

A Comparative Study on Temperature Accuracy between Tympanic, Rectal, and Axillary Sites

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Abstract

A new method recently used for measuring the temperature is using tympanic thermometer. The aim of this study was to compare the accuracy of this method with rectal and axillary measurement in children less than 6 years old. A total of 220 pair ears, axillaries, and rectal sites were used to determine the body temperature in patients aged between 3 months to 6 years who referred to Emergency Department of Fateme Zahra Hospital affiliated to Bushehr University of Medical Sciences. Rectal temperature (RT) was considered as gold standard. Fever was defined as $RT \geq 38^{\circ}\text{C}$, axillary temperature (AT) $\geq 37.2^{\circ}\text{C}$ and tympanic temperature (TT) $\geq 38^{\circ}\text{C}$. Correlation between rectal and tympanic temperature was statistically significant. The mean difference between RT and TT was 0.3°C and between RT and AT was 0.1°C . When cutoff point was considered 38°C for TT, the sensitivity was 46%, specificity was 97% and positive predictive value (PPV) and negative predictive value (NPV) were 92% and 72% respectively.

ROC curve showed the best cutoff point for TT as 37°C , which increased the sensitivity to 92% and PPV to 0.98 but decreased the specificity to 90% and NPV to 0.57. Kappa test showed a good agreement rate between RT and TT. Age had significant effects on the TT/RT relationship. If the cut off point for TT is set at 38°C the sensitivity and NPV will be unacceptably low and a number of children with fever may be missed by screening with a tympanic thermometer. If the cutoff point is 37°C , the sensitivity and NPV will improve and TT can be used as a safe, easy, rapid, and accurate method in pediatrics.

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Keywords • Tympanic • axillaries • rectal temperature • pediatric • fever

Introduction

Accurate determination of body temperature is a key in diagnosis and treatment of a febrile patient in pediatric populations.¹ Temperature can be measured at various sites but the best site is still a matter of controversy.^{2,3} Traditionally, oral, rectal and axillary sites have been used,⁴ but RT was reported to be a core temperature and is the gold standard.^{4,5} Detecting temperatures from esophagus, bladder, and pulmonary arteries are more accurate than rectal but are invasive and needs anesthesia.⁶

Although RT determines core body temperature, a recent study has revealed some limitations for this method.⁷ This method results in stress in children and their parents because the parents are afraid of hurt and sexual abuse of their children.⁸

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On the other hand, RT can be time-consuming, and uncomfortable.⁹ Likewise, RT also lags behind the core temperature by up to 20 minutes and injuries such as rectal perforation and probable cross-contamination infection may occur.⁴

Obtaining an AT provides some advantages, but the child must be undressed and the arm should be immobile for at least 5 minutes. In addition, some studies have shown that ambient temperature and the shunting of blood from the skin surface during fever would result in unreliable axillary readings.^{8,9} On the other hand, mercury-in-glass thermometers are potentially dangerous if are broken. They can pose a serious threat not only to patients but also to the environment.⁵ So the American Academy of Pediatrics recommended not to use mercury-in-glass thermometers.⁴

False determining of temperature can cause morbidity and mortality in children.^{10,11} Although TT offers a fast and non-invasive recording, but early studies indicated many contradictory findings about its accuracy and reliability.¹²⁻¹⁶

The purpose of this study was to determine the accuracy of TT in children and clarify if TT is reliable and accurate when compared with axillary and rectal temperature in young children.

Patients and Methods

The Ethical Committee of Bushehr University of Medical Sciences approved the study and the parents signed a consent form. To determine the temperature accuracy, it was measured from four sites (rectal, axillary, and the two ears). Rectal temperature was considered as the gold standard.⁹⁻¹⁷ Fever in this study was defined as a RT $\geq 38^{\circ}\text{C}$, TT $\geq 38^{\circ}\text{C}$ and AT $\geq 37.2^{\circ}\text{C}$.^{17,18} The setting was the Pediatric Emergency Department of Fateme Zahra Hospital affiliated to Bushehr University of Medical Sciences.

Convenience sampling method was used to select 220 samples from the children aged 3 months to 6 years who had no history of surgery and trauma in rectum, axillaries, or ears. Children were grouped into 4 age categories; 0-1, 1-2, 2-3, and 3-6 years old. We compared these 4 age groups because some previous research reported that tympanic thermometer had some limitations, specifically in recognizing fever in infants and young children.¹ Besides, we wanted to evaluate the effect of age on tympanic-rectal mean differences. Each group consisted of 55 subjects.

The three instruments used were tympanic thermometer (Gentle 510, Omron factory, Philippines), axillaries temperature (Flex temp CE 0197, Omron, Philippines) and rectal digital temperature (Protemp CE 0473, Omron, Philippines). We used digital rectal thermometer as

it was as accurate as rectal glass mercury thermometer.¹⁹ All the instruments were calibrated by the manufacturer before use.

As the technique was important to insure consistency, three registered nurses received unique instruction by the researcher and followed specific manufacturer recommended procedures to obtain the temperatures. There was one data collector for each instrument. Temperatures were obtained sequentially on each subject in the order of tympanic, axillaries and rectal to minimize subject agitation. Environmental temperature was measured in patients' room. Existing of ear wax and otitis media was checked. In analyzing the data, a Pearson's Correlation Coefficient was used to determine the relationship between temperature readings for all subjects. The ROC curve was used to determine the best cut off point [sensitivity, specificity, negative predictive value (NPV) and positive predictive value (PPV)]. Kappa test was used to determine the non-probability agreement in all methods. We used ANOVA to compare mean temperature differences in all age groups and *t* test to compare the temperature difference between the two groups. Multi-variety regression was used to determine if age, fever, otitis media, ears wax, use of antipyretic and environmental temperature predicted temperature reading between the thermometers. We compared the mean of RT, AT and TT in two age groups simultaneously by multivariate analysis of variance (MANOVA).

Results

Of the referred patients 47% were febrile, 12% had otitis media in right ears and 9% in left ears, 8% had ear wax, 14% had used antipyretic drugs, 15% had used wet sponge 30 minutes before the temperature determination. Environmental temperature was between 24-28.5°C. 22.4% of the patients had respiratory infection, 3.7% had accident and injury in the body except for axillary and rectum, 0.9% had topical skin infection, 5.5% had systematic infection, 1.4% had asthma and 43.6% had gastroenteritis.

The mean difference between TT and RT was 0.3°C (95% CI: 0.22 to 0.38), and between RT and AT was 0.1°C (95% CI:-0.08 to 0.17%). Paired *t* test between each two methods showed significant mean differences ($p < 0.001$) except between right and left tympanic ($P = 0.39$) (table 1).

Sensitivity, specificity, PPV and NPV in TT (with cutoff point of 38°C) was poor (46%, 97%, 92% and 72% respectively) but in adjusted cutoff point of 37°C they were 92%, 90%, 57% and 98% respectively, which shows significant improvement (table 2).

Table 1: Distribution of measurements

Method of measurement	mean	Minimum	Maximum	SD
Rectal	36.7	34.7	39.1	0.92
right tympanic	36.4	34.9	39	0.85
left Tympanic	36.4	34.8	39.3	0.82
Axillary	36.6	34.4	39.5	0.98

Table 2: Result of ROC curve (%) in several method of measurement

Method of measurement	Cutoff point	sensitivity	specificity	P.P.V	N.P.V	Kappa ratio
right tympanic	37°C	92	90	57	98	0.66
right tympanic	38°C	46	97	92	72	0.51
left tympanic	37°C	89	88	53	98	0.60
left tympanic	38°C	42	99	92	85	0.53
Axillary	37°C	92	83	98	44	0.52
Axillary	37.2°C	85	88	97	52	0.58

Correlation between the four methods was between 74%-90%. Correlation was visible between right and left tympanic ($r= 0.87$), rectal and tympanic ($r= 0.76$), tympanic and axillary ($r= 0.80$), and between axillaries and rectal ($r= 0.74$). The correlation between RT and TT was higher than RT and AT.

To analyze the effect of selected independent variables (age, presence of fever, presence of otitis media and ears wax, use of an antipyretic and bath, and environment temperature) on the rectal temperature differences, multi-variety regression was used. Those variables that demonstrated effect were age and antipyretic usage. Lower the age of the patient, higher the rectal-tympanic temperature difference. In 0-2-year-old children, rectal temperature was higher than tympanic (0.4°C) but in 2-3-year-olds, RT was lower than TT (0.15°C). These differences were statistically significant ($P= 0.013$).

In case of antipyretic (Ibuprofen) use, the rectal-tympanic differences increased ($p= 0.71$). We compared the mean of RT, AT, and TT in age groups simultaneously. Multivariate analysis of variance showed no significant differences ($p=0.685$). Followed univariate analysis of each variable in age groups also showed no significant differences ($p=0.637$ to 0.998).

Discussion

Variability in research designs and inconsistent/mixed findings limit the comparability of this and the previous research. However, the results of this study support the debate on the accuracy of tympanic thermometry in determining fever in children under the age of 6 years. Correlation between rectal and tympanic temperature was moderate ($r= 0.76$, $p< 0.005$) and the difference between rectal and tympanic temperature was clinically significant. Lanham in 1999 studied 241 children under 6 years old. He suggested poor agreement between rectal and tympanic temperatures.¹

Ferallow in 1991 showed that the temperatures of tympanic and pulmonary arteries didn't have significant differences but rectal is warmer than pulmonary artery.²⁰ He determined the correlation between tympanic and pulmonary arteries, which was high ($r= 0.91$) but the correlation between rectal and tympanic was moderate ($r= 0.52$). Based on above inconsistency we can suggest that tympanic method may be accurate but rectal as a gold standard can not predict the accurate body temperature, further research needs to determine RT accuracy to be as gold standard.

In another study, Robinson et al. showed that mean difference between TT and pulmonary artery temperature (PAT) was lower than RT and PAT.⁶ Conversely, the bulk of the published literature suggests that rectal thermometry is the best available non-invasive method for measurement of core body temperature.²¹ Steven et al. reported better agreement between rectal and PAT than between tympanic and PAT.²²

The accuracy of tympanic thermometer to detect fever was determined by sensitivity, specificity, PPV and NPV with 38°C set as the threshold of tympanic temperature defining fever. Sensitivity was low (0.46%), specificity was high (97%), and PPV was (92%), which represents the percentage of subjects with an TT reading of $\geq 38^{\circ}\text{C}$ who were also identified as being febrile by rectal measurement.

NPV, the percentage with a negative TT reading that was also febrile by rectal measurement was 72%. After adjusting the TT threshold to 37°C , sensitivity (92%) and NPV (98%) improved, but specificity (90%) and PPV (57%) decreased. Based on our results we suggest that TT with 37°C threshold can determine the accurate body temperature.

Previous investigations have also suggested that tympanic thermometry was a poor predictor of rectal temperature in infants. Brennan et al. found that tympanic thermometry had a sensitivity of only 0.76 for detecting fever

in children 6 months to 6 years old.²³ Hooker reported that tympanic thermometers had a sensitivity of 0.67 to detect rectal fever in patients younger than 6 years.²⁴ Muma et al. reported that tympanic thermometer had a sensitivity of 0.55 for detecting fever in 87 children younger than 3 years.²⁵ Conversely, some researchers concluded that TT provided data consistent with traditional thermometry in the pediatric population.²⁶

Age and antipyretic usage were two variables that significantly affected the rectal-tympanic differences. One possible explanation of this finding may be the difficulty in obtaining a true tympanic reading in small children and infants. This suggests the possibility that a redesign of the probe may be necessary for use in younger children. Lanham in his study showed that with increasing age, mean difference between RT and TT would be higher. He demonstrated that this difference was for the lower diameter of the ear meatus (4 mm) in children under 2 years old, however tympanic thermometer probe is 8 mm.¹ Several variables are involved in obtaining an accurate temperature via any site that can make variation in tympanic temperature reading. If the tip of the tympanic probe does not fit tightly into the canal, the probe may instead register the temperature of the skin, external auditory canal, or cerumen. Teaching of proper technique and correct seal of the tympanic thermometer is critical to obtain an accurate reading. However in this study, the data collector had instruction for using TT but more research are necessary to assess nurses' skills for proper technique. While Terndrup noted that many health care professionals may be unfamiliar with the proper technique for use of TT,²⁷ Brennan found that technique had no statistically significant effect on the results.¹⁸

In this study ibuprofen consumption caused a higher rectal-tympanic difference, which maybe due to delay in rectal temperature changes. Some studies showed that when body temperature change, RT would lower blood flow, and the changes in temperature would be delayed. Greens showed that if an antipyretic was administered several minutes before the temperature was measured, the TT might accurately reflect a lowered core body temperature, while the rectal temperature still reflected the preceding fever.²⁸ Future studies evaluating the changes in TT and rectal temperatures in response to changes in core body temperature would be interested.

Other independent variables did not affect TT and AT relationship. Several articles however suggest that the presence of otitis media and/or cerumen has no effect on TT measurement.

Limitations of this study were inability to use esophageal or PA temperature as gold standard, and study only on children. So, our results cannot be generalized for all ages. Convenience sampling was used in our study, which decreases generalizability on the finding. Low sample size was another shortcoming.

The strength of study was that data collection methods were clearly outlined, and one data collector was available for one instrument, which may control the collector bias.

Conclusion

This study adds to the knowledge base about the use of TT in pediatric population. The findings of this research suggest that the use of TT with cutoff point 38°C may not be accurate to determine the presence of fever in children less than 6 years. If we reduced cutoff point of TT to 37°C we can use it as an accurate, safe and easy method. Otitis media and ear wax had not effect on TT reading. We must use TT in children less than 3 years with caution.

Competing Interest

Research Administer Committee of Bushehr University Medical Sciences is financial supporter of this survey.

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