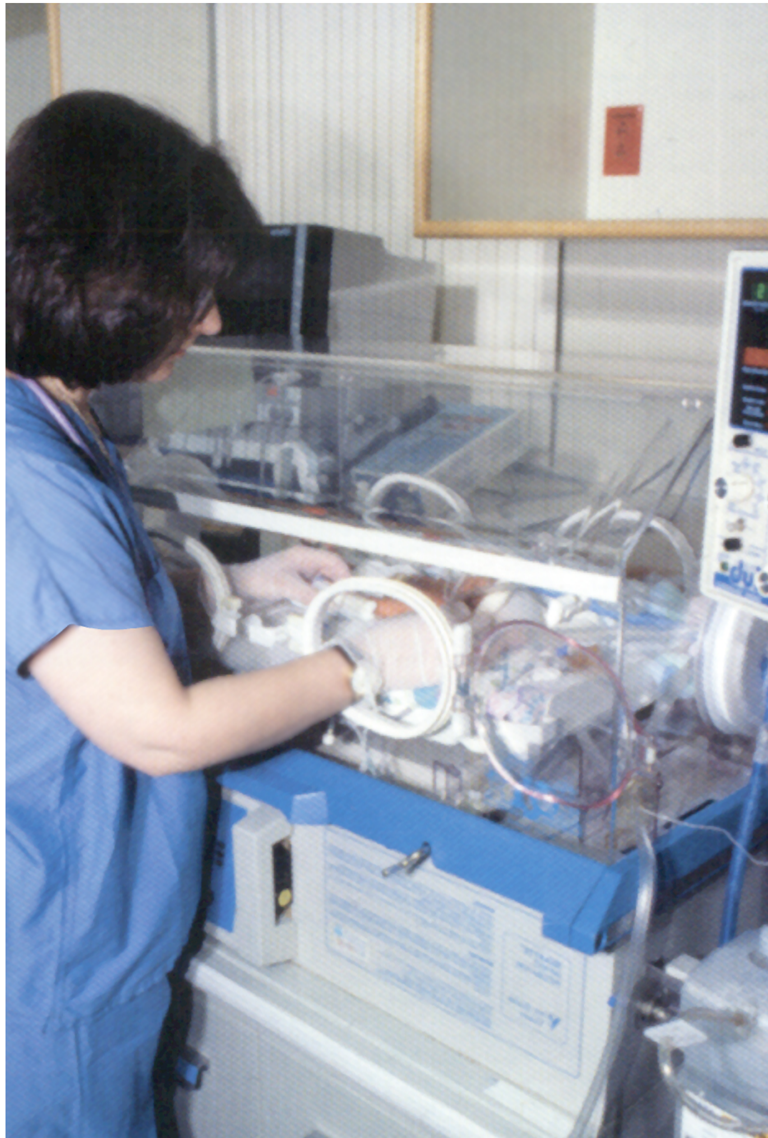
March/April 2003

PEDIATRIC NURSING

Evaluation of a New, Wearable, Precision Phase-Change Thermometer in Neonates



The primary purpose of this research was to examine the quantitative relationship between a new, wearable, continuous-read, precision phase-change thermometer (WCPPT) and a glass-mercury thermometer used in the axilla (GMA) in neonates. The study design was prospective and quasi-experimental with each subject acting as his/her own control. Data were collected in a tertiary teaching facility in the Southwestern United States from a convenience sample of 29 neonates. Simultaneous test and reference temperature measurements were taken from each neonate. Measurements were compared to determine clinical bias (mean difference +/-1 standard deviation [SD]) and clinical agreement portrayed graphically (mean difference and limits of agreement plotted against the mean of both test and reference measurements) (Bland & Altman, 1986). Key findings included a clinical bias between the GMA and the TraxItTM WCPPT of 0.04° C (+/-0.22) (mean difference +/-SD) during the first measurement session with the GMA slightly higher, and -0.11°C (+/- 0.17) (mean difference +/- SD) during the second measurement with the WCPPT slightly higher. Bland and Altman representations supported these findings. These outcomes support a conclusion that the TraxIt WCPPT is neither clinically nor statistically different from the GMA on initial placement and exceeds GMA readings during prolonged, continuous axillary contact. Continuous thermometer placement eliminates drawdown, the transitory, local cooling effect of intermittent thermometer placement.

Naja E. McKenzie, PhD(c), MN, RN, is Clinical Research Consultant, McKenzie & Associates LLC, Tucson, AZ, and a PhD candidate at the University of Arizona College of Nursing. Acknowledgments: The author would like thank Robin E. Rogers, MSN, RN, CPNP, who helped collect data for this study. Robin, along with colleagues Cheryl McGaffic, PhD, RN, CCRN, and Barbara Monroe, MS, CCRN, were murdered by a disgruntled student at the University of Arizona College of Nursing on October 28, 2002. The author would also like to acknowledge Eileen Jones, PhD, RN, and the nurses of the College of Nursing who helped facilitate this study.

Note: Sponsored by an unrestricted research grant from Medical Indicators, Inc.

Accurate body temperature measurement is an essential part of caring for patients of all ages. In neonates, the conventional methods of taking temperature in the mouth are not acceptable because this population cannot safely hold a thermometer, whether mercury-in-glass or electronic, in the sublingual cavity. Due to its invasiveness and potential risk (Bailey & Rose, 2001; Fleming, Hakansson, & Svenningsen, 1983), rectal temperature measurement is also becoming unacceptable to parents (Kai, 1993) and caregivers. In practice, nurses use both conventional thermometers and personal continuous-read precision phase-change thermometers (CPPT) between the skin and the mattress in neonates (Blackburn et al., 2001; Kunnel, O'Brien, Munro, & Medoff-Cooper, 1988), Infrared ear thermometers were an exciting alternative when introduced in the late 1980s. However, time, experience, and clinical research have shown that they are difficult to use correctly, especially in children (Androkites, Werger, & Young, 1998; Erickson & Woo, 1994; Sganga, Wallace, Kiehl, Irving, & Witter, 2000; Weiss, Poeltler,
& Gocka, 1994).

Currently the American Academy of Pediatrics (AAP) (1995), the American College of Obstetricians and Gynecologists (ACOG) (AAP & ACOG, 1997) and the National Association of Neonatal Nurses (NANN) (1997) recommend axillary temperature measurement as the standard of care for neonates. However, the time and cost involved with taking a conventional temperature with a glass thermometer is burdensome in the current health care environment. For example, a per diem nurse paid $30 per hour taking an axillary temperature with a dwell time of 11 minutes would impose a cost of $5.50 per temperature taken without accounting for the cost of the glass-mercury thermometer. Predictive thermometers, when placed into or upon a body site, produce a predicted thermal endpoint based on the initial temperature rise entered into a proprietary algorithm. As a result, a temperature reading is presented in 4 to 45 minutes depending on the age of the technology employed in the thermometer. Contact equilibrium thermometers, on the other hand, produce a temperature by remaining in contact with a body site until the thermometer has attained the temperature of the tissue in which it has been placed. The literature on required dwell time for axillary temperature equilibration has long been equivocal with recommendations ranging from 3 to 11 minutes or more (Bailey & Rose, 2001). The evidence supporting the use of predictive thermometers in the axilla has been similarly inconclusive. Some authors find predictive unacceptable in the axilla (Ogren, 1990), while others find it an acceptable substitute for a contact equilibrium temperature (Fallis & Christiani, 1999; Weiss & Richards, 1994). For the purpose of clinical testing, the American Society for Testing and Materials (ASTM) recommends against the use of predictive thermometers as reference devices (ASTM, 2001a). As a result, neonatal clinicians are still searching for a viable, low-cost alternative to both conventional glass, electronic, and infrared thermometers; preferably one that minimizes disturbance of and poses no risk to neonates. The TraxItTM (WCPPT) and NexTempTM (CPPT) are possible candidates.

Purpose

The purpose of this research was to determine the approximate, average quantitative difference in degrees or fractions of degrees Celsius between WCPPT, the TraxIt (Medical Indicators Inc., Pennington, NJ) and the current axillary temperature standard of care in neonates. The magnitude of this relationship is sought in order to decide whether the new device can reasonably be substituted for the old device in clinical practice. The research consisted of simultaneous comparisons between readings of axillary mercury-in-glass thermometers (GMA), contra lateral axillary TraxIt (AxTraxIt), and skin-to-mattress NexTemp (SkNexTemp) in newborns. The main hypotheses of the research were that the mean differences between reference (axillary) and test devices (TraxIt, NexTemp) would be (a) statistically non-significant (a=0.05), (b) low enough to have little or no impact on clinical judgment (<0.15°C) (Bailey & Rose, 2001; Yetman, Coody, West, Montgomery, & Brown, 1993), and (c) with limits of agreement under +/- 1°C so clinicians could rely on minimal variances. The main variable of interest was the difference between reference axillary and TraxIt temperature. Other variables of interest included the difference between axillary and skin-to-mattress temperature and the difference between TraxIt and NexTemp skin-to-mattress temperature.

Specific Aims and Outcome Measures

The specific aim of this research was to determine the approximate, average quantitative difference in degrees or fractions of degrees Celsius between the TraxIt and the axillary standard of care. This relationship is expressed in terms of agreement using axillary temperature measured by glass-mercury thermometer as reference standard in a sample of neonates measured on more than one occasion. Secondarily, the same quantitative relationship between the TraxIt and the NexTemp was studied in order to separate the site effect (glass-mercury axillary vs. TraxIt axillary) from the device effect (TraxIt CPPT vs. NexTemp CPPT). The outcome measures selected to describe agreement were: (a) clinical bias -the mean difference between the reference standard (an axillary glass-mercury thermometer) and the test devices (TraxIt, NexTemp) in the selected sample, and uncertainty- expressed here as one standard deviation calculated from the mean of differences (ASTM, 2001a; International Organization for Standardization, 1993); and (b) limits of agreement– a graphic representation of the dispersion of the differences between test and reference measurements graphed against the average of the test and reference measurement from each measurement pair (Bland & Altman, 1986, 1995). This type of analysis is intended to help clinicians evaluate whether a new method can be used interchangeably with an existing method of measuring a physical parameter (Bland & Altman, 1986). A secondary aim of the study was to determine the relationship of skin-to-mattress temperature measured with a NexTemp CPPT to temperature measured in the axilla using the same outcome measures. Using the mean difference (or clinical bias) as the variable of interest has become the accepted practice when testing new thermometers against their reference standard (ASTM, 2001a; Bailey & Rose, 2001; Fallis & Christiani, 1999). Furthermore, the work of Bland and Altman (1986, 1995) has provided sound statistical rationale for using a form of graphic analysis for comparing a new method of measurement with a standard method.

Clinical significance in neonatal thermometry has not been established through research, but authors have suggested mean differences of 0.06°C (Weiss & Richards, 1994), 0.16°C (Fallis & Christiani, 1999), and 0.2°C (Yetman et al., 1993) as being clinically non-significant. The criterion for clinical non-significance for this study was defined as a mean difference of 0.15°C.

Research Methods and Procedure

The study design was quasi-experimental with each subject acting as their own control. Study neonates with a postnatal age of >4 hours and <30 days and a gestational age of greater than or equal to 27 weeks were recruited from the neonatal intensive care unit (NICU) and nursery in a 300-bed Southwestern teaching hospital. Exclusion criteria included isolation, neonatal distress, and any circumstance considered relevant by the caregiver. Unit nurses recommended study participants, and both male and female subjects were sought. The convenience sample was based on available census and not randomly selected.

The Institutional Review Board (IRB) of the study site reviewed the protocol to insure full protection of the rights of human subjects. The parents of each prospective study participant received a short flier explaining the devices and procedure to be used. Informed parental consent was obtained for all subjects, and at least one parent was present during the data collection. Data were treated confidentially and were identified by subject number only. Parents received a small sample pack of the test devices in appreciation of their participation and no other compensation.

Three different nurses collected data for this study. Before beginning data collection, all data collectors were thoroughly trained in the placement and interpretation of both the reference standard (axillary glass-mercury [GMA]) and test measurements (TraxIt, NexTemp). After training, each data collector demonstrated proficiency. The study coordinator monitored data collection through interim observation of data collectors during the course of the study.

Each study subject was assessed on two occasions at least one hour apart. On each of the two occasions, three measurements were obtained (TraxIt, NexTemp, and GMA) for a total of six measurements per neonate. Data collectors obtained 174 measurements in all. The initial session consisted of the placement and equilibration of the wearable thermometer, axillary mercury-in-glass temperature measurement, and skin-to-mattress measurement. Data collectors then recorded all three readings along with pertinent demographic data. The subsequent session consisted of repetition of the axillary and skin-to-mattress measurements and reading the phase change thermometer by gently abducting the arm of the neonate.

Reference Devices

Reference temperatures were obtained with glass-mercury thermometers (TemCon, Florida Medical, Riviera Beach, FL), some of which were calibrated to a reference thermometer that is traceable to the National Institute of Standards and Technology (NIST). In the case of glass-mercury thermometers, calibration refers only to the definition of error in each individual device. Unlike some electronic thermometers, adjustment of the thermometer's performance is impossible. The error is determined by placing the thermometer(s) into a stirred water bath controlled by a NIST -traceable reference thermometer. By comparing the reading on the thermometer with the setting of the water bath thermometer, one can determine the error at various points in the temperature scale. For the purpose of clinical studies, thermometers are tested at physiologically high (e.g., 41°C) and physiologically low (e.g., 35.5°C) temperatures. The average error is then approximated, as it may not be the same at each temperature point tested, and each reading of a given device is adjusted for that error.

As is noted in the study limitations, approximately half of the temperatures in this study were taken with glass-mercury thermometers that later broke, though not during data collection. The replacements were not calibrated due to lack of time. The original, as well as the thermometers obtained as replacements (Tem-Con, Florida Medical, Riviera Beach, FL), are certified to conform to the ASTM E667 specification. This specification requires thermometers to be accurate within a maximum error of +/- 0.3°C at <35.8°C and >41°C; +/- 0.2°C at 35.8 to <37°C and >39 to 41°C; and +/- 0.1°C at 37 to 39°C (ASTM, 2001b).

Test Devices

TraxIt (Medical Indicators, Inc., Pennington, NJ) is a WCPPT for use in children's underarms. The manufacturer recommends that it can be left in place for up to 48 hours. It is an adhesive-backed thermometer consisting of a dot matrix of heat-responsive indentations. The adhesive used (Hy-Tape, Patterson, NJ) is zinc oxide-based, protective in nature, and intended for extended wear use, especially in newborns and children (Hy-Tape, 2001). Zinc oxide is a natural moisture barrier and helps to reduce transepidermal water loss (TEWL) (Mendenhall & Eichenfield, 2000) in the area under the thermometer. The device is applied to the neonate's underarm area and read after a minimum of two minutes. It is available in either Fahrenheit or Celsius resolution. After initial equilibration, the child's body temperature can be read by merely lifting the arm and inspecting the TraxIt temperature matrix. The reduced need for disturbing the infant may provide sufficient justification for using a very mild adhesive. The use of an adhesive device was approved by the IRB of the institution.

NexTemp (Medical Indicators, Inc., Pennington, NJ) is a similar, but non-adhesive strip device for intermittent use and available in disposable and personal reusable versions. Dot matrix thermometers with different properties but similar patterns of use have been tested in children aged O to 45 months (Erickson, Meyer, & Woo, 1996) and found to overestimate axillary temperature in some children. However, the devices tested in that study included a designed offset or intentional adjustment built into the device in the manufacturing process in order to improve its accuracy at certain temperature levels. The precise nature of this offset and how it is applied is proprietary to the manufacturer. Neither the TraxIt nor the NexTemp have a designed offset. These CPPTs, if found to be inter-changeable with glass thermometers for accuracy, could simplify temperature taking in the neonatal population and, in institutions where glass-mercury thermometers are still used, help remove a significant source of mercury from the acute care waste stream.

Results

A total of 29 neonates participated in the study, 21 females and 8 males. Of these, 6 were in the NICU, 2 in isolettes, and 4 in open cribs. The main diagnosis of all the NICU neonates was prematurity. Twenty-three neonates were in the newborn nursery in open cribs. All but one of the nursery samples had an admitting diagnosis of average gestational age (AGA). The average weight of the sample was 2994 (+/- 597) grams (range 1,644 to 3,941 grams).

Differences between readings were calculated and summarized as clinical biases mean differences with uncertainty as +/- standard deviation [SD]) between the 3 sets of comparisons (GMA - AxTraxIt, GMA - SkNexTemp, and AxTraxIt - SkNexTemp). In all instances, a positive mean difference means that the device listed first in the calculation was higher,

while a negative mean difference means that the device listed first was lower. Mean temperatures from both sessions are reported in Table 1. Axillary temperatures measured by the continuous reading TraxIt were significantly (p <= 0.000) higher during session 2 when compared with session 1. Temperatures measured by axillary glass and skin NexTemp thermometers did not differ significantly between session 1 and session 2.

Table 1. Mean Temperatures (+ SD) for All Neonates (o C)

Site & Device	Session 1	Session 2	Significance by *t*-test (α = 0.05)
GMA	36.81(0.34)	36.88(0.26)	Non-significant
AxTraxIt™	36.77(0.40)	36.99(0.26)	< = 0.00041
SkNexTemp™	36.62(0.38)	36.67(0.34)	Non-significant

Table 2. Clinical Bias (mean difference +1 SD) between Methods (o C)

Methods	Session 1	*p*	Session 2	Significance by *t*-test
GMA – Ax TraxIt	0.04 (0.22)	NS	-0.11 (0.17)	< 0.002
GMA – SkNexTemp	0.19 (0.31)	< 0.003	0.21 (0.29)	< 0.000
AxTraxIt – SkNexTemp	0.15 (0.35)	< 0.026	0.33 (0.31)	< 0.000

The clinical biases (mean differences with uncertainty as +/- SD) between the three methods are reported in Table 2. The clinical bias between the GMA and the TraxIt WCPPT was 0.04 (+/- 0.22)°C (NS) during the first measurement session and -0.11 (+/- 0.17)°C (p <0.002) during the second. Neither result was clinically significant according to the conservative criterion (<0.15°C) set for the study. The NexTemp CCPT on the skin was consistently lower than the GMA during the first (0.19 [+/- 0.31]°C) and second (0.21 [+/- 0.29]°C) session. The clinical biases for the NexTemp were both statistically and clinically significant by the criterion set for this study. Other studies (Yetman et al., 1993) have used a higher clinical significance criterion. The significant (p < = 0.000) mean temperature difference between the axilla (both glass and CPPT TraxIt) and the skin is expected (Kunnel et al., 1988) and remains stable from one session to the next. Further evaluation of the agreement between methods was performed using Bland-Altman graphic analysis.

Graphic Analysis

Bland and Altman (1986) point out that it is very unlikely that two methods of measuring the same biological parameter will agree in all individuals. They submit that what is important to know is how much a new method differs from an old method and if such a difference is substantial enough to present problems in clinical interpretation. They further suggest that two different methods of measuring the same thing should be evaluated by comparing the individual differences between the two in the context of the average of their readings within the limits of agreement (mean difference +/- 2 SD). This is done by plotting the individual differences (y-axis) against the average of the individual temperatures (x-axis) (Bland & Altman, 1995). Using such an analysis will provide information about the relationship throughout the range of possible measurements. If differences occurring within the limits of agreement are not considered clinically important, the two methods could be considered interchangeable (Bland & Altman, 1986). Clinical importance in Bland-Altman analysis is suggested as the number of difference points that fall within the upper and lower limits of agreement, if those limits of agreement would not lead to a difference in clinical decision-making. Figures 1 through 6 show the level of agreement between the three methods from both measurement sessions as defined by Bland and Altman.

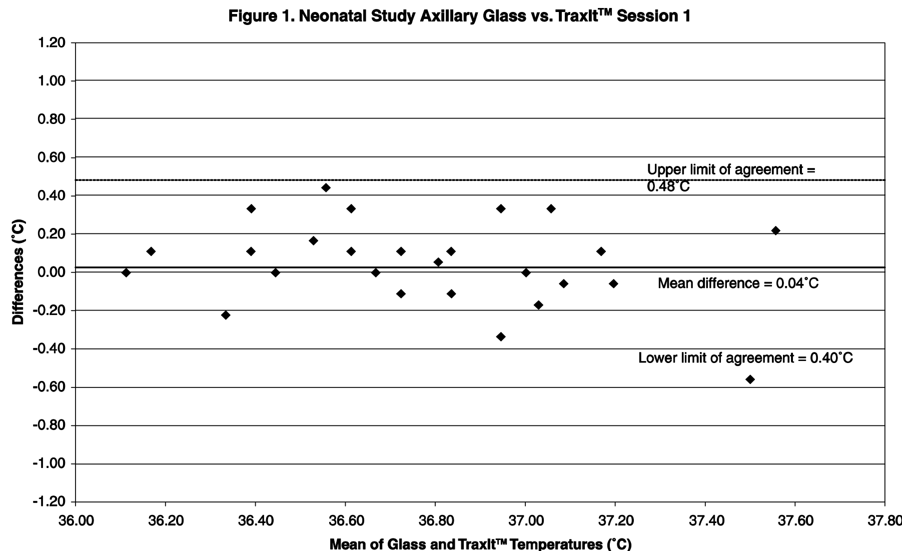
Bland-Altman Plots

GMA versus AxTraxIt. Session 1 GMA versus AxTraxIt clinical bias (mean difference) (see Figure 1) was very small at 0.04°C and the limits of agreement were within +/- 0.5°C. This level of agreement is expected since the same site was used for both the reference and test device and both were placed in contralateral axillae at the same time. The clinical bias and readings within the limits of agreement are well within clinical acceptability because a clinical decision is unlikely to be altered by readings falling within these limits of agreement. Session 2 GMA versus AxTraxIt clinical bias (mean difference) (see Figure 2) is also quite small at -0.11°C with even smaller limits of agreement. However, in session 2, the AxTraxIt readings were higher than the GMA readings. The same site was used again, but this time, the AxTraxIt had been in place for at least one hour, while the GMA had been placed again.

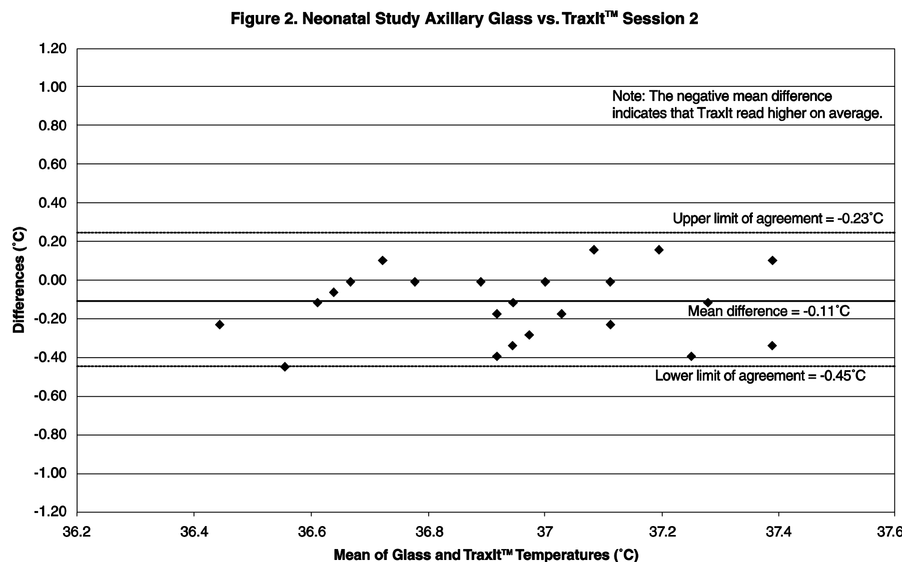
GMA versus SkNexTemp. GMA versus SkNexTemp (see Figures 3 and 4) showed clinical bias of -0.2°C with the axillary measurement being higher and limits of agreement of about +/- 0.6°C. The relationship between the two sets of measurements was consistent from session to session, clustering was similar and central, and there were few outliers. The stability of the relationship suggests the SkNexTemp method could be used with the knowledge that readings would be about 0.2°C lower than GMA readings.

AxTraxIt versus SkNexTemp. AxTraxIt versus SkNexTemp (see Figures 5 and 6) described a clinical bias of -0.15°C in session 1 and 0.33°C in session 2. The limits of agreement were smaller in session 2 than in session 1. AxTraxIt remained in place between sessions and produced higher readings in session 2. The lack of stability of the relationship is due to the higher TraxIt temperatures after equilibration.

Independent variables were also examined. Neither weight nor age had a significant effect on the differences between methods. Insufficient data were collected in artificially warmed environments (only two study participants in isolettes) to study their effect on temperature measurement with the devices used here.



Notes: The mean difference is the average of differences between the two methods graphed. Limits of agreement are the mean difference ± 2 standard deviations (SD).



Notes: The mean difference is the average of differences between the two methods graphed. Limits of agreement are the mean difference ± 2 standard deviations (*SD*).

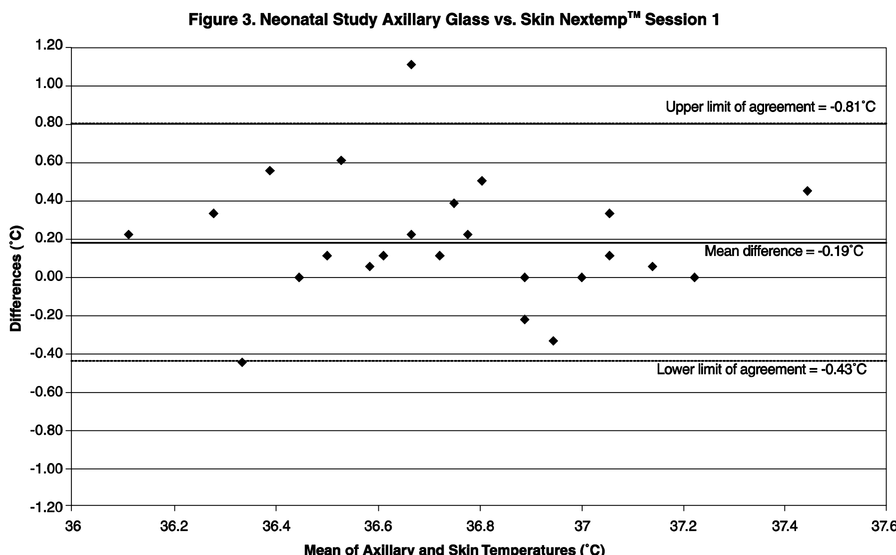
Discussion

The above analysis supports a finding that the axillary glass-mercury (GMA) and axillary TraxIt can be used interchangeably given the very small clinical bias and limits of agreement. Not only was the clinical bias statistically nonsignificant, it also fell well within the defined criterion of clinical nonsignificance. When compared to other studies that compare axillary thermometers, the clinical bias was very low. Weiss and Richards (1994) compared monitor and predictive modes of a single

electronic thermometer in contralateral axillae of neonates and found an overall mean difference of 0.06°C (+/- 0.17) 0.1°F (+/- 0.3). The current findings are similar although different devices were used. Fallis and Christiani (1999) also studied predictive and monitor mode axillary readings using a single thermometer in neonates. The mean difference between methods was a statistically significant but clinically non-significant 0.08°C. No standard deviation was reported. Given these findings, the TraxIt performed exceedingly well although it was compared to a different device.

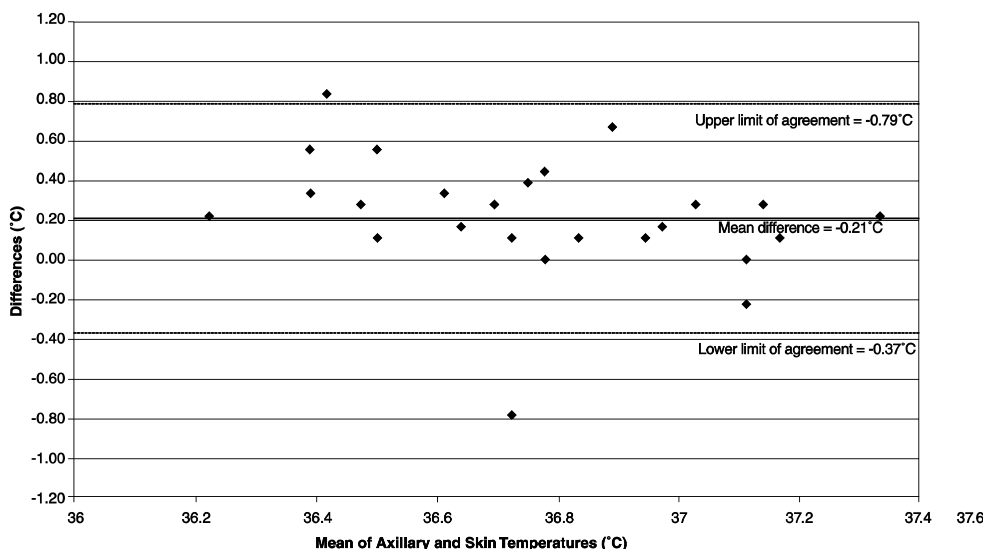
There is some evidence to suggest that the measurement obtained with the TraxIt, after it has been in place for at least one hour, may be more reflective of true body temperature. To explain the increased difference between GMA and TraxIt after more than an hour of equilibration, one can refer to the phenomenon known in the thermometry literature as drawdown. Drawdown is the conductive heat loss effect that occurs when two objects come into contact and heat passes from the warmer to the cooler object (Beck & Campbell, 1975; Giuliano et al., 2000; Thomas, 1994). The awareness of drawdown is a reason for warming equipment prior to contact with infants. In the short term, drawdown affects the accuracy of temperature readings when the thermometer used is cooler than the body site it is measuring by drawing heat from the tissue with which it is in contact. Drawdown recovery time with tympanic thermometer use has been described by Fritz and colleagues (1996). Their findings indicated that repeat same ear measurements were significantly and progressively lower unless at least two minutes were allowed to elapse between readings. After an hour (or perhaps less), the skin at the TraxIt site is no longer subject to drawdown, while the axillary glass-mercury thermometer causes local cooling of the skin each time the device is placed in contact with the skin. Further, given the small gradient between shell and core body temperature in neonates (Keeling, 1992), there could be reason to speculate that the well stabilized and protected TraxIt in the neonatal underarm area might be more reflective of core temperature than the axilla measured with intermittently placed glass-mercury thermometer. This effect should be studied specifically and in a larger sample.

The findings also suggest that the use of the NexTemp thermometer between the neonate's skin and the mattress is similar to using an axillary glass thermometer if the reading is adjusted upward by 0.2°C. The consistent relationship, close and central clustering, relatively small limits of agreement, and presence of few outliers or exceptions support this finding. Axillary TraxIt and skin NexTemp, however, are not interchangeable because of the lack of stability of the relationship between the two devices. This relationship is most likely due to the difference in measurement sites and the influence of drawdown on the measurement site upon placement. No drawdown effect exists with the TraxIt once it has equilibrated to the body's temperature.



Notes: The mean difference is the average of differences between the two methods graphed. Limits of agreement are the mean difference ± 2 standard deviations (*SD*).

Figure 4. Neonatal Study Axillary Glass vs. Skin Nextemp™ Session 2



Notes: The mean difference is the average of differences between the two methods graphed. Limits of agreement are the mean difference ± 2 standard deviations (*SD*).

Limitations of the Study

Glass thermometers. The original protocol for this study called for the use of glass-mercury thermometers that had been calibrated to a reference thermometer traceable to the National Institute of Standards and Technology (NIST). Calibrated glass thermometers were on hand and distributed to the data collectors. However, for unexplained reasons, most of them broke while in the possession of data collectors, although not during data collection. Among this original batch of thermometers, the average error was +/- 0.17°C (range 0 to + 0.30 C) at the time of calibration. New thermometers were obtained, but there was not sufficient time to calibrate them. Therefore, since the readings of all the glass-mercury readings could not be adjusted, the data reflect the normal slight variation of mass production thermometers.

Small sample size. The original protocol called for a sample that included 30 neonates in each of three environments: open cribs, incubators (isolettes), and radiant warmers. Due to NICU access difficulties, insufficient data were obtained from neonates in artificially warmed environments to analyze them separately. Weiss and Richards (1994) examined term and preterm neonatal axillary temperature in controlled and open environments and found differences in temperatures. If a difference due to environments does exist, it could not be concluded from the data obtained.

Implications for Nursing

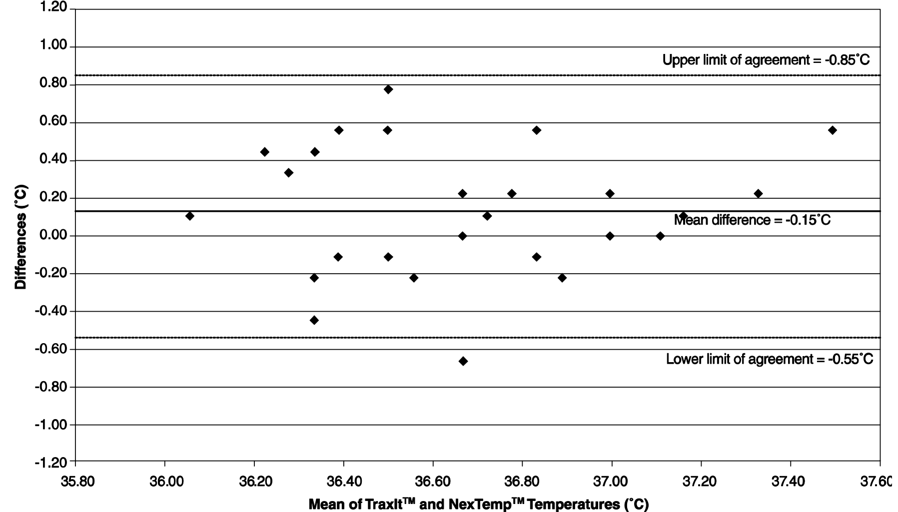
This study sought to evaluate the performance of two precision phase change thermometers when compared with glass-mercury thermometers used in the axillae of neonates. Using analysis recommended by Bland and Altman (1986), the data support a conclusion that the TraxIt WCPPT worn in the axilla can be used interchangeably with an axillary glass thermometer. The data also suggest that the TraxIt readings may indeed more closely reflect core body temperature by eliminating the effect of drawdown after at least 1 hour of contact.

This study found that NexTemp precision phase change thermometers used between the skin and the mattress of neonates closely trend the temperature measured by axillary glass thermometers though reading approximately 0.2°C lower, which was defined as clinically significant. This small discrepancy is more likely to be due to the difference in body temperature measurement sites than through any shortcoming of the thermometer. This finding suggests that sites other than the axilla may be suitable for use of the TraxIt wearable thermometer, since the NexTemp, though not identical, is similar in many respects. A protocol for testing the TraxIt at other neonatal skin temperature measurement body sites (abdomen, groin, and back) is under development.

The findings presented here represent an important step in a process of introducing less intrusive, less harmful devices to neonatal temperature measurement practice. The use of a wearable thermometer provides nurses with a convenient solution to the problem of measuring accurate neonatal temperature while spending a minimum of nursing time. After the initial placement and equilibration, the TraxIt requires only inspection of the device to obtain a reading. This could save considerable time for nurses without sacrificing accuracy. An even greater benefit of this type of product is the lack of neonatal disturbance associated with its use and the elimination of mercury from the waste stream.

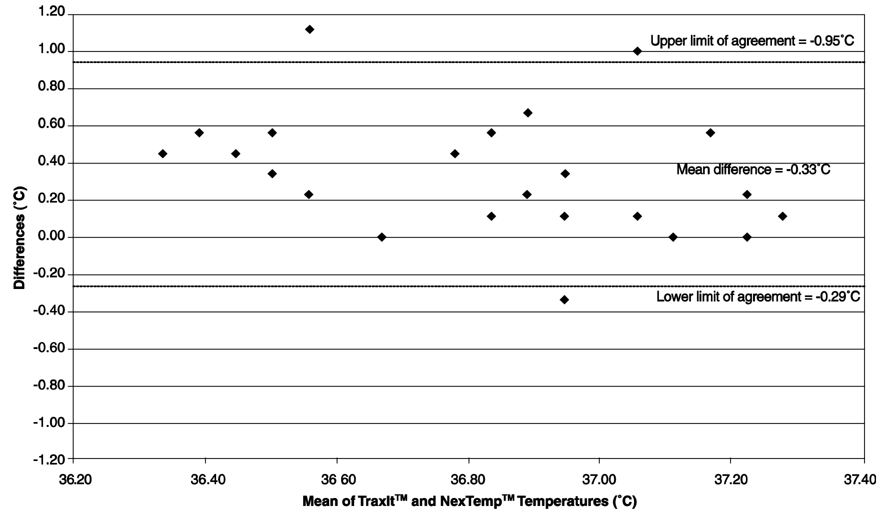
In addition to testing the TraxIt at other neonatal body sites and in controlled as well as open environments, future research should include sick as well as healthy and preterm as well as term neonates. A larger sample size from multiple sites would help lend greater generalizability to the findings. Additionally, while no negative effects were experienced in the course of this project, the effect of the zinc oxide adhesive should be more precisely studied using existing indicators of effect on skin (Mendenhall & Eichenfield, 2000). Cost comparisons in thermometry are usually based on 3 factors: (a) cost of purchase or lease of equipment, (b) cost of disposable parts of the equipment, and (c) cost of staff time required for use (Stavem,

Figure 5. Neonatal Study Axillary Traxit™ vs. Skin Nextemp™ Session 1



Notes: The mean difference is the average of differences between the two methods graphed. Limits of agreement are the mean difference ± 2 standard deviations (*SD*).

Figure 6. Neonatal Study Axillary Traxit™ vs. Skin Nextemp™ Session 2



Notes: The mean difference is the average of differences between the two methods graphed. Limits of agreement are the mean difference ± 2 standard deviations (*SD*).

Saxholm, & Erikssen, 2000). In the case of TraxIt, there is no high cost initial equipment purchase, because each device is single-patient use only. The cost of each TraxIt wearable thermometer (about $1.00) is more than the cost of one probe cover in electronic systems (about $0.08), but only one is used every 48 hours. As in most other purchases of this kind, price is dependent on volume purchased.

The cost of staff time is similar to any thermometer for the initial placement. However, subsequent readings are almost instantaneous and require only reading the dots to obtain the temperature. Single-use digital thermometers are more costly, approximately $7.00 each, and also contain electronic components that can cause pollution. More precise cost comparisons should be carried out that would yield the exact savings possible as has been done elsewhere (Stavem et al., 2000). Glass-mercury thermometers, regardless of cost, are not recommended for routine use in many facilities due to potential hazards to patients and staff. Several countries have banned the use of glass-mercury thermometers. Indeed, a U.S. Senate Bill (S351) proposes banning them to reduce mercury pollution and contamination of fish for human consumption. TraxIt and NexTemp provide a more environmentally friendly alternative. As health care responds to technological developments, it is important to evaluate changes and innovations for their usefulness as well as their convenience. Progress is not always improvement but improvement is always progress.

References:

American Academy of Pediatrics (AAP). (1995). Hospital stay for healthy term newborns (RE9539). Policy Statement. *Pediatrics, 96, 788-790.*

American Academy of Pediatrics (AAP) and American College of Obstetricians and Gynecologists (ACOG). (1997). Guideline for perinatal care (4th ed.). Washington DC: Author.

American Society for Testing and Materials (ASTM). (2001a). Standard specification for infrared thermometers for intermittent determination of patient temperature (E1965-98). Annual Book of ASTM Standards, 14.03, 601-616.

American Society for Testing and Materials. (2001b). Standard specification for mercury-in-glass, maxi- mum self-registering clinical thermometers (E667-98). Annual Book of ASTM Standards, 14.03, 355-360.

Androkites, A.L., Werger A.M., & Young, M.L. (1998). Comparison of axillary and infrared tympanic membrane thermometry in a pediatric oncology outpatient setting. Journal of Pediatric Oncology Nursing, 15(4), 216-222.

Bailey, J., & Rose, P. (2001). Axillary and tympanic membrane temperature recording in the preterm neonate: A comparative study. Journal of Advanced Nursing, 34, 465-474.

Beck, W.C., & Campbell, R. (1975). Clinical thermometry. Guthrie Bulletin, 44, 175-194.

Blackburn, S., DePaul, D., loan, L.A., Marbut, K., Taquino, L.T., Thomas, K.A., & Wilson, S.E. (2001). Neonatal thermal care, part III: The effect of infant position and temperature probe placement. Neonatal Network - Journal of Neonatal Nursing, 20(3), 25-30.

Bland, J.M., & Altman, D.G. (1986, February 8). Statistical methods for assessing agreement between two methods of clinical measurement. The Lancet, i, 307-310.

Bland, J.M., & Altman, D.G. (1995). Comparing methods of measurement: Why plotting difference against standard method is misleading. Lancet, 346, 1085-1087.

Erickson, R.S., & Woo, T.M. (1994). Accuracy of infrared ear thermometry and traditional temperature methods in young children. Heart & Lung, The Journal of Critical Care, 23(3), 181-195.

Erickson, R.S., Meyer, L.T., & Woo, T.M. (1996). Accuracy of chemical dot thermometers in critically ill adults and young children. Image, Journal of Nursing Scholarship, 28(1), 23-28.

Fallis, W.M., & Christiani, P. (1999). Neonatal axillary temperature measurements: A comparison of electronic thermometer predictive and monitor modes. JOGNN, 28, 389- 394.

Fleming, M., Hakansson, H., & Svenningsen, N.W. (1983). A disposable new electronic temperature probe for skin temperature measurements in the newborn infant nursery. International Journal of Nursing Studies, 20(2), 89-96.

Fritz, U., Rohrberg, M., lange, C., Weyland, W., Brauer, A., & Braun, U. (1996). Infrared thermometry in the auditory canal: Evaluation on the Diatek 9000 Instatemp and Diatek 9000 Thermoguide. Der Anesthesist, 45, 1059-1066.

Giuliano, K.K., Giuliano, A.J., Scott, S.S., Maclachlan, E., Pysznik, E., Elliot, S. & Woytowicz, D. (2000). Temperature measurement in critically ill adults: A comparison of tympanic and oral methods. American Journal of Critical Care, 9(4), 254-261.

Hy-Tape Clinical Update. (2001). Stabilizing endotracheal tube in the neonate. Retrieved from http://www.hytape.com

International Organization for Standardization. (1993). ISO guide to the expression of uncertainty in measurements. Geneva, Switzerland: Author.

Kai, J. (1993, October 16). Parents' perceptions of taking babies' rectal temperature. British Medical Journal, 307, 1005.

Keeling, E.B. (1992). Thermoregulation and axillary temperature measurements in neonates: A review of the literature. Maternal-Child Nursing Journal, 20(3,4), 124-140.

Kunnel, M.T., O'Brien, C., Munro, B.H., & Medoff-Cooper, B. (1988). Comparisons of rectal, femoral, axillary, and skin-to-mattress temperatures in stable neonates. Nursing Research, 37(3), 162-164, 189.

Mendenhall, A.K., & Eichenfield, L.K. (2000, August). Back to basics: Caring for the newborn's skin. Contemporary Pediatrics, 17(8). Retrieved from http://cp.pdr.net/cp/public.htm?path=content/ journals/k/data/2000/0800/keichenfield.html

National Association of Neonatal Nurses (NANN). (1997). Neonatal thermoregulation guidelines for practice. Glenview, IL: Author.

Ogren, J.M. (1990). The inaccuracy of axillary temperatures measured with an electronic thermometer. American Journal of Diseases of Children, 144(1), 109-111.

Sganga, A., Wallace, R., Kiehl, E., Irving, T.A., & Witter, L. (2000). A comparison of four methods of normal new- born temperature measurement. MCN, The American Journal of Maternal/Child Nursing, 25(2), 76-79.

Stavem, K., Saxholm, H., & Erikssen, J. (2000). Tympanic or rectal temperature measurement? A cost-minimization analysis. Scandinavian Journal of Infectious Diseases, 32(3) , 299-301.

Thomas, K. (1994). Thermoregulation in neonates. Neonatal Network, 13(2),15-22.

Weiss, M.E., Poeltler, D., & Gocka, I. (1994). Infrared tympanic thermometry for neonatal temperature assessment. JOGNN, 23(9), 798-804.

Weiss, M.E., & Richards, M.T. (1994). Accuracy of electronic axillary temperature measurement in term and preterm neonates. Neonatal Network, 13(8), 35-40.

Yetman, R.J., Coody, D.K., West, M.S., Montgomery, D., & Brown, M. (1993). Comparison of temperature measurements by an aural infrared thermometer with measurements by traditional rectal and axillary techniques ***. Journal of Pediatrics, 122, 769-773.***