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Original Article

Comparison of the accuracy of body temperature measurements with temporal artery thermometer and axillary mercury thermometer in term newborns

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Abstract

Background Rectal mercury thermometer (RT) has been considered to be a clinical thermometer that measures body temperature close to core temperature. Unfortunately it is relatively uncomfortable to the patient. Axillary mercury thermometer (AT) is a relatively safe method, but time consuming and its accuracy has been questioned. Temporal artery thermometer (TAT) is relatively a new method that can measure body temperature faster, and well tolerated.

Objective To compare the accuracy of temperature measurement between TAT and AT in neonates.

Methods Cross-sectional analytic study was conducted at Neonatology Division at Sanglah Hospital, Denpasar. Every healthy term newborn who met the criteria were measured their body temperature by using three kinds of thermometer consecutively. The limits of agreement, correlation and linear regression analysis were done to find TAT and AT's agreement and correlation to RT.

Results One hundred and thirty four newborns were enrolled in this study. TAT had a better agreement to RT with the mean difference of -0.01ºC with 2 SD lower limit of -0.26ºC and upper limit of 0.23ºC, compared to agreement between AT and RT, with mean difference -0.35ºC, 2 SD lower limit -0.70ºC and upper limit of 0.00ºC. There was a significant linear association between TAT and RT with correlation coefficient r = 0.87 ($p<0.001$), intercept 0.987 and slope 0.509. The linear association between AT and RT showed the correlation coefficient r = 0.76 ($p<0.001$), intercept 10,271 dan slope 0,730.

Conclusion TAT is more accurate than AT for body temperature measurement in the healthy term newborns. **[Paediatr Indones. 2010;50:67-72]**.

Keywords: *body temperature measurement, temporal artery thermometer, axillary thermometer, healthy term newborn*

Neonatal period is a period that susceptible for heat loss such as from external manipulation during body temperature measurement, due to thinner skin layer and large body surface area which contacted to the examiner. Therefore, an ideal thermometer for the neonate should not be only measure body temperature accurately and safely, but also quick to use in order to prevent the unnecessary heat loss.[1-3]

Rectal mercury thermometer (RT), is a clinical thermometer that measures body temperature close to the core temperature. Despite its accuracy, RT measurement is not a comfortable method, relatively time consuming, and without proper sterilization RT may have a potential to spread diseases. Even though the incidence of rectal perforation is very rare (1 in 2 million measurements), we cannot say that RT measurement is a totally safe method for body temperature measurement.[4,5] On the other hand axillary thermometer is a relatively safe

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and comfortable method for body temperature measurement, but it is time consuming and their accuracy is being questioned.[6,7] Temporal artery thermometer is a new method for body temperature measurement that measures body temperature in seconds, and it is said to be safe and more comfortable. The purpose of this study is to determine the accuracy of temporal artery thermometer measurement compared to axillary thermometer measurement by using rectal thermometer measurement as a reference and to know whether those thermometers can be used interchangeably with rectal mercury thermometer.

Methods

A cross-sectional study was conducted in Neonatology Division, Department of Child Health Medical School, Udayana University, Sanglah Hospital from June to July 2008. We included term neonates aged 24 hours or more, with appropriate body weight for the gestational age, and excluded babies with local trauma/inflammation and local birth trauma upon the measurement.

Sample size was calculated based on hypothesis test for the difference of correlation coefficient in two population groups, using level significant (P) <0.05 and power 80%, the minimal sample size needed was 104 subjects. Subjects were collected via consecutive sampling and written informed consents from the parents/legal guardians were required.

Temperature measurements were done by one medical doctor that had been trained regarding study's protocol and the proper usage of those thermometers. Each subject was measured using three thermometers. Temporal artery temperature measurement was done by using infrared TAT, Exergen TAT-5000, made in Watertown, Ma, USA. Axillary temperature measurement was done by using AT, Safety®-KL 0901000259 made in Japan, and rectal temperature measurement was done by using RT, Clinical thermometer-CE 0197®, made in China.

Temporal artery temperature was measured by placing the probe in the middle of the forehead. Afterwards, depressed and held the "on" button and moved the probe laterally to the hair line before released the "on" button. Axillary temperature measurement was done by placing the metal part of AT on the top of axillary triangle and kept it tight for 5 minutes. Rectal temperature was measured by inserted the RT approximately 2.5 cm deep into the rectum and held for 3 minutes.

Statistical analysis was done by comparing the accuracy of the TAT and AT, by using RT as a reference thermometer. Both TAT and AT were assessed for their ability to predict rectal temperature.

The limits of agreement, used Bland and Altman methods, was performed to assess if the tested thermometers could be used interchangeably with the reference thermometer (RT) and to know their accuracy. The computation was done by using a computer program, and the results were presented in graphs. The vertical axis (y) showed the difference between each result of the tested thermometer with the rectal thermometer (TAT – TAR or TAA – TAR), meanwhile the horizontal axis (x) showed the mean difference of the each result of tested thermometers with rectal mercury temperature (the average of TAT and TAR or TAA and TAR). With the Bland and Altman methods, the difference of the 2 methods of temperature measurements (bias) and their 95% limits of agreement of 2 SD could be calculated. The presentation of the 95% limits of agreement was for visual judgment of how good the two methods of measurement agree. The smaller the range between these two limits, the better the agreement was.[9,10] A tested thermometer measurement had a good agreement with the rectal mercury thermometer if the difference between those measurements was not meaningful for clinical interpretation. Some previous studies considered that the measurement of temperature to be reliable (good agreement between any two methods of measurement) if temperature value differed by ≤ 0.5 C and being considered have discrepancy >0.5C to be clinically important.[11,12]

The linear regression analysis was done and Pearson correlation coefficient was then calculated to find the relation between TAT and RT and for the relation between AT and RT. The hypothesis was done by using level of confidence (α) $P<0.05$ and 95% confidence interval.[8] The study protocol was reviewed and approved by Ethics Committee on Research Udayana University/Sanglah Hospital, Denpasar.

Results

During the study, there were 215 babies born; 63 newborns were excluded because of several reasons, and 18 newborns were discharge before the measurement done. Therefore**,** there were 134 newborns included in this study; the characteristics of the subjects are described in **Table 1**.

Each newborn were measured with three thermometer, and the mean of temperature RT was 37.08 (SD 0.26), TAT was 37.7 (SD 0.23) and AT was 36.73 (SD 0.27)^{o}C (**Table 2**).

The limits of agreement analysis between TAT and RT showed the mean difference of -0.01^{o}C (95%CI, 0.33; 0.09) with upper limit +0.23^{o}C and lower limit -0.26^{o}C (**Figure 1**).

The horizontal line in the middle indicate the mean difference of two measurements, and two additional lines indicate $\pm$ 2 SD above and below the mean.

The limits of agreement analysis between AT and RT showed the mean difference of -0.35^{o}C (95%CI, -0.382; 0.320) with upper limits -0.0^{o}C and lower limits of -0.70^{o}C (**Figure 2**).

The horizontal line in the middle indicate the mean difference of two measurements, and two additional lines indicate $\pm$2 SD above and below the mean.

Table 1. The characteristics of the subjects

Characteristics	n = 134
Sex, male, n (%)	
Age of gestational, week, mean (SD)	69 (51.5)
Age of subjects during	39.3 (1.22)
temperature measurements, hour, mean (SD)	35.5 (12.87)
Birth weight, gram, mean (SD)	3193 (345.3)
Mode of delivery, n (%)	
Spontaneous vaginal delivery	114 (85.1)
Sectio Caesarean	18 (13.4)
Forceps delivery	1 (0.7)
Vacum extraction delivery	1 (0.7)

The Pearson correlation between TAT and RT temperature showed a significantly good correlation with r value = 0.87, P<0.001 and RSq = 0.76 (**Figure 3**).

The linear regression analysis showed a linear association between TAT and RT temperature. The intercept was 0.987 and slope was 0.509, with a regression formula y = 0.509 + 0.987 X1. The Pearson correlation showed a moderate correlation between AT and RT with r value of 0.76 and RSq = 0.58, and statistically significant, P<0.001 (**Figure 4**).

The linear regression showed a relation between TAA and TAR. The intercept was 10.271 and slope

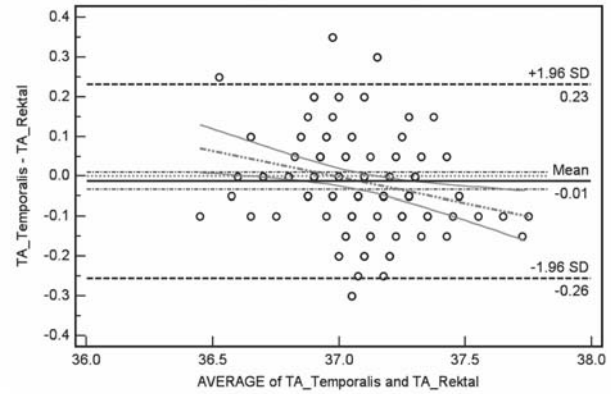

Figure 1. Bland and Alman plot

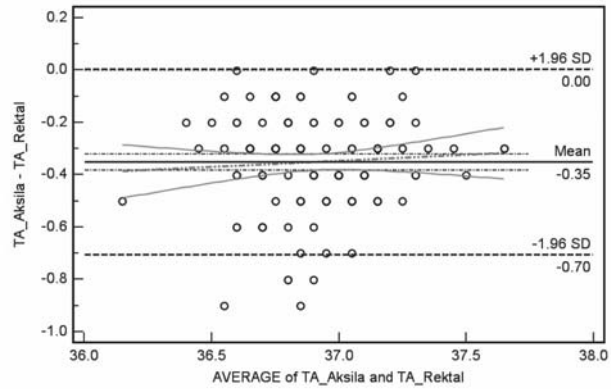

Figure 2. Bland and Alman plot

Table 2. Results of temperature measurement with RT, TAT, and AT

Method	Mean (ºC)	Minimum (ºC)	Maximum (ºC)	Standard Deviation (SB) (ºC)	The mean difference to rectal mercury thermometer (ºC)
RT	37.08	36.40	37.80	0.26	
TAT	37.07	36.40	37.70	0.23	0.01
AT	36.73	35.90	37.50	0.27	0.35

Note: RT = rectal mercury thermometer; TAT = temporal artery thermometer; AT = axillary mercury thermometer

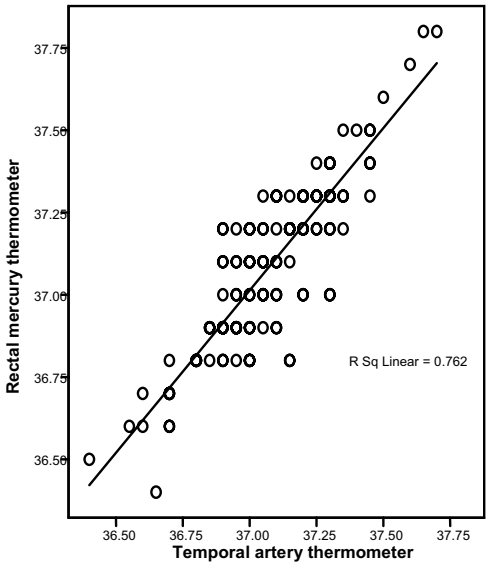

Figure 3. Scatter plot of the correlation between RT and TAT

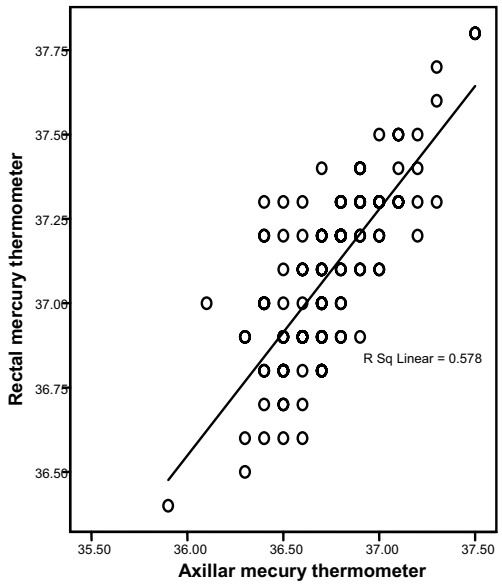

Figure 4. Scatter plot of the correlation between RT and AT

was 0.509, with a regression formula y = 10.271 + 0.730 X2.

Discussion

In this study, the temporal artery temperature was found to have a stronger correlation to rectal mercury temperature compared to axillary mercury temperature (r-value 0.87 vs 0.76). The strength of TAT and RT correlation is almost equal to previous study done by Green DS et al.[13] In that study, TAT was compared to tympanic membrane thermometer by using rectal thermometer as standard criterion in 304 babies younger than 1 year old and found that TAT had strong correlation with r = 0.83 and RSq =0.79. This strong correlation between TAT and RT possibly due to the TAT measures temperature in the superficial temporal artery. This artery is lying so close to the skin surface and it can be easily accessible in the temporal part of the forehead and this area is relatively lesser fat tissue. Besides that, temporal artery is not an anastomosing vessel (a vessel that established a connection between arteries, veins, or between lymph vessels), so the perfusion remains relatively constant, therefore the temperature in the temporal artery reflects the temperature in the aorta.

In the measuring body temperature, TAT uses arterial heat balance method. In this methods infrared thermometer accounts for the radiated heat loss by measuring ambient temperature. At the same time it measures the absolute temperature of the skin surface over the temporal artery. Then compute arterial temperature by restoring the measured heat loss from skin surface over the temporal artery. So the thermal loss to the environment will then be zero and the temperature measured is a temperature in the temporal artery. In the mean while the axillary mercury thermometer measure temperature of axillary artery, by measuring temperature over the skin on the axillary triangle. That area contains lots of fat/ brown fat tissue, anastomoses of the arteries, veins, and lymph node, and largely is influenced by the environmental temperature which can effects the accuracy.[3,14]

We analyzed limits of agreement by using Bland and Altman methods. Between AT and RT showed that 95% the axillary temperature could be anywhere between 0.0°C and 0.71°C below RT temperature. This range is too wide from the difference that clinically acceptable ($\pm$0.5°C). The paired of the TAT and RT temperature showed that 95% of TAT temperature lays between 0.23°C above and 0.26°C below of the rectal temperature. This difference is clinically acceptable, therefore TAT and RT is considered could be used interchangeably. This result is different with previous study done by Hebbar, et al.[11]

In that study, TAT and AT were compared using RT as a reference thermometer in 44 pediatric intensive care unit patients, with 25th -75th percentile of age was between 2-34 months. The mean difference of TAT and RT was 0.035^{o}C (SD 0.94^{o}C) and the difference of AT and RT was 0.16ºC (SD 0.47^{o}C). Although TAT had narrower mean difference compared to AT, but the mean standard deviation remained wider. So in that study AT found to be more accurate to TAT. The difference results from our study probably due to difference characteristics of the population, those patients were admitted due to respiratory distress, cardiac disease, sepsis, neurologic disorder, hematologic-oncologic disorders. Most of those patients were intubated and some of those patients were diagnosed in a circulatory shock state and received vasopressor infusions. Neurologic disorder especially involved the hypothalamus and hypoxia may decrease norepinephrine response to thermogenesis, and shock and sepsis may induce peripheral vasoconstriction that may affect the TAT temperature measurement.[15]

There were linear associations between TAT/AT and RT. TAT intercept was 0.509 and slope was 0.987, with regression formula; y (RT temperature) = 0.509 + (0.987 x TAT temperature). If the temperature measured with TAT showed 37^{o}C, at the same time we considered that rectal temperature was 37.03^{o}C.

AT intercept was 10.271 and slope was 0.73, and regression formula; y (RT temperature) = 10.271 + (0.730 x AT). It means that if measured temperature with AT showed 37^{o}C, at the same time we considered the rectal temperature was 37.28^{o}C.

The limitation of this study was the rectal thermometer is not a gold standard for measuring core temperature. Core temperature only can be measure by placing a thermistor catheter in the distal of esophagus or in the pulmonary artery. Both of those measurement are invasive proccedures that almost impossible done in the clinical daily based setting.[3,13] In this study, rectal thermometer was used as a reference thermometer due to compared to others clinical thermometer, rectal temperature is considered the closest temperature to core temperature.[16] The other limitation, this study used only healthy newborns, so we do not know if the results would be the same if those thermometers are used in the sick newborns population.

We conclude that temporal artery thermometer is more accurate than axillary mercury thermometer and if the difference of $\leq$0.5^{o}C between methods of temperature measurement is being considered not significantly important for the clinical decision, TAT can be used with RT interchangeable. The authors suggest more variety of population including sick babies and if it is possible, next study should use a core temperature as gold standard for comparison.

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