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A comparison of axillary and tympanic temperature measurement in the preterm infant

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A COMPARISON OF AXILLARY AND TYMPANIC TEMPERATURE MEASUREMENT IN THE PRETERM INFANT

By

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Abstract

The transition of the newborn to extrauterine life, especially the preterm infant, necessitates adaptation to environmental changes in temperature (Levene, Tudehope & Thearle, 1987). The need for a method of measuring an infant's temperature rapidly and with minimal disturbance is critical and accurate temperature measurement in a preterm infant is a vitally important nursing procedure. However, the literature is inconclusive regarding the optimum placement time required to achieve an accurate temperature measurement and few studies had been conducted to ascertain the reliability and usefulness of tympanic thermometers in preterm infants.

The study of 81 hospitalised preterm infants, compared axillary mercury, axillary digital and tympanic thermometers to determine optimum placement times, accuracy and any difference in temperature readings in the preterm infant. A statistically significant difference between the temperatures was obtained using the three thermometers (F (2, 79) = 5.25, $p < .01$). However, the mean temperature differences between the thermometers was not greater than 0.13°C and therefore, the small mean differences obtained, were not considered clinically significant for use in normal neonatal care.

Furthermore, correlations between the three thermometers were high: $r = .84$, $r = .75$ and $r = .78$. The results demonstrated that 5.5 minutes are required to accurately measure a preterm infant's temperature using a mercury thermometer, 1.75 minutes are needed for the digital thermometer at the 'beep' time and less than 2 seconds for the tympanic thermometer. Results also showed that variables such as birthweight, age, gestation, nursery temperature, sex and the number of wraps covering the infant, did not affect the time taken for the temperatures to stabilise. This study has established the minimum time required to obtain an accurate axillary temperature in a preterm infant and has further clarified both the accuracy and usefulness of tympanic thermometry in this high risk population.

DECLARATION

"I certify that this thesis does not incorporate, without acknowledgement, any material previously submitted for a degree or diploma in any institution of higher education and that, to the best of my knowledge and belief, it does not contain any material previously published or written by another person except where due reference is made in the text".

Signature

Date 9th November 1993.

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Chapter I

Introduction

Background and Significance of the Study

During transition of the newborn to extrauterine life, adaptation to environmental changes in temperature is essential (Levene, Tudehope & Thearle, 1987). By maintaining the newborn, in particular the preterm infant, in a stable and appropriate environmental temperature, there has been a significant decline in neonatal morbidity and mortality. Hypothermia, or conversely hyperthermia can result in increased oxygen consumption and metabolic needs and may result in severe hypoglycaemia or death (Schreiner & Bradburn, 1988).

The need for a method of measuring an infant's temperature rapidly and with minimal disturbance is, therefore, critical. Accurate temperature measurement in a preterm infant is a vitally important nursing procedure. However, the literature is inconclusive regarding the optimal placement time required to achieve an accurate temperature measurement. Axillary thermometer placement times in both fullterm and preterm infants has varied from 2 (Haddock, Merrow & Vincent, 1988) to 11 minutes (Schiffman, 1982).

Inconsistencies in practice were also found during a brief informal survey (conducted by the present author) of metropolitan public and private hospitals. This survey revealed that of the 14 hospitals surveyed, none had a written or formal

policy on neonatal axillary thermometer placement time for either fullterm or preterm infants. The thermometer placement time varied from 2 to 5 minutes (using a mercury in glass thermometer) and several hospitals were seeking alternative methods of temperature estimation using either digital or tympanic thermometers.

This obvious lack of agreement among researchers and the continued inconsistencies in current clinical practice, indicated the need for further research in this important area of neonatal nursing. Additionally, there have been very few studies undertaken which have researched the use of either tympanic or digital thermometers for measurement of preterm infant temperature. These thermometers are non-invasive and offer both rapidity and ease of measurement.

Purpose of the Study

The purpose of this study was to compare axillary mercury, digital and tympanic thermometers, to determine the time required using each of them, to accurately measure a preterm infant's temperature. Most studies that have investigated temperature measurement in infants, have also taken into account a number of other variables which may influence the length of time required to obtain an accurate temperature. Therefore, these variables have also been included in the present study.

Research Questions

The research questions in this study were as follows:

1. How long does it take to accurately measure the axillary temperature of a preterm infant using a mercury thermometer?
2. How long does it take to accurately measure the axillary temperature of a preterm infant using a digital thermometer?
3. How long does it take to accurately measure the temperature of a preterm infant using a tympanic thermometer?
4. Is there any relationship between the time taken to measure temperature accurately using each of the three thermometers and the following variables: birthweight, age, gestation, nursery temperature, sex and the number of wraps covering the infant?
5. Are there any differences between the temperatures obtained using the three types of thermometer?

Definition of Terms

For the purpose of this study, the following definitions were determined:

Corrected gestational age.

The documented gestational age plus the number of weeks since birth.

Gestational age.

The duration of gestation as measured from the first day of the last menstrual period and as documented by the consultant neonatologist or his/her delegate (Kelnar & Harvey, 1987).

Intermediate care nursery (level two).

A nursery in which an infant no longer requires intensive care, but continues to require specialised care and observation.

Mothercrafting nursery (level one).

A nursery in which an infants' condition has stabilised sufficiently to permit preparation for his/her discharge.

Optimum placement time.

Is defined as the point at which temperature stabilisation takes place after three consecutive stable readings at 30 second intervals on at least 90% of the infants.

Preterm infant.

Any infant born before 37 completed weeks of gestation.

Wraps.

The actual blankets or any additional linen coverings placed over the infant to provide extra warmth.

Chapter II

Review of the Literature

Newborn temperature is used to assess the physiological adaptation of the infant to the immediate physical environment. Accurate and rapid temperature measurement is an extremely important aspect of neonatal nursing care, especially within the preterm population. Deviations from the normal temperature range in an infant signifies the need for further assessment and potential nursing intervention. This is supported by Schreiner and Bradburn (1988, p.42) who argued that "Maintaining the newborn, especially the premature, in the appropriate environmental temperature has become one of the most important factors in decreasing neonatal mortality and morbidity."

The following literature review examines and discusses relevant research relating to the types of instruments and anatomical sites used to measure neonatal temperature and the optimum thermometer placement times in both fullterm and premature infants.

Thermometer Types and Placement Sites in Infants

Both axillary and rectal sites have been used to measure neonatal temperature, but the increased risk of bowel perforation has resulted in the axilla being used as the preferred site. In 1969, Greenbaum, Carson, Kincannon and O'Loughlin examined two cases of pneumoperitoneum of the newborn caused by

perforation of the rectum by a rectal thermometer. Lau and Ong (1981) reviewed 15 cases of broken and retained rectal thermometers in infants and young children below five years of age. Increasing awareness of the apparent risks associated with the use of rectal thermometers in fullterm and preterm infants, has resulted in the ongoing search for alternative temperature measurement sites which offer both safety and accuracy, with minimal disturbance to the sick or premature neonate.

Axillary temperature measurements using mercury in glass thermometers are commonly used in newborn nurseries and have demonstrated a close correlation with rectal temperatures. Torrance (1968) compared rectal and axillary temperatures in 120 preterm infants and found that the differences in temperature readings obtained were not clinically significant. Schiffman (1982) also discovered a strong positive correlation between the axillary and rectal temperatures of 46 full term infants. Furthermore, Khan, Ahmad, and Fakhir (1990) studied the temperatures of 30 term and 20 preterm infants using four different sites. The investigators reported that the axillary temperature is likely to be as accurate as rectal temperature and that rectal temperatures were only about 0.48 °C and 0.24 °C higher than axillary in fullterm and preterm babies respectively.

Conversely, Eoff, Meier, and Miller (1974) examined axillary and rectal temperatures in 30 infants and found that the difference in temperature for the two methods was significant and that the rectal temperature was 0.5 °F (0.27 °C) higher than the axillary temperature. However, the researchers concluded that axillary and

rectal temperatures are closely related and such small differences in temperature would not make a great difference when assessing infant's health status.

These findings are similar to that of Haddock, Merrow, and Vincent (1986) who examined the temperatures of 31 infants using both the rectal and axillary sites with a mercury in glass thermometer. They concluded that 94% of infants had only 0.4 °F (0.2 °C) difference in these two temperatures and that the measurement of axillary temperatures was less intrusive.

Although studies measuring rectal and axillary temperatures in newborn infants have demonstrated a close relationship between readings at the two sites, there remains controversy in the use of rectal thermometers in cases of neonatal hypothermia. Several authors have highlighted the dangers of hypothermia in infants and the importance of its early detection. Schreiner and Bradburn (1988) indicated that, aside from the danger of rectal perforation, rectal temperature is less useful than skin or axillary temperatures because it actually reflects the core temperature which can remain normal even if the infant becomes hypothermic. As changes in the rectal or core temperature are revealed much later in neonates' responses to cold stress, temperature measurement via this route may, therefore, be less useful in cases of apparent hypothermia. With further research and improved knowledge, there has been a decline in the use of rectal thermometers and a search for alternative temperature measurement sites.

Apart from the use of the axilla and rectum, researchers have explored a number of different sites to measure temperature in infants. Kunnel, O'Brien, Munro, and Medoff-Cooper (1988) compared the accuracy of temperature recordings at four sites in the neonate which included femoral and skin-to-mattress readings. The investigators found that measurement of optimal temperatures across the four sites were similar. Conversely, Bliss-Holtz (1989) compared rectal, axillary and inguinal (femoral) temperatures in fullterm infants and discovered a strong correlation between maximum inguinal and rectal temperature readings (r = .91), between inguinal and axillary readings (r = .81) and found a weaker correlation between rectal and axillary readings (r = .60).

More recently, as a result of the associated risks of rectal thermometers and concerns regarding mercury hazards, there has been an increase in the use of digital thermometers in neonatal populations (Dodman,1987). There are, however, few studies reported that have used digital thermometers to measure temperature via either the rectum or axilla. Fleming, Hakansson, and Svenningsen (1983) studied and discussed the use of an electronic temperature probe with a digital display, for measuring neonatal skin and rectal temperatures in newborn infants. The digital thermometer was found to be reliable, less time consuming and more convenient for babies and nurses. The researchers also concluded that measurement of the axillary temperature is as accurate a measure of body temperature as the rectal site for both fullterm and preterm babies in a steady environment.

Several other researchers (Weiss 1991; Newbold 1991; Hunter 1991) have also compared digital thermometers with other thermometers and determined optimum placement time for axillary readings in neonatal populations.

The tympanic thermometer is a relatively new innovation in temperature monitoring. It measures temperature by infrared thermometry of the tympanic membrane when a non invasive disposable ear probe is placed in the external ear. The tympanic membrane is also known to share the same vascular supply that perfuses the hypothalamus and is thus thought to more closely approximate a core body temperature (Rogers, LeBlanc, Curley, Libman, Driscoll, McCarty & Kerrigan, 1991).

Tympanic thermometry in the neonatal population is slowly increasing and there have been a small number of studies conducted, which support the use of tympanic thermometers in both infants and young children (see Table 1). Newbold (1991) compared both tympanic and axillary temperature measurements in 25 neonatal and paediatric patients and found that axillary readings were 0.3 (0.16 °C) to 0.5 °F (0.27 °C) lower than the tympanic readings. The tympanic measurements were preferred to axillary measurements by most of the paediatric patients. Similary, a study was undertaken by Terndrup and Milewski (1991) comparing typanic and rectal temperatures in 303 paediatric patients. The correlation of rectal and tympanic temperatures ($\underline{r}$ = .70) was reported to be similar

to other studies in children. The study also reported that in clinical practice tympanic thermometers are usually reliable, easy to use and are well accepted by children, parents and nursing staff.

The usefulness of tympanic thermometers in both fullterm and preterm infants was also explored by Johnson, Bhatia, and Bell (1991) who found this portable device a promising method of measuring the body temperature of newborn infants. It proved to be non-invasive, atraumatic, rapid and involved minimal disturbance to the infant. Accuracy was found to be dependent on the mode used and there was no difference in the temperatures obtained using either the ear facing uppermost or the ear that the infant was lying on. Therefore, in the present study, only the ear that was facing uppermost was used for tympanic thermometer measurement.

Weiss (1991) studied tympanic infrared thermometry in 22 fullterm and 12 preterm neonates and concluded that tympanic temperature is as accurate an estimation of body temperature in the neonate as axillary temperature. Furthermore, additional research was recommended by the investigator to confirm the results with a larger sample size.

In a study by Khan et al. (1991) temperatures at four different sites, including tympanic, axillary, rectal and between skin and mattress, were compared in fullterm and preterm neonates. Results showed that there was a significant difference in tympanic and rectal temperatures only and that the temperatures were

significantly higher in the term infants.

The correct technique in tympanic temperature measurement and an understanding of the anatomical differences in the ear canals of infants and adults is fundamental in obtaining accurate temperature readings. Pransky (1991) in a study which involved 100 paediatric patients, found that the technique of measurement in infants is different to that of adults and older children. This was thought to be due to the possible variation in the anatomy of the external auditory canal. The researchers concluded that tympanic thermometry is useful, safe and accurate, but requires the application of the correct technique for reliable readings in infants. Weiss (1991) also emphasised the importance of probe placement and highlighted several other factors which could affect the accuracy of tympanic thermometry. These factors included variations in technique and whether the data collector was either right or left handed.

Optimum Thermometer Placement Times in FullTerm and Premature Infants

A number of studies have been undertaken to attempt to determine the length of time required to accurately measure an infant's axillary temperature. There remains, however, controversy regarding the length of time required to accurately measure an infant's axillary temperature using a mercury in glass or digital thermometer. The findings of a number of studies (see Table 2) demonstrate this inconsistency, with the recommended length of time for axillary thermometer

placement varying from 2 to 11 minutes in both term and preterm infants (Bliss-Holtz, 1989; Eoff et al., 1974; Fleming et al., 1983; Haddock et al., 1986; Haddock, Merrow & Vincent, 1988; Hunter, 1991; Johnson & Shorten, 1991; Khan et al., 1990; Kunnel et al., 1988; Mayfield, Bhatia, Nakamura, Rios & Bell, 1984; Moen, Chapman, Sheehan & Carter, 1987; Schiffman, 1982; Stephen & Sexton, 1987; Torrance, 1968).

This variation in temperature measurement time, could be attributed to other variables such as birthweight, age, gestation, nursery temperature, sex and the number of wraps covering the infant. Some of these variables have been investigated in previous studies, but only one study (Hunter, 1991) has systematically reviewed all of these variables, as was accomplished in the present study.

A number of studies were examined that addressed optimum axillary placement time in both fullterm and preterm infants. Hunter (1991) studied axillary temperature measurements in 40 healthy fullterm infants using both mercury in glass and digital thermometers. Stabilisation occurred within 3 minutes for 100% of the sample using both thermometer types and it was concluded that 3 minutes is a clinically appropriate length of time to measure healthy newborn temperature. This result was similar to that of Haddock et al. (1988) who compared the axillary and rectal temperatures of 30 preterm infants and found that 90% of subjects reached their optimum axillary temperature within 3 minutes. The finding of this

study was also comparable to that of Moen et al. (1987) who studied the axillary and rectal temperatures of 25 preterm infants at 3, 5, 8 and 10 minutes using mercury thermometers. Results indicated that 3 minutes was a clinically adequate time to measure a preterm infant's axillary temperature.

A number of other studies have reported longer placement times in both fullterm and preterm infants. Torrance (1968) found that 95% of all axillary temperatures in preterm infants (n = 120) stabilised within 4 minutes. Stabilisation was referred to as the point at which the mercury in the glass thermometer failed to rise.

In their earlier study of 31 healthy fullterm infants, Haddock et al. (1986) discovered that 90% of the infants reached the optimal axillary temperature (0.2 °F or 0.11 °C less than the maximum reading) within 5 minutes. These findings supported the conclusion that mercury thermometers placed in the axillae of preterm infants stabilise more quickly than in fullterm infants. Bliss-Holtz (1989) and Mayfield et al. (1984) investigated temperature readings at different sites in both fullterm and preterm infants. Bliss-Holtz (1989) compared rectal, axillary and inguinal (femoral) temperatures in a sample of 120 full term infants. Results established that at least 90% of infants reached temperature stabilisation at all sites by 5.5 minutes. This finding was supported by Mayfield et al. (1984) in their study of 44 preterm and 99 fullterm infants' temperatures using four different sites. Measurement sites including rectal, core, axillary and between the skin and the

mattress recorded temperature readings that were stable within 5 minutes for 90% of the infants. Mercury in glass thermometers were used for both the rectal and axillary temperature readings. Similarly, Khan et al. (1990), in a study of fullterm and preterm infants using four measurement sites, reported that temperatures at all sites had stabilised within 5 minutes.

Considerably longer thermometer placement times were found by a small number of other researchers. A study by Johnson and Shorten (1991) of 100 full term infants, revealed that the optimum thermometer placement time for recording an accurate axillary temperature was 6 minutes. Mercury thermometers were used for all temperature readings. Kunnel et al. (1988) simultaneously measured the temperatures of 99 stable, fullterm infants utilising four sites (rectum, femoral, axilla and skin to mattress). Optimum placement times, (defined as the time when 90% of the subjects reached optimum temperature), were 11 minutes for the axillary and femoral sites and 5 minutes rectally.

Other research studies have also found that temperatures failed to stabilise over a 10 to 11 minute period. Schiffman (1982) studied 46 full term infants to investigate the difference between temperature measurement using both the rectal and axillary site. The temperatures were compared minute by minute and it was found that axillary readings did not stabilise over a 10 minute period, but there was a significant positive correlation between the axillary and rectal temperatures. Similarly, Stephen and Sexton (1987) measured the axillary

temperatures of 60 term and 40 preterm infants using merc in glass thermometers. The temperatures of all neonates failed to stabilise over an 11 minute time span and they concluded that the small increase in temperature (0.36 °F or 0.2 °C) from 3 to 11 minutes was not clinically significant.

The majority of these studies were restricted by a small sample size, whereas in the present study, a much larger sample of preterm infants were used. A comprehensive review of the literature also suggested that a number of studies (Haddock et al., 1986, 1988; Newbold, 1991; Rogers et al., 1991; Stephen & Sexton, 1987) failed to report calibration of their instruments for accuracy. An extremely thorough calibration process was used throughout the present study to ensure reliability and accuracy of the instruments and to avoid detracting from the significance of the findings.

Summary and Conclusion

Accurate temperature measurement in the preterm infant remains an extremely critical component of current neonatal nursing practice. The avoidance of hyperthermia or conversely, hypothermia and the maintenance of a neutral thermal environment for these small, fragile infants, enhances physiological adaptation to extrauterine life. A review of the prevailing literature reflects a continuing lack of consistency in the determination of an optimum thermometer placement time for either term or preterm infants. In particular, there remains a

lack of consensus concerning the length of time required to take an infant's axillary temperature and there have been fewer studies undertaken in relation to the preterm infant who is at greater risk of temperature instability.

Furthermore, the need for an instrument that measures temperature both accurately and rapidly with minimal disturbance to the sick preterm infant, has major clinical significance to neonatal nursing practice. The limited number of studies that have examined the use of tympanic thermometers in the preterm infant population indicates the need for further investigation into the accuracy and reliability of this instrument.

Therefore, further research is essential to establish and substantiate the optimum placement time for measurement of axillary temperature in preterm infants and also to investigate the efficacy and accuracy of tympanic thermometry in this high risk population. The present study will provide vital information regarding optimum thermometer placement times for preterm infants and will compare mercury, digital and tympanic thermometry.

Table 1

Tympanic Thermometry

Authors	Sample Size	Correl. Tympanic/ axilla	Site	Optim. time (mins)	Thermom. type used	Calib. used
Johnson et al. (1991)	7 term 24 prem	Not Applic	Axilla Rectal Tympanic	No concl reached	Mercury Tympanic	Yes
Khan et al. (1990)	30 term 20 prem	Not Applic	Axilla Rectal Tympanic Skin/matt	5.0	Mercury Tympanic	Yes
Newbold (1991)	25 (30 days- 16 years)	Not Applic	Axilla Tympanic	No concl reached	Digital Tympanic	No
Pransky (1991)	100 (7 months -3 years)	Not Applic	Oral/ Tympanic	Not Applic	Digital Tympanic	Not Reported
Rogers et al. (1991)	108 (30 days- 16 years)	$r = .41$ $p = .0001$	Axilla Tympanic Oral Rectal	No concl reached	Digital Tympanic	No
Terndrup & Milewski (1991)	303 (0-16 years, M = 1.6)	Not Applic	Rectal Tympanic	Not Applic	Mercury Tympanic	Yes
Weiss (1991)	22 term 12 prem	$r1 = .61$ $r2 = .62$	Axilla Tympanic	No concl reached	Digital Tympanic	Yes

KEY:

Applic. = Applicable, Calib. = Calibration, Concl. = Conclusion

Correl. = Correlation, Optim. = Optimum, Prem. = Preterm,

Stabil. = Stabilised, Temp. = Temperature, Thermom. = Thermometer.

Table 2

Digital and Mercury Thermometry

Authors	Sample size	Temp stabil. %	Site	Optim time (mins)	Thermom type used	Calib used
Bliss-Holtz (1989)	120 term	95	Axilla Rectal Inguinal	5.5	Mercury	Yes
Fleming et al. (1983)	18 term/ prem	Not Applic	Axilla Rectal	0.20 2.5-3.0	Digital Mercury	Yes
Haddock et al. (1986)	31 term	90 87	Axilla Rectal	5.0 4.0	Mercury	No
Haddock et al. (1988)	30 prem	90 93	Axilla Rectal	3.0 3.0	Mercury	No
Hunter (1991)	40 term	100	Axilla	3.0	Mercury Digital	Yes
Johnson et al. (1991)	100 term	90	Axilla	6.0	Mercury	Yes
Kunnel et al . (1988)	99 term	90	Axilla Rectal Femoral Skin/matt	11.0	Mercury	Yes
Mayfield et al. (1984)	99 term 44 prem	90	Axilla Rectal Skin/matt Core	5.0	Mercury Digital	Yes
Schiffman (1982)	46 term	Not Applic	Axilla Rectal	No concl reached	Mercury	Yes
Stephen & Sexton (1987)	60 term 40 prem	Not Applic	Axilla	No concl reached	Mercury	No
Torrance (1968)	120 prem	95 90	Axilla Rectal	4.0 3.0	Mercury	Yes

Chapter III

Conceptual Framework

The conceptual framework guiding this study was based on Roy's (1980) Adaptation Model, which considers the infant as an adaptive system in relation to the maintenance of a neutral thermal environment. Roy (cited in Marriner, 1986, p.302) stated that "Nursing has a unique goal to assist the person in his adaptation effort by managing the environment."

Preterm infants function optimally within an environmental temperature zone that is known as the neutral thermal environment (Schreiner & Bradburn, 1988). The maintenance of this environment results in minimal caloric expenditure and low oxygen consumption by the infant during the potentially stressful period of adaptation to extrauterine life. The neutral thermal environment is influenced by a number of factors: age, gestation, weight, room temperature or environment and the number of wraps.

Preterm infants, however, are at much greater risk for thermal instability when compared to full term infants. They have a large surface area in comparison to body weight, inability to shiver, reduced amount of subcutaneous fat and brown adipose tissue, reduced flexion and increased body water content which results in greater evaporative heat losses. The preterm infant will attempt to

maintain a normal body temperature within the neutral thermal zone by using vasomotor adjustments, such as vasoconstriction to conserve heat and vasodilation to dissipate heat. When the infant is placed in an environment outside the neutral thermal range, oxygen and metabolic needs and caloric expenditure rapidly increase. The infant aims to adapt to these thermal instabilities utilising a variety of physiological responses. As a result of their inability to shiver, heat production in infants relies on the metabolism of brown fat. This is referred to as 'non-shivering thermogenesis' and is the most important means of heat production for the neonate. Brown fat has a rich vascular supply, abundant sympathetic innervation and a great capacity to oxidise fatty acids and generate heat. Although these metabolic processes generate heat, they require both oxygen and glucose resulting in tissue hypoxia, metabolic acidosis, hypoglycaemia and pulmonary vasoconstriction. If hypothermia becomes extreme, death may ultimately occur (Schreiner & Bradburn, 1988).

As a result of an ever changing physical environment, the preterm infant must adapt positively to these changes to ensure temperature stability within the neutral thermal zone. The preterm infant is assisted where necessary to adapt to environmental temperature fluctuations by a variety of nursing interventions aimed at effecting positive adaptation in the physiological mode (see Figure 1). The only definitive means of determining hyper/hypothermia is by monitoring the preterm

infant's body temperature. The normal axillary temperature range is considered to be 36.5 to 37.0 °C and the maintenance of this temperature range constitutes positive thermal adaptation to the environment.

An essential aspect of neonatal nursing care is conservation of a normal body temperature, or thermoregulation. Meticulous attention to the prevention of thermal stress can facilitate the infant's adaptation to extrauterine life and assist in decreasing mortality and morbidity. The importance of nursing assessment and accuracy of temperature measurement is crucial if the nurse is to be effective in modifying the infant's environment so as to enhance adaptation.

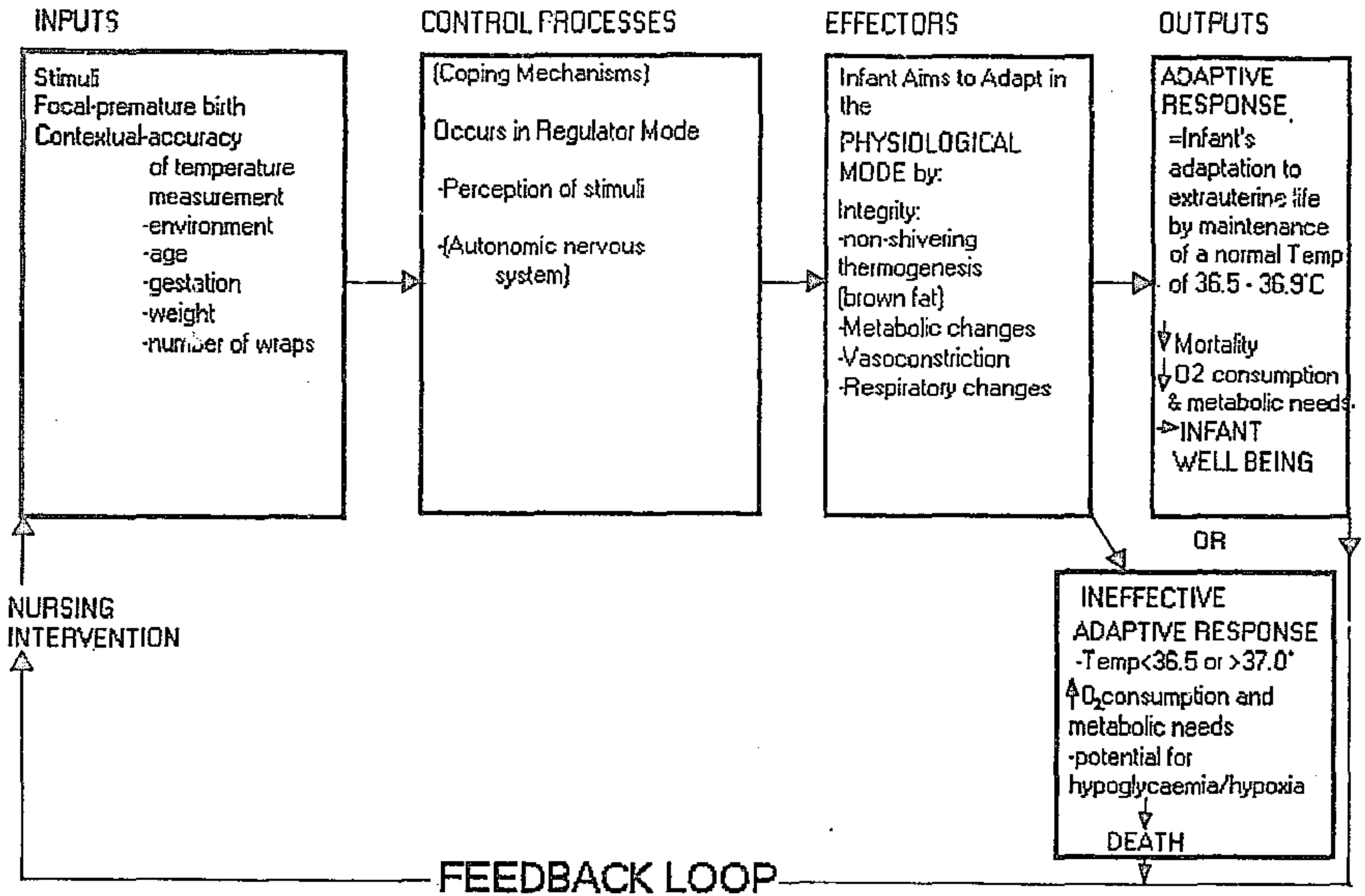

Figure 1. Application of Roy's adaptation model to assist the preterm infant to positively adapt to environmental temperature (adapted from Roy, 1980).

Chapter IV

Method

Design

This was a descriptive design used to measure the temperatures of preterm infants utilising mercury, digital and tympanic thermometers. The length of time taken to register the temperatures using each thermometer, was recorded using a data collection sheet (see Appendix A). In addition, the actual temperatures obtained using each thermometer were compared to detect any differences between the three instruments.

Setting and Sample

This study was undertaken at a major public obstetric teaching hospital in Perth, Western Australia. This hospital is the primary referral centre for the state's sick premature infants. A convenience sample of 86 infants were selected from the intermediate care (level two) and the mothercrafting (level one) nurseries. To gain entry into the study, the infant was required to be at least 12 hours of age to ensure physiological stability of the infant post delivery. Infants were nursed in open metal or plastic perspex cots. Infants were excluded from the study if they were unwell, on antibiotics, nursed in an incubator, or had any known

abnormality. Temperature measurement was also avoided on infants that had recently been bathed or breastfed, as these activities may have ultimately influenced the results of the study.

Informed parental consent (see Appendix B) was obtained before enrolling each infant in the study. Each parent approached agreed to allow their infant to participate. However, of the total number of infants enrolled, three were transferred to other hospitals before data could be obtained, one remained in an incubator at completion of the study and one was withdrawn by the researcher due to parental anxiety. The final response rate was 94%.

Data collection and statistical analyses were performed on the remaining 81 infants, of which there were 44(54%) males and 37(46%) females. The age of the subjects ranged from 1 to 10 weeks and all infants were less than 37 weeks gestation (corrected age) at the time of the study, with gestational ages ranging from 26 to 36 weeks. While the infants' birthweights ranged from 820 to 4310 grams, their actual weights at the time of data collection ranged from 1370 to 3900 grams. At the time of recording the data, the temperature of the nursery ranged from 24 to 27 °C and the number of wraps covering the infants ranged from one to four. A summary of the infants' demographic and other details including the mean, standard deviation and range are described in Table 3.

Table 3

Summary of Demographic and Other Details of Infants

Variable	Mean	SD	Range
Gestational age (weeks)	32.8	2.5	26-36
Age (weeks)	2.2	2.1	1-10
Birthweight (grams)	1885	593	820-4310
Current weight (grams)	2003	420	1370-3900
Number of wraps	2.0	0.6	1-4
Nursery temperature (° C)	25.8	0.6	24-27
(N = 81)			

Instruments

A data collection sheet was designed specifically for use in this study (see Appendix A). Five standard Becton Dickinson (B-D)™ self registering mercury in glass thermometers with bulb ends were used for measurement. These thermometers measured degrees Celsius at 0.1 °C intervals from 35 to 42 °C. Two

B-D digital fever thermometers were also used in the study. These are electronic temperature measurement devices utilising a liquid crystal display to indicate the temperature reading and are capable of measuring temperatures from 32 to 42 °C at 0.1 °C intervals. These thermometers provide continuous measures of the infants' temperatures via a digital display readout. They are classified as predictive thermometers that are calibrated to give results consistent with a glass thermometer read at three minutes. They also provide an audible beep when a stabilised temperature has been reached.

Prior to data collection, the mercury thermometers were numbered from 1 to 5 by etching the glass with the required number. The digital thermometers were also etched and subsequently numbered one and two for the duration of the study. All of the thermometers remained labelled in this way for the duration of the study. Both the digital and mercury thermometers were designed for axillary use in neonatal populations.

The tympanic thermometer used in this study was a First Temp® Genius™, which is a thermometer that measures temperature by sensing the spectrum of infrared energy radiated from the tympanic membrane. Only a standard specula designed for use with the FirstTemp Genius thermometer was used in the study and the specula had no physical contact with the tympanic membrane at any time. The

tympanic thermometer measured temperature in 0.1 °C intervals and the temperature was displayed via electronic digital display. The thermometer gave a triple beep when the optimum temperature was registered and also displayed "done" in the display window.

Reliability.

Reliability for all thermometers used in the study was established immediately before and after data collection. This was achieved by immersing the mercury and digital thermometers in a Grant temperature controlled water bath which provided constant agitation of the water in the bath while heating. The mercury thermometers were shaken down to below 35 °C and the digital thermometers were turned on until the correct commencement display was observed.

The two digital and the five mercury thermometers were then immersed in a glass beaker within the water bath which had been preheated to 35 °C prior to commencement of the calibration procedure. The number on each thermometer was also noted and recorded. A certified digital reference thermometer which had been calibrated to a National Association of Testing Authorities, Australia (NATA) certified reference standard specifying an accuracy of + or - 0.05 °C, was also placed into the water bath. The thermometers were then tested by checking them against the reference thermometer throughout a temperature range of 35 to 39 °C.

Both the beep time and the stabilised time of the digital thermometers were read and recorded. The temperatures of the mercury thermometers were read and recorded at the stabilised time. The stabilised time for both types of thermometer was when the thermometers registered a stable temperature for three consecutive minutes.

Detailed graphs (see Appendix C) of the temperature readings obtained from testing, were used to establish the accuracy of the thermometers and to demonstrate their linear conformity to one another. This was achieved by plotting the temperatures obtained from the reference thermometer (X axis) against the temperatures obtained from each of the digital and mercury thermometers (Y axis). Following testing of the thermometers, it was found that all five mercury thermometers were accurate (to within 0.1 °C across the range of testing) when compared to the reference thermometer. Conversely, the digital thermometers consistently registered higher temperature readings at the beep time (up to 0.2 °C higher) and at the stabilised time (up to 0.4 °C higher) when compared to the reference thermometer. These findings are verified by the manufacturer, who reports that in a water bath, the readings from these digital thermometers will be about 0.2 °C higher than standard glass mercury thermometers, but this difference will not be apparent in patient use. The manufacturer also recommends, that the

digital thermometer gives the best results when it is removed at the time of the audible beep. If the thermometer is left after this time, there will be a slight increase in the displayed temperature. The tympanic thermometer was calibrated by the manufacturer directly prior to and immediately after data collection. The thermometer was calibrated on a Genius 3000A-CL electronic calibrator and was within the required specifications (+ or - 0.1 °C) both before and after data collection. The three thermometers were tested in the same manner, immediately before and on completion, of data collection. The tests for accuracy, were performed to ensure that reliability and precision of temperature measurement was maintained throughout the study.

The room temperature was monitored throughout the data collection procedure using a calibrated precision digital thermometer, which had been certified for accuracy. A new precise digital stopwatch was used for the timing of thermometer placement. The manufacturers guaranteed an accuracy of + or - 0.1 °C for all the thermometers used in this study. This degree of accuracy was accepted for the study.

Procedure

For several weeks prior to the commencement of data collection, temperatures were taken on infants at a nearby paediatric hospital, where similar thermometers were used in actual clinical practice. The purpose of this was to establish reliability in data collection procedures, equipment and technique in temperature measurement.

Immediately following the infant's identification for inclusion into the study, data such as sex, age in weeks, birthweight, current weight, gestation, and the number of wraps was recorded on the data collection sheet (see Appendix A). Each subject was included only once in the study and had remained in the nursery for at least one hour prior to data collection.

All data collection was undertaken by the researcher independently and was usually carried out in the early evening, as this minimised disruptions in routine nursing care and the interaction between parents and their infants. Just before commencing data collection, the ambient nursery temperature was read and recorded and the glass and digital thermometer numbers were documented. If the infant was crying excessively or was particularly restless, the temperature was not taken, as excessive activity may have affected thermometer placement and subsequent accuracy.

The mercury thermometer was shaken down to below 35 °C and the digital thermometer subsequently turned on and checked for the correct commencement display. A disposable plastic sheath was used to cover the probe of the digital thermometer to assist in guarding against cross infection. The infant was then positioned on his/her side if lying prone, or if the infant was already on its' side, the position was left unchanged. The type of clothing and the number of wraps in situ prior to data collection was dependent on the infants' thermoregulatory needs at the time. The arm to be used was freed from the jacket and the infant was kept as well covered as possible throughout the procedure.

Both the digital and mercury thermometer bulbs were, then, placed simultaneously in the central region of the axilla (pressed between the arm and the thorax) with the thermometer graduations/readout clearly visible. Care was taken to keep the infant well covered and the arm was held gently and securely close to the body to ensure a firm seal. Then a stopwatch was immediately started and the temperatures of both thermometers were read and recorded each 30 seconds untilastable reading was displayed for three consecutive minutes for each thermometer. A recording of the temperature at the beep time of the digital thermometer was also documented.

Once stabilisation of both axillary thermometers had been achieved, the thermometers were removed and the tympanic speculum was placed very gently into the outer part of the infant's ear as per the recommended guidelines for use. The tympanic thermometer was used on the 'tympanic' mode with an 'oral' equivalence. This meant that the thermometer primarily measured a clinical temperature which was then optionally adjusted to an appropriate equivalent (oral, rectal, or core temperature). Based on clinical studies, the Genius thermometer compensates for the average difference in temperature at each of these sites. Genius will then adjust its reading to a user selected equivalence based on statistical differences.

In this study, the oral equivalent was used for the tympanic thermometer as this mode was recommended by the manufacturer as most closely reflecting an axillary temperature reading. A disposable probe cover was used for each infant and care was taken to ensure that both ambient light and air were sealed out whilst gently directing the probe down the ear canal. The ear that was facing upwards was always used for measurement to ensure consistency of temperature readings. The scan button was then pressed and the temperature read and recorded when the beeps sounded and the word 'done' was displayed. The time required for measurement and the temperature displayed was then recorded. As the researcher was collecting the data unaided, some difficulty was experienced recording the

tympanic thermometer placement time, due to its extremely rapid response time of about one to two seconds. Both the mercury and digital thermometers were washed thoroughly with soap and cold water between subjects and were then wiped with sterile alcohol swabs to prevent cross infection.

Ethical Considerations

The study commenced following approval from the ethics committees of Edith Cowan University, School of Nursing and the participating hospital. Once an infant was identified as meeting the selection criteria, informed parental consent was obtained. Parents were given an information sheet (see Appendix B) and a verbal explanation of the study. Written consent was obtained prior to data collection. Parents were also informed that they may refuse to participate or withdraw their infant at any time without consequence.

Particular care was taken to ensure confidentiality of all subjects and only group data was reported. A master list containing the participant's name and corresponding code number was kept separate from the data collection sheets in a locked file. The consent forms were kept in a different, secured filing cabinet and available only to the researcher. Assurance that the procedure was safe and non invasive was supplied to the participating hospital (see Appendix D).

Chapter V

Results

Data were analysed using the Statistical Package for the Social Sciences (SPSS for Windows, Release 5.0.1). An alpha level of .05 was established for use throughout the data analysis.

Optimum Thermometer Placement Times

A cumulative percentage was calculated to determine how long it took for 90% of the thermometer readings to reach the maximum temperature using axillary mercury, digital and tympanic thermometers. Maximum temperature was deemed to have been achieved when temperature stabilisation took place after three consecutive stable readings at 30 second intervals.

As shown in Figure 2, the length of time required to obtain the preterm infant's maximum axillary temperature using a mercury in glass thermometer ranged from 1.5 to 8.5 minutes ($\underline{M}$ = 3.5 minutes, $\underline{SD}$ = 1.5). Cumulative frequency showed that 90% of infants' temperatures stabilised in 5.5 minutes.

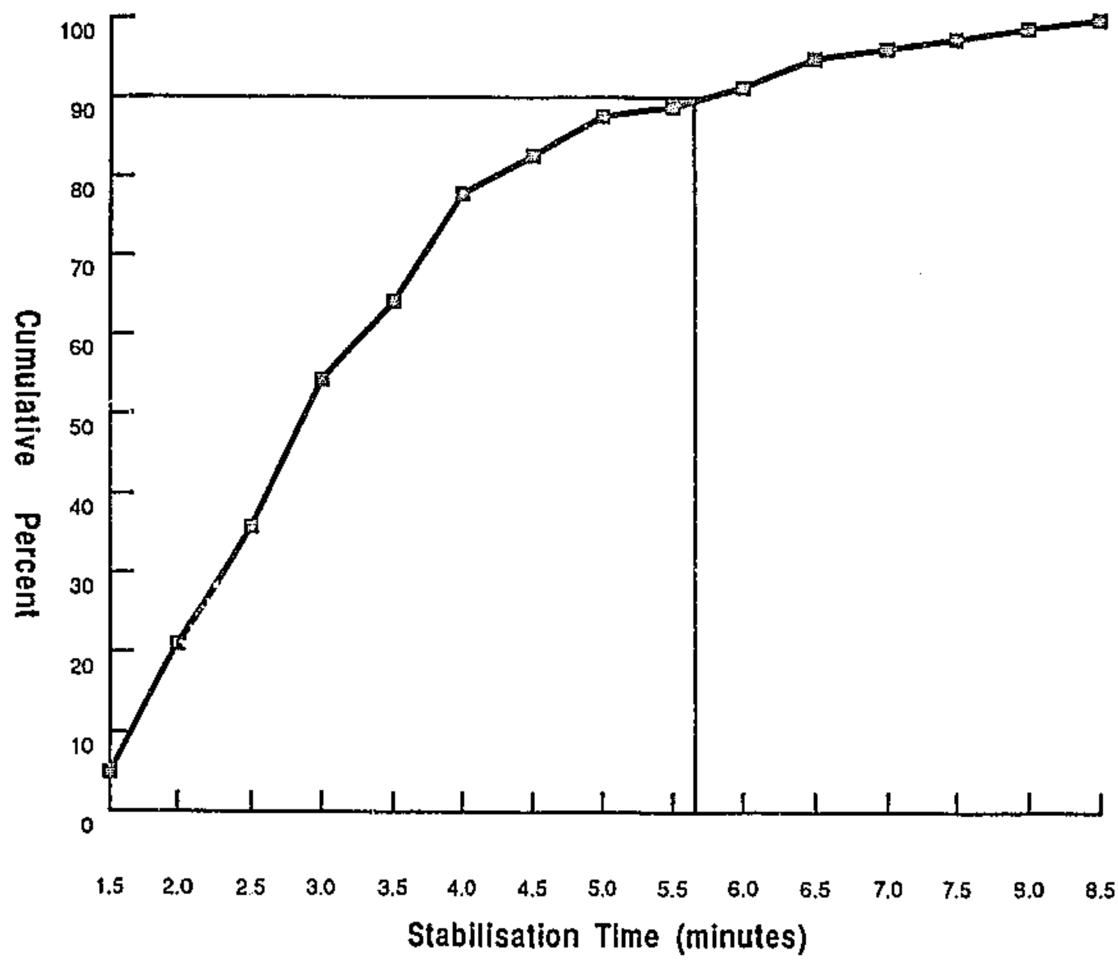

Figure 2. Cumulative percentage polygon showing stabilisation time of the mercury thermometer.

The length of time required to obtain the preterm infant's maximum axillary temperature using a digital thermometer ranged from 1.5 to 7.5 minutes (M = 3.0 minutes, SD = 1.4). Cumulative frequency (see Figure 3) showed that the optimal stabilised axillary thermometer placement time, using a digital thermometer, for 90% of the infants was 5.0 minutes.

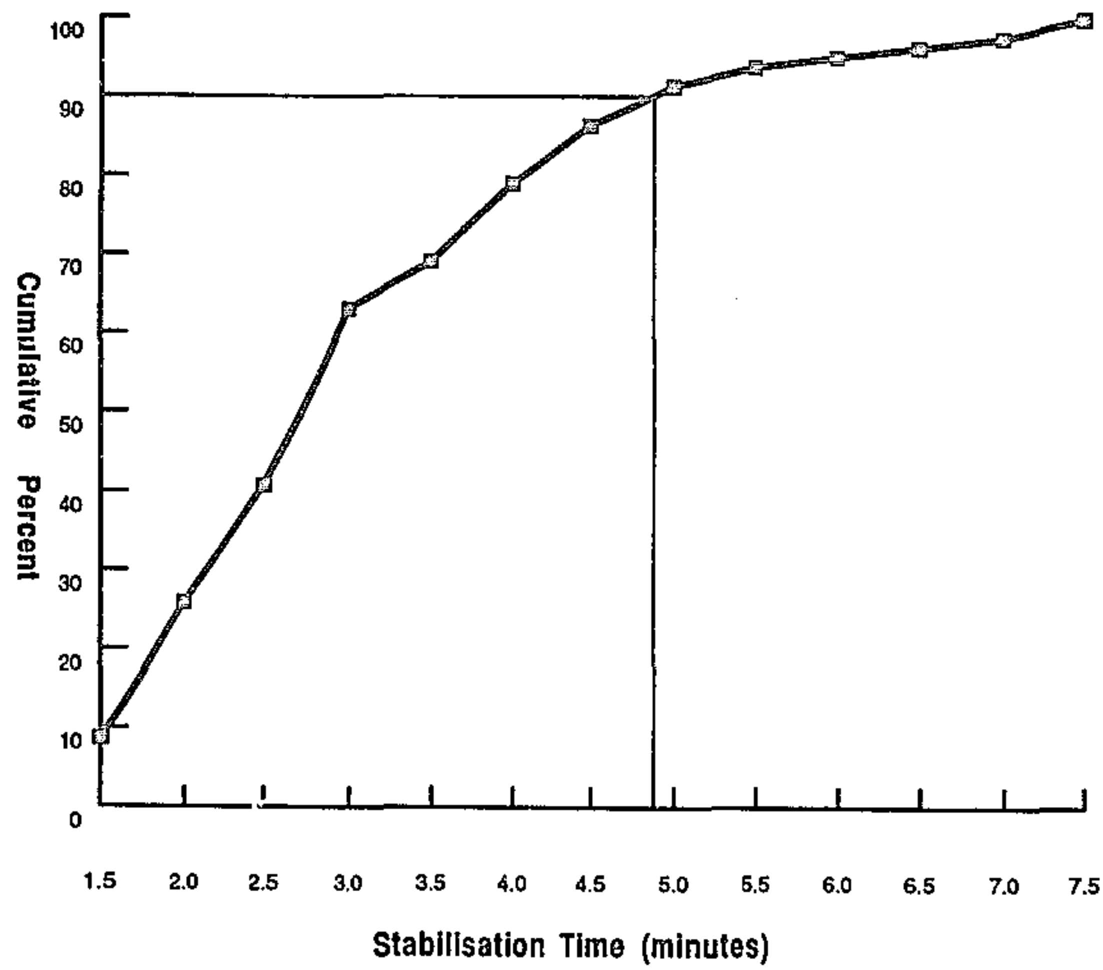

Figure 3. Cumulative percentage polygon showing stabilisation time of the digital thermometer.

In clinical practice, the manufacturer recommends that the digital thermometers used in this study are normally read and recorded at the time of the audible beep ('beep' time), in preference to the stabilised time. Therefore, the temperatures of the digital thermometers were also recorded at the beep time to detect any differences in the time taken to reach a maximum axillary temperature.

The length of time required to obtain a preterm infant's maximum axillary temperature using a digital thermometer at the beep time, ranged from 1 to 2.5 minutes (M = 1.5 minutes, SD = 0.3). Cumulative frequency (see Figure 4) demonstrated that 90% of infants' temperatures stabilised at the beep time by 1.75 minutes.

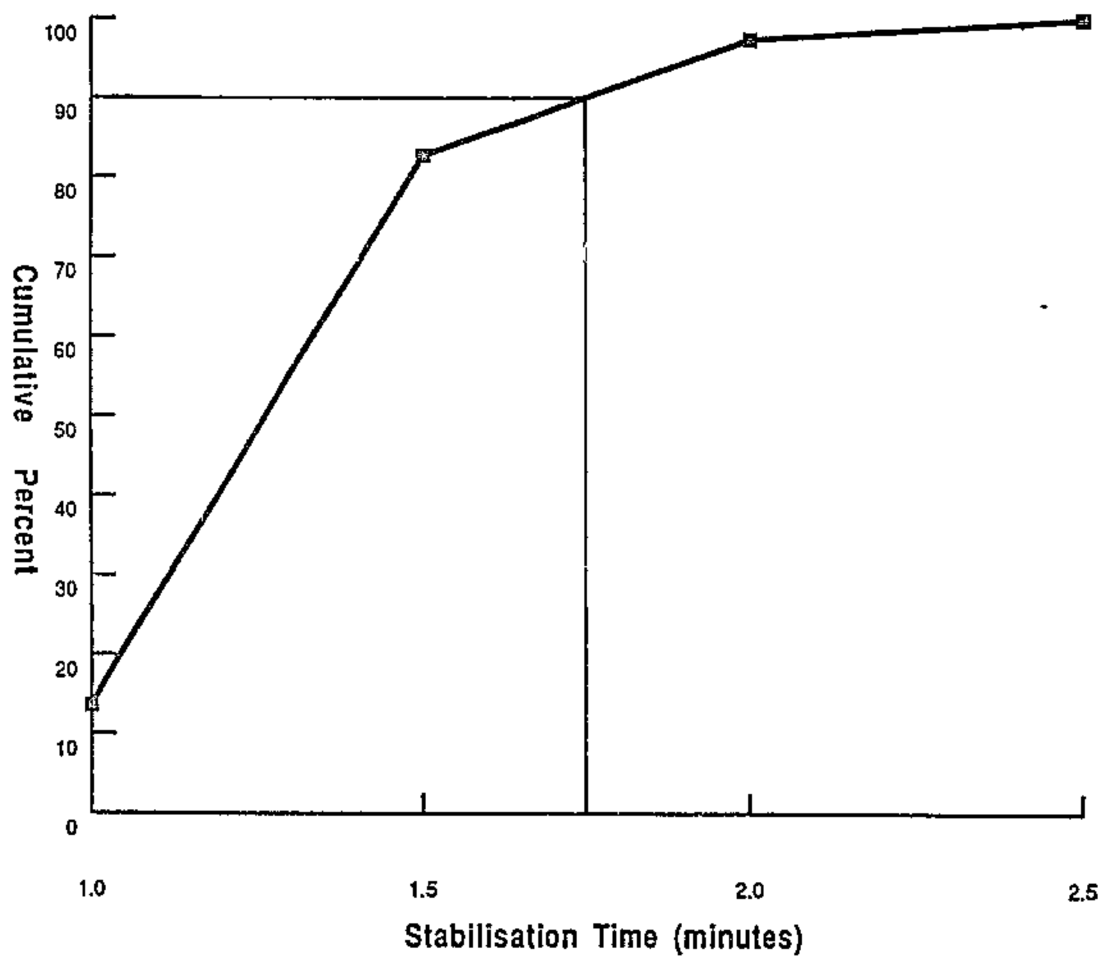

Figure 4. Cumulative percentage polygon showing stabilisation of the digital thermometer at the beep time.

The third type of thermometer used in this study was a tympanic thermometer. Tympanic thermometry provides extremely rapid temperature estimation and all infants' maximum aural temperatures were registered using the tympanic thermometer by a maximum of 2 seconds.

In summary, therefore, 90% of the time, the mercury thermometer stabilised by 5.5 minutes, the digital thermometer stabilised by 5.0 minutes (though it beeped 90% of the time by only 1.75 minutes) and the tympanic thermometer always took less than 2 seconds.

In current clinical practice, shorter mercury thermometer placement times of between 2 and 3.5 minutes are often used in measuring neonatal temperature. Therefore, mean temperatures recorded at certain time intervals were compared with the mean temperature of the optimum placement time of 5.5 minutes. These temperatures were then subtracted from the mean temperature recorded at 5.5 minutes to determine the difference between the mean temperatures of the mercury thermometers at 2.0, 2.5, 3.0 and 3.5 minutes (see Table 4). It was assumed that temperatures did not alter after stabilisation was reached. Thus, for example, an infant whose temperature had stabilised at 36.8 °C at 1.5 minutes was assumed to have remained at the same temperature at 5.5 minutes, although this was not actually measured.

Table 4

Comparison of Mean Mercury Temperatures at Various Time Intervals

Time (Minutes)	Temperature (°C)	Diff Between Temp at 5.5 Mins & Temp (°C) at Time Intervals
2.0	36.92	0.15
2.5	36.97	0.10
3.0	37.00	0.07
3.5	37.02	0.05
5.5	37.07	0.00

(N = 81)

The Relationship Between Other Variables and the Time Taken to Reach Maximum Temperature

Pearson correlation coefficients were calculated to detect any relationship between the time taken to reach maximum temperature and the variables of age in weeks, birthweight, gestation, nursery temperature and the number of wraps covering the infant. As shown in Table 5, there was no significant correlation found between the above variables and the time taken for the digital thermometer

to beep and the temperatures of both the mercury and digital thermometers to stabilise.

Table 5

Correlation Coefficients Between Time Taken to Reach Maximum Temperature and Selected Variables

Pearson Correlation Coefficients

	Stabilised Mercury	Stabilised Digital	Beep Time Digital
Age	.084	.120	.135
Gestation	-.120	-.048	-.081
Current Weight	-.009	-.103	-.136
Birthweight	-.060	-.140	-.196
Nursery Temperature	.024	.033	-.187
Wraps	.039	-.079	.061

(N = 81)

T Tests were performed to compare the differences between male and female infants in the time taken for the thermometers to stabilise. There was no

significant difference in the time taken for the mercury thermometer to stabilise in males (M = 3.6) and females (M = 3.4), t(79) = .60, p>.05. Similarly, there was no significant difference in the time taken for the digital thermometer to stabilise in male (M = 3.3) and female infants (M = 3.1), t(79) = .69, p>.05. Furthermore, there was no significant difference in the time taken for the digital thermometer to register maximum axillary temperature at the beep time in male (M = 1.5) and female infants (M = 1.6), t(79) = 1.72, p>.05.

Therefore, there is no evidence that any of the other variables such as age, gestation, current weight, birthweight, nursery temperature, or the number of wraps, are related to the time taken for the thermometers to reach maximum temperature and whether the infant is male or female.

Effect of Thermometer Type on Temperature Measurement

A repeated measures Analysis of Variance (ANOVA) was performed to determine whether there were any differences between the temperatures obtained using the mercury, digital and tympanic thermometers. The digital thermometer temperatures were measured at both the stabilised and beep times. The mean temperatures obtained using the three thermometers were significantly different, F(2, 79) = 5.25, p<.01. The mean temperatures are illustrated in Table 6.

Table 6

Comparison of Thermometer Types and Recorded Temperatures

Mean Temperatures (° C)	Mean	SD	Range
Axillary Mercury (stabilised time)	37.07	.28	36.50 - 37.70
Axillary Digital (stabilised time)	37.39	.31	36.80 - 38.20
Axillary Digital (beep time)	37.11	.28	36.60 - 37.80
Tympanic	36.98	.27	36.30 - 37.80
(N = 81)			

Paired t tests were used to determine between which particular thermometers temperature differences lay. The mean axillary mercury temperature was 0.09 °C higher than the mean tympanic temperature, $t(80) = 4.90$, $p < .05$. The mercury axillary was 0.04 °C lower than the digital (beep time) temperature, $t(80) = 2.28$, $p < .05$. Although statistically significant, these differences would not be considered

clinically significant in practice. Therefore, the temperatures obtained using the tympanic and digital (at the beep time) thermometers, were very similar to those obtained with the mercury thermometers.

Furthermore, all thermometers were tested for accuracy and as a result of this testing, the mercury thermometers were found to best emulate the reference thermometer. Consequently, all thermometers, (with the exception of the digital stabilised thermometer) were found to be accurate when compared to the reference thermometer.

However, when the digital beep time and stabilised digital thermometer temperatures were compared, a much greater temperature difference was found. The mean difference between the maximum digital and digital beep time temperatures was 0.28 °C, $t(80) = 16.58$, $p < .05$. The findings of this study indicate that although the temperature recorded at the beep time is accurate, the temperature obtained at the stabilised time is unacceptably high.

The number of infants that recorded mean temperatures greater than 37.0 °C using the three thermometers, were also reported in this study. It was found that maximum axillary temperatures greater than 37.0 °C occurred in 51% of infants using a mercury thermometer, 38% using a tympanic thermometer and 53% using a digital thermometer at the beep time. Furthermore, 10% of infants recorded temperatures in excess of 37.3 °C using all of the three thermometers and 15% of

the 81 infants had more than two wraps covering them. A correlation was then performed to find out whether the number of wraps covering the infants had affected the temperatures obtained. Analysis revealed no significant relationship existed between the maximum temperature reached and the number of wraps covering the infants, $r(79) = -.114$, $p > .05$.

Pearson correlation coefficients were computed to determine the strength of the relationship between the axillary mercury, digital and tympanic temperatures. The correlation demonstrated a significant positive relationship between the temperature of the mercury and the digital thermometer at the beep time $r(81) = .84$, $p < .001$. Furthermore, the correlation between the mercury and tympanic temperatures was $r(81) = .78$, $p < .001$ and between the tympanic and digital beep time temperature was $r(81) = .75$, $p < .001$. Figures 5, 6 and 7 display scatterplots to show the temperatures obtained using the three types of thermometer. The lines drawn through the graphs are not the lines of best fit, but the line of identity (ie. the line that the points would fall on if both thermometers agreed exactly).

Summary

The results of this study found that the optimum placement time for an axillary mercury thermometer in a preterm infant was 5.5 minutes. Furthermore, the optimum axillary thermometer placement time for a digital thermometer at the

beep time, was 1.75 minutes and for the stabilised digital thermometer, the optimum placement time was 5 minutes. The tympanic thermometer recorded a maximum temperature in less than 2 seconds.

There was no significant correlation found between the time taken to measure temperature accurately using each of the three thermometers and the variables of age, birthweight, current weight, gestation, number of wraps, nursery temperature and the infants' sex.

Furthermore, mercury, digital and tympanic thermometers were compared to detect any differences in the temperatures obtained. Statistically significant differences in the temperatures were found, however, the mean temperature differences obtained between the mercury, digital (beep time) and tympanic thermometers did not exceed 0.13 °C. The mean temperature differences were much hi[illegible] between the stabilised digital and the temperatures of the mercury, tympanic and digital thermometers at the beep time. The correlation between the mercury, tympanic and digital (beep time) thermometers demonstrated a strong positive relationship.

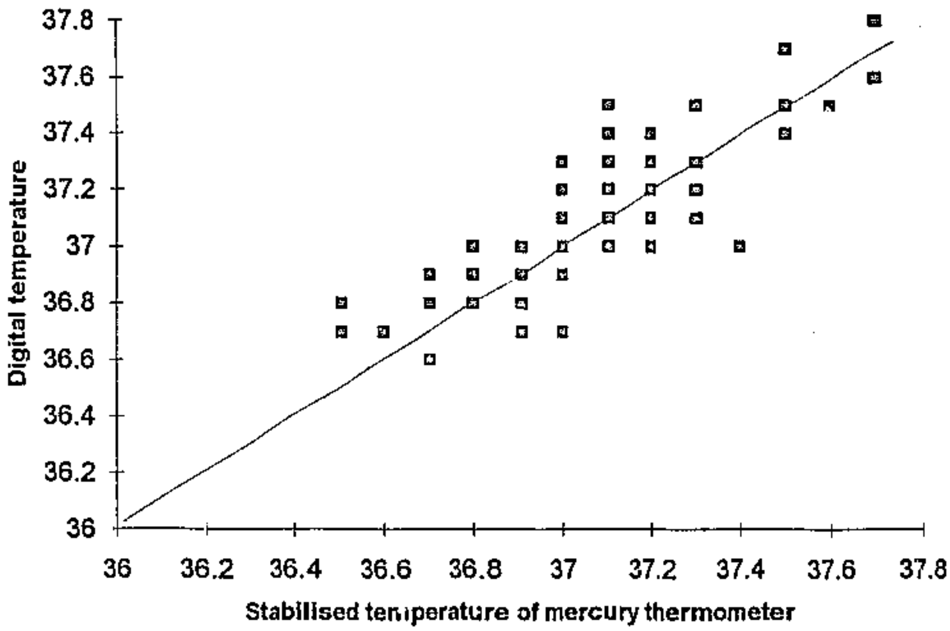

Figure 5. Scatter plot of temperatures as measured by mercury and digital themometers at the beep time.

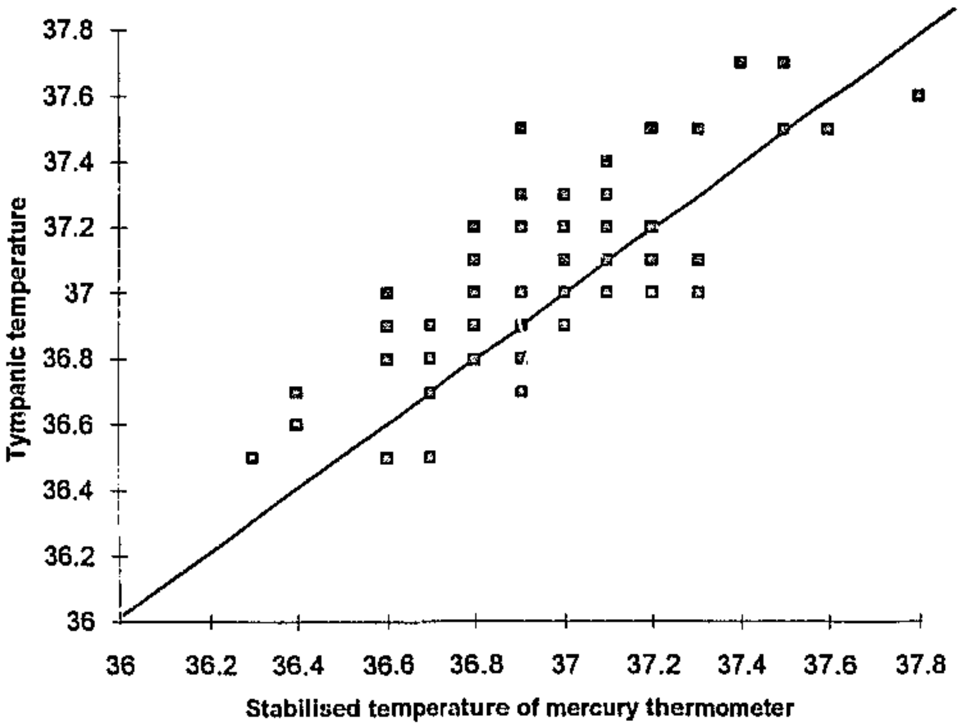

Figure 6. Scatter plot of temperatures as measured by mercury and tympanic thermometers.

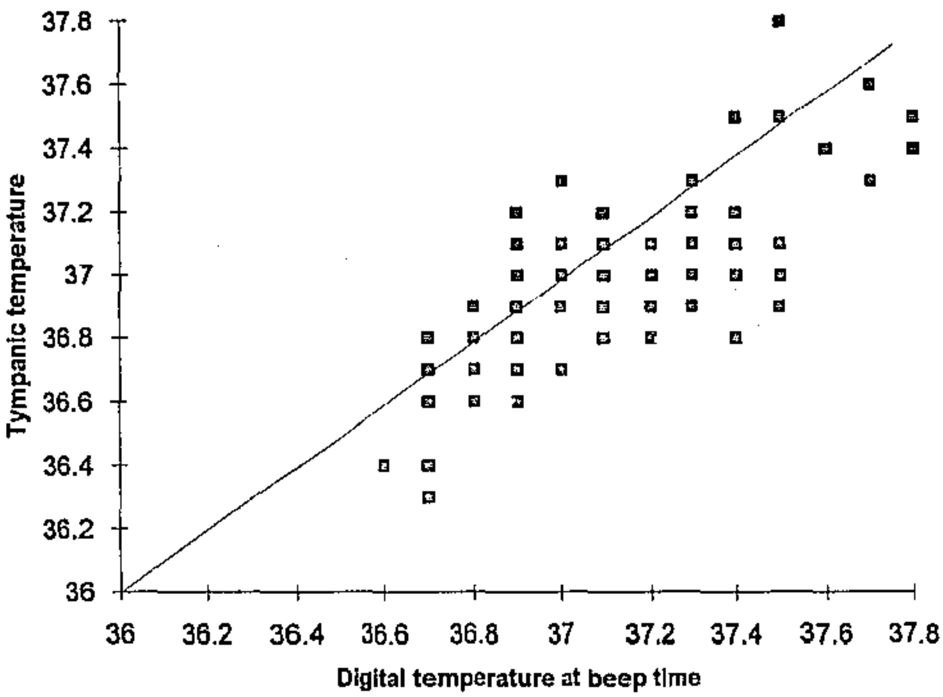

Figure 7. Scatterplot of temperatures as measured by tympanic and digital thermometers at the beep time.

Chapter VI

Discussion

The importance of maintaining a neutral thermal environment for the vulnerable, premature infant is a vital facet of neonatal nursing practice. A variety of nursing interventions, including accurate temperature measurement, facilitate the infants' adaptation to the surrounding environment.

The main purpose of this study was to compare digital, tympanic and mercury thermometers to determine the time needed using each of them to accurately measure a preterm infant's temperature.

Optimum Thermometer Placement Times

Mercury Thermometer.

The results of this study demonstrated that the length of time required to obtain a preterm infant's maximum axillary temperature using a mercury thermometer ranged from 1.5 to 8.5 minutes. The majority (90%) of infants reached their maximum axillary temperature in 5.5 minutes and furthermore, 95% of the infants' maximum temperatures were obtained by 6.5 minutes.

Based on these findings, it can be concluded that 5.5 minutes are required to measure accurately a preterm infant's axillary temperature using a mercury thermometer. In the present study, the length of time taken to accurately measure

a preterm infant's temperature was at least as long as, and on several occasions longer than, the time reported in the majority of other studies. The findings are similar to those of Mayfield et al. (1984) and Khan et al. (1990) who found that 90% and 95% of infants respectively, achieved temperature stabilisation within 5 minutes. Conversely, Haddock et al. (1988) and Torrance (1968) found that the temperatures of the infants in their studies had stabilised in 3 minutes for 90% of infants and 4 minutes for 95% respectively.

The finding that 90% of preterm infants in this study reached maximum axillary temperature in 5.5 minutes, also differs from that of Stephen and Sexton (1987) who studied temperature measurement in 60 term and 40 preterm infants. The study reported that temperatures of all subjects continued to rise over 11 minutes of monitoring and therefore no conclusion was reached. The reason for the obvious difference in results between the present study and previous studies is unclear. One explanation for this difference may have been the lack of thorough testing of the instruments against a calibrated reference thermometer. In the present study, care was taken to ensure thorough testing of all instruments used for data collection. Furthermore, a number of other studies (Haddock et al., 1986, 1988; Newbold, 1991; Rogers et al., 1991; Stephen & Sexton, 1987) failed to test the instruments used and this factor may have contributed to the differences in the results obtained between the various studies.

Although the results of this study indicate that the axillary mercury thermometer must be left in place for 5.5 minutes to obtain a maximum temperature in a preterm infant, it was interesting for the researcher to find that the mean temperature recorded at 2.5 minutes was only 0.09 °C lower than that of the temperature recorded at 5.5 minutes. Furthermore, the mean temperature recorded at 3.5 minutes displayed an even smaller mean difference of only 0.05 °C. Therefore, the small mean temperature differences obtained from this study would be regarded as clinically insignificant in actual neonatal nursing practice.

A number of studies have discussed the difference in thermometer placement time between fullterm and preterm infants. In clinical practice, it is often acceptable to use identical axillary thermometer placement times for both term and preterm infants, although the literature does not fully support this view. Several studies have suggested that shorter thermometer placement times are required in preterm when compared to fullterm infants.

Haddock et al. (1988) found that preterm infants' axillary temperatures stabilised more rapidly than that of fullterm infants. Similarly, Mayfield et al. (1984) also reported lower temperatures in preterm infants at all temperature sites, as did Khan et al. (1990) who found significant temperature differences between preterm and term infants at the rectal and aural sites.

In the present study, the optimum axillary temperature obtained using

mercury thermometers in 90% of preterm infants was 5.5 minutes. This finding, when compared to other studies that have reported the temperatures of mature, full term infants, suggests that there is not a great difference in the length of time required for the axillary thermometers to register a stable temperature in the preterm infant population. Therefore, it may be reasonable to suggest identical thermometer placement times for both fullterm and preterm infants, which would thus increase uniformity in the practice of neonatal temperature measurement.

Digital Thermometer.

The length of time required to measure a preterm infant's stabilised axillary temperature using a digital thermometer ranged from 1.5 to 7.5 minutes. According to the operational definition utilised in this study, the optimal axillary thermometer placement time using a digital thermometer at the stabilised time was 5 minutes for 90% of infants. However, the length of time required to measure a preterm infant's temperature using a digital thermometer at the 'beep' time, ranged from only 1 to 2.5 minutes and by 1.75 minutes, 90% of preterm infants reached a stable axillary temperature.

Of particular interest, in the present study, was the high mean temperature obtained using the digital thermometer at the stabilised time. Mean differences

between axillary mercury and stabilised axillary digital temperatures were as high as 0.32 °C. The mean differences between stabilised axillary digital and tympanic temperatures were also considerably higher at 0.41 °C. The findings from this study showed that if the axillary digital thermometer was left to stabilise, it required a placement time of 5 minutes. However, if the thermometer was read at the beep time it recorded a stable temperature in 2.5 minutes in 100% of infants.

These results show that when using the type of axillary digital thermometer employed in this study, the thermometer must always be read and recorded at the 'beep' time rather than that of the stabilised time. Furthermore, the manufacturer of the digital thermometer states that the temperature must be read at the time of the audible beep to ensure accuracy of temperature recordings. The much higher mean temperature differences obtained if the digital thermometer is left to stabilise, would also have clinical significance in nursing practice. The implication of this finding for nursing practice would be in relation to the much longer time taken to measure temperature and the subsequent inaccuracy of the instrument, as reflected by the higher temperatures obtained.

There have been no other studies conducted which have reported optimum placement times for axillary digital thermometers in preterm infants, as was described in the present study. Only Hunter (1991) who studied the temperatures of 40 healthy fullterm infants, used both axillary digital and mercury thermometers

and found that stabilisation for 100% of the sample occurred within 3 minutes using both thermometer types. Similarly, in the present study, 100% of preterm infants' temperatures stabilised in 2.5 minutes using the digital axillary thermometer at the 'beep' time.

Tympanic Thermometer.

In the present study, all infants' maximum aural temperatures using the tympanic thermometer were registered in a maximum of two seconds. It was, of course, impossible to record the exact time taken for the tympanic thermometer to register a stable temperature because of the very short time taken for the thermometer to display a temperature reading. When comparing the speed of temperature measurement using the different thermometer types, the tympanic thermometer certainly provides an extremely rapid form of temperature assessment which would undoubtedly save nursing time. This speed of measurement clearly provides important advantages in the care of the fragile, premature infant, who requires minimal handling and has poorly developed thermoregulatory adaptive abilities.

The results of this study have also shown the tympanic thermometer to reflect accurate temperature readings when compared to mercury and digital (at the beep time) thermometers. The mean difference between axillary mercury and

tympanic temperatures was only 0.09 °C. The difference between axillary beep time digital and tympanic temperatures was only 0.13 °C.

In a study by Weiss (1991) the temperatures of preterm and fullterm infants were examined using both tympanic and axillary digital sites. The mean temperature differences between tympanic and axillary readings, which varied from 0.19 to 0.22 °C, were much higher than those found in the present study. The reason for the marked temperature differences in Weiss' study may have resulted from variation in the technique of measuring tympanic temperature. Furthermore, Weiss' study was also limited by a small preterm sample size ($\underline{n}$ = 12).

Before the commencement of this study, it became apparent to the investigator that the importance of technique in using the tympanic thermometer should not be disregarded. In the studies by Pransky (1991) and Weiss (1991) the authors found the use of the tympanic thermometer required the application of the correct technique to obtain reliable and accurate results in infants. In the present study, the researcher ensured that the correct technique was employed. Prior to the study, the researcher contacted the manufacturer in the United States to obtain the correct method for temperature measurement and then practised the correct technique on newborn infants. Therefore, failure to consolidate the correct technique of tympanic temperature measurement, especially in the small preterm infant, could produce inaccurate readings and compromise the infant's condition.

The use of the tympanic thermometer has demonstrated both accuracy and speed of temperature measurement and the present study has confirmed its significance for use in the small preterm infant.

Comparison of the Thermometer Types Used

This study compared the use of mercury, digital and tympanic thermometers in preterm infants and determined whether there was any difference between the temperatures obtained using the three thermometers.

Whilst the findings showed there was a statistically significant difference between the three thermometers used, the issue of clinical versus statistical significance has emerged. The mean temperature differences obtained using each thermometer (see Table 6) has no practical significance in actual clinical practice. Overall, the mean temperature difference (excluding axillary digital stabilised temperature) between the three thermometers was not greater than 0.13 °C. Furthermore, there was a strong positive correlation between the temperature of the mercury, tympanic and the digital thermometer at the beep time (all above $r = .70$).

Although very few studies have been conducted that have examined the use of tympanic compared to axillary mercury or digital thermometers in the infant population, the present study has demonstrated significantly higher correlations between the temperatures obtained using the three thermometer types. Weiss (1991) reported a weaker correlation ($r = .43$ to $.62$) between axillary digital and

tympanic temperatures of preterm infants. Similarly, Rogers et al. (1991) reported low to moderate correlations (r = .41) between the axillary digital and tympanic temperatures obtained in a sample of 108 paediatric patients. The observed differences in the correlations obtained from these studies when compared to the present study, could have resulted from smaller sample sizes or variation in the technique of using the tympanic thermometer.

Relationship of Other Variables and Time Taken to Reach Maximum Temperature

This study also examined a number of variables which may have influenced the length of time needed to obtain an accurate temperature in a preterm infant. These included the variables of birthweight, age, sex, gestation, nursery temperature and the number of wraps covering the infant. However, no significant correlation was detected between the above variables and the time taken for the digital thermometer to beep and the temperatures of both the mercury and digital thermometers to stabilise. This finding is consistent with a number of other studies (Johnson & Shorten, 1991; Stephen & Sexton, 1987; Torrance, 1968) which have examined similar variables and their effect on the time taken to reach maximum temperature. Furthermore, in the present study, there was no significant difference in the time taken for the thermometers to stabilise between male or female infants. Very few studies have reported gender as a factor affecting the time taken for

infants' to attain maximum temperature. However, Haddock al. (1986, 1988) and Torrance (1968) found that male infants' reached their maximum temperatures sooner than female infants.

Febrile Infants

It was interesting to observe, in the present study, that there was an unexpectedly high number of hyperthermic infants. The normal, acceptable temperature range for the healthy preterm neonate is 36.5 to 37.0 °C, but maximum axillary temperatures greater than 37.0 °C using a mercury thermometer, occurred in 51% of the infants in this study. Furthermore, digital axillary temperatures recorded at the 'beep' time that exceeded 37.0 °C were recorded in 53% of infants and similarly, tympanic temperatures in excess of 37.0 °C were recorded in 38% of infants. A further 10% of infants recorded temperatures, using all three thermometers, that exceeded 37.3 °C. This finding is particularly significant in the preterm infant population, as any temperature that falls outside the neutral thermal zone of 36.5 to 37.0 °C, could result in adverse physiologic effects.

At first, it was thought that this high incidence of hyperthermia could be due to the fact that 15% of infants had more than two wraps covering them at the time of temperature measurement. A correlation was performed to detect if any significant relationship existed between the number of wraps and the temperatures obtained.

However, no significant relationship was found between these two variables.

An implication of this finding is that the incidence of hyperthermia is in excess of what would be considered normal and so shorter placement times of axillary mercury thermometers, as in current neonatal nursing practice, may eventuate in undetected hyperthermia. In this study, both the axillary digital thermometer at the 'beep' time and the tympanic thermometer also detected elevated temperatures, but required a much shorter placement time.

The preterm infant requires vigilant and expert nursing care to assist its adaptation to an ever changing environment. Temperature measurement remains an exceptionally important nursing procedure for these fragile, vulnerable infants who have diminished thermoregulatory abilities. Therefore, an instrument that provides both accuracy, speed of measurement and saves nursing time has great importance in current neonatal nursing practice.

The results of this study suggest that all three thermometers could confidently be used in the preterm infant to accurately measure temperature. However, tympanic thermometry provides an extremely rapid form of temperature assessment, entails minimal handling and has demonstrated accurate temperature readings when compared to both axillary digital and mercury thermometers.

Limitations

The findings of this study are limited by the use of a convenience sample of preterm infants and accuracy of the measurement instruments. In this study, however, stringent measures were taken to test and maintain the accuracy of all thermometers used. The time that the infant was last fed or handled was not recorded and this could have affected the temperature obtained due to mild dehydration, change in blood glucose levels, or an increase in the muscular activity.

Chapter VII

Conclusions, Implications and Recommendations

Conclusions and Implications for Neonatal Nursing Practice

The significance of accurate temperature measurement in the preterm infant remains an extremely critical aspect of neonatal nursing care. During the preterm infant's transition to extrauterine life, adaptation to the environment is facilitated by nursing measures that assist in maintaining a neutral thermal environment. Any difficulty experienced during this period of transition may result in maladaptation to the surrounding environment. As a consequence, the infant may experience fluctuations in body temperature which may lead to either hyperthermia or, conversely, hypothermia. Further adverse physiologic responses may occur and therefore, prompt and accurate temperature determination will assist in reducing further compromise to the fragile and vulnerable preterm infant. The results of this study assisted in confirming optimum placement times of axillary thermometers and have analysed the effectiveness and accuracy of tympanic thermometers in the preterm infant population.

Accurate temperature in the preterm infant is achieved by ensuring correct and appropriate thermometer placement times for both axillary mercury and digital thermometers. Findings of this study demonstrated that the optimum thermometer

placement times were 5.5 minutes for the mercury, 1.75 minutes for the digital (beep time) and less than 2 seconds for the tympanic thermometer. In conclusion, the tympanic thermometer registered temperature extremely rapidly and provided minimal disturbance to the infant. Although the digital thermometer registered temperature fairly quickly and proved easy to use, it involved more handling of the infant, as did the mercury thermometer.

Another important finding of this research was the demonstration of strong, positive correlations observed between the three thermometers used. Although statistically significant differences were found between the three thermometers, the small difference in the mean temperatures obtained were considered clinically acceptable for use in normal neonatal nursing care. Therefore, any of these thermometers could be confidently used in the preterm population to accurately measure temperature.

A further interesting finding of this study was the large number of hyperthermic infants. Effective neonatal nursing practice ensures the maintenance of a neutral thermal environment for the neonate. It is vital that nursing staff monitor these infants closely to avoid large fluctuations in body temperature. Although there was no significant correlation between the number of wraps and the temperatures obtained, other extraneous factors may have accounted for the large percentage of elevated temperatures.

The results of this study will have important implications for future neonatal nursing practice, management and education.

An important consideration is the potential cost effectiveness of using either the digital or tympanic thermometer. Current economic constraints have increased the search for cost saving equipment and any possible alteration in nursing practice that will service this need. Both the tympanic and digital thermometer demonstrate speed and accuracy in temperature measurement and, therefore, would greatly save nursing time and thereby reduce overall cost. In addition, because tympanic thermometers also involve minimal handling of the infant, their use and accuracy in the neonatal population warrants further investigation.

Furthermore, the importance of the correct technique of tympanic temperature measurement has been highlighted in this study. Inservice education before using tympanic thermometers is, therefore, essential. When used correctly, tympanic thermometers are as accurate in reflecting body temperature in the preterm infant as are axillary thermometers. With reference to the digital thermometer, the findings of this research suggest it should be read and recorded at the time of the audible beep rather than left to stabilise in the axilla. If the digital thermometer is left to stabilise, inaccurate and elevated temperature readings are recorded.

Recommendations For Future Research

Current neonatal nursing practice demands both accuracy, rapidity and reliability in temperature measurement, especially in the preterm infant. The potential benefits of using tympanic or digital thermometers and as a result of the relative lack of research in this area, further studies in relation to the accuracy of these thermometers is justified. The use of the tympanic thermometer in preterm infants under radiant heaters and in incubators also requires further investigation. Extremely low birthweight and small or large for gestational age infants could also be studied. Further research could be carried out in infants less than twelve hours of age, to investigate the accuracy of thermometers whilst the infant is adapting to extrauterine life. Another consideration for future research is the technique employed in tympanic temperature measurement and the subsequent accuracy of the readings obtained.

Summary of Recommendations

* The optimum axillary placement time is 5.5 minutes for a mercury, 1.75 minutes for a digital (beep time) and less than 2 seconds for a tympanic thermometer.

* The axillary digital thermometer used in this study should be read only at the time of the audible beep and not left to stabilise.

* Shorter thermometer placement times of 3 to 3.5 minutes using an axillary mercury thermometer, demonstrate an acceptable degree of accuracy for use in normal neonatal practice.

* The use of tympanic thermometers in the preterm population should be further investigated.

* Thorough inservice education, in relation to the technique of temperature measurement, should be accomplished prior to the clinical use of the tympanic thermometer.

Chapter VIII

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CHAPTER IX

APPENDICES

A = Data Collection Form

B = Parent Consent and Information Sheet

C = Graphs Related to Thermometer Testing

D = Correspondence from USA regarding Thermometer Safety

APPENDIX A

DATA COLLECTION SHEET

Age(in Wks) ___________ Subject I.D.___________

Sex M___ F___ Gestation(at birth)______

Birthweight ___________g Nursery Temp___________°C

Number of wraps________

Mercury thermometer

temperature at: 1 min_______
2 min_______
3 min_______
4 min_______
5 min_______
6 min_______
7 min_______
8 min_______
9 min_______
10 min_______
11 min_______
12 min_______

Digital thermometer

temperature at: 1 min________
2 min________
3 min________
4 min________
5 min________
6 min________
7 min________
8 min________
9 min________
10 min________
11 min________

Tympanic thermometer Time taken_______seconds

Temperature

APPENDIX B
PARENTAL CONSENT AND INFORMATION SHEET

Dear parent,

I am a registered nurse and midwife with 9 years experience caring for newborn infants. I am currently conducting research into the length of time needed to take preterm infants' temperatures accurately. This research is being conducted as part of the requirements for a Bachelor of Health Science (Nursing) with Honours at Edith Cowan University.

The preterm baby is very prone to heat loss and accurate temperature measurement is an extremely important part of his\her care. Therefore, in this study, I will be taking the temperature of each baby ONLY once, using three types of thermometer. I will wait until the temperature reading of each thermometer has stabilised and then record how long it took for stabilisation to occur. The procedure will take no more than 12 minutes. It is hoped that your participation in this study will help to improve care of preterm infants.

This study has the approval of the School of Nursing at Edith Cowan University and King Edward Memorial Hospital for Women.

When the results of this study are reported neither you nor your baby will be identifiable in any way. Participation in this study is entirely voluntary and the care given to you and to your baby will not be affected in any way whether or not you choose to participate in the study. You are free to withdraw your infant from the study at any time.
Should you have any queries at all, please feel free to contact me at any time.

Sue Bearsby
Home - [redacted]

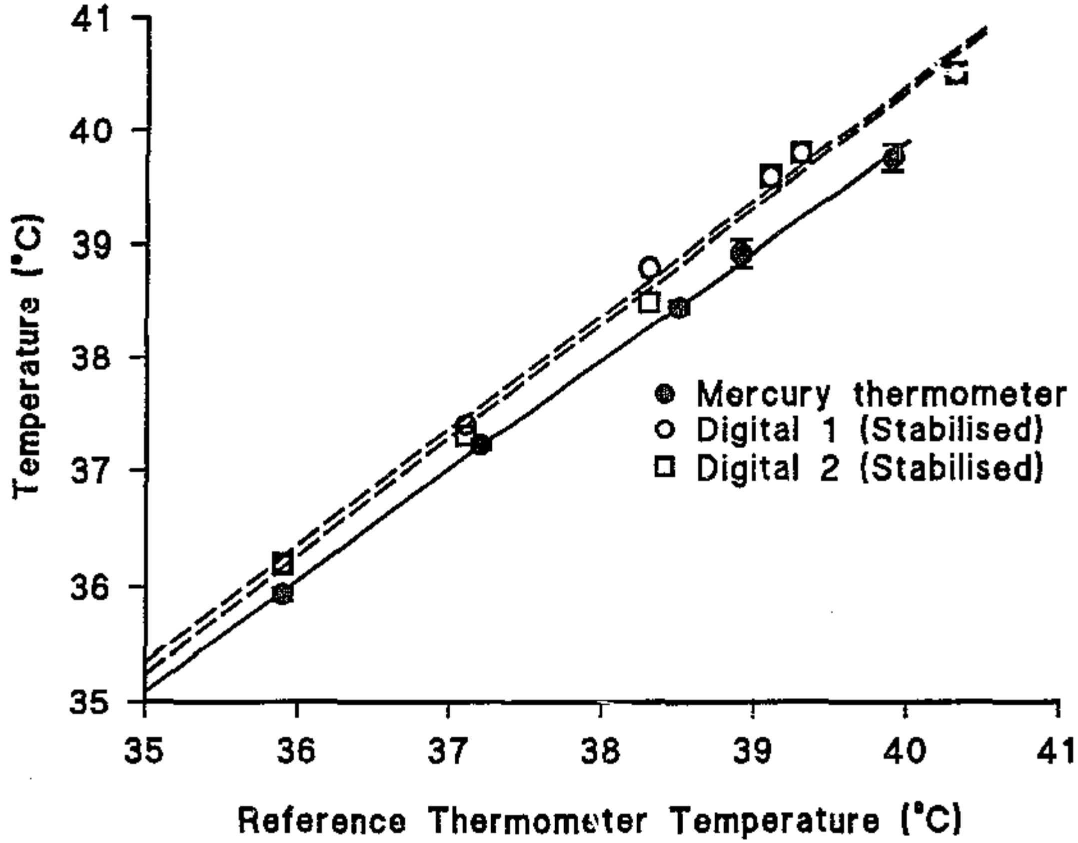
I,..
Parent's Family Name Given Name

of...Address
having read the above information and having had the research explained to me by Sue Bearsby, agree to allow my baby to participate in this study designed to find out how long it takes to measure preterm infant's temperatures accurately.

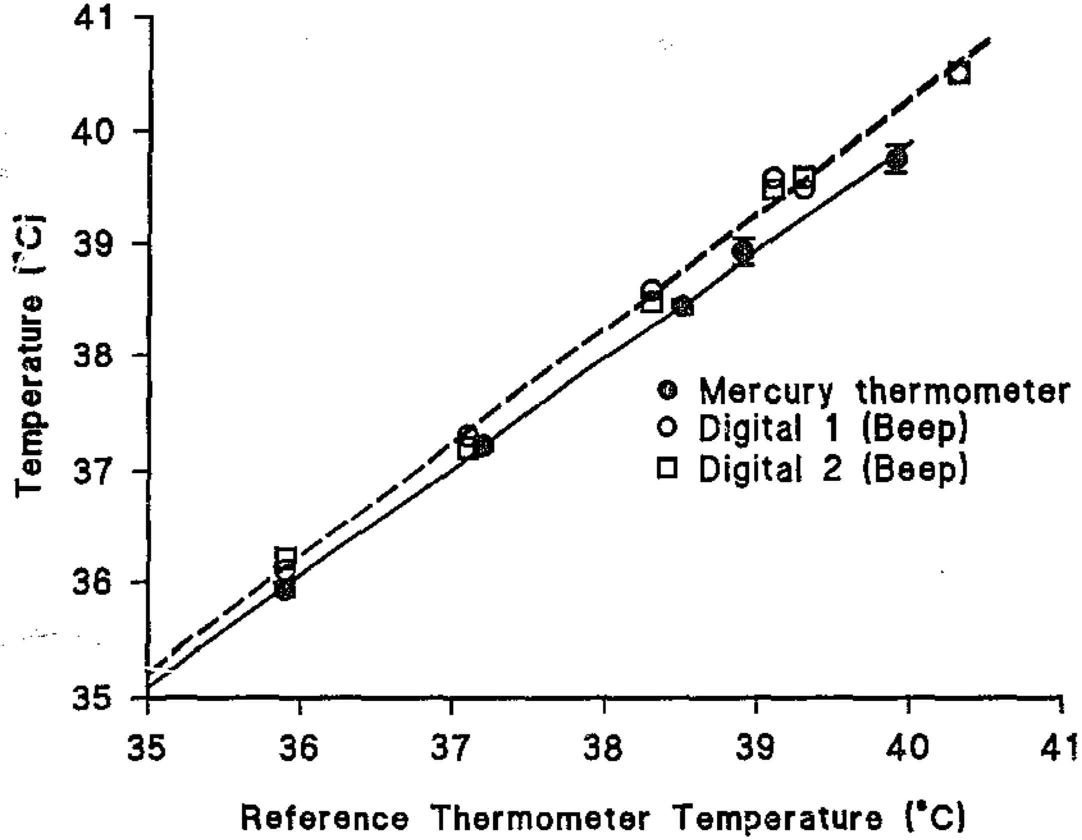
Baby..
Family Name Given Name

Parent..Date..

Researcher...Date..



Data for mercury and stabilised digital thermometer temperatures plotted against reference thermometer temperature.



Data for mercury and stabilised digital thermometer temperatures plotted against reference thermometer temperatures.

APPENDIX D

The University of Iowa
Iowa City, Iowa 52242

College of Medicine
Department of Pediatrics
Division of Neonatology

319/356-4005

8 July 1992

Susan Bearsby
c/o Ms. M. McAllister
School of Nursing
Edith Cowan University
Fax 61-09-383-8699

Dear Mrs. Bearsby:

Thank you for your letter regarding our paper on infrared thermometry. First, you should have no concerns about the safety of infrared thermometry. It is a noninvasive technique that measures temperature by sensing the spectrum of infrared energy radiated from the tympanic membrane. We used the standard specula for the FirstTemp thermometer, which are too large to fit into the ear canal of small preterm infants; however, if the speculum is carefully directed into the canal, the instrument can be used even with very small infants. As we stated in our paper, the FirstTemp is accurate for small infants only when used in the "Cal-surface" mode, which directly transduces surface temperatures without an automatically applied correctional algorithm (unfortunately based on the relations among rectum, ear, and mouth temperatures of adults).

If your concern is about the measurement of tympanic membrane temperature with the electronic telethermometer and thermistor (Yellow Springs Instruments), this technique appears to be safe if carefully applied. The thermistor probe is very thin (0.024 inches diameter) and soft (and consequently easily damaged) but could probably injure the ear if used carelessly. We examined the ear with an otoscope before and after probe placement in nearly 100 infants and saw no evidence of trauma.

You should also understand that this probe (YSI 511) is not designed for use as a tympanic probe, nor is it intended for use with a 400-series telethermometer, as we did. Consequently, the temperatures shown on the telethermometer were not accurate until corrected using an experimentally derived regression equation relating apparent to true temperature. The probe was designed for tissue implantation. If you use it as we have to measure tympanic temperature, you must take care to assure that it is in gentle contact with the tympanic membrane.

I am pleased that you have chosen to work in this important area, and I wish you the best of luck. If I can be of further assistance, please feel free to write. I would be interested in the results of your research when it is completed.

Sincerely,

Edward F. Bell, M.D.
Professor of Pediatrics
Director of Neonatology

Fax 319-356-8669