

Accuracy and Precision of Digital Thermometer in Neonatal Temperature Measurement

Ratchada Kitsommart, M.D.*, Sopida Phatthanasiriwetin, M.H.**

*Department of Pediatrics, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok 10700, Thailand, **Nursing Department.

ABSTRACT : **Objective :** The purpose of this study was to determine the accuracy and precision of digital thermometer for axillary and rectal thermometry in neonates. **Study Design :** A prospective study was conducted. One hundred infants, 0 to 28 days old, weighing 860 to 3750 gm with a gestational age of 26 to 43 weeks were measured by a gold standard mercury-in-glass thermometer and then a digital thermometer for axillary and rectal temperatures, respectively. The accuracy was analyzed by the accepted difference between mercury-in-glass versus digital thermometer of 0.1 °C and 0.2 °C. **Results :** For rectal thermometry, accuracy of ± 0.1 °C and ± 0.2 °C was 68% (95%CI=58.3%, 76.3%) and 87% (95%CI=79%, 92.2%), respectively. For axillary thermometry, accuracy was 64 % (95%CI=54.2%, 72.7%) and 78% (95%CI=68.9%, 85%) for ± 0.1 °C and ± 0.2 °C, respectively. The precision of the digital thermometer was 86% (95%CI=77.9%, 91.5%) and 75% (95%CI=65.7%, 82.5%) for rectal and axillary digital thermometry, respectively. **Conclusions :** The digital thermometer could be used instead of the mercury-in-glass thermometer in relatively healthy neonates who could accept a wider range of temperature fluctuation within ± 0.2 °C. But for sick or critical neonates, the mercury-in-glass thermometer is still the recommended thermometer.

Key words : neonates, temperature measurement, digital thermometer

Temperature measurement is one of the fundamental monitoring parameters in general pediatric practice, especially for neonates. Both extrinsic factors, such as environmental temperature or clothing, and intrinsic factors such as infection or metabolic disturbances can cause temperature instability in newborn infants. Furthermore, neonates as a group are much more susceptible to developing abnormal temperature which can be manifested by various signs or symptoms. Therefore, temperature regulation reflects very basis neonatal well-being and its accurate assessment is one of the most important tasks of newborn care.

Measurement of temperature in neonates can be obtained either through the rectal or axillary route^{1,2}. The gold-standard of such methods is the mercury-in-glass thermometer. However, according to a review done by Craig (2000), as well as the study of Jirapaet (2000)³, such a device must be held in place for a relatively long time in order to achieve accurate temperature measurement⁴. During such periods, the method necessitates that each neonate is subjected to cold exposure. Moreover, mercury contamination is a true concern should the glass thermometer break⁵⁻⁷, as well as intestinal perforation from glass splinter injuries⁸⁻¹². In the past decade, various techniques have been proposed as an alternative to the mercury-in-glass thermometer, such as electronic digital thermometry and infrared tympanic thermometry. The infrared tympanic membrane thermometry has been deemed limited in accuracy and reliability in the neonatal population due to the specific ear canal anatomy^{2,13-15}. Most electronic digital thermometers require that the temperature measuring sensor reads the temperature at the equilibrium point, thus achieving accurate temperature reading in a shortened amount of time when compared to the conventional glass thermometer. Electronic digital thermometry is available in oral (sublingual), axillary and rectal routes but, according to difficulties in placement, the oral route is impractical for use in neonates.

Although rectal and axillary measurements are widely accepted routes of temperature measurement in neonates, determination of accuracy of the digital thermometer specific for newborn infants is limited⁴.

OBJECTIVE

This study's objective was to evaluate the accuracy and precision of digital electronic thermometry in rectal and axillary temperature measurements in neonates compared to the standard mercury-in-glass thermometry.

The primary function of the study was to test the accuracy of the digital thermometer compared to the gold-standard mercury-in-glass thermometer when the accepted difference between the digital and the mercury-in-glass thermometer is not more than 0.1 °C and 0.2 °C. The secondary outcome was to test the precision of the digital thermometer.

STATISTICAL ANALYSIS

The sample size was calculated with a two-sided 95% confidence interval for a single proportion, using the large sample normal approximation, extending 0.050 from the observed proportion to an expected proportion of 0.950. The calculated sample size was 73.

SUBJECTS

One hundred term and preterm neonates aged 0-28 days admitted to the nursery, intermediate care unit and NICU at the Department of Pediatrics, Siriraj Hospital participated in the study. The criteria for exclusion included:

1. Newborn infants who had signs or symptoms that suggested NEC.
2. Newborn infants who had anal fissure.
3. Newborn infants who had congenital malformations of the lower gastrointestinal tract.

4. Newborn infants who had a serious illness with signs or symptoms of cardiovascular instability.

MATERIALS AND METHODS

Prior to the study, four mercury-in-glass thermometers were standardized in a water bath (set at 37 °C). The technique for taking temperatures using the mercury-in-glass thermometer was based on routine practice in our division and findings from the literatures¹⁻³. Recordings were made in the Celsius scale and timed with a stop clock.

The electronic digital thermometer used in this study was the Sure Temp Plus 690 (Welch Allyn®). The manufacturer's operating instructions were used as the accepted technique for the electronic thermometer and calibrated by technicians prior to beginning the study.

Temperatures were taken by both mercury-in-glass thermometry and digital thermometry. Each infant was placed in a supine position; one side of the axillary thermometry was first measured using the mercury-in-glass thermometer, followed immediately by the digital thermometer. The mercury-in-glass thermometer was placed in the interaxillary fold; the temperature was read after 7 minutes in term and 5 minutes in preterm infants. When using the digital thermometer, the axillary probe was covered with a disposable probe-cover shield before placing in the same position of each infant. The temperature was read after 10 to 15 seconds as indicated by the ready-tone of the thermometer. After completing one side of the axillary measurement, temperature measurement on the other side was done, following the same process.

After completing the axillary temperature measurement, rectal temperatures were measured in the same order. First, using the mercury-in-glass thermometer inserted 2.5 cm for preterm infants and 3 cm for term infants rectally after lubrication with petroleum gel, the temperature was read after 3 minutes. When using the digital thermometer, after the rectal probe was covered with a disposable probe-cover and lubricated, we inserted the probe 2 cm rectally. The temperature was read after 10 to 15 seconds as indicated by the ready- tone.

RESULTS

One hundred infants were enrolled in the study between October 2004 and December 2004 from the neonatal nursery, intermediate care unit and NICU at the Department of Pediatrics, Siriraj Hospital. Demographic details are shown in Table 1. The majority of the popula-

TABLE 1 : Demographic data

	Mean ± SD	
	GA<37 weeks (n=66)	GA 37 weeks (n=34)
Gestational age (weeks)	32.1 ± 3.00 (26-36)	38.44 ± 1.58 (37-43)
Birth weight (g)	1591.82 ± 516.67 (860-3400)	2647.65 ± 625.03 (1490-3750)
Postnatal age (days)	8.73 ± 8.41 (1-28)	7.03 ± 5.54 (1-23)
Weight (g)	1592.58 ± 542.07 (670-3550)	2660.44 ± 643.66 (1470-3990)

tion were preterm infants (66%). The sex distributions of these infants are shown in Table1. Their mean birthweight was 1,950.80±747.11 g (range 860-3,750g), mean gestational age of 34.25±3.99 weeks (range 26-43 weeks) and mean postnatal age of 8.15±7.57 days (range 0-28 days).

The accuracy was analyzed for accepted differences between the mercury-in-glass and the digital thermometer of 0.1°C and 0.2°C. For rectal thermometry, the accuracy of $\pm 0.1^{\circ}\text{C}$ and $\pm 0.2^{\circ}\text{C}$ was 68% (95%CI= 58.3%,

76.3%) and 87%(95%CI=79%,92.2%), respectively. For axillary thermometry, the accuracy was 64% (95%CI= 54.2%, 72.7%) and 78% (95%CI=68.9%, 85%) for $\pm 0.1^{\circ}\text{C}$ and $\pm 0.2^{\circ}\text{C}$, respectively.

The precision of digital thermometry was 86% (95%CI=77.9%, 91.5%) and 75% (95%CI=65.7%, 82.5%) for rectal and axillary digital thermometry, respectively. Precision of rectal and axillary thermometers is shown in Figure 1.

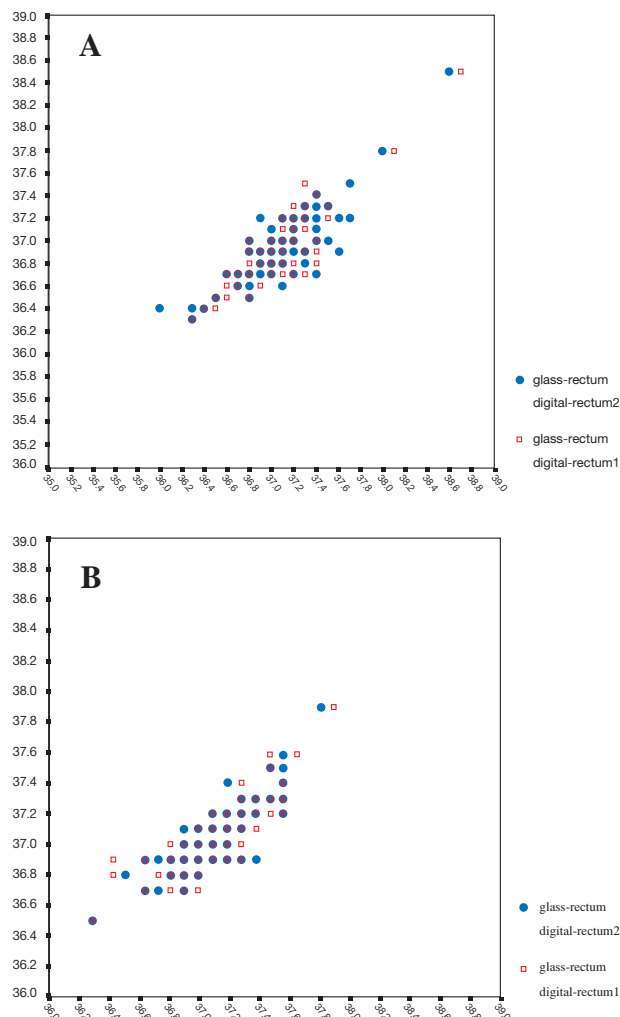


Fig 1. Precision of the digital axillary (A) and digital rectal thermometers (B). The box represents the related temperature between mercury-in-glass versus the first digital thermometer and the circle represents the related temperature between mercury-in-glass versus the second digital thermometer.

DISCUSSION

Glass thermometers have been considered the gold standard method of temperature measurement in newborn infants. However, anal perforation, accidental breakage and mercury contamination are risks associated with this method, in addition to being time-consuming and exposing neonates to room temperature which can cause hypothermia.

For these as well as other reasons, digital thermometry has been used instead of the traditional mercury-in-glass thermometer. It has a thermistor at the tip that measures the peak temperature reached in the surrounding tissue and converts it to a digital display. However, most published literatures that supported the use of this type of thermometer was done beyond the

neonatal period¹⁶⁻¹⁹. There were only a few studies where neonates, especially in preterm infants, were the selected patient group. Leick-Rude and Bloom (1998) found that the digital thermometer had the highest correlation with the glass thermometer for axillary temperature²⁰. Dollberg et al (2001) studied electronic digital thermometry in term and near-term infants. The study accepted the accuracy and precision of the instrument with a difference of $\pm 0.2^{\circ}\text{C}$ ²¹.

Our specific interest was having an understanding of the accuracy and reliability of axillary and rectal thermometry. The British Standards Institution accepted the accuracy for the mercury-in-glass thermometer of $\pm 0.1^{\circ}\text{C}$ and -0.15°C ²². It is generally presumed that a temperature difference from standard mercury-in-glass thermometry within 0.2°C is acceptable for clinical practice. If a particular neonate is in the sensitive area of temperature instability, such as preterm infants, the difference should not be more than 0.1°C . So we consider the difference of 0.1°C and 0.2°C as the acceptable level in this study.

Our results indicated that if we accept the difference of not more than 0.2°C , the accuracy of both rectal and axillary digital thermometers was acceptable compared with the mercury-in-glass thermometer. On the other hand, the accuracy of a difference of less than 0.1°C was not acceptable. These results were similar when we separately analyzed them in term and preterm infant groups.

In consideration of precision, the rectal digital thermometer is precise but the axillary digital thermometer is not. Digital thermometry is not a perfect device to be used instead of the standard mercury-in-glass thermometer in all neonates. It depends on the acceptable range of accuracy shown in the study. Hence, we might use it for relatively healthy infants who have an acceptable wider range of temperatures but not for sick or preterm infants. In addition, the relatively low number of samples in this study limited our ability to assess the correlation of the two methods of measurements.

Apart from considering it as a less time-consuming device, the digital thermometer is used in general nursing care should be of concern about its possible role as a vector in the transmission of nosocomial infections. There were reports of an outbreak of *Enterobacter cloacae* in the NICU related to disinfected thermometers^{23,24}. Others have reported outbreaks in which the thermometer transmit *Clostridium difficile* and *Salmonella spp*^{25,26}. Replacement with a disposable probe cover is one suitable way to prevent problems but we have to be concerned about the common digital device and its technique. However, the disposable probe cover is relatively expensive; the cost-effectiveness should be taken into account that should be considered for use in general care.

CONCLUSION

Precise assessment of temperature measurement is one of fundamental care for either healthy or sick neonates. It is essential in determining the appropriate course of action for treatment. For this reason, the study indicated that, for temperature measurement of relatively healthy infants who had an acceptable range of measured temperature of 0.2°C , rectal digital thermometry could be an appropriate device instead of the mercury-in-glass thermometer in order to decrease disturbance time during measurement and decrease the work load of care givers. In sick or critically-ill patients, the mercury-in-glass thermometer should be the standard device. Moreover,

factors of cost effectiveness, understanding the equipment and infectious control have to be considered in each situation.

ACKNOWLEDGEMENT

We thank Professor Kriangsak Jirapaet, Head of Division of Neonatology, Department of Pediatrics, Faculty of Medicine Siriraj Hospital, for his kind encouragement and helpful suggestions throughout this study.

REFERENCES

- Mayfield SR, Bhatia J, Nakamura KT, Rios GR, Bell EF. Temperature measurement in term and preterm neonates. *J Pediatr* 1984;104:271-5.
- Yetman RJ, Coody DK, West MS, Montgomery D, Brown M. Comparison of temperature measurements by an aural infrared thermometer with measurements by traditional rectal and axillary techniques. *J Pediatr* 1993;122:769-73.
- Jirapaet V, Jirapaet K. Comparisons of tympanic membrane, abdominal skin, axillary, and rectal measurements in term and preterm neonates. *Nurs Health Sci* 2000;2(1):1-8.
- Craig JV, Lancaster GA, Williamson PR, Smyth RL. Temperature measured at the axilla compared with rectum in children and young people: systematic review. *BMJ* 2000;320:1174-8.
- Blumenthal I. Which thermometer? *Lancet* 1991;337:1483.
- Blumenthal I. Should we ban the mercury thermometer? Discussion paper. *J R Soc Med* 1992;85:553-5.
- Goldman LR, Shannon MW. Technical report: mercury in the environment : implications for pediatricians. *Pediatrics* 2001;108:197-205.
- Segnitz RH. Accidental transanal perforation of the rectum; an obscure cause of peritonitis in infancy and childhood. *AMA J Dis Child* 1957;93:255-8.
- Fonkalsrud EW, Clatworthy HW, Jr. Accidental perforation of the colon and rectum in newborn infants. *N Engl J Med* 1965;272:1097-100.
- Greenbaum EI, Carson M, Kincannon WN, O'Loughlin BJ. Rectal thermometer-induced pneumoperitoneum in the newborn. Report of two cases. *Pediatrics* 1969;44:539-42.
- Frank JD, Brown S. Thermometers and rectal perforations in the neonate. *Arch Dis Child* 1978;53:824-5.
- Lau JT, Ong GB. Broken and retained rectal thermometers in infants and young children. *Aust Paediatr J* 1981;17:93-4.
- Sganga A, Wallace R, Kiehl E, Irving T, Witter L. A comparison of four methods of normal newborn temperature measurement. *MCN Am J Matern Child Nurs* 2000;25:76-9.
- Jean-Mary MB, Dicanzio J, Shaw J, Bernstein HH. Limited accuracy and reliability of infrared axillary and aural thermometers in a pediatric outpatient population. *J Pediatr* 2002;141:671-6.
- McKenzie NE. Accuracy of aural infrared temperature device. *J Pediatr* 1995;126:324-5.
- Davies SP, Kassab JY, Thrush AJ, Smith PH. A comparison of mercury and digital clinical thermometers. *J Adv Nurs* 1986;11:535-43.
- Smith J. Are electronic thermometry techniques suitable alternatives to traditional mercury in glass thermometry techniques in the paediatric setting? *J Adv Nurs* 1998;28:1030-9.
- Kongpanichkul A, Bunjongpak S. A comparative study on accuracy of liquid crystal forehead, digital electronic axillary, infrared tympanic with glass-mercury rectal thermometer in infants and young children. *J Med Assoc Thai* 2000;83:1068-76.
- Jensen BN, Jensen FS, Madsen SN, Lossel K. Accuracy of digital tympanic, oral, axillary, and rectal thermometers compared with standard rectal mercury thermometers. *Eur J Surg* 2000;166:848-51.
- Leick-Rude MK, Bloom LF. A comparison of temperature-taking methods in neonates. *Neonatal Netw* 1998;17:21-37.
- Dollberg S, Lahav S, Mimouni FB. Precision of a new thermometer for rapid rectal temperature measurement in neonates. *Am J Perinatol* 2001;18:103-5.
- Closs J. Oral temperature measurement. *Nurs Times* 1987;83:36-9.
- van den Berg RW, Claahsen HL, Niessen M, Muytjens HL, Liem K, Voss A. *Enterobacter cloacae* outbreak in the NICU related to disinfected thermometers. *J Hosp Infect* 2000;45:29-34.
- Donkers LE, van Furth AM, van der Zwet WC, Fetter WP, Roord JJ, Vandenbroucke-Grauls CM. [Enterobacter cloacae epidemic on a neonatal intensive care unit due to the use of contaminated thermometers]. *Ned Tijdschr Geneesk* 2001;145:643-7.
- McAllister TA, Roud JA, Marshall A, Holland BM, Turner TL. Outbreak of *Salmo nella eimsuettel* in newborn infants spread by rectal thermometers. *Lancet* 1986;1:1262-4.
- Jernigan JA, Siegman-Igra Y, Guerrant RC, Farr BM. A randomized crossover study of disposable thermometers for prevention of *Clostridium difficile* and other nosocomial infections. *Infect Control Hosp Epidemiol* 1998;19:494-9.

บทคัดย่อ

การศึกษาความถูกต้องและความแม่นยำของเครื่องวัดอุณหภูมิระบบดิจิทัลในการวัดอุณหภูมิทารกแรกเกิด

รัชฎา กิจสมภารก พ.บ.*, ไสภิดา พัฒนศิริเวทิน พย.ม.**

* ภาควิชากุมารเวชศาสตร์ คณะแพทยศาสตร์ศิริราชพยาบาล มหาวิทยาลัยมหิดล ** ฝ่ายการพยาบาล โรงพยาบาลศิริราช

วัตถุประสงค์การศึกษา

เพื่อศึกษาความถูกต้องและความแม่นยำของเครื่องวัดอุณหภูมิระบบดิจิทัลในการวัดอุณหภูมิทางรักแร้และทวารหนักทารกในแรกเกิด

ระเบียบ : ศึกษาทารก 100 คน อายุ 0 ถึง 28 วัน อายุครรภ์ตั้งแต่ 26 ถึง 43 สัปดาห์ น้ำหนักแรกเกิดตั้งแต่ 860 ถึง 3750 กรัม ทารกแต่ละคนได้รับการวัดอุณหภูมิทางรักแร้และทวารหนักโดยใช้ปรอทแก้วมาตรฐานตามด้วยการวัดโดยใช้เครื่องวัดอุณหภูมิระบบดิจิทัล จำนวนความถูกต้องของเครื่องวัดอุณหภูมิระบบดิจิทัล เปรียบเทียบกับค่าที่วัดได้จากปรอทแก้ว โดยยอมรับความแตกต่างไม่เกิน 0.1 °ซ และ 0.2 °ซ

ผลการศึกษา : ความถูกต้องของเครื่องวัดอุณหภูมิระบบดิจิทัลจากการวัดอุณหภูมิทางทวารหนักเท่ากับ 68% (95%CI=58.3%, 76.3%) และ 87% (95%CI=79%, 92.2%) สำหรับการยอมรับความแตกต่างไม่เกิน 0.1 °ซ และ 0.2 °ซ ตามลำดับ ส่วนการวัดอุณหภูมิทางรักแร้ จำนวนค่าความถูกต้องได้เท่ากับ 64% (95%CI=54.2%, 72.7%) และ 78% (95%CI=68.9%, 85%) สำหรับการยอมรับความแตกต่างไม่เกิน 0.1°ซ และ 0.2 °ซ ตามลำดับ และจากการคำนวณค่าความแม่นยำของเครื่องวัดอุณหภูมิระบบดิจิทัลจากการวัดอุณหภูมิทางทวารหนักและทางรักแร้ได้เท่ากับ 86% (95%CI=77.9%, 91.5%) และ 75% (95%CI=65.7%, 82.5%) ตามลำดับ

สรุป : สามารถนำเครื่องวัดอุณหภูมิระบบดิจิทัลมาใช้แทนปรอทแก้วในการวัดอุณหภูมิทางรักแร้และทวารหนักได้ในทารกที่ไม่อยู่ในภาวะเจ็บป่วยรุนแรงที่สามารถยอมรับการเปลี่ยนแปลงของอุณหภูมิภายใต้ไม่เกิน 0.2 °ซ ส่วนทารกที่อยู่ในภาวะเจ็บป่วยซึ่งจำเป็นต้องวัดอุณหภูมิให้ถูกต้องและแม่นยำเพื่อการควบคุมอุณหภูมิภายใต้ห้องที่เสมอ ควรใช้ปรอทแก้วเป็นเครื่องมือในการวัดอุณหภูมิเช่นเดิม

