COMPARISON OF INFRARED TYMPANIC AND DIGITAL ELECTRONIC AXILLARY THERMOMETERS WITH GLASS-MERCURY RECTAL THERMOMETERS IN THAI CHILDREN

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ABSTRACT :

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This prospective observational study assessed the accuracy and factors that influenced the infrared tympanic and digital electronic axillary thermometers compared with glass mercury rectal thermometers in 200 Thai children aged 1 day - 48 months in Nakhonpathom hospital. Temperature measurements were obtained simultaneously at three body sites with infrared tympanic (rectal mode), digital electronic axillary and glass-mercury rectal thermometers three times for each thermometer and determined averaged values. The mean rectal temperature (38.00 ± 0.91°C) was higher than the mean tympanic (37.77 ± 0.95°C) and the mean axillary temperature (37.71 ± 0.86°C) significantly ($p < 0.05$). Rectal temperatures showed excellent correlation with both tympanic and axillary temperatures ($r = 0.93$ and 0.90, respectively, $p < 0.001$). In detecting fever, tympanic thermometer was 72% sensitive, 98% specific and 85.5% accurate. Axillary thermometer was 68% sensitive, 99% specific and 84% accurate. Quantity of cerumen and acute otitis media had no effect on the accuracy of the tympanic thermometer. Range of rectal temperature, age group and ambient temperature influenced on the accuracy of digital axillary thermometer more than tympanic thermometer. Tympanic thermometer had slightly better performance than axillary thermometer. Because of low sensitivity, both thermometers should not be substituted for glass-mercury rectal thermometer in newborn infants and young children now.

บทคัดย่อ :

สุธัญญา บรรจงภาค, อารีย์ ก้องพานิชกุล. ประสิทธิภาพของเทอร์โมมิเตอร์ชนิดอินฟราเรดวัดทางหูและชนิดอิเล็กทรอนิกส์วัดทางรักแร้ เปรียบเทียบกับชนิดปรอทแก้ววัดทางทวารหนักในเด็กไทย. (วารสารแพทย์เขต ๔ ๒๕๔๒ ; ๓ : ๑๕๙-๑๖๙.)

กลุ่มงานกุมารเวชกรรม, รพ. นครปฐม.

การศึกษาแบบไปข้างหน้าเชิงทดลอง เพื่อศึกษาประสิทธิภาพและปัจจัยที่มีอิทธิพลต่อการวัดอุณหภูมิกายทางหูด้วยเทอร์โมมิเตอร์ชนิดอินฟราเรดและการวัดอุณหภูมิกายทางรักแร้ด้วยเทอร์โมมิเตอร์ชนิดอิเล็กทรอนิกส์เปรียบเทียบกับการวัดอุณหภูมิกายทางทวารหนักด้วยเทอร์โมมิเตอร์ชนิดปรอทแก้ว ในผู้ป่วยเด็กจำนวน ๒๐๐ คน ตั้งแต่แรกเกิด ถึงอายุ ๔๘ เดือน ที่มารับการตรวจรักษาในโรงพยาบาลนครปฐม โดยวัดพร้อมกันทั้ง ๓ ตำแหน่ง ตำแหน่งละ ๓ ครั้งในช่วงเวลาใกล้เคียงกันและคำนวณค่าเฉลี่ยมาวิเคราะห์ พบว่าอุณหภูมิกายเฉลี่ยที่วัดทางทวารหนัก (๓๘.๐๐ ± ๐.๙๑° ซ) สูงกว่าอุณหภูมิกายเฉลี่ยที่วัดทางหู (๓๗.๗๗ ± ๐.๙๕° ซ) และอุณหภูมิกายเฉลี่ยที่วัดทางรักแร้ (๓๗.๗๑ ± ๐.๘๖° ซ) อย่างมีนัยสำคัญทางสถิติ ($p < 0.05$) และมีความสัมพันธ์ในทางเดียวกันอย่างมีนัยสำคัญทางสถิติ ($r = 0.๙๓$ และ 0.๙๐ ตามลำดับ, $p < 0.001$) ในการวัดไข้ เทอร์โมมิเตอร์ชนิดอินฟราเรดวัดทางหู มีความไว (sensitivity) ร้อยละ ๗๒ ความจำเพาะ (specificity) ร้อยละ ๙๘ ความถูกต้อง (accuracy) ร้อยละ ๘๕.๕ และเทอร์โมมิเตอร์ชนิดอิเล็กทรอนิกส์วัดทางรักแร้ มีความไวร้อยละ ๖๘ ความจำเพาะร้อยละ ๙๙ ความถูกต้องร้อยละ ๘๔ ปริมาณขี้หูและหูชั้นกลางอักเสบไม่มีอิทธิพลต่อความถูกต้องแม่นยำ ต่อการวัดอุณหภูมิทางหู ส่วนช่วงพิสัยอุณหภูมิกาย อายุและอุณหภูมิห้องมีอิทธิพลต่อการวัดอุณหภูมิทางรักแร้มากกว่าการวัดทางหู เทอร์โมมิเตอร์ชนิดอินฟราเรดวัดทางหู มีความถูกต้องแม่นยำมากกว่าชนิดอิเล็กทรอนิกส์วัดทางรักแร้ แต่เทอร์โมมิเตอร์ทั้ง ๒ ชนิดยังไม่สามารถใช้แทนที่ปรอทแก้วที่วัดทางทวารหนักได้เพราะความไวต่ำ

Introduction

Temperature is one of four cardinal vital signs. Fever is most common chief complaint to provoke sick child and emergency visits and is often a sign of infectious diseases. Occult bacteremia typically occurs among children with rectal temperatures above 39.0°C.[1] Patterns of fever may be clues to specific diagnosis.[2] Certain management actions are specified in the presence of fever or high fever.[3,4] Accurate detection and quantification of fever is essential in appropriate management of children. Of the readily accessible sites, rectal temperature is frequently considered the best reflection of core temperature but it responds sluggishly to change in hypothalamic temperature.[5] The rectum and axilla are standard measurement sites in newborn infants.[6,7] Tympanic membrane has been reported to be an ideal site for detection of fever because it shares it's blood supply with the hypothalamus and is excellent indicator of core body temperature[8-10] and better than rectum.[11,12] Infrared tympanic thermometers have many attractive properties : speed, patient comfort, lack of external influence, no mucous membrane contact, non invasive procedure, preservation of patient modesty, minimal contraindications, minimal risk of disease transmission and suitability for young or unco-operative patients.[13] How concerns have been raised about the accuracy. The purpose of this study was to determine the accuracy and factors that influenced the new infrared tympanic and digital electronic axillary thermometrys compared with glass-mercury rectal thermometry in Thai children.

Materials and Methods.

Two hundred children were examined ranging in age from 1 day to 48 months in Pediatric Department of Nakhonpathom hospital. Preterms, terms (birth weight < 3,000 gm.), children having abnormal otic, abnormal rectal structure, diarrhea and contagious skin disease were excluded. Demographic data including age, gender, presence of otitis media, quantity of cerumen and ambient temperature were recorded. After obtaining parental permissions, subjects underwent rectal, tympanic and axillary temperature measurements simultaneously with water bath calibrated glass mercury rectal thermometers, an infrared tympanic thermometer (model 9000, Welch Allyn, InC, San Diego, California) and water bath calibrated digital electronic thermometers (model C 202, Terumo Corporation, Tokyo) by two investigators instructed to use the three thermometers accurately before the study started.Glass-mercury rectal thermometer was used by placing the bulb at a depth of 2 cm. of rectum in neonates and 3 cm. in older infants and children for one minute period as routine using in this hospital. Tympanic temperature measurement (rectal mode) was performed by placing the ear probe of thermometer in the right external ear canal with tightly seal, retracting pinna postero-superiorly (posteriorly for infants) and pressing the scan button then temperature was displayed in digital reading within 1 second. Axillary thermometer was used by placing the probe in the right axilla with adducting the arm then holding it firmly and waited for "beep sound" within one and a half minutes a stable reading was obtained. Each thermometer obtained

temperatures at three times and average values were determined. Ear evaluation was performed after completely taken temperatures.

Statistical analysis, including dependent t-test, independent t-test, analysis of variance (ANOVA), and Pearson' s product-moment correlation analysis, were calculated using standard formulas.[14] Sensitivity, specificity, positive predictive value, negative predictive value, accuracy, and ROC curves (receiver operating characteristic curves) were calculated for evaluate the performance of infrared tympanic and digital electronic axillary thermometer.[15]

Results

The study group consisted of 200 children aged 1 day to 48 months. Boys comprised 53% of patients. Categorization of patients in demographic data, mean rectal temperatures, mean disparity and correlation between rectal and both tympanic and axillary temperatures and statistical test were shown in Table 1. In Figure 1 and Figure 2, rectal temperatures showed excellent correlation with tympanic and axillary temperatures ($r = 0.93$ and 0.90, respectively : $p < 0.001$) but there were low correlation in range of rectal temperature subgroups. The mean rectal temperature (38.00 ± 0.91° C) was significantly higher than tympanic (37.77 ± 0.95° C) and axillary temperature (37.71 ± 0.86° C) at $p < 0.05$. The male and female mean rectal temperature were similar. The mean disparity between rectal and tympanic temperature was 0.23 ± 0.34° C and between rectal and axillary temperature was 0.29 ± 0.40° C. The temperature differences between rectal and other two readings in individual patients are presented in a histogram (Figure 3). Rectal and tympanic temperatures differed from 0-0.4° C in 73% of the subjects, 0.5-0.9° C in 26%, and 1-1.4° C in 1%. Rectal and axillary temperatures differed from 0-0.4° C in 68% of the subjects, 0.5-0.9° C in 25.5%, 1.0-1.4° C in 5.5%, 1.5-1.9° C in 0.5% and 2.0-2.4° C in 0.5%. The disparity between rectal and tympanic temperatures displayed less variability than the disparity between rectal and axillary temperatures. With regard to the disparity between rectal and tympanic temperatures, analysis of subgroups failed to find a statistically significant effect of gender, range of rectal temperature, presence of cerumen or acute otitis media. Age groups had influenced disparities. In the age group of 25-48 months, the disparity between rectal and tympanic temperatures was the least contrast to the disparity between rectal and axillary temperatures which was the least in o month group. Range of rectal temperature and ambient temperature had effect only on axillary temperatures not on tympanic temperatures. When rectal temperature ≤ 36.9° C the disparity between rectal and axillary temperatures was the least significantly. Ambient temperature ≤ 29° C, the disparity between rectal and axillary temperature was less than ambient temperature 32.0-33.9° C group significantly and was the least (not significantly). Sensitivity, specificity, positive predictive value, negative predictive value and accuracy for the prediction of rectal fever (≥ 38° C) and rectal high fever (≥ 39° C) are shown in Table 2. Sensitivity in detecting fever and high fever of both tympanic

Table 1 Analysis of subgroup's effect on the relationship between rectal and both tympanic and axillary temperatures

		mean temperature (mean. ± SD, °C)	disparity of temperature (mean. ± SD, °C)		correlation (r)	
Variable	N	R	R-T	R-A	R-T	R-A
Total	200	38.00 ± 0.91	0.23 ± 0.34	0.29 ± 0.40	0.93	0.90
Age (mo)						
o	59	37.51 ± 0.83	0.21 ± 0.29	0.01 ± 0.21*	0.94	0.97
1-12	51	37.93 ± 0.70	0.34 ± 0.40	0.40 ± 0.37	0.88	0.86
13-24	41	38.43 ± 0.94	0.21 ± 0.35	0.46 ± 0.48	0.93	0.87
25-48	49	38.29 ± 0.91	0.14 ± 0.32	0.36 ± 0.39	0.94	0.92
p value		p = 0.001	p = 0.04	p = 0.001		
Gender						
male	106	38.08 ± 0.93	0.25 ± 0.34	0.26 ± 0.40	0.94	0.91
female	94	37.90 ± 0.89	0.20 ± 0.35	0.32 ± 0.41	0.92	0.89
p value		p = 0.18	p = 0.37	p = 0.29		
Rectal temp. (°C)						
≥ 36.9	25	36.72 ± 0.25	0.13 ± 0.30	-0.05 ± 0.22*	0.65	0.62
37.0-37.9	79	37.47 ± 0.30	0.23 ± 0.36	0.28 ± 0.38	0.44	0.34
38.0-38.9	65	38.40 ± 0.27	0.30 ± 0.32	0.38 ± 0.38	0.61	0.51
≥ 37.0	31	39.55 ± 0.39	0.14 ± 0.37	0.38 ± 0.48	0.74	0.42
p value		p = 0.001	p = 0.07	p = 0.001		
Ambient temp. (°C)						
≥ 29.9	30	37.78 ± 1.04	0.08 ± 0.38*	0.09 ± 0.35*	0.96	0.94
30.0-31.9	75	37.88 ± 0.88	0.28 ± 0.35	0.30 ± 0.38	0.92	0.90
32.0-33.9	59	38.09 ± 0.95	0.25 ± 0.33	0.34 ± 0.45	0.94	0.88
≥ 34.0	36	38.26 ± 0.72	0.20 ± 0.30	0.35 ± 0.36	0.91	0.88
p value		p = 0.09	p = 0.05	p = 0.02		
Presence of otitis media						
Presence	10	37.76 ± 0.43	0.27 ± 0.42			
Absence	190	38.01 ± 0.93	0.22 ± 0.34			
p value		p = 0.41	p = 0.41			
Presence of cerumen						
Clear	70	37.94 ± 0.76	0.17 ± 0.38			
Partial abstruction	96	37.99 ± 0.99	0.25 ± 0.32			
Complete abstruction	34	38.12 ± 0.98	0.26 ± 0.34			
p value		p = 0.65	p = 0.29			

R = Rectal temperature, T = Tympanic temperature, A = Axillary temperature, *No significant difference between mean rectal and mean tympanic or axillary temperature

Table 2 Performance of tympanic and axillary thermometer in the detection of rectal fever (≥ 38° C) and rectal high fever (≥ 39° C)

Variable	Actual value		Predicted value *		ROC**	
Tympanic	Fever	Highfever	Fever	Highfever	Fever	Highfever
Accuracy	85.5	96.0	88.5	96.5	89.0	93.5
Sensitivity	72.0	77.4	83.3	83.9	91.7	96.8
Specificity	98.0	99.4	93.3	98.8	86.5	92.9
Positive predictive value	97.2	96.0	92.0	92.9	86.3	71.4
Negative predictive value	79.0	95.5	85.8	97.1	91.8	99.4
Axillary						
Accuracy	84.0	94.0	90.0	95.0	91.0	90.0
Sensitivity	67.7	67.7	85.0	84.0	89.6	100
Specificity	99.0	98.8	94.0	97.0	92.3	87.6
Positive predictive value	98.5	91.3	93.2	83.9	91.5	59.6
Negative predictive value	76.9	94.4	87.5	97.0	90.6	100

* using predicted value from linear regression equation (tympic temperrature = 0.89 rectal temperature + 4.229, axillary temperature = 0.956 rectal temperature + 1.96)

** revised using optimum thresholds for detecting fever (tympanic and axillary ≥ 37.6° C) and high fever (tympanic ≥ 38.5° C, axillary ≥ 38.3° C)

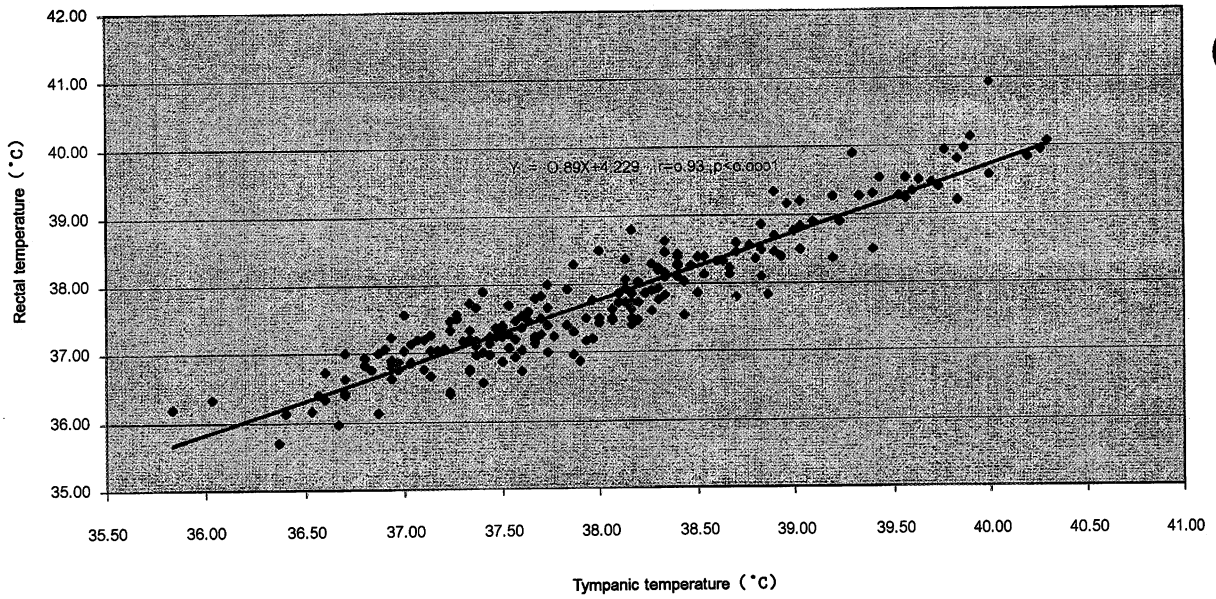

Figure 1 Scattergram of infrared tympanic temperature and rectal temperature

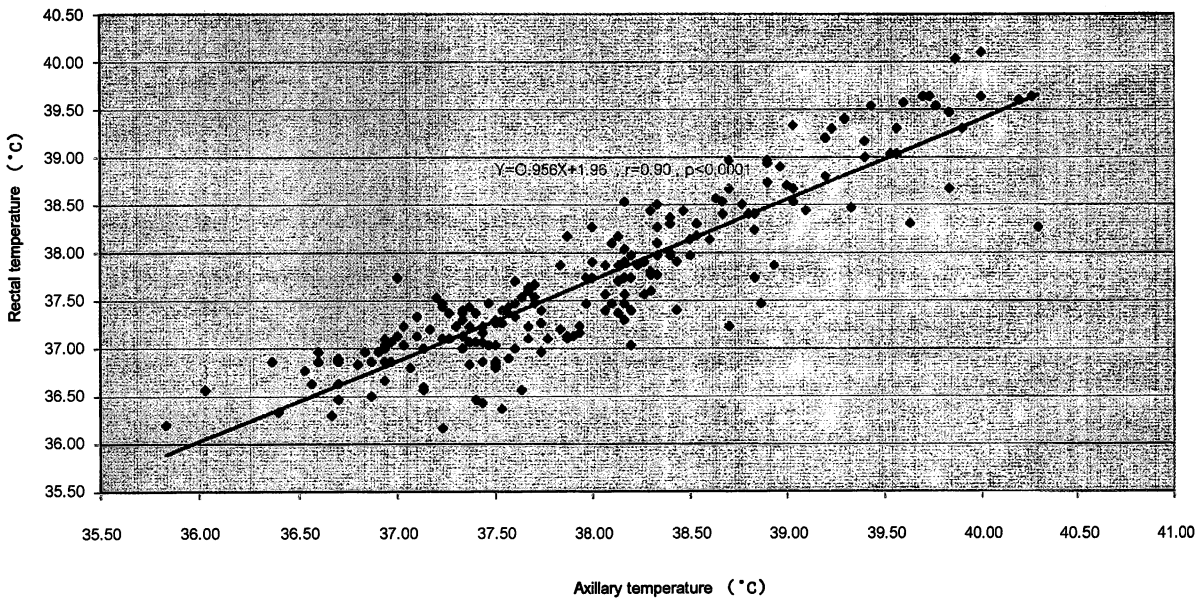

Figure 2 Scattergram of digital electronic axillary temperature and rectal temperature

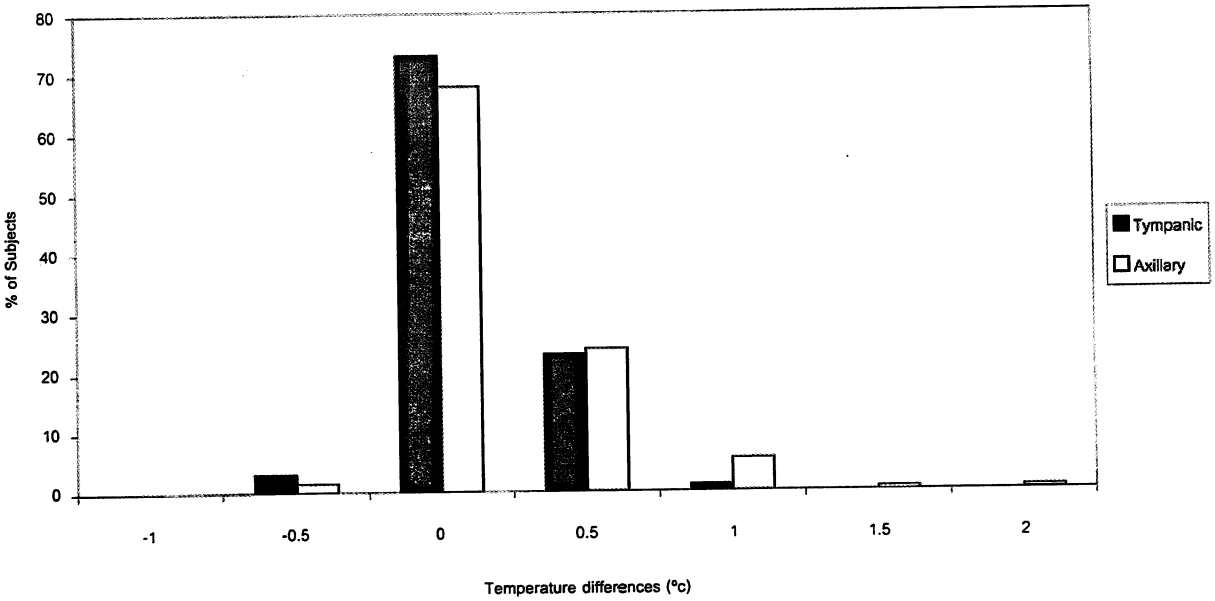

Figure 3 Frequency of differences between rectal temperatures and other two temperatures

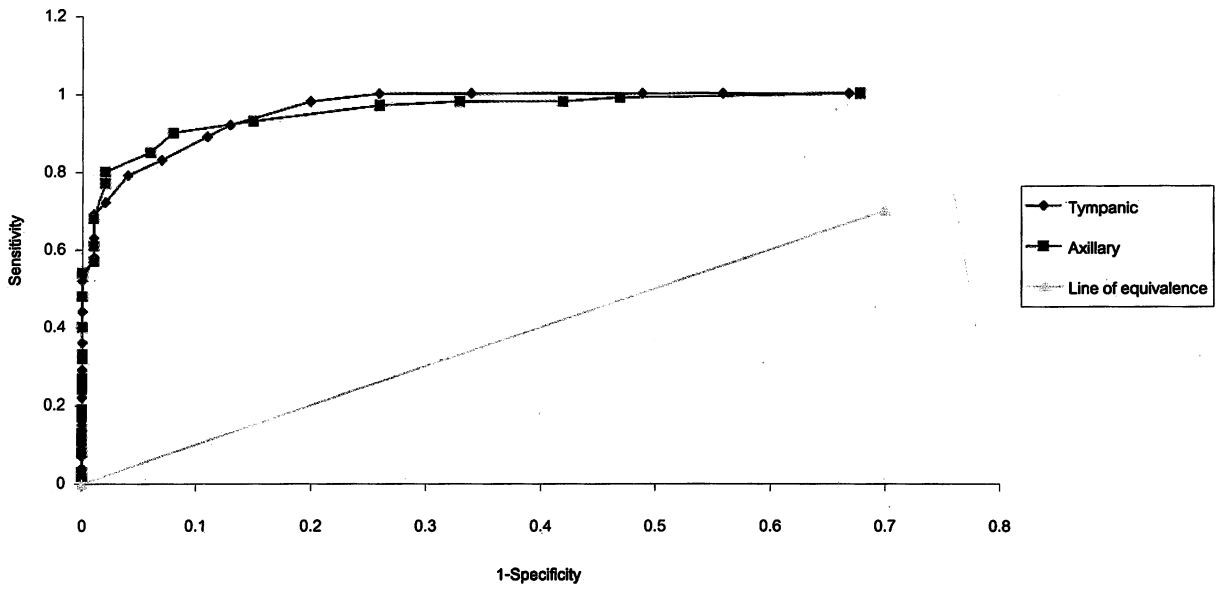

Figure 4 ROC curves for diagnosis of rectal fever by infrared tympanic thermometry and axillary thermometry

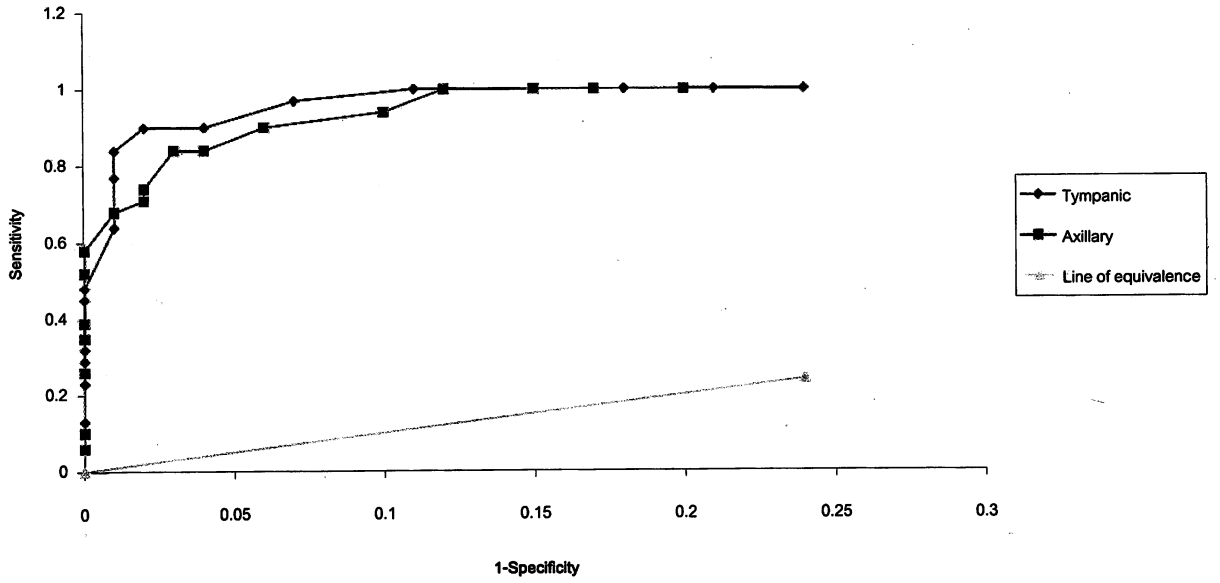

Figure 5 ROC curves for the diagnosis of rectal high fever by infrared tympanic thermometry and axillary thermometry

and axillary thermometry were low. By plotting sensitivity versus 1-specificity, receiver operating characteristic curves were constructed (Figure 4, 5). By choosing the points on these curves that were farthest from the equivalent line were the best points to give optimum sensitivity and specificity. After using revised threshold temperature (tympanic and axillary temperature ≥ 37.6° C) in detecting fever, sensitivity, negative predictive value and accuracy were increased in both thermometrys contrast with specificity and positive predictive value were slightly decreased. In the detecting high fever, sensitivity and negative predictive value were increased in both thermometrys contrast with specificity and accuracy were slightly decreased but positive predictive value were markedly decreased. When predicted values from linear regression equation were used in detecting fever and high fever the results were nearly similarity as using revised threshold temperature except positive predictive value in detecting high fever of axillary thermometry was slightly decreased.

Discussion

Preliminary studies of the accuracy of the infrared tympanic thermometers have had mixed results in children.[16-26,29-31,33,34,36] There were different in sample sizes, sample age groups, reference thermometer, modes, distribution of reference temperatures, manufacturers, time lapse between two measurements, design of studies and methodology. The pitfalls in these conditions were avoided in this study.

According to our data the glass-mercury rectal temperature was significantly higher than the infrared tympanic and electronic axillary temperature. The result was agreed with most other studies[16-24] in contrast to two studies in children by Kenny et al[25] and Stewart and Webster[26] that had almost no differences between rectal and infrared tympanic temperature. Kenny et al's study [25] included patients older than 48 months and Stewart and Webster's study[26] included small sample size especially in newborns. The disparity between rectal temperature and both temperatures was smaller than previous studies.[17,23,24,27]

Quantity of cerumen and acute otitis media had no effect on the accuracy of the infrared tympanic thermometry as other studies.[17,24,25,28-34] Age groups, range of rectal temperature and ambient temperatures influenced on the accuracy of digital axillary thermometry but had little effect on the infrared tympanic thermometry. Excellent correlation between the infrared tympanic temperatures with rectal temperatures was similar to Stewart and Webster's result[26] ($r = 0.93$, $p < 0.001$) and good correlation between digital electronic axillary temperatures with rectal temperatures was similar to Schiffman's result[35] ($r = 0.91$, $p < 0.05$). The low correlation in subgroups of range of rectal temperature corresponded to Muma et al's result [24] and Hooker's result[36] because of considering in a smaller interval of temperatures it was masked by the scatter in the data. Chamberlain, et al concluded that the 95 th percentile for infrared tympanic temperatures in normal children younger than 11 years old was 37.6° C.[32] According to our data and Chamberlain et al's,[32] infrared tympanic

temperatures (from rectal modes) ≥ 37.6° C should be cut off point to define fever. The cut off point to define high fever was temperture ≥ 38.5° C for tympanic temperature and temperature ≥ 38.3° C for digital electronic temperature. Comparing between both thermometers in this study, the infrared tympanic thermometer had slightly better performance than the digital electronic axillary thermometer.

Conclusion

Neither the infrared tympanic nor digital electronic axillary thermometry should be substituted for glass-mercury rectal thermometry now because of low sensitivity. But in cases that have contraindication to use rectal thermometry or some conditions that we require rapidity, convenience and safety the infrared tympanic thermometry may be an alternative thermometry in detecting fever of children older than 12 months if we adjust reading values by using linear regression equation or define fever ≥ 37.6° C. We suggest using digital electronic axillary thermometry as an alternative to rectal thermometry in newborns and infants or in detecting hypothermia.

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