)	9 (6.1)	0.107
Rectal (Median, IQR)*	37.6 (1.7)	38.8 (1.1)	37.0 (0.9)	<0.001
Axilla (Median, IQR)*	37.0 (1.6)	37.9 (0.6)	36.3 (0.9)	<0.001
RAT (Median, IQR)*	37.0 (1.3)	37.7 (0.8)	36.4 (0.9)	<0.001
LAT (Median, IQR)*	37.0 (1.4)	37.7 (1.2)	36.4 (1.0)	<0.001
IFR_F (Median, IQR)*	36.8 (1.4)	37.8 (1.6)	36.6 (1.0)	<0.001
IFR_N (Median, IQR)*	37.1 (1.7)	38.1 (1.8)	36.7 (1.1)	<0.001
IFR_B (Median, IQR)*	37.1 (1.4)	37.7 (1.3)	36.6 (1.2)	<0.001

*Data are presented as °C. Rectal (u=0); Axilla (u=268); RAT: Right tympanic (u=547); LAT: Left tympanic (u=665); IFR_F: Infrared over forehead (u=1184); IFR_N: Infrared over carotid artery (u=900); IFR_B: Infrared over jugular notch (u=1150.5).

Table 2. ROC analysis of temperature measured with axillar, tympanic, infrared neck, jugular, and forehead for rectal fever (≥ 38°C)

Total	AUC	SE	p	95% CI
Axilla	0.942	0.018	<0.001	0.906-0.979
RAT	0.882	0.033	<0.001	0.817-0.948
LAT	0.857	0.032	<0.001	0.794-0.920
IFR_N	0.806	0.038	<0.001	0.732-0.881
IFR_B	0.752	0.043	<0.001	0.669-0.836
IFR_F	0.745	0.045	<0.001	0.656-0.834

AUC: Area under the curve; RAT: Right Tympanic; LAT: Left tympanic; IFR_N: Infrared over carotid artery; IFR_B: Infrared over jugular notch; IFR_F: Infrared over forehead.

Table 3. Comparison of temperature measurements with rectal measurement providing Bonferroni t values with Post- huc Dunn's test

	Median (IQR)	P
Rectal	37.6 (1.7)	
Axilla	37.0 (1.6)	
RAT	37.0 (1.3)	
LAT	37.0 (1.4)	<0.001[a,b,c,d,e,f]
IFR_N	36.8 (1.4)	
IFR_F	37.1 (1.7)	
IFR_B	37.1 (1.4)	

a: Rectal-Axilla (t=157.7); b: Rectal-RAT (t=163.8); c: Rectal-LAT (t=149.2); d: Rectal-IFR_F (t=114.6); e: Rectal-IFR_N (t=69.4); f: Rectal-IFR_B (t=124.7).

membrane shares a vascular supply with the hypothalamus [6]. However, studies of the accuracy of tympanic thermometers have given inconsistent results [7-10]. A non-contact infrared thermometer (IFR) is an alternative for quick, simple, and convenient measurement of body temperature. Typically, the forehead skin, which is supplied by the temporal artery, is used for this purpose. However, studies of IFR-forehead (IFR-F) have given conflicting results [11-15]. What about IFR neck (IFR-N) and IFR jugular notch (IFR-B) skin measurements? The skin on the lateral side of neck is near the carotid artery, a larger artery than the temporal artery. Could this be more reliable than IFR-F or other methods? Only one English-language study has examined the accuracy of IFR-N measurements in children [16]. The jugular notch may be a reliable place to measure the temperature by IFR because the skin in this area is thin and there are many vessels under the skin; in addition, there is less perspiration in this area than on the forehead or neck. To our knowledge, no study has examined the reliability of the IFR-B method.

In this study, we measured the skin temperature over the forehead, jugular notch, and neck and compared all three IFR skin sites, plus ADT and IFR tympanic membrane (IFR-T) readings with rectal digital temperature readings in children in a pediatric emergency observation unit. We also examined the ability of each method to predict the rectal reading. This study is the first to compare five different temperature measurement methods used in gene-ral pediatric practice with the rectal temperature in children.

Materials and methods

This prospective, single-center study was approved by the Ethics Committee of Katip Çelebi University, and conducted in the Pediatric Emergency Observation Unit of Tepecik Education and Training Hospital in the summer of 2016. Written informed consent was obtained for participation from all parents. A total of 139 children from 1 month to 4 years of age presenting with or without fever to the emergency

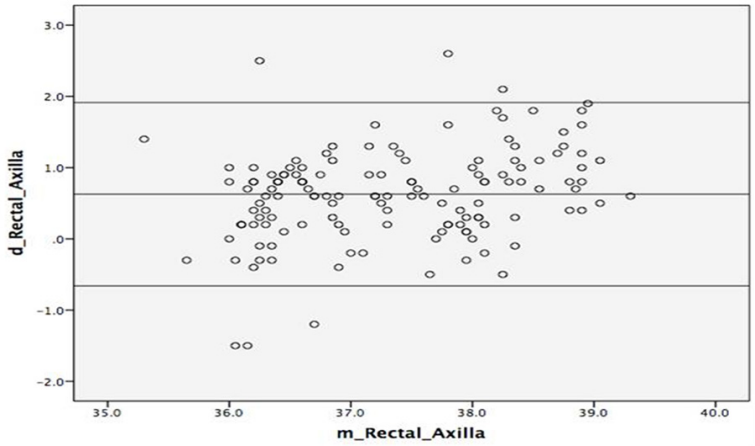

Figure 1. The Bland-Altman plot of difference comparing axillary and rectal temperatures with mean difference was 0.55 (-1.5; 2.6)°C with 95% limits of agreement.

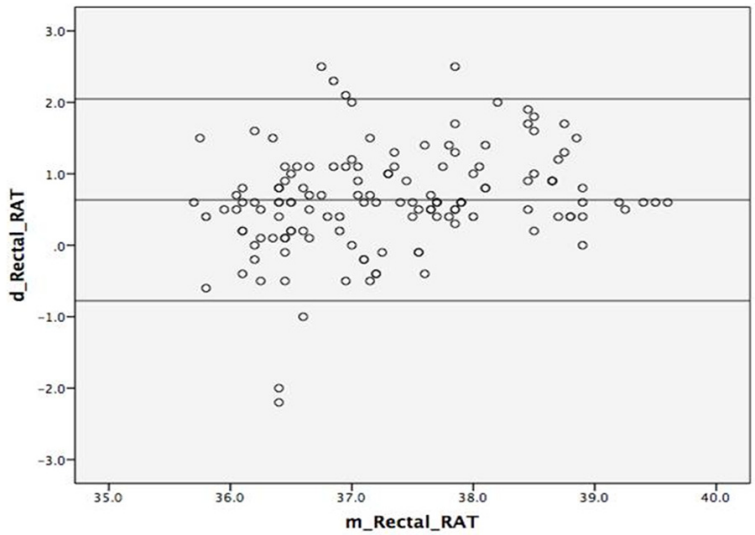

Figure 2. The Bland-Altman plot of difference comparing right tympanic and rectal temperatures with mean difference was 0.15 (-2.2; 2.6)°C with and 95% limits of agreement.

observation unit from 9:00 to 11:00 a.m. were enrolled. Those with otitis externa/media, soft tissue infection, trauma, severe illness, septic shock, unstable medical conditions requiring intensive care unit admission, taking any medication before presenting to the observation unit and unwilling to participate were excluded. Two nurses were trained on the devices and the study protocol before starting the study. All devices were used as prescribed in their user manuals. The non-contact IFR and IFR-T thermometers were calibrated every day. During the examination of each child, 17 temperatures were measured within 10 minutes: including six tympanic membrane readings [three right (RAT) and three left (LAT)], three IFR readings at each of the three sites, one ADT, and one rectal reading.

The same nurse performed, read, and recorded the rectal and axillary readings. Immediately, the second nurse then performed, read, and recorded all of the IFR skin and IFR-T readings. The ambient temperature was maintained at 25-27°C during the study period. The rectal and axillary temperatures were measured using an ECTO1 Mesilife. The tympanic temperatures were measured using a Genius 2 Tympanic Thermometer (Covidien). The IFR non-contact skin temperatures were measured with an ST840 (Elite) thermoscope. Fever was defined as a rectal temperature ≥ 38°C. The age, sex, and body weight of each patient were also recorded.

Statistical analysis

We checked the normality of distributions using the Kolmogorov-Smirnov test for numeric data. Categorical variables are presented as frequencies and percentages and numerical variables as medians and the interquartile range (IQR). We used Bland-Altman plots to examine the concordance between the rectal and other temperatures. The relationship between two nominal parameters was analyzed using the chi-square test. The Mann-Whitney *U*-test was used to compare two independent medians and the Kruskal-Wallis test to compare more than two independent medians. Finally, we used receiver operational characteristic (ROC) analysis to understand the predictive ability and to calculate area under the curve (AUC) for different type measurements. A p value less than 0.05 was considered statistically significant.

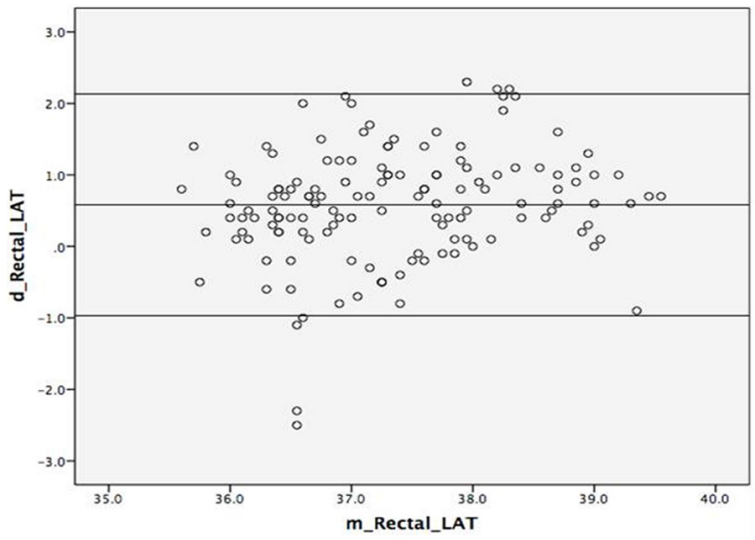

Figure 3. The Bland-Altman plot of difference comparing left tympanic and rectal temperatures with mean difference was - 0.1 (-2.5; 2.3)°C with 95% limits of agreement.

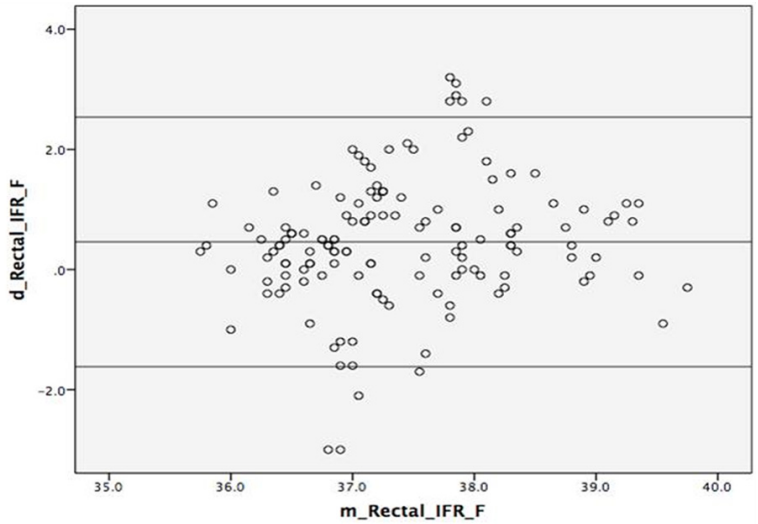

Figure 4. The Bland-Altman plot of difference comparing infrared forehead and rectal temperatures with mean difference was 0.1 (-3; 3.2)°C and 95% limits of agreement.

Results

The study enrolled 139 children ranging in age from 1 month to 4 years (median ± IQR 10 ± 21 months). They comprised 56 febrile and 83 afebrile children based on a rectal temperature ≥ 38°C. There were 90 (64.7%) boys and 49 (35.3%) girls. The body weight distributions were comparable in the two groups (p=0.107) (**Table 1**).

Table 1 shows the medians, IQRs, and temperature ranges measured with the rectal digital thermometer (RDT), ADT, RAT, LAT, IFR-N, IFR-F, and IFR-B. The highest median temperature was measured with RDT, followed by IFR-N and IFR-B. The measurements with all thermometers in the febrile group were significantly (p< 0.01) higher than those in the afebrile group.

The ability of the thermometers to predict rectal fever (temperature reading of ≥ 38 °C) was investigated using ROC analysis. The highest AUCs were 0.942, 0.882, 0.857, and 0.806 for ADT, RAT, LAT, and IFR-N, respectively (**Table 2**). This indicated that ADT has the most powerful ability to predict rectal temperature.

Overall, the rectal readings were slightly and significantly higher than all of the other measurements (p<0.01) (**Table 3**). The Bland-Altman plots revealed concordance between the rectal readings and ADT (mean difference =0.55, 95% limits of agreement), LAT, RAT, and IFR-F, IFR-N, IFR-B, but the latter measurements were not in good agreement with the standard readings (**Figures 1-6**).

Discussion

This study showed that the axillary temperature can be used as a non-invasive method for estimating rectal temperature, which accurately reflects the near core temperature in children 1 month to 4 years of age, as recommended by the NICE guidelines [http://wwww.nice.org.uk/guidance/CG160]. Crawford and his colleagues obtained the same results [4]. Measuring rectal temperature is not always desirable for parents or children and it has some disadvantages, although it is still used in Turkey. Axillary thermometers require parents and nurses to undress the child, wipe the axilla, and hold the device in the axilla for at least 3 minutes, so it is not practical

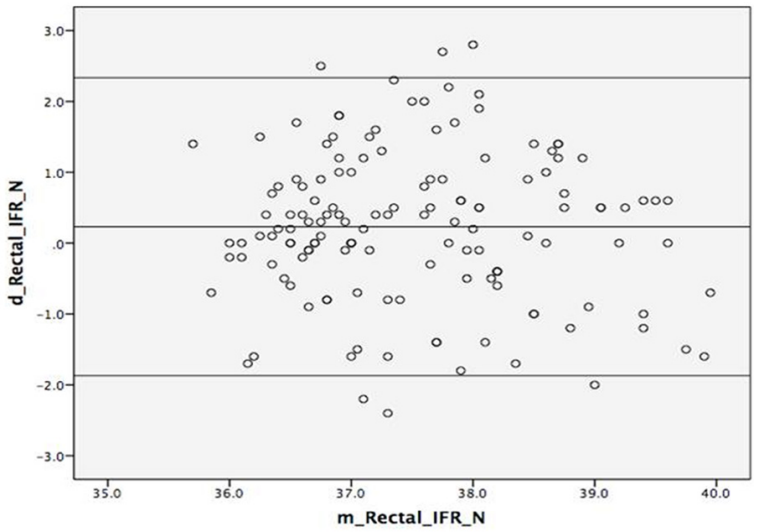

Figure 5. The Bland-Altman plot of difference comparing infrared neck and rectal temperatures with mean difference was 0.2 (-2.4; 2.8)°C with 95% limits of agreement.

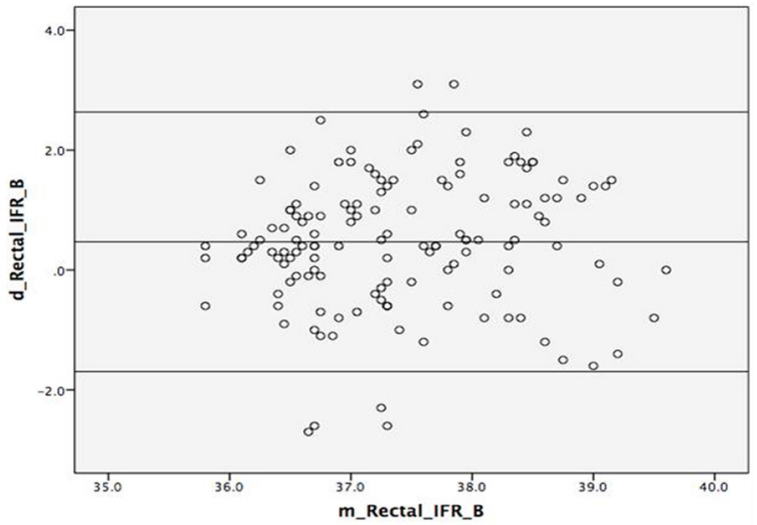

Figure 6. The Bland-Altman plot of difference comparing infrared jugular and rectal temperatures with mean difference was 0.2 (-2.7; 3.1)°C with 95% limits of agreement.

in a busy emergency observational unit. IFR-T thermometers are easier to use, speedy, and accurate when there is no ear wax or otitis media, which can be ruled out in the physical examination.

The main finding of our study was that IFR-T measurement is the second best method, but is not optimal for consecutive measurements when compared with rectal temperature measurement. Gasim and his colleagues compared IFR-T and an axillary mercury glass thermometer in children older than 1 year and similarly concluded that IFR-T was as reliable and as accurate as an axillary mercury glass thermometer [17]. However, they used axillary temperature as a measure of core temperature rather than the rectal temperature and only obtained a single reading. El-Radhi and his colleagues compared IFR-T measurements, ADT, and rectal readings in 106 infants, and concluded that IFR-T measurement correlated more closely with rectal temperature (r= 0.87) than did axillary measurement (r=0.69), and recommended the use of IFR-T in the pediatric emergency setting [18]. They also obtained a single reading and did not consider the influence of ear infections or ear wax on the true temperature of the tympanum. Zhen and his colleagues performed a meta-analysis of the accuracy of IFR-T, and demonstrated that the mean difference between rectal and IFR-T readings was large; they concluded that the accuracy of IFR-T in children is poor, and it cannot replace rectal thermometry in clinical practice [9]. Our findings support the use of IFR-T thermometers because of their safety, ease of use, and speed after an ear examination to rule out otitis and the presence of ear wax.

The third thermometer examined in our study was the infrared skin thermometer at three different sites. All three of the IFR measurement sites had a lower predictive ability for rectal temperature than the IFR-T and axillary measurements. Most studies of children in the English-language literature have demonstrated that IFR measurements were unreliable for predicting rectal fever [19-22]. The various authors concluded that rectal measurement cannot be replaced by non-contact IFR measurement. Two studies compared IFR with mercury-

in-glass [11] and electronic rectal thermometers [12]. The former reported a strong correlation with rectal readings while the latter, which recruited 200 children, reported moderate agreement with rectal temperatures [11, 12]. We found poor correlations between the IFR measurements sites and rectal measurements in the Bland-Altman plots. Despite the significant difference between the median rectal temperature and median IFR temperatures, the neck IFR measurements were a better predictor of (rectal) temperature than the jugular notch or forehead IFR measurements. We think that forehead IFR readings are less reliable than neck or jugular readings because the blood supply to the forehead may be limited by vasoconstriction, and the forehead may perspire, as in adults [23]. Consequently, jugular and neck IFR measurements may more closely reflect rectal readings than forehead IFR. Our results support the first study of neck IFR measurements reported in English [16]. Those authors concluded that IFR measurements over the carotid artery were the most reliable in children aged 2-6 years.

There are some limitations to our study. We did not measure the true core body temperature. Measurement of esophagus, bladder, and pulmonary artery temperatures as a gold standard is used only in intensive care units. These are invasive methods and have serious complications. We tried to find an alternative method that can be used in pediatric emergency observation rooms. Therefore, we used rectal measurements as the standard measurement in our study. Furthermore, our study did not include large numbers of subjects in different age groups to determine the influence of age on body temperature measurement.

Conclusion

In this study, we demonstrated that axillary thermometry was as reliable and accurate as rectal thermometry in children aged 1 month to 4 years. However, in busy settings or in emergency observation rooms where the body temperature should be measured repeatedly, infrared tympanic thermometry can be used after ruling out ear wax or otitis media with a physical examination, because it is easy to use, quick, and the second most reliable predictor of rectal fever. Measuring the body temperature of children aged 1 month to 4 years via the skin over the carotid artery (neck) appears to be more reliable than over the forehead or jugular notch.

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Disclosure of conflict of interest

None.

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