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Tympanic temperature versus temporal temperature in patients with pyrexia and chills

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Abstract

Accurate body temperature (BT) measurement is critical for immediate and correct estimation of core BT; measurement of changes in BT can provide physicians the initial information for selecting appropriate diagnostic approach and may prevent unnecessary diagnostic investigation. This study aimed to assess differences in tympanic and temporal temperatures among patients with fever in different conditions, especially in those with and without chills. This prospective study included patients from the emergency department between 2011 and 2012. All temperature measurements were obtained using *tympanic thermometers* and infrared skin thermometers. Differences in tympanic and temporal temperatures were analyzed according to 6 age groups, 5 ambient temperature groups, and 6 tympanic and temporal temperature subgroups. General linear model analysis and receiver operating characteristic curve analysis were used to estimate the differences in mean tympanic and temporal temperatures. Of the 710 patients enrolled, 246 had tympanic temperature more than 38.0°C, including 46 with chills (18.7%). Fourteen patients (3.0%) had chills and tympanic temperature less than 38°C. In the tympanic temperature subgroup of 39.0 to less than 39.5°C, approximately one-third of the patients had chills (32.3%). In the tympanic temperature subgroup of 38.0 to less than 39.0°C, the tympanic temperature was 0.4°C higher than the temporal temperature in patients without chills and 0.9°C higher in patients with chills. In the tympanic temperature subgroup of 39.0°C or more, tympanic temperature was 0.7°C higher than temporal temperature in patients without chills and 0.8°C higher in patients with chills. Temporal thermometer is more reliable in the age group of less than 1 year and 18 to less than 65 years. When the patients show tympanic temperature range of 38.0 to less than 39.0°C, 0.4°C should be added for patients without chills and 0.9°C for patients with chills to obtain core temperature. However, in patients with tympanic temperature of 39.0°C or more, 0.7°C to 0.8°C should be added, regardless of the presence of chills.

Abbreviations: ambient T = ambient temperature, AUC = area under the ROC curve, BT = body temperature, LR− = negative likelihood ratio, LR+ = positive likelihood ratio, ROC = receiver operating characteristic, temporal T = temporal skin temperature, tympanic T = tympanic temperature.

Keywords: body temperature, chills, difference, infrared skin thermometer, pyrexia, tympanic temperature

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W-CY and H-TK contributed equally to this work.

The authors have no conflicts of interest to declare.

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1. Introduction

Immediate and accurate measurement of core body temperature (BT) and BT change is valuable for physicians for the initial assessment of patient condition and in determining further diagnostic steps.[1–3] Physically, core BT reflects the temperature of the hypothalamus, which is the thermoregulatory center. The gold standard for measuring core BT is via the pulmonary artery; however, this approach is not used in routine clinical practice, as it is an invasive procedure. Rectal thermometers are generally considered as the gold standard among noninvasive thermometers, but is also not used commonly because of several disadvantages including significant time consumption, discomfort, emotional distress, and possibility of complications, such as perforation and transmission of microorganisms.[4–7] Axillary temperature is considered less accurate for measuring core BT, as it reflects the skin temperature rather than core BT.[1,3,8,9]

Accurate determination of BT is critical in some clinical conditions such as infection in neonates and geriatric patients, immunodeficiency, organ transplantation, heart failure, chronic lung diseases, and metabolic disturbances.[10–12] Among other noninvasive thermometers, tympanic membrane thermometry, and noncontact infrared skin thermometer are commonly used in the clinical setting owing to their convenience and non-invasiveness. Tympanic membrane temperature is generally accepted as the thermometer of choice for patients older than

3 months of age. However, certain limitations may impede accurate measurement of BT in patients, such as improper technique, presence of earwax, and coexisting ear pathology. Noncontact infrared skin thermometers do not have such limitations.

This study aimed to analyze the potential factors that may interfere with the measurement of skin temperature using infrared skin thermometers and determine the difference between temporal temperature and tympanic temperature of patients with fever in clinical settings.

2. Materials and methods

2.1. Patient population

All patients in this prospective study were enrolled from the emergency department of a medical center in central Taiwan from 2011 to 2012. Exclusion criteria for recruitment were selected considering the influence of confounding factors such as extreme hypothermia, excessive earwax, and ear-related pathologies. The Institution Review Board and Ethics Committee approved the study protocol, and a written informed consent was obtained from all the study participants or their caretakers if the participants included children.

2.2. Data analysis

The following variables were analyzed: age, sex, body weight, ambient temperature (ambient T), and the temporal skin temperature and tympanic temperature (tympanic T) on both sides. Differences in tympanic temperatures and in mean tympanic and mean temporal skin temperatures on both sides were also recorded for further analysis. Temperature readings were grouped according to age (<1 year, 1 to <6 years, 6 to <12 years, 12 to <18 years, 18 to <65 years, and ≥65 years), ambient temperature (≤15°C, 15 to ≤ 20°C, 20 to ≤ 25°C, 25 to ≤30°C, and ≥ 30°C). BTs were grouped, based on the mean of tympanic temperatures of both the sides, into 6 subgroups: 36.0°C or less, 36.0 to 38.0°C or less, 38.0 to 38.5°C or less, 38.5 to 39.0°C or less, 39.0 to 39.5°C or less, and 39.5°C or more.

Differences in mean tympanic temperature and temporal skin temperature were further analyzed according to the parameters of age and BT. The mean difference of tympanic and temporal temperatures in different conditions was calculated. Temperature readings were obtained with the infrared tympanic thermometer (model 3000A, First Temp@, Genius@; Intelligent Medical System, Inc., Carlsbad, CA) and temporal skin thermometer (model TAT 5000, Exergen, Watertown, MA). Two researchers experienced in operating these devices examined all the patients.

2.3. Statistical analysis

Values were calculated as means ± standard deviation. Significant differences between values of the groups with and without chills were analyzed by Student *t* test, and comparison among temperature readings at different sites and other clinical variables was analyzed by Jonckheere Terpstra test. The Bland-Altman Plot was used to analyze the relationship of the differences in tympanic and temporal temperature between chills and nonchills groups at different BT levels. Then, general linear model analysis was used to predict the difference in the tympanic and temporal temperatures. Finally, the receiver operating characteristic (ROC) curve was applied in each group to determine the ideal cut-off values for difference in tympanic and temporal temperatures. The test characteristics of different cut-off values, including sensitivity, specificity, area under the ROC curve (AUC), positive likelihood ratio (LR^+), and negative likelihood ratio (LR^-) were also examined.

The AUC, calculated using the trapezoidal rule, was considered a standard measure for the diagnostic value of the parameter. An optimal test result had a value of 1.0, while a useless test result had a value of 0.5. The LR^+ and LR^- were calculated for the best cut-off values. The criterion value indicated the value corresponding to the highest accuracy (minimal false negative and false positive results). Statistical significance was set at $P<0.05$. All statistical analyses were performed using the SPSS software (version 16.0, SPSS, Inc., Chicago, IL).

3. Results

During the study period, 710 patients were enrolled. The female to male ratio was 1.36 (410/300). According to age group, there were 12, 169, 58, 28, 383, and 52 patients for the 1 or less, 1 to 6 or less, 6 to 12 or less, 12 to 18 or less, 18 to 65 or less, and 65 or more years age groups, respectively. Of the 246 patients with tympanic temperature more than 38°C, 46 (18.7%) had chills. Fourteen (3.0%) patients with chills had tympanic temperature less than 38°C.

3.1. Chills versus body temperature

Analysis of chills and BT (Table 1, Fig. 1) revealed that mean temporal T was less than mean tympanic T in the 2 groups. The mean temporal T and mean tympanic T in the group with chills were both higher than those in the group without chills ($P<$ 0.001). As shown by the distribution of differences between the mean tympanic T and mean temporal T in the 2 groups, differences in the group with chills was significantly higher than that in the group without chills ($P<0.001$).

According to the distribution of the difference based on different tympanic T subgroups, when tympanic T was more than

Table 1

Consolidation of body temperatures between patients with and without chills.

	No chills			Chills			
	N	Mean	SD	N	Mean	SD	*P* value
Mean Tym T, °C*	(650)	37.4	1.0	(60)	38.5	0.7	<0.001
Mean temp T, °C*	(650)	37.1	0.9	(60)	37.9	0.8	<0.001
ΔTym-temp T*	(650)	0.2	0.7	(60)	0.6	1.0	<0.001

P value by Student *t* test.

* *P* value < 0.05.

Mean temp T = mean of bilateral temporal temperature, Mean Tymp T = mean of bilateral tympanic temperature, SD = standard deviation, ΔTym-temp T = difference of tympanic and temporal temperature.

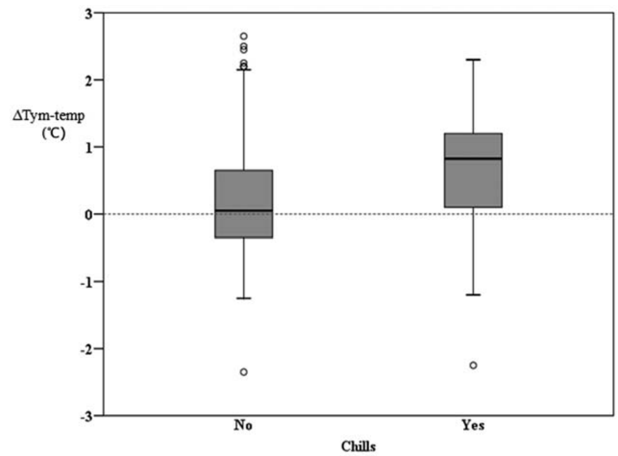

Figure 1. The distribution of differences of tympanic and temporal T between chills and nonchills group.

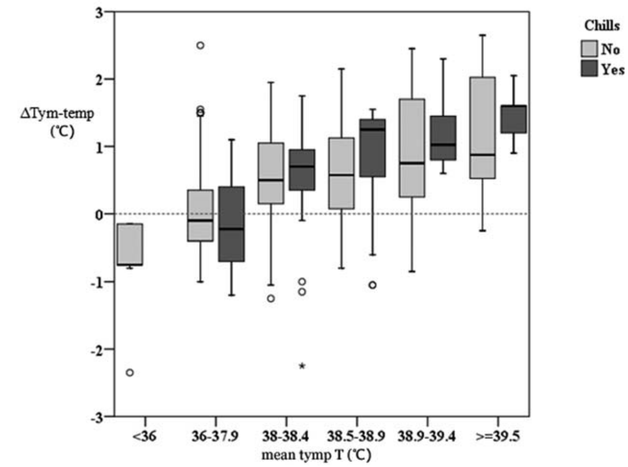

Figure 2. The distribution of differences of tympanic and temporal T between chills and nonchills group in different tympanic T groups.

38°C, the difference in mean tympanic T and mean temporal T increased in both with and without chills groups. Consolidating the difference among patients with different ages and those with or without chills based on different tympanic temperature subgroups (Table 2, Fig. 2), it was observed that an increase in tympanic T was associated with a significant increase in the difference in mean tympanic and temporal temperatures ($P < 0.001$). The difference significantly increased in patients with chills when the mean tympanic T was above 38.5°C. Moreover, chills occurred in patients with fever in all age groups.

3.2. Age versus body temperature

The difference in mean tympanic and temporal temperatures was higher in patients aged 1 to 18 years than in those in the other age groups (Table 3). The age group of 6 to less than 12 years showed the biggest difference among all age groups; in the age groups less than 1 year and 18 to less than 65 years, tympanic T was almost equal to temporal T. The mean age of patients with tympanic T of 39.5°C or more was 12.95 years, which was lower than that of patients in the other tympanic T subgroups ($P < 0.001$) (Table 4).

Table 2

The Correlation of difference of tympanic temperature and temporal temperature in different age and mean tympanic temperature groups.

	<1			1 to <6			6 to <12			12 to <18			18 to <65			≥ 65			
Age (years)	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	***P* value**
Mean Tym T, °C*	(12)	38.2	0.9	(169)	38.1	0.8	(58)	38.2	0.7	(28)	37.4	1.0	(383)	37.0	0.8	(52)	37.9	1.0	<0.001
Mean temp T, °C*	(12)	38.2	0.7	(169)	37.8	0.8	(58)	37.6	0.7	(28)	37.0	0.7	(383)	36.8	0.7	(52)	37.5	0.9	<0.001
ΔTym-temp T$^{\Psi}$	(12)	0.0	0.8	(169)	0.4	0.8	(58)	0.7	0.7	(28)	0.5	0.6	(383)	0.0	0.7	(52)	0.4	0.8	<0.001
	<36			**36 to <38.0**			**38.0 to <38.5**			**38.5 to < 39.0**			**39.0 to <39.5**			**≥ 39.5**			
Mean Tym T, °C	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	***P* value**
Mean temp T, °C*	(13)	35.8	0.8	(451)	36.8	0.6	(116)	37.7	0.7	(82)	38.1	0.8	(31)	38.2	0.9	(17)	38.5	0.8	<0.001
ΔTym-temp T*	(13)	-0.6	0.6	(451)	0.0	0.6	(116)	0.5	0.8	(82)	0.6	0.8	(31)	1.0	0.8	(17)	1.2	0.8	<0.001

Mean temp T = mean of bilateral temporal temperature, Mean Tymp T = mean of bilateral tympanic temperature, SD = standard deviation, ΔTym-temp T = difference of tympanic and temporal temperature.

Table 3

Compression of body temperature in different age groups and chills group.

mean Tym T, °C	**<36**			**36 to <38.0**			**38.0 to <38.5**			**38.5 to < 39.0**			**39.0 to <39.5**			**≥ 39.5**			
variables	**(N)**	**Mean**	**SD**	**(N)**	**Mean**	**SD**	**(N)**	**Mean**	**SD**	**(N)**	**Mean**	**SD**	**(N)**	**Mean**	**SD**	**(N)**	**Mean**	**SD**	***P* value**
Age, y																			
<1				(4)	−0.5	0.5	(2)	−0.3	0.0	(4)	0.4	1.1	(1)	0.5		(1)	0.8		0.072
1 to <6*	(1)	−0.8		(66)	0.2	0.6	(44)	0.3	0.7	(38)	0.7	0.8	(10)	1.0	0.9	(10)	1.0	0.7	<0.001
6 to <12*				(16)	0.3	0.6	(20)	0.6	0.6	(15)	0.7	0.6	(4)	1.2	1.2	(3)	1.8	0.5	0.015
12 to <18*				(19)	0.2	0.6	(7)	1.1	0.5				(2)	0.6	0.0				0.004
18 to <65*	(12)	−0.6	0.6	(318)	0.0	0.5	(27)	0.8	0.9	(15)	0.2	0.9	(9)	1.0	0.5	(2)	1.1	1.7	<0.001
≥ 65*				(24)	0.0	0.6	(14)	0.4	0.7	(8)	1.0	0.3	(5)	1.0	1.4	(1)	2.7		<0.001
Chills*				(14)	−0.1	0.7	(17)	0.4	1.0	(14)	0.8	1.0	(10)	1.2	0.6	(5)	1.5	0.4	<0.001

P value by Jonckheere Terpstra Test.

* *P* value < 0.05.

Mean Tymp T = mean of bilateral tympanic temperature, SD = standard deviation, ΔTym-temp T = difference of tympanic and temporal temperature.

Table 4

General linear model of regression analysis in the difference of tympanic and temporal temperatures among different variables.

Predictors	Estimate	SE	95% CI			*P* value
Intercept	–0.5	0.134	–0.725	–	–0.201	0.001
Gender						
Female	0.0					
Male*	0.2	0.051	0.085	–	0.286	<0.001
Chills						
No	0.0					
Yes*	0.5	0.093	0.271	–	0.635	<0.001
Mean Tym T, °C						
<36	0.0					
36 to <38.0*	0.7	0.135	0.428	–	0.958	<0.001
38.0 to <38.5*	0.5	0.161	0.153	–	0.785	0.004
38.5 to <39.0*	0.3	0.170	0.007	–	0.672	0.045
39.0 to <39.5	–0.2	0.189	–0.541	–	0.200	0.367
≧39.5*	–0.7	0.289	–1.242	–	–0.107	0.020

The group of "Estimate = 0" is reference group.

* *P* value < 0.05.

CI = confidence interval, Mean Tymp T = mean of bilateral tympanic temperature, SE = standard error.

There were significant differences between tympanic and temporal temperatures among different tympanic T subgroups for all age groups except in the age group less than 1 year (Table 2). The difference in mean tympanic T and mean temporal T increased significantly when the tympanic T was 39.0°C or more in patients with chills. However, when tympanic T was 39.0°C or more, the mean difference increased by more than 1°C except for 2 age groups (<1 year and 12 to <18 years). In the age groups of less than 1 year and 18 to less than 65 years with tympanic T less than 38.0°C, the mean tympanic T was lower.

3.3. Ambient temperature versus body temperature

Although the ambient T revealed statistically significant difference in the tympanic T sub-groups, such as when the ambient T was 15.0°C or more, the BT increased with the increase in ambient T; further, the difference in tympanic and temporal temperatures was not significant among the different ambient T groups.

3.4. Tympanic temperature versus temporal temperature

When the tympanic T was within normal range, the temporal T was close to the tympanic T (Table 5). However, the difference in

Table 5

The ROC curves analysis to predict the difference of tympanic and temporal temperature in 2 body temperature groups.

	Mean Temp T 38.0 to <39.0°C										
	Criterion values and coordinates of ROC curve					Area under the ROC curve					
Predictor	Value	Sens	Spec	LR^+	LR^-	Area	SE	95% CI			*P* value
No chills*	0.4	57%	78%	2.595	0.546	0.707	0.024	0.661	–	0.754	<0.001
Chills	0.9	48%	66%	1.403	0.788	0.516	0.076	0.366	–	0.666	0.830
Age, y											
1 to <6	0.8	40%	76%	1.667	0.788	0.547	0.045	0.459	–	0.635	0.291
6 to <18	0.9	45%	80%	2.212	0.688	0.619	0.061	0.499	–	0.738	0.058
18 to <65*	0.4	62%	84%	3.770	0.456	0.734	0.050	0.635	–	0.833	<0.001
≧65*	0.3	68%	77%	2.922	0.415	0.671	0.078	0.519	–	0.824	0.036
Mean Tymp T, °C											
36 to <38.0*	0.4	90%	77%	3.824	0.136	0.869	0.015	0.839	–	0.898	<0.001
Mean Temp T ≥ 39°C											
No Chills*	0.7	67%	78%	2.981	0.429	0.763	0.046	0.673	–	0.853	<0.001
Chills*	0.8	87%	60%	2.167	0.222	0.784	0.063	0.662	–	0.907	0.001
Age, y											
1 to <6*	0.8	75%	71%	2.599	0.351	0.740	0.062	0.618	–	0.862	0.001
6 to <18*	2.0	44%	100%		0.556	0.727	0.103	0.526	–	0.928	0.027
18 to <65*	0.7	91%	83%	5.455	0.109	0.878	0.039	0.801	–	0.955	<0.001
≧65	1.4	67%	96%	15.333	0.348	0.743	0.152	0.445	–	1.040	0.055
Mean Tymp T, °C											
36 to 38.0*	1.4	100%	94%	17.452	0.000	0.992	0.004	0.984	–	1.000	<0.001
38.0 to <33.5*	0.7	100%	100%		0.000	1.000	0.000	1.000	–	1.000	<0.001
38.5 to <39.0*	0.3	100%	100%		0.000	1.000	0.000	1.000	–	1.000	<0.001

* *P* value < 0.05.

Area = area under the curve, CI = confidence interval, LR^+ = positive likelihood ratio, LR^- = negative likelihood ratio, Mean Tymp T = mean of bilateral temporal temperature, ROC = receiver operating characteristic, Sens = true positive rate, Spec = true negative rate, Value = difference of tympanic and temporal temperature.

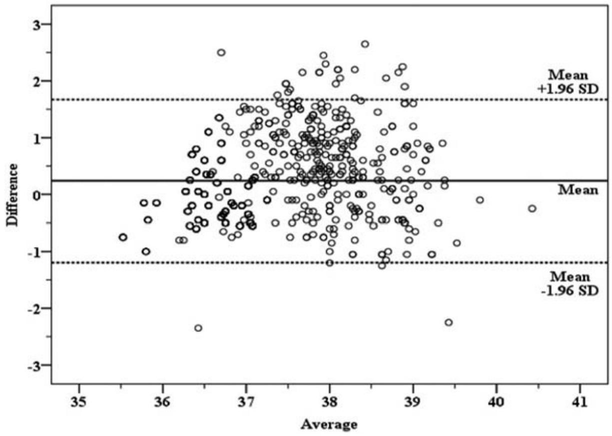

Figure 3. Bland-Altman Plot analysis of the difference of tympanic and temporal temperature between chills and no chills groups.

mean tympanic and temporal temperatures increased as the tympanic T increased ($P<0.001$). The difference increased by more than 1°C when the mean tympanic T was 39.0°C or more. The distribution of differences of tympanic and temporal temperatures in different tympanic T subgroups is presented in Fig. 2. Bland-Altman Plot analysis of the difference of tympanic and temporal temperature between chills and no chills groups is shown in Fig. 3. When the tympanic temperature is less than 36.0°C, the temporal T is higher than tympanic T; however, when the tympanic temperature rises rapidly with chills, the temporal T does not show a corresponding rapid increment.

The parameter estimation of the general linear model analysis for prediction of the difference in mean tympanic and temporal temperatures (Table 6) demonstrated that the significant factors included temporal T subgroups, presence of chills, and sex ($P<0.05$). However, in this model, when the mean temporal T was 39.0°C or more, the difference in mean tympanic and temporal T decreased.

By the ROC curve analysis for predicting the difference in tympanic T and temporal T in the 38.0 to less than 39.0°C tympanic T subgroup, the tympanic T was 0.4°C higher than the temporal T among patients without chills and 0.9°C higher among patients with chills (sensitivity 89.6%; specificity 76.6%; LR^+ 3.82; LR^- 0.13; and AUC 0.869). In the 39.0°C or more tympanic T subgroup, the tympanic T was 0.7°C higher than the temporal T among patients without chills and 0.8°C higher among patients with chills (sensitivity 100.0%; specificity 100.0%; LR^+ –; LR^- 0; and AUC 1.00).

4. Discussion

As in a homeothermic animal, the human body attempts to maintain its core temperature in the normal range when the ambient temperature range is narrow. The body has many homeostatic mechanisms for regulation of BT, including shivering and sweating. However, infection may reset the set point of BT, and patients may show shivering or chills; the resultant increased body heat further elevates the BT. Clinically, patients with chills usually present with cold extremities and even cold frontal skin. The temporal skin is supplied by the temporal artery, which is a branch of the external carotid artery and may show vasodilation under the influence of external and internal factors. The temporal thermometer was used widely owing to the benefit of being untouched.

In this study, presence of chills in a patient is an important factor that affects temporal T. According to the general linear model, the mean tympanic T of patients with chills is approximately 0.4°C higher than that of patients without chills when the variables of chills and fever are not considered. Similar to findings of previous studies, our study emphasized the characteristic feature of the temporal T, which is presence of a lag when there are rapid changes in core BT.[2,3] In previous studies, temporal T has been reported as having low sensitivity and low specificity for predicting fever.[2] In this study, when the BT was within a normal range, temporal T was very close to tympanic T. This may be attributed to the very small difference in tympanic and temporal T in the normal BT range. The distribution of difference between tympanic and temporal temperature in different tympanic T groups emphasizes the lag characteristic of temporal temperature in Bland-Altman Plot analysis.

On the basis of the results of ROC analysis, in moderate fever (38.0°C–38.9°C), the temporal T in patients without chills is

Table 6

The parameters estimation of general linear model analysis to predict the difference of mean tympanic and temporal temperature.

Variable	Predictors	Estimate	SE	95% CI	*P* value
ΔTymp-temp T	Intercept	−0.463	0.134	-0.725–0.201	0.001
	Gender*				
	Female	0.000			
	Male	0.186	0.051	0.085–0.286	<0.001
	Chills*				
	No	0.000			
	Yes	0.453	0.093	0.271–0.635	<0.001
	Mean temp T, °C				
	<36	0.000			
	36–37.9*	0.693	0.135	0.428–0.958	<0.001
	38–38.4*	0.469	0.161	0.153–0.785	0.004
	38.5–38.9*	0.340	0.170	0.007–0.672	0.045
	38.9–39.4	−0.170	0.189	-0.541–0.200	0.367
	≥ 39.5*	−0.675	0.289	-1.242–0.107	0.020

The group with estimate = 0 as the referent group.
* $P<0.05$.
Ambient T = ambient temperature, Mean temp T = mean of bilateral temporal temperatures, ΔTymp-temp T = difference of tympanic and temporal temperatures.

0.4°C less than the tympanic T, whereas in patients with chills, the temporal T is 0.9°C less than the tympanic T. In the high-fever status (BT ≥39.0°C), this difference between chills and nonchills groups decreases, and the temporal T is 0.7°C to 0.8°C less than the tympanic T. We observed the trend in BT change as follows: when patient begins to develop chills, the BT decreases initially and may fall below 36.0°C; additionally, the temporal T is observed to be 0.5°C higher than the tympanic T and then increases quickly. In the entire process of increase in BT, temporal T lags behind the tympanic T, and the trend is obvious when BT shows rapid changes in the presence of chills. When the BT rises above 39.0°C and the chills are nearly resolved, the difference in chills and non-chills groups becomes similar, and the temporal T is observed to be 0.7°C to 0.8°C less than the tympanic T. Clinically, when only a temporal thermometer is used to measure BT, patients with chills should be carefully assessed. Further, primary clinicians may be able to calculate the exact BT based on the findings we have presented.

Ambient T may influence the BT in some studies, which reveal that BT in the winter season is 0.1°C lower than that in summer.[2] However, in this study, both temporal and tympanic T are not highly affected by the ambient T. The effects of ambient T are not apparent because patients commonly present with high fever; moreover, ambient T shows no significant correlation with the difference in the tympanic and temporal T even in the general linear model analysis. Accordingly, the effect of ambient T on the temporal T may be ignored.

Both young children and the elderly may have relatively weaker regulatory mechanisms for controlling changes in BT and hence, they may not show adequate compensatory responses. In some studies, the tympanic T of elderly individuals is reported to be approximately 0.2°C lower than that of adults and approximately 0.3°C lower than the rectal T.[13] In this study, the greatest difference in tympanic and temporal T was observed in the age group of 6 to 12 years; additionally, as the elderly (≥ 65 years) presented with high BT, which was 39.0°C or more, the difference in tympanic and temporal T was observed to increase significantly. The lag response of temporal T is clearly observed in the elderly and preschool children. The younger children (< 1 year old) have the least difference, which is similar to that in the age group of 18 to less than 65 years. In other words, temporal thermometer is more reliable in the age group of less than 1 year and 18 to less than 65 years.

When the BT is maintained within the normal range, temporal T is considerably close to the tympanic T. The major factors affecting temporal T include the presence of chills and levels of BT, whereas ambient T has no effect on temporal T. From a conservative viewpoint, temporal T and infrared skin thermometer are recommended for routine measurements; however, if the temporal T exceeds the 36.4°C to 37.6°C range and the patient has chills, measurement of tympanic T should be considered first.

In conclusion, temporal temperature may be affected by age, presence of chills, and severity of fever. Temporal thermometer is more reliable in the age group of less than 1 year and 18 to less than 65 years. When patients show tympanic temperature from 38.0 to less than 39.0°C, 0.4°C should be added for patients without chills and 0.9°C should be added for patients with chills to obtain the core temperature. In patients with tympanic temperature of 39.0°C or more, 0.7°C to 0.8°C should be added regardless of the presence of chills.

References

[1] Craig JV, Lancaster GA, Williamson PR, et al. Temperature measured at the axilla compared with rectum in children and young people: systemic review. BMJ 2000;20:1174–8.

[2] Paes BF, Vermeulen K, Brohet RM, et al. Accuracy of tympanic and infrared skin thermometers in children. Arch Dis Child 2010;95:974–8.

[3] Davie A, Amoore J. Best practice in the measurement of body temperature. Nurs Stand 2010;24:42–9.

[4] Frank JD, Brown S. Thermometers and rectal perforations in the neonate. Arch Dis Child 1978;53:824–5.

[5] Greenbaum EI, Carson M, Kincannon WN, et al. Rectal thermometer-induced pneumoperitoneum in the newborn. Report of two cases. Pediatrics 1969;44:539–42.

[6] Donkers LE, van Furth AM, van der Zwet WC, et al. Enterobacter cloacae epidemic on a neonatal intensive care unit due to the use of contaminated thermometers]. Ned Tijdschr Geneeskd 2001;145:643–7.

[7] van den Berg RW, Claahsen HL, Niessen M, et al. Enterobacter cloacae outbreak in the NICU related to disinfected thermometers. J Hosp Infect 2000;45:29–34.

[8] Sener S, Karcioglu O, Eken C, et al. Agreement between axillary tympanic, and mid-forehead body temperature measurements in adult emergency department patients. Eur J Emerg Med 2012;19:252–6.

[9] Rubia-Rubia J, Arias A, Sierra A, et al. Measurement of body temperature in adult patients: comparative study of accuracy, reliability and validity of different devices. Int J Nurs Stud 2011;48:872–80.

[10] Sun HL, Wu KH, Chen SM, et al. Role of procalcitonin in predicting dilating vesicoureteral reflux in young children hospitalized with a first febrile urinary tract infection. Pediatr Infect Dis J 2013;32:e348–354.

[11] Wu KH, Tsai C, Wu HP, et al. Human application of ex vivo expanded umbilical cord-derived mesenchymal stem cells: enhance hematopoiesis after cord blood transplantation. Cell Transplant 2013;22:2041–51.

[12] Wu KH, Wu HP, Chan CK, et al. The role of mesenchymal stem cells in hematopoietic stem cell transplantation: from bench to bedsides. Cell Transplant 2013;22:723–9.

[13] Lu SH, Leasure AR, Dai YT. A systematic review of body temperature variations in older people. J Clin Nurs 2009;19:4–16.