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The Analysis on Diagnostic Accuracy of Tympanic Membrane and Forehead Temperature in Various Environments

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Abstract

Background/Objectives: This study is to confirm the diagnostic accuracy of tympanic membrane and forehead temperature in various environments.

Methods/Statistical analysis: The subjects were 155 people who visited two clinics for treatment, and the accuracy of forehead and tympanic membrane temperature was confirmed in pre-hospital and controlled-hospital conditions where temperature and humidity are not controlled. The collected data were analyzed using descriptive statistics, paired t-test, Pearson correlation coefficient, linear regression, and Bland-Altman plot operated by SPSS 25.0.

Findings: There was the significant difference statistically between tympanic membrane temperature and forehead one in pre-hospital situation (t=3.34, p=.001), and hospital situation (t=2.71, p=.007). In ROC analysis, the cut-off between pre-hospital situation and hospital condition was 37.5℃. While sensitivity being 100.0%, specificity 97.9%, positive predictive value 80.0%, and negative predictive value 100% in pre-hospital conditions, sensitivity was 100%, specificity 99.3%, positive predictive value 83.0%, negative predictive value 92.3% in hospital situations.

Improvements/Applications: Medical practitioners such as 119 paramedics who must measure body temperature in various environments need to consider measuring forehead temperature to prevent the infection of the subject, and should provide the guidelines according to thermometers and measurement sites.

***Keywords*: B**ody temperature, Temporal artery, sensitivity, Specificity, Measurement

1. Introduction

Since body temperature is the sensitive and reliable indicator that reflects the patient's basic condition, body temperature that best reflects central body temperature should be measured [1,2]. As the non-invasive method for measuring body temperature in clinical practice at hospital level, body temperature was measured in the areas such as rectum, oral cavity, axilla and tympanic membrane [2]. However, because the measurement of rectum, oral cavity and axillary body temperature is at risk of infection and safety while causing discomfort, the temperature measurement on tympanic membrane and forehead is currently being used as the non-invasive method to shorten body temperature measurement time due to the difficulties in general use at clinical practice [1].

The tympanic membrane is the good area to measure central body temperature, but earwax or middle ear diseases should not block auditory canal while the canal being straight. Tympanic membrane is a good area to measure central body temperature, but has the disadvantage that the auditory canal should be straight while earwax or middle ear diseases not blocking the canal. In addition, there is a hassle of changing the disposable probe cover due to the difference in measured values under the influence of atmospheric temperature and the risk of hospital infection through the probe [1,3]. On the other hand, forehead temperature is measured in temporal artery, which is connected to carotid artery

and located near skin surface, and more accurately reflects the central body temperature than tympanic membrane temperature or axillary one [4-8]. In addition, there is no difference in the measured value of forehead, and there is no risk of infection because it does not come into contact with skin because the measurement is convenient and quick [2,8].

When analyzing the results of previous studies, the studies were conducted mainly to check the accuracy as well as the precision or to compare the diagnostic accuracy of fever condition with reference to central body temperature, oral, rectal, axillary and tympanic temperature [7,8]. As a result, forehead body temperature is highly consistent with reference standard body temperature, which is useful in clinical trials at hospital-level [2,9] and has been proposed as a screening tool that can confirm the group fever such as COVID-19 [10]. But in some studies, data was collected with the thermometer that did not undergo calibration test, and the sensitivity was low while false negative rate being high due to the problems related to measurement process as well as measurement environment [4,7]. Thus, previous studies to date have verified the accuracy of forehead temperature by controlling temperature and humidity in the clinical circumstances at hospital stage, and no study has been found to verify the accuracy of forehead temperature at pre-hospital stage. However, occupations such as 119 paramedics must accurately measure the patient's body temperature while preventing infection even when the environment is not controlled due to the nature of the work.

Therefore, since this study compared the accuracy of forehead temperature at pre-hospital situation where the environment, such as temperature and humidity, is without or with control, we would like to provide a scientific basis for the usefulness of forehead temperature without risk of infection at pre-hospital stage.

2. Research Methods

2.1. *Research design*

This study is a prospective descriptive investigation study (Observational Study) aimed at confirming the diagnostic accuracy of forehead temperature as a reference standard in pre-hospital and uncontrolled hospital conditions that temperature and humidity are not controlled.

2.2. *Subjects and sampling method*

The study subjects were adults aged 19 years or older with no lesions in the ear such as otitis media, no damage to temporal artery area, and 155 people who agreed to participate in the study understanding the purpose.

2.3. *Research method*

Braun Thermoscan IRT-6030 was used to measure tympanic membrane temperature while Hubidic Non-contact FS-300 being used to measure forehead temperature. Two thermometers used to take body temperature were commissioned by the National Institute of Calibration, the Institute of Calibration, to check the calibration status. In order to minimize the measurement error before data collection, training was carried out by remembering the usage method suggested by each thermometer company and one person carried out the gauging for the consistency between testers. In order to confirm the diagnosis accuracy of body temperature measurement, the tympanic membrane and forehead temperature were checked twice at the entrance to hospital building in pre-hospital situation where temperature and humidity are not controlled. In the hospital stage where temperature with humidity were controlled, tympanic membrane and forehead temperature were measured twice at the hospital in 15 minutes after checking body temperature in pre-hospital situation.

2.4 *Data analysis method*

SPSS/WIN 25.0 Program was used to analyze the collected data, and technical statistics and paired t-tests were used to compare general characteristics as well as tympanic body temperature and forehead body temperature. The relationship between forehead and tympanic temperature was confirmed by scatter plot while Pearson correlation coefficient and simple regression analysis and Bland-Altman plot being used for the agreement between forehead and tympanic membrane temperature. For the calculation of sensitivity, specificity, positive predictive value, and negative predictive value for confirming the diagnostic accuracy of forehead temperature with respect to the fever condition, tympanic membrane temperature of 38°C. or higher was used as the basis for fever.

2.5 *Ethical consideration*

For ethical consideration of the research subjects, data was collected after approval through deliberation (IRB No: D**-2020-04-001-02) of D Institutional Review Board (IRB).

3. Results

3.1. Comparison between forehead temperature and tympanic membrane temperature

Under uncontrolled pre-hospital conditions, the average temperature was 4.7±2.32 and the average humidity was 74.69±13.65. In pre-hospital situation, the reference standard tympanic membrane temperature ranged from 34.1°C to 38.9°C while forehead temperature ranging from 34.5°C to 38.7°C. The average of tympanic membrane temperature was 36.46±0.76℃, which was 0.11℃ more than the average of 36.34±0.64℃ of forehead temperature (t= 3.34, p=.001).

The average temperature was 22.2 ± 0.93, and the average humidity was 46.60 ± 8.04 in controlled hospital environment. In hospital conditions, the tympanic membrane temperature ranged from 35.5°C to 38.9°C, and the forehead temperature ranged from 35.6°C to 38.7°C. The average body temperature of tympanic membrane was 36.49 ± 0.65°C, which was 0.10°C lower than the average value of forehead body temperature of 36.59±0.54°C (t=2.71, p=.007) (Table 1).

Table 1: Comparison of Tympanic Temperatures and Temporal Artery Temperatures. (N= 155)

	Body temperatures (℃)	Min	Max	M±SD	95% CI	t (*p*)
Pre-hospital	Tympanic 1	34.1	38.9	36.44±0.77		
	Tympanic 2	34.2	38.9	36.48±0.76		
Environmental	Tympanic mean	34.1	38.9	36.46±0.76		
condition	Temporal artery 1	34.5	38.5	36.32±0.65		
Average	Temporal artery 2	34.6	38.7	36.36±0.65		
temperature	Temporal artery mean	34.5	38.5	36.34±0.64		
4.7±2.32	Tympanic - Temporal artery mean	-1.0	1.7	0.11±0.44	0.04~0.18	3.34(.001*)
Average humidity 74.69±13.65						
In-hospital	Tympanic 1	35.5	38.8	36.65±0.64		
	Tympanic 2	35.5	38.9	36.70±0.65		

Environmental condition Average temperature 22.2±0.93 Average humidity 46.60±8.04	Tympanic mean	35.5	38.8	36.49±0.65		
	Temporal artery 1	35.8	38.5	36.58±0.54		
	Temporal artery 2	35.6	38.7	36.60±0.55		
	Temporal artery mean	35.7	38.5	36.59±0.54		
	Tympanic - Temporal artery mean	-1.0	2.0	0.08±0.39	0.02~0.14	2.71(0.07*)

12 patients (7.74%) had fever with tympanic membrane temperature above 38.0°C (Table 2). The distribution of measurements for forehead and tympanic membrane temperature is shown in figure 1, and both pre-hospital situation (r=.49, p<.001) and hospital condition (r=.36, p<.001) showed high correlation between the two measurements.

Through simple regression analysis, the following regression equations for predicting body temperature with tympanic membrane temperature in pre-hospital and hospital situations were derived. First, in the pre-hospital situation, forehead temperature(°C) and be calculated as .834 X tympanic membrane temperature(°C) + 6.438.

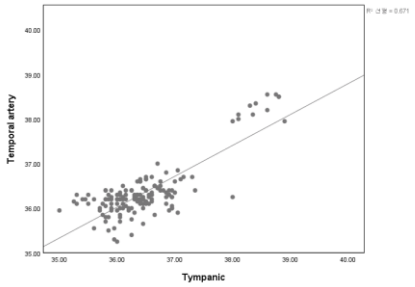
Forehead temperature(°C) = .834 x tympanic membrane temperature(°C) + 6.438.

According to the equation above, in pre-hospital condition, the tympanic membrane temperature of 38.0°C, which is the standard of fever, corresponds to forehead temperature of 38.1°C.

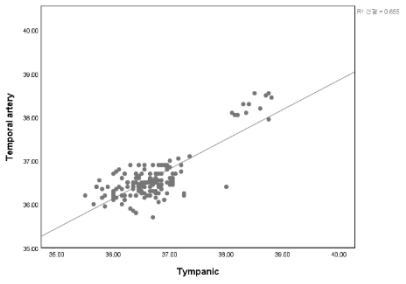
In hospital situation, forehead temperature(°C) and be estimated as .848 X tympanic membrane temperature(°C) + 6.006.

Forehead temperature(°C) = .848 x tympanic membrane temperature(°C) + 6.006.

According to the above equation, the tympanic membrane temperature of 38.0°C, which is the standard of fever in hospital conditions, corresponds to the forehead temperature of 38.2°C.



(a) Pre-hospital



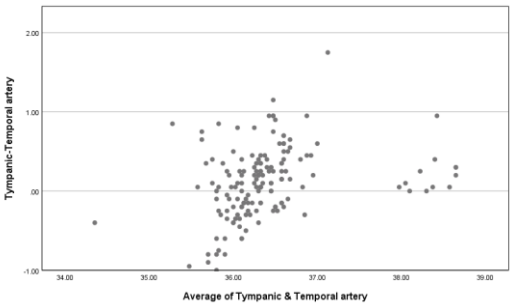
(b) In hospital

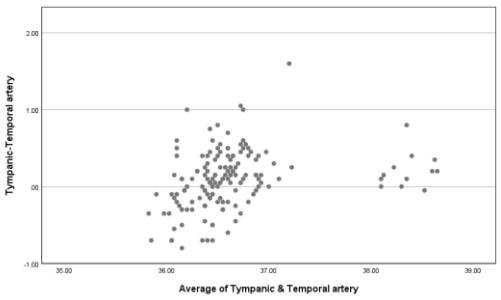
Figure 1. Scatter plot showing the relationship between temporal artery temperatures and tympanic temperatures.

3.2. Concordance forehead temperature and tympanic membrane temperature

Figure 2 shows the difference between forehead temperature and tympanic membrane temperature as a result of confirming 95% agreement through Bland-Altman plot in pre-hospital and hospital situation. In pre-hospital situation, the mean of differences was 0.11 (95% confidence interval 0.04~0.18), while in hospital situation, the mean of differences was 0.08 (95% confidence interval

0.02~0.14) (Figure 2).





(c) Pre-hospital **(d)** In hospital

Figure 2. The Bland-Altman plot comparing the difference between temporal artery temperatures and tympanic temperatures

3.3. Formatting of Mathematical Components

Table 2 shows the sensitivity, the specificity, the positive predictive validity, and the negative predictive validity of forehead temperature. ROC Based on the combined optimal score of the sensitivity and the specificity presented in ROC analysis, the cut-off between pre-hospital and hospital situation was 37.5℃. In pre-hospital conditions, the sensitivity was 100%, the specificity 97.9%, the positive predictive value 80.0%, and the negative predictive value 100%. In hospital conditions, the sensitivity was 100%, the specificity 99.3%, the positive predictive value 83.0%, the negative predictive value 92.3% (Table 2).

Table 2: Comparison of Sensitivity, Specificity, Positive Predictive Value, and Negative Predictive Value at Temperature Cutoff Points (N= 155)

	Variable	Categories	Tympanic temperatures			Sensitivity %	Specificity %	PPV %	NPV %
			≥38.0℃	＜38.0℃	Total				
Pre-Hospital	Temporal artery temperatures	**≥37.5℃**	12	3	15	100	97.9	80	100
		＜37.5℃	0	140	140				
		Total	12	143	155				
In-Hospital	Temporal artery temperatures	**≥37.5℃**	12	1	13	100	99.3	83	92.3
		＜37.5℃	0	142	142				
		Total	12	143	155				

4. Discussion

This study attempted to confirm the usefulness of applying forehead temperature in various environments by confirming the diagnostic accuracy of tympanic membrane temperature with forehead

body temperature in pre-hospital and hospital conditions. As a result of the study, high positive correlation was found in forehead as well as tympanic membrane temperature both in pre-hospital conditions where temperature and humidity were not controlled (r=.49, p<.001) and in hospital situations where the environment was controlled (r=.36, p<.001). This is not a thesis comparing tympanic membrane temperature with forehead temperature as in this paper, so it is difficult to directly compare them. But it was consistent with the results of the previous study [2] comparing forehead temperature using axillary temperature as a reference standard and a study [10] comparing forehead temperature using rectal temperature as reference standard. However, a high correlation between reference standard body temperature and forehead temperature does not mean that the two methods are consistent [2,12]. As a result of evaluating the degree of agreement by the method proposed by Bland and Altman [12], the matching range was found to be 0.04~0.08 in 95% confidence interval and 0.02~0.14 in hospital situation, showing high precision. The result of this study is similar to the results of previous study [2], which assessed the degree of agreement between axillary and forehead temperature in adult patients admitted to the ward and analyzed the degree of agreement between forehead temperature and rectal temperature [10], found to be more precise because this result was distributed within narrower range. Therefore, it was confirmed that forehead temperature can be the body temperature that can replace tympanic membrane temperature both in environment-uncontrolled pre-hospital and in environment-uncontrolled hospital situation.

Fever is a useful factor to show the patient's condition, and it is a measurement method with excellent predictability and sensitivity in order to determine how to use this factor [2,13]. In pre-hospital situation, the standard of fever was set at the tympanic membrane temperature of 38.0°C or higher and the tympanic body temperature of 38.0°C or higher was classified as 3.81 °C or higher. As a result of evaluating the diagnostic accuracy, the sensitivity was 100%, the specificity 97.9%, the positive prediction 80.0%, and the negative prediction 100%. In hospital situation, the standard of fever was set at tympanic membrane temperature of 38.0°C or higher and the tympanic body temperature of 38.0°C or higher was classified as 3.82°C or higher. In the diagnostic accuracy, the sensitivity was 100%, the specificity 99.3%, the positive prediction 83.0%, and the negative prediction 92.3%. This result was similar to the results of a previous study [2] comparing forehead with axillary temperature, and higher than the study comparing forehead with rectal body temperature [10]. These results confirm that forehead body temperature measurement, which is easy to use, has short measurement time, is convenient to operate, and has the advantage of rapidity, is effective in the screening subjects who do not have fever, even when the environment is not controlled.

Moreover, the boundary score between pre-hospital situation and hospital situation is 37.5℃ based on the optimal sum scores of the sensitivity and the specificity presented in ROC analysis. Therefore, in pre-hospital situation and the hospital situation, it was verified that forehead temperature is effective in screening the fever from 37.5°C, not only in the case of fever above 38.0°C. These results indicate that forehead thermometer is non-invasive, does not cause the cross-infection, is easy to use, and can be quickly measured, whether in controlled environment or uncontrolled environment at the time of the spread of infectious diseases such as COVID-19 worldwide. It can be confirmed that forehead thermometer is an ideal body temperature measurement method.

5. Conclusion

This study attempted to confirm the diagnostic accuracy of forehead body temperature by using tympanic membrane temperature as a reference standard in pre-hospital and controlled-hospital conditions where temperature and humidity are not controlled in adult patients. As a result of the study,

forehead and tympanic membrane temperature in both pre-hospital and hospital conditions showed high correlation, high agreement and relatively high diagnostic accuracy. Therefore, it can be said that forehead temperature is valid for checking whether fever is present. In addition, the measurement of forehead temperature using infrared forehead thermometer showed high specificity and negative predictability in pre-hospital and hospital situations, and was proved to be useful as a screening tool for screening the fever of subjects in various situations. Moreover, this study is significant since forehead temperature was verified to be effective in screening low fever from 37.5℃. However, in order to minimize the error range between the measurement, one researcher was trained on the correct use of thermometer and measurement position, and then measured the temperature. So, when measuring forehead temperature with forehead thermometer in various environments and occupations, it is necessary to become experienced with accurate measurement methods and precautions for training. The follow-up study is suggested to confirm the diagnostic accuracy of forehead temperature in various situations and subjects reported to 119.

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