Physiologic response of the preterm infant during the early initiation of breastfeeding versus bottlefeeding: a dissertation

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CHAPTER ONE

Recommendations by both the American Academy of Pediatrics and the World Health Organization state that breast milk is the optimal milk for babies in the first six months of life (American Academy of Pediatrics, 1978). The nutritional and immunologic value of breast milk for infants has been noted by many authors (Anderson, Atkinson, & Bryan, 1971; Lemons, Moye, Hall, & Simmons, 1982; and Raiha, 1976). Because of immunologic qualities of breast milk, it may be especially important for the preterm infant (PTI). However, PTIs are less likely to be breast fed than full term infants (FTI) despite the unique benefits of breast milk. This is due to several factors including a delay in the initiation of breastfeeding based on the assumption that breastfeeding is more physiologically taxing than bottlefeeding. The physiologic instability of preterm infants usually requires that the neonate needs intensive care. The more premature the infant, the more acute the transition from intrauterine to extrauterine life. The underlying principle of neonatal intensive care is to enhance physiologic stability so that the infant can grow (Avery, 1987; Klaus & Fanaroff, 1982; and Korones, 1986). The initial days/weeks of life focus on providing environmental support to limit the energy expenditure required by the infant. Continuous monitoring of physiologic measures such as heart rate, respiratory rate, and blood oxygenation provide information about the infant's physiologic stability. As the infant's physiologic state improves, the care shifts to maximizing intake while preventing physiologic destabilization, e.g., abnormalities in heart rate, respiratory rate, and/or blood oxygenation.

Initial nutritional support for the small PTI involves parenteral therapy. With the initiation of oral feeding bottlefeeding is usually the method of choice. This choice is based on the belief that there is less energy expenditure required of the PTI during bottlefeeding than during breastfeeding. This practice is based on clinical assumptions; there is no empirical evidence linking breastfeeding activity to an increase in energy expenditure in the PTI.

Some of the assumptions which are put forward to explain an increase in energy expenditure include length of feedings and the effect of removing the PTI from the isolette. The length of time to complete a breastfeeding is typically longer than to complete a bottlefeeding, therefore, there is an assumption that the infant has to work harder to receive milk from the breast. In addition, it is speculated that increasing the length of time that the PTI is outside of the isolette exposed to cold stress increases energy expenditure unnecessarily.

Statement Of The Problem

The study will examine the assumption that breastfeeding, in comparison to bottlefeeding, places an increased demand for energy on the PTI. The question to be researched based on this problem is: Does the method of feeding, breast versus bottle, produce a difference in the physiologic response of the PTI during the early initiation of oral feedings?

Significance To Nursing

Breastfeeding the PTI is significant for nurses because they are the primary health care professionals involved with assisting mothers with breastfeeding. Because of the practice of delaying breastfeeding, initial breastfeeding usually occurs close to the infant's discharge from the hospital. Initiating breastfeeding after prolonged bottlefeeding is met with two major obstacles, a diminished breast milk supply in the mother, and a baby who has learned a pattern of sucking that may not be compatible with breastfeeding. The infant may not be able to suck in a manner to obtain milk and/or the milk is decreased to a point that the infant's sucking efforts are not positively reinforced. Consequently, the infant may become frustrated with the change in suck pattern required and the decreased milk volume available. The frustration in the infant usually leads to crying. The nurse assisting the mother may then become anxious about the effects of the crying on the infant's stability.

Nurses have a responsibility to maintain infant equilibrium. If it is found that infants remain stable or have improved physiologic status as a result of early breastfeeding, nurses may play a key role in promoting breastfeeding opportunities. Further, it is possible that early introduction of breastfeeding may avoid some of the frustrations described.

Summary

In conclusion, the initiation of breastfeeding in the PTI is delayed because of concern about physiologic stability during feeding. However, the rationale for delaying breastfeeding because of the concern of physiologic stability is not supported empirically in the literature. This study will address the research question posed.

CHAPTER TWO

Review Of The Literature

The primary focus of care for the preterm infant (PTI) during the initial days in the neonatal intensive care unit (NICU) is on physiologic stability. Once physiologic stability is attained, the focus shifts to maximizing growth through nutritional management. Growth, according to Wennberg & Goetzman (1985), is dependent on the intake of sufficient calories over and above the requirements necessary for temperature control and physical activity. The method chosen to enhance growth must provide adequate nutrition while minimizing expenditure of energy in the PTI.

Early nutritional management of the small PTI involves parenteral therapy so that the physical demand of oral feedings and/or coordination of a suck/swallow pattern is not required. As the PTI stabilizes and matures, enteral feedings are begun using either orogastric or nasogastric tube feedings. Weight and postconceptional age are commonly used as criteria for advancing an infant from gavage feedings to "suckled" feedings. These criteria have no research-based data to correlate with the readiness of the infant to nipple feed (McCoy, Kadwoaki, Wilks, Engstrom, & Meier, 1988).

The pattern of suckled feeding is initially once a day, progressing to once every 8 hours, to every third feeding, and then to every other feeding, until all feedings are tolerated using this method. Typically, the method of suckled feeding that is initiated is bottlefeeding with the transition to breastfeeding occurring after bottlefeeding has been established and is well tolerated. This progression implies that bottlefeeding is less stressful on the PTI than breastfeeding.

This chapter will review the general physiological function of the PTI and discuss relevant literature regarding general sucking behavior of infants, physiologic response during infant feeding, and behavioral responses as they relate to feeding.

General Physiological Function In The Preterm Infant

During intrauterine life, the fetus receives oxygen from the mother via the placenta. In utero, the oxygen pressure of the blood is about 40 mmHg. This hypoxic environment is normal for the fetus and can be tolerated because anatomically the fetus is able to shunt blood with the highest concentration of oxygen directly to the brain and heart. In order for the fetus to make a successful transition to extra-uterine life, critical physiologic and anatomic changes must occur. These changes require a large increase in oxygen demand from fetal life. The increase in oxygen demand is mostly attributable to the increase in cardiovascular and respiratory work required for extrauterine life (Teitel, 1988).

During fetal life the lungs are fluid filled and constricted creating large vascular resistance in the pulmonary bed. This resistance prevents circulation of more than minimal blood flow through the pulmonary bed. Anatomically the fetal circulation is highly shunted via the ductus venosus in the liver, foramen ovale in the heart, and the ductus arteriosus in the ascending aorta. This shunting directs the majority of oxygenated blood in the combined ventricular output to the heart and brain where the highest demand for oxygen is present.

Multiple readjustments are required in the adaptation to extrauterine life. For the mature infant there is a rapid decline in pulmonary vascular resistance with lung expansion at birth. The decrease in pulmonary vascular resistance allows a rapid shift in blood flow through the pulmonary bed where exchange of gases takes place and subsequent rise in blood oxygenation occurs. Normal lung expansion and subsequent oxygenation of the blood precipitates closure of the fetal shunts in the heart. With adequate environmental support to prevent cold stress and asphyxia, these physiologic changes occur without incident in the mature infant.

The small PTI (<32 weeks), however, is compromised at birth because of its physiologic immaturity. At birth the fluid filled lungs may expand initially, but because of immaturity cannot remain expanded. Constriction of the lungs and increased pulmonary vascular resistance prevents the shift in circulation and subsequent oxygenation of the blood (Grylack, 1985). This leads to hypoxia with subsequent continuation of fetal circulation in order to prevent insult to the heart and brain.

In order to improve blood oxygenation the PTI attempts to increase oxygen consumption. Normally in the term infant an increase in oxygen consumption can be achieved through a rise in respiratory rate or the utilization of "brown fat". Establishing and maintaining a high respiratory rate is exhausting to the small PTI and quickly leads to physiologic destabilization characterized by abnormalities in respiration and heart rate. Utilization of "brown fat" is also ineffective in the small PTI since the deposition of these stores, which occurs late in gestation, is minimal.

Immaturity of the small PTI leads rapidly to physiologic destabilization. External support in the form of respiratory and cardiovascular support to prevent hypoxia, along with environmental control to prevent cold stress, are paramount to the early stabilization of the small PTI. Monitoring the physiologic responses in the PTI provides the clinician the assurance that physiologic stability is being maintained during treatment. In addition, monitoring alerts the clinician when physiologic destabilization may be occurring so that prompt therapy can be initiated to restore stability. This support is necessary to prevent unnecessary energy expenditure and/or insult to the minimal energy reserves available to the PTI.

Standard techniques used to monitor physiologic responses in the PTI include heart rate, respiratory rate, and blood oxygenation monitoring. Since hypoxia is the major cause of morbidity and mortality, stabilization of blood oxygenation is critical to the management of the PTI. Techniques which have evolved to monitor blood oxygenation will be discussed in further detail.

Blood Oxygenation Monitoring

The primary purpose of blood oxygen monitoring is to provide evaluation of hypoxemia. There are two ways of evaluating hypoxemia, oxygen pressure and oxygen saturation. Hypoxemia occurs in the PTI when arterial oxygen pressure is less than 45-50 mmHg. Maintaining an oxygen pressure of 45-50 mmHg correlates with an oxygen saturation in the blood of 90%, according to Avery (1987). Oxygen saturation is the percentage of oxygen bound to hemoglobin in the blood and therefore available to the organs and tissues.

Until recently, evaluation of arterial oxygenation required invasive procedures consisting of repeated arterial blood sampling for blood gas evaluation, either through individual arterial punctures or from an indwelling arterial line. There are major disadvantages of this technique including pain with repeated punctures, depletion of the PTIs blood supply leading to anemia, pulmonary embolism secondary to an indwelling catheter, and delay in treatment during analysis. In addition, blood gases were not able to provide warning of destabilization. Techniques for non-invasive measurement of blood oxygenation are a recent development which has virtually eliminated the need for repetitive arterial sampling for blood gases.

There are two techniques of non-invasive monitoring of blood oxygenation that will be described. They are transcutaneous oxygen pressure (tcPO2) monitoring and pulse oximetry, which is a transcutaneous measure of oxygen saturation.

The technique of tcPO2 monitoring was developed as a clinical tool in the 1970's (Huch & Huch, 1976) and has been extensively used in both clinical management and research. The technique of tcPO2 monitoring includes using a warming electrode which is applied to the infant's skin, usually on the thorax. Once in place, the electrode warms the skin increasing the blood flow to that location. The sensor in the electrode then measures the oxygen pressure transcutaneously.

The major disadvantage of tcPO2 monitoring is that a decrease in blood oxygen pressure is slow to respond to a destabilizing event. It is therefore a technique that can provide information of the infants response to a destabilizing event but is not an early warning sign. In addition, the warming electrode used for monitoring oxygen pressure requires frequent repositioning and recalibration.

Arterial oxygen saturation can also be measured in a non-invasive manner using pulse oximetry. Pulse oximetry measurement has advantages because it provides rapid information regarding changes in oxygenation, therefore being an early warning sign of destabilization. In addition, there is ease in application of the probe. The disadvantage is that during movement there may be a loss of signal causing frequent false alarms.

The technique of pulse oximetry uses an instrument probe which contains two light-emitting diodes and a photosemiconductor. The probe is taped to an extremity, usually the foot or hand of a neonate. The probe produces two wave lengths of light directed through an arterial vessel. Each pulsation causes an alteration in the amount of light absorbed based on the amount of oxygenated and non-oxygenated hemoglobin present. The higher the amount of oxygenated hemoglobin, the higher the pulse oximetry measurement and vice versa. A destabilizing event creating depletion of oxygen from hemoglobin leads to a rapid decrease in pulse oximetry measurement.

Mok, McLaughlin, Pintar, Hak, Amaro-Galvez, & Levinson, (1986) compared tcPO2 and pulse oximetry values in order to determine any significant differences between the two techniques, and to establish normative data for pulse oximetry in infants.

The sample included 55 healthy term infants with a mean birth weight of 3390 grams and a mean gestational age of 39.8 weeks. Transcutaneous oxygen pressure monitoring was done using an electrode applied to the anterior chest wall. Pulse oximetry measurements were monitored with the probe applied to the infants' palm or digit. In addition, the infants were monitored for heart rate using standard electrodes on the chest and leg, respiratory rate using abdominal impedance monitoring, and infant state using the criteria of Prechtl (1974). The infants were studied while awake, feeding, and asleep during four time periods, the first week of life, at 6 weeks, 3 months, and 6 months. The mean tcPO2's and pulse oximetry measurements were noted for each minute from which mean values were calculated for each baby. Two-tailed independent sample t-tests were used to compare differences between the two measurement tools.

Of the 19 infants studied during a feeding in the first week of life, all had a decrease in blood oxygenation at the start of the feeding in both tcPO2 and pulse oximetry measurements, 17% and 20% below baseline, respectively. This pattern persisted in infants studied at six weeks of age with tcPO2 measurements decreasing 10% and pulse oximetry measurements decreasing 16%. It was concluded from the results that the technique of pulse oximetry was more sensitive than tcPO2 for monitoring isolated events.

This study provides useful information regarding the improved sensitivity of blood oxygenation measurement using pulse oximetry. In addition, the study provides guidelines for normal oxygenation patterns during different infant states in the term newborn. Pulse oximetry is a recent advance in technology that has wide acceptance as a clinical tool but has not been used extensively for clinical research. Consequently, the studies for review have utilized tcPO2 monitoring.

In summary, continuous blood oxygen monitoring provides useful information during early physiologic management as well as during specific procedures, such as feeding. Non-invasive oxygen monitoring such as tcPO2 and pulse oximetry provides continuous information. The study by Mok, et al. (1986) demonstrated the improved sensitivity of pulse oximetry especially during isolated activities such as feeding. The studies describing sucking behavior in infants will be reviewed in the following section.

Sucking Behavior In Infants

Development of Sucking

Sucking is a primitive reflex appearing as early as 15-16 weeks gestation (Ianniruberto & Tajani, 1981; Nilsson, Ingelman-Sundberg & Wirsen, 1965). There appears to be two distinct methods of sucking, nutritive and non-nutritive, which develop in the infant. Non-nutritive sucking refers to sucking activity when an object does not provide fluid or nutrition. This method of sucking is characterized by short, rapid motions (Daniels, Devlieger, Casear, Callens & Eggermont, 1986; Dubignon & Campbell, 1969; Kaye, 1967; Wolff, 1968) and appears to have a stabilizing effect on physiologic responses, such as blood oxygenation measured by tcPO2 (Anderson, Burroughs & Measels, 1983; Burroughs, Asonye, Anderson-Shanklin & Vidyasagar, 1978; Paludetto, Robertson, Hack, Shivpuri & Martin, 1984).

Nutritive sucking is the activity used when an object is providing fluid or nutrition. This motion is characterized by an organized pattern that is about half of the rate of non-nutritive sucking (Wolff, 1968). Under controlled experiments where the volume of milk per suck is regulated, nutritive sucking has not been shown to have a negative effect on physiologic response (Ashmead, Reilly & Lipsitt, 1980; Crook, 1976; Lipsitt, Reilly, Butcher & Greenwood, 1976).

Sucking and Swallowing in Infants

The process of feeding involves coordination of sucking and swallowing. The prevailing guidelines, based on textbooks, state that a gestational age of 32-34 weeks is prerequisite for the coordination of a mature suck/swallow mechanism (Avery, 1987; Klaus & Fanaroff, 1982; Merenstein & Gardner, 1985; Pernoll, Benda, Babson & Simpson, 1986; Wennberg & Goetzman, 1985). In addition, others note that a weight requirement of 1500 grams or greater is necessary before coordination of a suck/swallow mechanism is mature (Vidyasagar & Sarnaik, 1985). However, there is no empirical data to support this contention that a gestational age or weight affects the ability of the PTI to coordinate sucking and swallowing.

Wolff (1968) first described the organization of sucking in the infant. He described and compared the sucking of 10 full term infants (FTI) and 3 PTIs. The FTIs were from mothers with an uncomplicated pregnancy, labor and delivery, and were studied on the fourth day of life. The PTIs were clinically healthy without respiratory distress or neurologic abnormalities. There is no report of any demographic information in the PTI group such as gestational age, or weight at birth, or age when studied.

Sucking pressure and frequency was measured using a suckometer. All infants were tested 3 1/2 hours after a feeding while they were awake. Description included the categorization of sucking based on nutritive and non-nutritive patterns. Nutritive sucking was described as an organized pattern of uninterrupted sequence of sucks with a slow rate (mean = 1.0 suck/second). Non-nutritive sucking was described as being organized as an alteration of bursts with a relatively fast rate (mean = 2.1 sucks/sec).

Gryboski (1969) evaluated and described suck and swallow in the PTI. Forty PTIs with birth weights between 1700 and 2500 grams and gestational ages between 32 and 39 weeks at birth were studied. The infants were studied at their first feeding and 3, 7, and 14 days later. In addition, they were studied weekly until discharged from the hospital. The study procedure was not described except to note that non-nutritive sucking was tested just before the scheduled feeding. It is assumed that the infants were then studied for an entire feeding. Sucking was measured using a suckometer device that measured sucking frequency, sucking pressure, and milk flow. Swallowing was measured using an electrode placed over the thyroid cartilage. Continuous recordings were made during a feeding using a four-channel recorder.

In general, sucking frequency varied with milk flow. Descriptions of sucking patterns were described after dividing the infants into four groups based on weight. Infants weighing 1700-1790 grams demonstrated mostly mouthing activity (noted as twitching type movements on the tracing) and made only slight sucking attempts prior to 3 days of age. The first "true sucking" consisting of short sucking bursts occurred between 3 and 10 days after the initial feeding. Swallowing was disorganized either preceding or following sucking in these infants. This pattern of random swallowing was described as disorganized.

Infants weighing 1800-1890 grams also primarily mouthed the nipple during the first 3-5 days but were demonstrating sucking bursts by 5 days of age. However, swallowing organization was delayed for 2-4 weeks. Infants weighing 1900-2090 grams demonstrated mouthing of the nipple for the first 1-3 days with short bursts noted by 3 days. Swallowing organization had developed by 2 weeks. The infants weighing 2100-2500 grams mouthed the nipple during their first feeding with sucking bursts present during the first 5 days. Ability to swallow while sucking was present at 5 days.

The findings describe two components to the sucking pattern consisting of rate and coordination with swallowing. The immature pattern was characterized by sucking bursts that were short and rapid in duration and were either preceded or followed by swallowing. The mature pattern was characterized by prolonged slower sucking bursts with swallows occurring simultaneously with sucking. It is speculated from the study results that the immature suck-swallow pattern may be protective by preventing delivery of a large amount of fluid to the small, immature stomach.

In summary, both studies describe what is known about the development of sucking and swallowing in infants. The numbers in the study are small and both studies utilized a bottlefeeding method. It is therefore difficult to generalize the information to infants who are breastfeeding. What is known about the pattern of sucking during breastfeeding will be described later in this chapter.

<u>Mechanics of nutritive sucking</u>

The majority of the literature available describes bottlefeeding behavior in infants. The studies describing sucking during breastfeeding have included full-term infants during the first week of life and the older infant. Ardran, Kemp & Lind (1958a, 1958b) utilized radiography to investigate and describe the mechanics of infant feeding during bottle and breastfeeding. In the breastfeeding study, forty-one infants ranging in age from a few days to several months old were studied. The mother's nipple and areola were thinly coated with a barium cream. Radiographic films taken during breastfeeding demonstrated that after the infant pulled the nipple into the proper position the infant alternately raised and lowered its jaw and used the tongue to express the milk from the areola into the pharyngeal cavity.

In the bottlefeeding study, Ardran, Kemp & Lind (1958b) studied a total of 35 infants between one hour and 6 months of age. The infants were fed a formula containing a barium suspension. The radiographic films demonstrated a chewing action primarily between the upper gum and the tip of the tongue which propelled the milk into the pharyngeal cavity. The primary difference noted between the two methods was the expressive action of the tongue during breastfeeding versus the chewing action used during bottlefeeding. The major limitation to these studies was that the visualization was confined to the lateral plane of the mouth, therefore limiting the description of sucking mechanics to the bony structures of the mouth.

More recently, Smith, Erenberg, Nowak & Franken, (1985) used real-time ultrasound to investigate the mechanics of sucking during breastfeeding in 16 normal infants. Ultrasonography is a non-invasive technique, which was used to directly visualize the areola and nipple within the infant's mouth during feeding. It is superior to radiography for two reasons. It improves the visualization of the soft tissues in the mouth and eliminates unnecessary exposure of the mother and infant to radiation. At the time of testing, the infants were between 60-120 days old. They were studied during active breastfeeding and had not been fed for approximately three hours. Each infant was studied using three projections; the horizontal transbuccal plane (probe placed at a 90 degree angle to one cheek), the transverse submental plan (probe placed laterally under the chin at a 90 degree angle to the trachea), and the longitudinal submental plane (probe placed at a 90 degree angle to the inferior side of the chin). Ultrasound images were videotaped for the length of a breastfeeding. The motion of sucking was deduced by analyzing the videotapes frame by frame.

The pattern of sucking was consistent in all the infants studied. The analysis highlighted the role of the tongue and buccal surfaces of the infants' mouth during breastfeeding. This data demonstrated that the tongue and buccal surfaces provide the seal, compression, and peristaltic action used to express milk from the areola. In conclusion, the data confirmed the earlier work by Ardran, et al. (1958) that the tongue plays a major role in sucking during breastfeeding.

Weber, Woolridge & Baum (1986) also investigated sucking mechanics using ultrasound. The scans were recorded during bottle and breastfeeding in 12 infants, 6 were bottlefed and 6 were breastfed. Each baby was studied only once between days 2-6 of life. Scanning began after the feed was initiated with the scanhead positioned midline in the sagittal plane from the submental aspect. (In other words, under the chin). In addition, all respirations were recorded using an apnea monitor with a pneumobelt around the infant's abdomen. Neither the length of the recordings nor how long into the feeding that recording began is stated.

Analysis of the recordings was done in two different ways. The first approach was to print still pictures approximately every 3 frames. This provided a series of pictures depicting the movements. This method was used to describe the internal anatomy of the babys mouth during all aspects of feeding. The second approach traced the breathing signal over a 15 second period then reviewed the video frame-by-frame making note of events such as swallowing or changes in the nipple on the breathing tracing. This approach provided a "simultaneous" picture of the anatomical and physiological changes occurring during feeding.

Differences in the mechanics of sucking between breast and bottlefeeding were observed. Anatomically, the tongue action during breastfeeding was described as peristaltic compared to a piston-like action with bottlefeeding. Using the second analytic approach, it was found that all infants, regardless of method of feeding, interrupted breathing during swallowing. Findings also showed that sucking and breathing seemed to be uncoordinated in the 2-3 day old baby with improvement in infants 4-5 days old.

In summary, the mechanics of nutritive sucking have been deduced by studying infants during bottle and breastfeeding using radiography and more recently ultrasonography. The first three studies reviewed are limited because they describe sucking mechanics of healthy older infants with established sucking patterns. The study of Weber, et al. (1986) does describe the mechanics of sucking in healthy full-term infants initiating feeding. However, these descriptions may not be applicable to the PTI during the initiation of feeding.

Energy Requirements of Nutritive Sucking

Little information is available which describes the energy requirements involved during nutritive sucking. One of the reasons probably stems from the complexity involved with measuring total energy expenditure in humans. Consequently, there are assumptions made using physiological measurements which may not reflect accurate information in the PTI. For example, in the following study reviewed, it was assumed that the mechanical efficiency of the buccal muscles is 100% and that the respiratory quotient was 0.82. These assumptions are standard terms used in the calculation of energy expenditure in the term newborn but may differ significantly in the PTI.

Jain, Sivieri, Abbasi & Bhutani (1987) studied both FTIs and PTIs to develop a technique for quantifying the mechanics and energy requirements of sucking. Eighteen infants were divided into two groups of 9 infants each, based on gestational age. The FTIs had a mean gestational age at birth of 38.6 weeks. At the beginning of the study, their mean age was 18.4

days with a mean weight of 2890 grams, and they had been fed for a mean of 10.3 days prior to the study. The PTIs had a mean gestational age at birth of 35.2 weeks. At the beginning of the study the mean age of the PTIs was 21.9 days with a mean weight of 1990 grams and they had been fed for a mean of 11.7 days prior to the study.

All infants were bottlefed using a special nipple which measured sucking pressure, volume, and flow during feeding. Each infant was held in a cradled position by the examiner or the mother and offered 60 cc for a maximum duration of 30 minutes. An assistant continuously adjusted the position of the reservoir during feeding to prevent gravity from affecting the flow of milk. Data regarding sucking pressure, flow, & volume were measured via pressure transducers and recorded using a four-channel recorder. Work done by the infant was then calculated per individual suck as the product of the pressure and flow. Data from PTIs and FTIs was compared using unpaired t-tests. Linear regression analysis was performed to describe the interrelationship between the volume ingested and work expended between FTIs and PTIs. Analysis of the data revealed that the FTIs had a higher frequency of sucking response or sucking rate, attained greater peak negative pressure, and obtained a greater peak flow ($p<.01$). The work done per suck was also significantly higher in the FTIs ($p<.01$). In other words, the volume of formula and the work done with each suck was significantly higher for FTIs than for PTIs. Even though the assumptions used for calculations may not be accurate for the PTI, the energy requirement was calculated similarly on sucking pressure generated and flow delivered per individual suck.

The data suggests that the PTI expends significantly less energy to suck the same volume from a bottle than does the FTI. The results of this study seem contradictory to logical thinking. However, it may be that the FTI is "overactive" in his or her sucking in order to provide adequate stimulation required to initiate lactation physiologically. Whereas, the PTI recognizing his or her own low reserves will suckle milk if available, but will not overexert at the expense of reserves.

<u>Summary of Infant Sucking Behavior</u>

Sucking is a primitive reflex which differentiates into non-nutritive and nutritive after birth. The process of feeding includes the coordination of sucking and swallowing which appears to mature quickly in the FTI and mature more slowly in the PTI. The studies describing the coordination of sucking and swallowing were done using bottlefeeding and therefore have limited use for the breastfeeding infant.

The mechanics of sucking are described in the healthy, mature infant with good coordination of sucking and swallowing. There are differences noted between the mechanics of breastfeeding and bottlefeeding. These differences apply anatomically with reference to the tongue and soft tissues of the mouth. One study was reviewed which made a crude calculation of work done by infants during bottlefeeding. The findings suggest that the PTI expends significantly less energy to suck the same volume as the FTI during bottlefeeding. The applicability of this data from bottlefeeding to breastfeeding is questionable because the accessibility to milk flow may be very different during breastfeeding. The studies reviewing physiologic stability with feeding will be discussed in the following section.

Physiologic Stability of the Infant During Feeding

Feeding Behavior of the Preterm Infant

Initiation of suckled feeding in the PTI is delayed until there is evidence that the infant can tolerate feedings by the gavage method. At that point bottlefeeding is traditionally begun with breastfeeding being delayed until the infant is tolerating bottlefeeding completely. There have been few reports, other than anecdotal, about early breastfeeding in the PTI. The following is a review of research which describes the ability of the PTI to breastfeed.

Pearce & Buchanan (1979) described management of 17 PTIs less than 1500 grams with breastfeeding. The PTIs studied were consecutive admissions to the NICU with a mean birth weight of 1272 grams (range 750-1500 grams). Breastfeeding was initiated when sucking movements were noted, regardless of gestational age or weight. There was no definition of sucking movements offered and feeding protocols were not described. It was reported that 12 of the PTIs began breastfeeding at a mean weight of 1324 grams and a mean age of 11 days. In addition, 10 of the 12 infants were fully breastfed by a mean weight of 1600 grams and a mean age of 27 days. It was speculated that success with breastfeeding in this sample was due to the maintenance of the mothers milk supply and the fact that the breastfed babies were never bottlefed.

Meier & Pugh (1985) described breastfeeding behavior of three mother-infant pairs with small PTIs (<32 weeks at the time of the initial oral feed). The study posed four research questions: Do small PTIs demonstrate the ability to breastfeed as soon as they coordinate sucking and swallowing mechanisms, independent of weight; how does breastfeeding behavior differ from bottlefeeding behavior; how does an infant's breastfeeding behavior change over time; and, which maternal and infant characteristics influence feeding behavior.

The infants included in the study had to be less than 1500 grams at the time of the initial feeding without structural or functional defects, and their mothers had to have indicated a desire to breastfeed and a willingness to initiate lactation. The study began when bottlefeeding was started, with the first breastfeeding following within three days of the initial bottlefeeding. From that point the method of feeding was alternated between breastfeeding and bottlefeeding. In this fashion each infant served as its own control for breast and bottlefeeding.

Study sessions included an entire feeding and were videotaped. Study sessions included two bottlefeedings and two breastfeedings per week and were performed from the time of the initial feeding through infant discharge. The principal investigator administered all videotaped bottlefeedings when the mother was not available. The reason given for this method was to allow the mother the time when visiting to breastfeed her infant. All bottlefeedings consisted of expressed breast milk from the infant's mother.

Both individual and comparative analysis of videorecordings were completed. During individual analysis, each tape was reviewed in order to develop a qualitative description of feeding behavior for the infant. Initially all three infants required repeated assistance in order to "latch-on" to the breast. The need for assistance decreased over time as mothers and babies gained experience. The major difference found between bottlefeeding and breastfeeding was the length of time of the feeding sessions, with 10-15 minutes taken for bottlefeeding and 45 minutes or longer taken for breastfeeding. From the initial breastfeedings it was observed that all infants engaged in nutritive and non-nutritive sucking. Nutritive sucking was characterized by short bursts with "relatively lengthy resting periods". There were no periods of distress exhibited during breastfeeding such as gagging, cyanosis, tachypnea, etc. During bottlefeedings, infants failed to seal around the nipple adequately and demonstrated an increase in burping and gagging behavior not seen with breastfeeding.

Longitudinal changes were also noted. Sucking rhythm for breastfeeding improved with bursts increasing in length as the infants matured. In addition, the infants progressed to taking both breasts during a feeding session. In comparison, as the infants grew, the time between sucking bursts or pause time decreased during bottlefeedings.

All four research questions were able to be answered from the data gathered. In response to the question, do small PTIs demonstrate the ability to breastfeed as soon as they coordinate sucking and swallowing mechanisms independent of weight, it was observed that ability to breastfeed was independent of weight in the study sample. In response to the question, how does breastfeeding behavior differ from bottlefeeding behavior, it was observed that during breastfeeding the infant engaged in both non-nutritive and nutritive sucking, and demonstrated sucking bursts and rests without any clinical signs of distress. In comparison, it was noted that infants burped and gagged more, and required more interruptions in feeding during bottlefeeding sessions.

In response to the question, how does an infant's breastfeeding behavior change over time, observations demonstrated that breastfeeding behavior was more infant paced than bottlefeeding, and sucking rhythm became more efficient as the infant matured. Finally, in response to the question, which maternal and infant characteristics influence feeding behavior, it was noted that the infant's state affected feeding, with feeding ability improved when the infant was alert at the initiation of the feeding.

From these observations it was concluded that PTIs are capable of breastfeeding at less than 1500 grams and that the infants in the study were able to organize sucking and swallowing more effectively during breastfeeding than during bottlefeeding. It was commented that an alert infant state seemed to be associated with improved ability to breastfeed. It was therefore recommended that the PTI be allowed to feed more on demand than on schedule.

Physiologic Responses During Infant Feeding

Physiologic responses, such as blood oxygenation, heart rate, and respiratory rate have been measured in relation to both non-nutritive and nutritive sucking. Generalizations are difficult to make because of the wide variety of methodologies used; small samples that included both term and preterm, sick and healthy infants; and the variation in the type of feeding used. However, review of these studies do provide a description of what is known about physiologic responses of infants during sucking. This study will focus on the physiologic response of blood oxygenation. Therefore a review of the studies which measure blood oxygenation response during sucking and feeding will be discussed.

Infant Sucking and Blood Oxygenation

Studies will be reviewed that investigate the effects of sucking on blood oxygenation using tcPO2 monitoring. Two studies focus on tcPO2 response during non-nutritive sucking and two on tcPO2 response during nutritive sucking. None of the literature reviewed utilized pulse oximetry monitoring as a measurement tool during non-nutritive sucking or nutritive sucking clinical trials.

Paludetto, et al. (1984) studied the effect of non-nutritive sucking on tcPO2, heart rate and respiratory rate in a group of healthy, sleeping PTIs at varying postconceptional ages. Fourteen infants were studied with a mean gestational age at birth of 29 weeks, and a mean birth weight of 1070 grams. The infants were studied from one to three times at two week intervals until discharge from the study hospital. All infants were studied in their isolettes or cribs while supine. The experiment lasted for 15 minutes, divided into three, five minute periods. The first period was pre-non-nutritive sucking, the second was non-nutritive sucking, and the third was post-non-nutritive sucking.

The study also observed and recorded infant behavioral states in order to identify changes in physiologic response which might be attributable to the behavioral state rather than the non-nutritive sucking treatment. Determination of infant sleep states, specifically active and quiet sleep, were done using definitions developed by Parmelee & Stern (1972). Active sleep was defined as a "combination of rapid eye movements visible under closed eyelids, frequent twitches of the face and extremities, and irregular respiration. Quiet sleep was defined by a combination of closed eyes without eye or body movements apart from occasional startles, and regular respiration" (Paludetto, et al. 1984). The observed sleep pattern was recorded for each one minute segment throughout the 15 minute study period in order to identify changes in infant state. Behavioral state was compared based on mean time spent in active sleep. A preterm pacifier, adapted to measure sucking pressure, was used for non-nutritive sucking. Oxygen pressure was monitored continuously using a transcutaneous electrode as described earlier in the chapter. Heart rate was monitored using chest and leg electrodes, and respiratory rate was determined using a nasal airflow sensor. All of the measures were recorded on a four channel recorder.

For analysis individual values for tcPO2 and heart rate were selected at 30 second intervals and respiratory rate was calculated based on the number of breaths which preceded the chosen value for tcPO2 and heart rate. Analysis of this data was done using two-tailed paired t-tests on 25 sets of measurements in 14 infants.

Results showed no differences in the mean amount of time spent in active sleep between the pre-non-nutritive sucking, non-nutritive sucking, or post-non-nutritive sucking periods. Respiratory rate did not change during the non-nutritive sucking period. During non-nutritive sucking, tcPO2 showed small but statistically significant increases for infants 32-33 weeks ($p<.01$) and 34-35 weeks ($p<.05$), with no significant changes noted for infants 36-37 or 38-39 weeks. Heart rate increased for all groups during non-nutritive sucking, but the increase was only statistically significant at 34-35 weeks ($p<.01$) and 36-37 weeks ($p<.02$). The rise in tcPO2 could not be explained by a change in respiratory rate, therefore the reason for improved oxygenation with non-nutritive sucking is unclear.

It is speculated that possible activation of muscles in the alae nasi of the nose during non-nutritive sucking may decrease upper airway resistance and therefore improve air flow without changing respiratory rate. The conclusions report a statistically significant rise for both tcPO2 and heart rate during non-nutritive sucking, however, the changes are so small that there is questionable clinical relevance. Limitations of the study include the fact that the infants were tested during sleep states rather than during alert periods and the small number of infants that were tested.

Burroughs, et al. (1978) studied the effect of non-nutritive sucking on tcPO2 in 11 preterm infants. The infants had a mean birth weight of 1594 grams, and a mean gestational age at birth of 31 weeks. Characteristics of the infants studied included 6 girls and 5 boys; all but one infant was appropriate for gestational age; four were on assisted ventilation at the time of the study and 6 were on room air. The infants were studied 1-3 times for a total of 26 sets of observations. All infants were studied during a pretreatment, treatment, and posttreatment period.

The measurement tools used during the study included a tcPO2 monitor, an electric suckometer, and an activity scale. The tcPO2 monitor recorded measures continuously using a standard tcPO2 electrode attached to the infant's skin. The electric suckometer measured the suction and expression pressures exerted by the infant's mouth during sucking. The activity scale was adapted by Anderson from one developed by Parmelee, Koop, & Sigman (1976). The scale ranges from 0-12 with quiet sleep states at the low end of the scale and extreme agitation states at the high end. The scale will be more fully described in the discussion of infant state.

A pretest-posttest design with three, eight minute observation periods was used. All the infants studied were being monitored for tcPO2 as part of their clinical management. Each infant was supine in its incubator or warmer during the study period. Pretreatment included eight minutes of continuous tcPO2 monitoring for baseline data. The eight-minute treatment period involved insertion of the nipple of the suckometer into the infant's mouth for the sucking opportunity. The posttreatment period of eight minutes began when the nipple was removed from the infant's mouth. Infant activity was observed and scores were assigned based on the first 20 seconds of each minute during the study time. Data collection was stopped if the infant was crying at anytime during the pretreatment period. Otherwise, the study periods were comparable for all infants.

The tcPO2 data was subjected to analysis of variance (ANOVA) for pre-treatment, treatment, and posttreatment periods. The results were significant at the $p<.01$ level indicating that sucking changed the oxygenation status of the PTIs. The data demonstrated an increase in tcPO2 during the sucking period which continued to increase in the posttreatment period. Further analysis was done after subdividing the subjects into those infants on assisted ventilation and those on room air. The ANOVA of tcPO2 levels in infants on room air was not statistically significant, whereas the ANOVA of the tcPO2 levels in infants on assisted ventilation was statistically significant ($p<.01$).

It was concluded that the noncrying PTIs studied were able to maintain or increase their tcPO2 levels during and after non-nutritive sucking opportunities. There is speculation made that sucking may serve as a trigger mechanism to enhance physiological response.

Shivpuri, Martin, Carlo & Fanaroff (1983) determined the effect of nipple feeding on ventilation and transcutaneous oxygen pressure in healthy PTIs. Ventilation was calculated from the measured values of respiratory rate and tidal volume. The sample consisted of 23 PTIs with mean birth weights of 1700 grams and a mean gestational age of 32.3 weeks at birth. The infants were studied at a mean postnatal age of 23 days. All infants were taking part or all of their caloric intake via nipple feeding and were awake during the study. The infants were divided into two groups depending on the postconceptional age at the time of the study: Group A was 34-35.9 weeks (n=12), and Group B was 36-38 weeks (n=11). Tidal volume and respiratory rate was measured using a nasal mask, and oxygen pressure was continuously measured by tcPO2 electrode. Feeding was done with a special nipple designed to measure sucking pressure and allow milk flow.

The study consisted of two control periods of two minutes each. In the control periods the infant was initially supine and then held in a semi-upright position for feeding. All infants were fed artificial formula through the special nipple. After the feeding, the nipple was removed and control data was again collected in a semi-upright position and then a supine position for 2 minute periods. All information was recorded using a polygraph. Data within each group of infants was analyzed using the two-tailed paired t-test, and an unpaired t-test was performed for comparison between the groups.

The results indicated stable respiratory rate when the infant was moved from the supine to the semi-upright position. A decrease in respiratory rate in all infants occurred during the initial burst of continuous sucking when compared to the semi-upright control period. The decrease was 52% in group A and 40% in group B. The fall in respiratory rate during continuous sucking occurred because of a decrease in both the tidal volume and respiratory rate. Transcutaneous oxygen pressure increased significantly when both groups were moved from supine to semi-upright positions during the pre-sucking control period. With the initial burst of continuous sucking the tcPO2's fell. There was subsequent recovery of tcPO2 during intermittent sucking in group B, but remained significantly lower in group A.

The results demonstrate that both respiratory rate and oxygenation are decreased during normal feeding in the preterm infant. The data indicated the effects are less severe in the older PTI. It is speculated that the reason for the decrease in respiratory rate and oxygenation is secondary to swallowing, which decreases the frequency of respiratory rate and length of inspiratory time.

Finally, Meier (1988) studied the effects of breastfeeding and bottlefeeding on transcutaneous oxygen pressure and temperature in the PTI. The purpose of the study was to compare the effects of bottle feeding and breastfeeding on tcPO2 and temperature in the small PTI. The study used a longitudinal design that followed five infants from the beginning of their oral feedings until discharge from the hospital for a total of 71 feedings (32 bottlefeeds and 39 breastfeeds).

Informed consent was acquired from the mothers as soon as possible following admission of the PTI to the NICU. Breastfeeding counseling that included techniques for milk expression, was done by the investigator and the hospital nursing staff. The decision to introduce oral feedings was made jointly by the investigator, primary nurse, and neonatologist, and was based on an individual infant's sucking ability. Sucking ability was evaluated while the infant received at least a portion of one bottlefeeding. The ability to bottlefeed without difficulty was not a prerequisite to beginning breastfeeding. Breastfeeding was initiated within 2 days of the first bottle feeding in all cases. There is no report of the total number of bottlefeedings received prior to the first breastfeeding.

Prior to feeding, the PTIs were dressed in one-piece sleepers and stockinette caps, wrapped in two receiving blankets, and transported in a bassinet to an adjacent data collection room. The tcPO2 electrode and temperature probe were applied at that time. The measurements were made twice weekly for both bottlefeeding and breastfeeding and included recordings of a ten-minute pre-feed baseline, the feeding period, and a ten-minute post-feed period. Infants were breastfed by their mothers and bottle fed by the investigator using expressed mothers milk. Bottlefeedings were ended when the prescribed amount of milk was ingested or when sucking ceased prior to ingesting the prescribed volume. Breastfeeding ended when sucking ceased.

Differences in tcPO2 patterns were analyzed qualitatively and quantitatively. Quantitative analysis using repeated measures ANOVA focused on differences at selected time points during the bottlefeeding and breastfeeding sessions.

Qualitatively, tcPO2 patterns differed between bottlefeedings and breastfeedings. The typical tcPO2 pattern during bottlefeeding showed a decline during periods of milk intake returning to or near baseline as sucking ceased, a period of plateau at or near baseline while the infant rested or burped, and a gradual decline between the end of feeding and 10 minutes post feed. This pattern became more pronounced as the infants matured.

During breastfeeding transcutaneous oxygen pressure fluctuated about the baseline. The lowest levels were evident during repositioning and burping. This is in contrast to bottlefeeding sessions in which the lowest tcPO2 was always recorded during sucking. There was no observable pattern of decline during breastfeeding between the pre-feed and post-feed measurements. Longitudinally, the cyclic patterns visible in early breastfeeding sessions became less variable over time as the infants matured.

Quantitative analysis of tcPO2 revealed a significant interaction ($p<.001$) between feeding method and tcPO2 change at pre-feed, feeding, and post-feed periods. The a posteriori difference in mean tcPO2 between feeding data and post-feed data was significant (p<.001) as tcPO2 continued to decline following bottlefeeding, but increased following breastfeeding. The a posteriori difference between pre-feed data and post-feed data was not significant.

Temperature patterns differed in the same infants depending on whether they were breastfed or bottlefed. Maximal temperature change was calculated by subtracting the pre-feed temperature from the most extreme temperature for each feeding session. Temperature change was +.20°C for bottlefeeding and +.49°C for breastfeeding ($p<.001$). In other words, the temperature in infants rose significantly during breastfeeding.

It was concluded that breastfeeding did not negatively affect physiologic response when compared to results obtained during bottlefeeding. A major limitation of the study was the fact that there was no measurement of the amount of milk taken by the infant during breastfeeding. Since the non-nutritive sucking data has demonstrated an increase in tcPO2 levels, the measurement of intake during breastfeeding is important in order to document nutritive sucking. Without the documentation of nutritional intake by the infant, critics could argue that the physiologic response during breastfeeding occurred because the method of sucking was non-nutritive rather than nutritive. Even with this limitation, the study provides the first empirical data to question the rationale for the clinical practice of restricting breastfeeding based on physiologic concerns.

Summary of Physiologic Stability of the Infant During Feeding

Physiologic response in the infant varies with the type of sucking performed. The two studies of non-nutritive sucking report improvement in physiologic response during treatment. The studies of nutritive sucking have conflicting results. The Shivpuri study reports a decrease in both respiratory rate and tcPO2 during bottlefeeding, whereas the Meier study reports a stabilization of blood oxygenation levels during breastfeeding when compared with bottlefeeding. It is difficult to compare the two studies since the methodologies are so different. Most of these studies suggest that the behavioral state of the infant has an effect on its physiologic response. Yet none of them attempted to collect information on behavioral state systematically. The concept of behavioral state will be more thoroughly reviewed in the following section.

Behavioral Responses

Infants have a variety of responses to their environment. The autonomic nervous system mediates the infant's behavioral responses just as it regulates the many physiologic responses (Gorski, Lewkowicz & Huntington, 1987). Behavioral responses or states have been systematically studied for several decades (Aylward, 1981; Michaelis, Parmelee, Stern & Haber, 1972; Parmelee, Wenner, Akiyama, Schultz & Stern, 1967; Prechtl, 1974; Stern, Parmelee, Akiyama, Schultz, & Wenner, 1969; and Wolff, 1959). Behavioral states reflect the level of arousal in the infant and appear to have a predictable pattern in the healthy, neurologically intact infant (Aylward, 1981). A number of studies have noted that an infant's response to stimulation may differ dramatically depending on his or her state. Therefore it is critical to understand infant states and the role they may play in physiologic responses.

The development of behavioral state descriptions began with two distinct patterns of sleep identified by Wolff (1959). Prechtl (1964) expanded Wolff's categorization into five states based on open or closed eyes, regularity of respirations, movements, and vocalization. Parmelee, et al. (1967) and Stern, et al. (1969) developed further criteria for sleep states and began to describe differences between term and preterm infants. The development of these behavioral state classifications were based on naturalistic observation of infants rather than as a response to manipulation. A major limitation of the early research was the neglect of behavioral states other than sleep.

Parmelee, et al. (1967) made observations and recordings of PTIs and FTIs during sleep. There is no report of the number of infants studied. The FTIs were recorded at 2-4 days of age and the PTIs at 1-2 weeks after birth and then every two weeks until their expected date of delivery. Three hour observation/recording periods were made between feedings from 8:00 pm to 12 midnight. Measurements of eye movements, heart rate, respiratory rate, chin electromyogram, and electroencephalogram were recorded using a 16 channel recorder. Observations were made of movement of the face, limbs or body, and eye movements under closed lids.

The results demonstrated two types of sleep, quiet and active. The greatest amount of active sleep was found in the PTIs with the youngest gestational ages. Quiet sleep gradually increased with maturation so that at their expected delivery date the amount of active sleep was comparable to the infants born at term. It was concluded that the concept of active sleep is primitive and researchers speculate that this is due to an immature central nervous system since it decreased with age.

Stern, et al. (1969) studied term and PTIs to document the duration and variability of the sleep cycle and to describe its component parts. The FTI recordings were obtained in the first week of life and PTI recordings were obtained around the expected date of delivery. Each 20 second period was classified into awake, active sleep, quiet sleep, or transitional sleep. Results showed that the length of the sleep cycle increased with age. In addition, the length of quiet sleep increased with age while the length of active sleep decreased in length. Full-term infants and PTIs differed in the length of quiet sleep at term ($p<.05$). These two studies not only recognized that different states exist during sleep but also identified differences in FTI and PTI abilities based on postconceptional age. The major limitation of these studies was the fact that they neglected behavioral states other than sleep.

Michaelis, et al. (1972) studied activity states in the PTI and FTI in the first few days of life. They developed a state scale with 10 levels in order to study infant behavior. The sample included a total of 21 infants, 7 PTIs born at 27-30 weeks, and 14 infants born at term. The PTIs were studied three times at 31-32 weeks, 34-36 weeks, and 38-42 weeks postconceptional age. The FTIs were studied once at 2-4 days of age. The study involved recording the activity state of infants repeatedly during the performance of a standard neurological exam. State was recorded 37 times during the examination using the 10 point scale, with 0-4 indicating sleep states, 5-6 quiet awake, 7-8 active awake, and 9 crying. The reliability and validity of the scale is not described.

The results indicated that the more immature the infants, the lower their activity state. With maturation, sleep scores decreased, quiet awake state changed little, active awake state decreased, and the amount of crying increased significantly ($p<.05$). There were also significant differences found between PTIs tested at 38-42 weeks postconceptional age and FTIs tested at term. Term infants had decreased sleep scores and increased crying scores ($p<.01$) when compared to the PTIs tested at 38-42 weeks postconceptional age. The results further indicated that the stimulation of handling during the exam quickly shifted the older infants from sleep to active awake or crying states. The more immature infants tended to have lower scores throughout the exam indicating that their response was generally lower. It was concluded that the PTI does not rise to and sustain as high a level of activity state at 38-42 weeks postconceptional age as infants born at term. It was speculated that the lower response of PTIs is indicative of their immaturity, and that the PTIs ability to maintain the quiet and active alert states may be more protective of limited reserves than the FTI who gets excessively irritable.

Finally, Gill, Behnke, Conlon, McNeely & Anderson (1984) investigated the behavior of infants during crying periods. Until their investigation, the crying state included any vocalization. The purpose of the study was to determine the time and behavior between the first oral cue and the first sustained cry. The sample consisted of 15 normal newborns of mothers with uncomplicated pregnancy, labor and delivery. The mean birth weight was 3258.7 grams and the mean gestational age at birth was 39.3 weeks. The procedure involved observing the infants upon admission to the nursery. Each infant was placed supine in a crib under a warming unit. Two instruments were used: the Senders, Signals, and Receivers System (SSR) and the Cry Scale. The SSR is a general method of encoding data in real time for subsequent high-speed transcription by computer. Inter-rater reliability reported a total percentage of agreement of 89%. The Cry Scale defines 5 levels of crying based on 5 categories of behavior. Data collection began when the first oral cue was observed and continued until the infant reached a sustained cry. The original definition of a sustained cry was that it lasted for one minute. The SSR encoded 19 observed behaviors in infants during the time period investigated.

The results demonstrated that the first oral cue for 6 of the infants was hand-to-mouth movement, for 5 infants - hand-passing-mouth, for 2 infants - intrinsic mouthing, and for 2 infants - tonguing. The mean time from first oral cue to first sustained cry was 30.9 minutes. In addition, the data showed that the longest period of continuous crying was 39.6 seconds with the mean for the 15 infants being 24.7 seconds. Adjustment of the original definition of sustained cry was necessary because none of the infants met the original criteria of one minute. It was concluded that the major finding was the short duration of the first cry and further speculated that circulatory immaturity was probably the reason for the shortened crying period.

Summary of Behavioral Responses

Measurement of behavioral responses in newborns has been developed over decades. The studies reviewed describe behavioral states exhibited in both the FTI and PTI. The works of Brazelton and Als' were briefly reviewed and determined not to be pertinent to this study. The Brazelton literature describes a technique of infant assessment while the examiner interacts with the infant (Brazelton, 1984). There is a primary focus on infant response during neurological examination and the recognition of the infant's ability to organize and reorganize his or her behavior during stimulation.

Als, Lester, Tronick, & Brazelton (1984) focused on the stable PTI and the development of a behavioral assessment to evaluate organization capacity. Both of these assessments are designed to elicit behavioral capabilities of infants. The focus of this study will be on identification of the observed state without stimulation so that the influence of behavioral state, if any, can be described.

Behavioral states may be important indicators of readiness for activities in infants, such as feeding. In addition, the physiologic responses of infants may be affected by their behavioral state. According to Aylward (1981) PTIs were slower to change states even with stimulation and therefore, may need less stimulation in order to achieve a state of readiness needed for feeding.

Chapter Summary

This chapter has reviewed the literature pertaining to general physiological function in the PTI, general sucking behavior of infants, physiologic response during infant feeding, and the utilization of behavioral state assessment in order to evaluate the level of arousal in the infant.

Techniques of noninvasive blood oxygen monitoring were reviewed with comparisons of transcutaneous oxygen pressure and pulse oximetry measurements (Mok, et al. 1986). Studies demonstrating the stabilizing effect of non-nutritive sucking on tcPO2 were described. Reports of studies measuring tcPO2 during nutritive sucking demonstrate varied results. In both the feeding studies (Shivpuri, et al. 1983; Meier, 1988), tcPO2 was found to decrease from baseline when infants were bottlefeeding. In contrast, the decrease from baseline of tcPO2's during breastfeeding was not significant.

Systematic studies rather than anecdotal notes describing the ability of the PTI to breastfeed are beginning to appear in the literature. In addition, studies have been completed that measure the physiologic response of the PTI during breast and bottlefeedings. The results have given initial empirical evidence to question the clinical practice of delaying breastfeeding, based on physiologic concerns, until bottlefeeding is well tolerated. Involved in the physiologic response of infants during feeding is the infant's behavioral state or state of readiness. Behavioral response in infants have been systematically studied for decades. The review describes behavioral states exhibited in both fullterm and preterm infants and discusses the observations of infants and the subsequent development of a method to assess infant state.

The following chapter will develop a framework to be used as a basis for studying the physiologic response of the PTI during the early initiation of breastfeeding and bottlefeeding. The framework will be developed from descriptive and empirical studies in the literature, as well as experiential observations made as a clinician.

CHAPTER THREE

Conceptual Framework

The assumption that bottlefeeding requires less work than breastfeeding is not supported with empirical evidence. In fact, recent evidence by Meier (1985), and Meier & Anderson, (1987) demonstrates clinical physiologic stability during breastfeeding in the small PTI. This chapter will propose a conceptual framework for investigating the physiologic response of the PTI during the early initiation of breastfeeding and bottlefeeding.

The theory chosen to guide this study is based on a physiologic framework. Human physiology is the study of the physical and chemical function in the human being (Guyton, 1986). An underlying principle of human physiology is that physiologic stability is maintained and optimal growth and development occurs when energy expenditure does not exceed energy reserves. Physiologic destabilization may be a response to increased energy expenditure, and/or decreased energy reserves.

The concepts of energy expenditure and energy reserve will be described as they relate to physiologic stability in the PTI. Activities that impact these concepts will be discussed in order to develop a framework for study. Assumptions inherent in the study will be identified, operational definitions of terms will be included, and a hypothesis will be proposed.

Energy Expenditure

Energy expenditure is the amount of work required to perform an activity. Activity can be voluntary, such as feeding, or involuntary, such as breathing. The amount of energy expended varies according to the physiologic maturity of the infant. Premature infants are at higher risk for physiologic instability because of their immaturity. The major insults to the PTI are hypoxia and cold stress.

Hypoxic insult is common in the PTI whose lungs are immature. The lungs of the preterm infant lack surfactant, a substance which is needed to maintain normal expansion of the lungs after birth. In the absence of surfactant the lungs do not expand normally and therefore oxygenation of the blood is compromised. Hypoxemia (low oxygen in the blood) triggers an increase in respiratory rate in an effort to increase oxygenation of the blood. The increase in respiratory rate requires a subsequent increase in energy expenditure.

The PTI is also at risk for cold stress. Their lack of fat, which can serve as insulation, and decrease in skin thickness allows for increase in heat loss. In addition, because of poor muscle tone the PTI maintains its extremities in an extended position which provides a larger surface area exposed and therefore increases the risk for heat loss with resulting hypothermia (decreased temperature). A decrease in temperature stimulates an increase in metabolic rate in an attempt to correct the hypothermia. This increase in metabolic rate requires additional energy expenditure.

For the PTI, external support is necessary to minimize energy expenditure so that physiologic stability can be established and maintained. Physiologic support with warmth and oxygen reduces the need for the infant to increase its own metabolic rate. Without external support, correction of the physiologic destabilization caused by cold stress and hypoxia is difficult for the PTI. Because of the immaturity of the respiratory system, oxygenation cannot be increased efficiently. Attempts by the PTI to increase respiratory rate require increases in energy expenditure leading to physiologic destabilization. Therefore, providing environmental warmth to prevent cold stress and oxygen if necessary to prevent hypoxia, can reduce energy expenditure and promote physiologic stability.

Total energy expenditure is a concept which can be measured accurately in a laboratory setting, but has limited clinical application due to the very complex and cumbersome techniques required. There are, however, indicators of physiologic function that provide a clinical measure of energy expenditure and are used for clinical research. Physiologic responses of heart rate, respiratory rate, and blood oxygenation in the normal range indicate clinical physiologic stability and imply that the energy expenditure is minimal. Physiologic responses which deviate from the normal range indicate physiologic destabilization and imply that the required energy expenditure is excessive.

Physiologic destabilization is reflected clinically by a decrease in blood oxygenation with subsequent abnormalities in both heart rate and respiratory rate. The normal range for heart rate and respiratory rate in the PTI is 100-150 beats per minute, and 35-60 respirations per minute, respectively (Korones, 1986). In the PTI, blood oxygenation is an important measure of physiologic stability. Current technology allows non-invasive measurement of blood oxygenation. One method measures the partial pressure of oxygen or oxygen tension (pO2) with normal values in the PTI ranging from approximately 50-70 mmHg (Avery, 1987). A decrease in the partial pressure of oxygen is a reflection of the extent of physiologic destabilization that has already occurred. In other words, a decrease in pO2 occurs subsequent to the destabilizing event.

A second method used to monitor blood oxygenation is oxygen saturation with a normal value in the PTI ranging from 90-100%. Oxygen saturation is a measure of the percentage of blood which is saturated with oxygen. When there is an increased energy demand, oxygen is liberated from the blood to the tissues therefore decreasing the blood oxygen saturation rapidly. A decrease in oxygen saturation occurs simultaneously with a destabilizing event and therefore, is an early indicator of physiologic destabilization.

A basic principle guiding neonatal care is to establish and maintain physiologic stability by minimizing energy expenditure. Once the initial problem of physiologic stability is controlled the focus of support and management turns to improving energy reserves.

Energy Reserves

In the term newborn, energy reserves are available in the adipose tissue. There are two types of adipose tissue which develops in the neonate, white adipose tissue and brown adipose tissue, also known as "brown fat". Development of adipose tissue occurs late in gestation (>34 weeks) as the pancreas matures. The major function of white adipose tissue is to provide insulation to prevent heat loss and energy reserves in the event of starvation. "Brown fat" is rich in glycogen and therefore is a quick energy source for the infant. Through the breakdown of "brown fat", known as chemical thermogenesis, the infant can liberate glucose and oxygen in small amounts, and sufficient heat to prevent minor cold stress insults. With "brown fat" as the quick energy reserve, chemical thermogenesis is the mechanism available to the newborn to protect against physiologic destabilization.

The development and storage of "brown fat" occurs late in gestation, >34 weeks (Evans & Glass, 1976). The maturation of the pancreas provides the PTI with the ability to synthesize fatty acids and "lay down fat". The small PTI is born before adequate reserves of adipose tissue is developed. Since the small PTI has limited reserves, heat loss is increased because of lack of insulation, and chemical thermogenesis is not available to prevent physiologic destabilization. Therefore, even small insults of cold stress and/or hypoxia can produce a rapid physiologic destabilization in the PTI.

As stated previously, maintenance of any energy reserves is the primary focus during the early management of the PTI. Once physiologic stability is achieved, the care shifts to a focus of developing energy reserves in the PTI. This is accomplished by maintaining physiologic stability so that immature organ systems can mature and by providing adequate nutrition so that the infant can synthesize fat. The target is to provide nutrition to allow for growth comparable to intrauterine standards (Avery, 1987). It is unclear whether "brown fat" ever develops if an infant is born early, or if reserves developed after birth are in the form of white adipose tissue.

Energy expenditure and energy reserves both effect physiologic stability. In the PTI it may be a combination of immaturity which increases the metabolic rate and therefore the energy expenditure, as well as the lack of energy reserves that can lead to physiologic destabilization. Because of the lack of reserves, it is critical that all energy expenditure in the PTI be minimized. Therefore, any activity with a potential to increase energy expenditure or deplete energy reserves must be evaluated carefully before initiation.

Activities That Affect Physiologic Response

In general, energy expenditure is minimized by providing external environmental support for the PTI. Initially, oxygen and/or ventilators are used to prevent hypoxia and nutrition is provided parenterally in order to limit energy expenditure. To reduce cold stress, isolettes or radiant warmers are used, progressing to bassinets after fully dressing, swaddling and covering infants with blankets.

Activities other than cold stress and hypoxia, that have been shown to affect physiologic response, include handling needed for procedures, and treatments such as chest physiotherapy. The activities of concern to this study include behavioral state, cold stress, and sucking activity.

Infant activity has been categorized into different behavioral states based on sleep, awake, and crying activities. These states have been described in both the full-term and PTI. Comparison of infant states in the full-term and pre-term infant have been made by Gill, et al. (1988) and Michaelis, et al.

(1972). The differences found between full-term and pre-term infants were that the FTI had a decrease in sleep states and active awake states with an increase in crying states when compared to the PTI. The amount of time the PTI spends in the quiet alert state remained comparable to the full-term infant and was found to be consistent with maturation.

Physiologic stability of the PTI differs in response to behavioral activity (Parmalee & Stern, 1972; Michaelis, et al. 1972). In general, it has been noted that patterns of blood oxygenation, heart rate and respiratory rate are within normal range during quiet alert and deep sleep states. The quiet alert state is characterized by wide open eyes with decreased body movements, and deep sleep is characterized by sleep associated with no body movement nor rapid eye movement (REM). In contrast, the physiologic response in active sleep and crying states include abnormalities in heart rate, respiratory rate and blood oxygenation which, if excessive, may lead to physiologic destabilization (Anderson, Burroughs & Measel, 1983). It has been demonstrated that the PTI spends more time in active sleep than in deep sleep (Stern, 1969).

The physiologic response of the PTI to sucking activity has also been described. Meier & Pugh (1985) report that there is an increase in non-nutritive sucking during breastfeeding versus bottlefeeding. Multiple authors (Anderson, et al. 1983; Measels & Anderson, 1979; Burroughs, et al. 1978) have recognized that non-nutritive sucking can promote stabilization of physiologic responses in the PTI.

Physiologic responses during feeding have generated many studies (Ashmead, et al. 1980; Crook, 1976; Durand, Leahy, Maccallum, Cates, Rigatto, & Chernick, 1981; Guilleminault & Coons, 1984; Holt, Davies, Hasselmeyer, & Adams, 1962; Johnson & Salisbury, 1975; Johnson & Salisbury, 1976; Lipsitt, et al. 1976; Meier, 1985; Meier, 1988; Meier & Anderson, 1987; Shivpuri, et al. 1983, Wilson, Thach, Brouillette, & Abu-Osba, 1982). Most of these studies have reported physiologic responses during bottlefeeding. Summarizing these studies, results demonstrate that during formula feedings, respiratory rate and inspiratory volume is altered, heart rate is unstable, and blood oxygenation is decreased. The actual mechanism for this response is unclear but has been attributed to either a decrease in inspiratory volume, the metabolic acidosis produced with the digestion of formula, or both.

There are recent studies which have investigated the physiologic response of PTIs during breastfeeding versus bottlefeeding. The results reported by Meier (1985), and Meier & Anderson (1987), demonstrate that blood oxygenation and skin temperature were more stable during breastfeeding when compared to bottlefeeding. Improved physiologic stability may be explained because PTIs are better able to regulate their feeding pattern during breastfeeding, which reduces their energy expenditure. Potential for physiologic destabilization during feeding may occur in relationship to cold stress when the PTI is removed from the isolette, and the activity required to initiate and maintain sucking in order to obtain the required volume. These potentials for energy expenditure apply to both bottlefeeding and breastfeeding methods. With bottlefeeding, the actual time involved in feeding may be less, therefore reducing the length of time outside of the isolette. However, the energy required during bottlefeeding may be more when compared to breastfeeding (Jain, et al. 1987). During breastfeeding the increased feeding time may be due to the increase in non-nutritive sucking (Meier & Pugh, 1985). Non-nutritive sucking has been correlated with physiologic stabilization in the PTI (Anderson, et al. 1983; Burroughs, et al. 1978; Mathew, Clark, & Pronske, 1985; Paludetto, et al. 1984;

Paludetto, Robertson, & Martin, 1986) and therefore may explain why physiologic stability is improved during breastfeeding. A significant decrease in core temperature was not demonstrated with either breast or bottlefeeding in small PTIs (Meier, 1988).

The conceptual framework developed emphasizes a balance between energy expenditure and energy reserves. The following sections describe assumptions inherent in this study, operational definitions, and a statement of the hypothesis for study.

Assumptions

Assumptions inherent in this framework are:

1. The potential for cold stress exists during breast and bottlefeeding opportunities.
2. Energy expenditure is required for both breast and bottlefeeding methods.

Operational Definitions

The following operational definitions will be used:

1. Physiologic response - Transcutaneous blood oxygen saturation will be the physiologic response measured using pulse oximetry with a probe taped to the infant's foot.
2. Suckled feedings - The intake of breastmilk through either bottlefeeding or breastfeeding techniques.

3. Early initiation of breastfeeding - Beginning breastfeeding within 48 hours of the initiation of suckled feedings.
4. Small PTI - An infant born prior to the completion of 32 gestational weeks determined by formal gestational age assessment (Dubowitz, 1970; Ballard, 1979).
5. Infant state - Designation of behavioral state based on observation using the Anderson Behavioral State Scale.
6. Infant temperature - Temperature measured using a skin probe taped to the abdomen below the right costal margin.

Hypothesis

The physiologic response of pulse oximetry measurement will not be significantly different during the early initiation of breastfeeding versus bottlefeeding in the small PTI.

Chapter Summary

The conceptual framework developed is based on a physiologic theory that purports when energy expenditure exceeds energy reserves, physiologic destabilization occurs. Activities that require energy expenditure, such as oral feedings, must be evaluated carefully in order to prevent physiologic destabilization. Oral feedings, both breastfeeding and bottlefeeding, include a set of activities that involve energy expenditure. The difference in the effect of these activities on physiologic stability during early breastfeeding situations versus bottlefeeding situations is not clear.

CHAPTER FOUR

Methods

A quasi-experimental design was used to test the hypothesis: The physiologic response of pulse oximetry measurement will not be significantly different during the early initiation of breastfeeding versus bottlefeeding in the small preterm infant (PTI). According to Woods and Catanzaro (1988) quasi-experiments include the components of manipulation and control but do not randomize subjects into groups. For this study, the method of feeding was manipulated for a group of PTIs. The treatment of breastfeeding was alternated with bottlefeeding for each baby. In this fashion each baby served as its own control.

This chapter will describe the components of the research design. Data from the pilot study, selection of the population and sample for study, the setting, the variables studied, the tools used for measuring variables, procedures for data collection, the analysis, and protection of human subjects will also be described.

Research Design

The study used an alternating treatment, repeated measures design. For this investigation, each baby was observed for the first two weeks of suckled feedings for a total of six study feedings. Data were collected according to a defined protocol described later in the chapter.

Threats to internal validity were minimized by alternating the treatment method for the PTI while measuring the physiologic response. Subjects were recruited from one of two neonatal intensive care units (NICU) in southern California. The philosophy of care and treatment in the neonatal intensive care units were similar. Enrollment of all eligible infants into the study eliminated the threat of experimental mortality from difference in treatment. Completion of data collection by one investigator minimized instrumentation error. In addition, using a defined, detailed protocol for data collection minimized instrumentation error. Events occurring between study observations, such as blood transfusions for the correction of anemia, could have influenced measurements in subsequent feedings but are unavoidable in clinical research. Both methods of feeding were completed during the same day as often as feasible in order to minimize a change in status affecting one feeding method differently from the other feeding method. All changes in status and/or changes in treatment were recorded in order to examine outcome measurements.

Testing effects may also have been threat. The baby may not have been "aware" of being studied but may (and probably was) aware of the difference in handling between its own mother during breastfeeding and a nurse during bottlefeeding. Whether this difference in testing protocol made a difference in the physiologic measure is hypothetical. The variety of people feeding the PTI increased the difference between the feeding methods and therefore strengthened the generalizability of the design (personal communication, Barbara Stewart, 1987).

Threats to external validity were minimal. The physiologic measure of pulse oximetry should not have been influenced by the fact that the infant was being studied. The design included prefeeding and postfeeding measurement periods so that the measures obtained during feeding could be compared to baseline periods. Because the study investigated physiologic response of PTIs, the information should be generalizable to other similar PTIs cared for in the NICU's involved in the study. It is questionable whether the information would be generalizable to infants in other NICU's, infants of other cultures, or infants not meeting the criteria for inclusion. These are areas that will require further study.

Summary of Pilot Study

A pilot study approved by the Oregon Health Sciences University Human Subjects Committee was conducted in 1987. The purpose of the study was to demonstrate whether the early initiation of breastfeeding influenced the physiologic response of pulse oximetry measurement in the PTI differently from early bottlefeeding. A convenience sample of three mother-infant pairs were recruited and participated in the study.

For the pilot study infants who were close to beginning suckled feedings were recruited. Their mothers had expressed the desire to breastfeed but had not established and maintained a full milk supply when recruited. Consequently, formula was used intermittently for both the breastfeeding and bottlefeeding sessions. The formula was provided during breastfeeding using a feeding tube device. The investigator assisted the mothers with the use of the feeding tube device.

Infants were prepared for monitoring during the feeding sessions by the investigator. A Hewlett-Packard monitor with chest and leg electrodes was used to monitor heart rate, chest impedance was used to monitor respiratory rate, and a Pulse Oximeter with a probe taped to the ball of the infant's foot was used to monitor the pulse oximetry measurement. All infants were weighed fully clothed and swaddled then transported to the feeding room. The infant was held by either the mother or a nurse assigned to do the feeding while the monitors were turned on and calibrated. A five minute baseline period was begun. The infant's temperature was taken using an axillary thermometer during the baseline period. In addition during the last minute the infant's behavior was observed for 30 seconds and the state was recorded using the Anderson Behavioral State Scale (see Appendix A).

The feeding period began at the end of the five minute baseline period and continued until the infant either stopped sucking voluntarily or the prescribed volume was taken. The time at the end of the feeding was recorded and a postfeeding baseline period of five minutes was begun. The infants temperature and behavioral state were taken again and recorded as described in the prefeeding baseline. At the end of the postfeeding baseline the infant was weighed, then returned to the isolette. All of the physiologic data was recorded into a reel to reel tape for later transcription.

The demographic characteristics of the three infants are described in Table 1.

Table 1

Demographic Characteristics for Pilot Study Subjects

	Infant A	Infant B	Infant C
Characteristic			
Birth Weight	1120 GMS	2115 GMS	1060 GMS
Gestational Age	28 WKS	35 WKS	29 WKS
Age at Enrollment	27 DAYS	4 DAYS	37 DAYS
Enrollment Weight	1410 GMS	1860 GMS	1550 GMS
Age at First Feed	28 DAYS	5 DAYS	35 DAYS
Age First Brfeed	28 DAYS	6 DAYS	37 DAYS

Results demonstrated that breastfeedings took longer than bottlefeedings, 35.61 minutes versus 16.33 minutes, respectively. Behavioral state scores were similar with prefeed scores of 9.17 for breastfeedings versus 7.5 for bottlefeedings; and postfeeding scores of 1.67 for breastfeedings versus 2.89 for bottlefeedings. Infant temperature showed a slight increase from prefeed to postfeed observations during breastfeeding, 36.72°C-36.76°C; and a slight decrease during bottlefeeding, 36.69°C-36.49°C.

Results of physiologic monitoring data were consistent for feeding and postfeeding periods. The prefeeding baseline data was inconsistently recorded and therefore was unable to be analyzed. A value for heart rate and pulse oximetry measurement was recorded for every 60 second interval during the feeding and postfeeding periods. During breastfeeding and bottlefeeding mean heart rate showed a slight decrease from feeding to postfeeding periods, 160.62 to 157.29 for breastfeeding sessions, and 170.74 to 165.56 for bottlefeeding sessions. Mean oxygen saturation also showed small changes from feeding to postfeeding periods, 95.00 to 90.95 during breastfeeding sessions, and 90.32 to 92.36 for bottlefeeding sessions.

The numbers of feedings available in the pilot study do not allow for statistical analysis. However, the information does demonstrate few if any changes in physiologic response. The changes noted do demonstrate an increase in infant temperature and a decrease in oxygen saturation during breastfeeding periods. The data are too limited to draw any conclusions. The pilot study, however, did demonstrate that using the described protocol, small PTIs did not exhibit any negative physiologic response when given the opportunity to initiate early breastfeeding.

Population and Sample

The population in the current study included a convenience sample of small PTIs in the NICU who met the following inclusion criteria: (a) infant born $\leq$ 32 weeks gestation with no evidence of neurologic abnormality nor congenital anomaly which would affect feeding ability, such as cleft lip or palate, (b) mother who expressed the intent to breastfeed and willingness to initiate and maintain lactation for the duration of the study, and (c) mother who spoke English and had transportation to visit her infant during hospitalization.

Potential eligible patients were identified following delivery. Prior to contacting the mother the investigator contacted the attending physician to confirm his/her concurrence that the patient would be an appropriate candidate for the study. All of the physicians contacted were very supportive of their patients being recruited for the study. A total of 13 mothers were initially approached to participate in the study. Two mothers declined to participate. One mother had been very ill with pregnancy-induced hypertension and was not sure she wanted to breastfeed. The other mother declined because her husband did not want her to participate. Interestingly, both mothers contacted the investigator at a later time requesting to be part of the study because either their milk supply was dwindling or their baby would not breastfeed. These mothers were not included in the study but were given breastfeeding assistance by the investigator. In addition, there was one instance where the infant became ineligible for continuation in the study. The data gathered on that subject was not analyzed and a new subject was recruited.

The total study sample consisted of 10 mother-infant pairs. Each mother-infant pair was observed for six feedings, 3 breastfeedings and 3 bottlefeedings. The total sample used for analysis consisted of 30 breastfeedings and 30 bottlefeedings. Based on a power analysis (Cohen, 1977) 25 observations of each method corresponds to a power of 0.80, an alpha of 0.05, and an effect size of 0.8. The larger sample was necessary to obtain equivalent number of breastfeedings and bottlefeedings for analysis.

Setting

The sample was selected from a population of small PTIs admitted to a tertiary level NICU. Two tertiary level centers were approached and gave the investigator support to proceed with Human Subjects Review. One institution was a University Medical Center with a 34-bed NICU. The other institution was a large private hospital that has a 70-bed NICU and is affiliated with the University Medical Center. Two of the infants were transferred after recruitment to hospitals closer to the mothers home. The investigator sought and was given approval to proceed with the protocol on those infants during their hospitalization. Preterm infants and their mothers meeting the criteria for inclusion were recruited within the first week following birth. Early recruitment was necessary to assist the mothers with the initiation and maintenance of lactation during the early weeks before infant feeding began. Subsequent data collection procedures will be described in detail.

The majority of the feeding observations (85%) used for data analysis took place in a private room close to but separate from the NICU. The remaining 15% were completed at the infant's bedside using screens to provide privacy for the mother. All breastfeedings were done by the mother of the infant with all bottlefeedings done by either the mother or nurse assigned to care for the baby for that shift. The decision to have the assigned nurse participate in the bottlefeeding was based on the following reasons:

(a) in reality, nurses provide the majority of bottlefeedings, therefore it would be consistent with current clinical practice; (b) having the nurse participate enhanced the systematic variance of the treatment; and (c) it seemed unethical to have mothers spend their time bottlefeeding their infant when they could be breastfeeding. The investigator found, however, that occasionally a mother requested to participate in a bottlefeeding observation and was given that opportunity.

This research was intended to demonstrate that PTIs could breastfeed at an earlier time than is currently practiced. In order to provide empirical data that would be clinically relevant every effort was made to maintain clinical care as prescribed by the PTIs primary provider.

Consistent with common clinical practice, all PTIs receiving breast milk had a human milk fortifier added during bottlefeedings. The fortifier supplements breast milk with calories in the form of additional protein and carbohydrate believed to be denatured during freezing and thawing. In addition, it provides supplemental minerals recommended for the growing PTI. During the bottlefeeding observations all PTIs had fortifier added to the breast milk. There is no information available that describes any difference in infant feeding behavior when a fortifier is added to breast milk. There is also no information that indicates the addition of a fortifier alters infant behavior. However, it is theoretically feasible that sucking behavior may be different during bottlefeeding when a fortifier is added. If there was a difference it should have been consistent for all PTIs during bottlefeeding observations.

Variables for Study

The independent variable was the method of feeding, i.e., breastfeeding or bottlefeeding. The dependent variable was the infants' physiologic response as measured by pulse oximetry. The data produced by this measure are continuous with ratio-level measurement. Other variables measured included infant temperature, infant heart rate, infant state, and infant weight gain.

The potential influence of the investigator

During this study the investigator was active in both the preparation of the mother for breastfeeding and participation during the breastfeeding observations. As this may have influenced the data, the involvement of the investigator during the study will be described.

Prior to the initial breastfeeding the investigator educated each mother by describing infant positioning during breastfeeding and what she might expect from her infant. During the breastfeeding observations, the investigator was available to assist the mother to position her infant in a "tummy-to-tummy", cradle-hold position at the breast. After correctly positioning the infant in the mother's arm, the investigator assisted the initial latch-on by gently compressing the mothers areola to conform to the plane of the infants mouth. Once the infant opened his/her mouth the investigator guided the infant's head toward the areola so that the infant could "latch-on" and begin suckling. If the infant was unable to open the mouth widely the investigator applied gentle, firm pressure on the chin to stimulate a wide open mouth. After the infant began suckling the investigator maintained the support of both the mother's breast and the infant to decrease the chance of release of the breast by the PTI.

This involvement was necessary for all infants for the first feeding with the exception of one subject who needed no assistance after initial positioning. All but two of the mothers were able to independently position and achieve latch-on of their PTIs by the end of the study's breastfeeding observations.

Data Collection Instruments

Four instruments were used to collect data. Pulse oximetry measured both transcutaneous oxygen saturation and heart rate; an abdominal skin probe measured temperature; infant state was measured using the Anderson Behavioral State Scale; and a digital weight scale was used for prefeeding and postfeeding weights.

Pulse Oximeter. The Nellcor pulse oximeter is a commonly used monitor that measures oxygen saturation transcutaneously. The monitor uses a Digit Oxisensor transducer taped to an extremity. For this study the transducer was placed on the ball of the foot. The data was displayed digitally and adapted to print out a recording of measures every 60 seconds. This study used a continuous recording so that other information obtained could be written directly onto the recording. The pulse oximeter and transducer was used according to the manufacturer's instructions in order to assure reliability and validity of the measurements.

The pulse oximeter has demonstrated reliability and validity in multiple studies (Fait, Wetzel, Dean, Schlein, & Gioia, 1985; Jennis & Peabody, 1985; Deckardt & Steward, 1984; Yelderman & New, 1983). Pulse oximetry measurements have been compared to direct arterial oxygen saturation measurements with reported correlation coefficients of 0.89 - 0.98 (Fait, et al. 1985; Jennis & Peabody, 1985; Yelderman & New, 1983). Predictive validity of the measure has been demonstrated by comparing the method with both direct arterial oxygen saturation measurement (Fait, et al. 1985) and transcutaneous oxygen pressure monitoring (Deckhardt & Steward, 1984).

Continuous skin temperature measurement. Skin temperature was monitored continuously using an Electromedics monitor with a probe taped to the skin just below the right costal margin. Recording of the infant's temperature was attempted every five minutes during the prefeeding, feeding, and postfeeding periods. The measurements were taken to document any change in temperature during feedings that might affect oxygen consumption and thereby influence pulse oximetry measurements.

Anderson Behavioral State Scale (ABSS). This tool (see Appendix A) is a 12-point scale which assesses infant state. The scale assigns a number to a cluster of activities observed. The scale is ordinal with sleep states given lower scores (1-4) and crying states given higher scores (10-12). Identification of infant state was necessary since their state could have affected their physiologic response during feeding.

The scale is scored by observing the infant for 30 seconds and recording the highest numbered state achieved from the scale. Anderson has reported an inter-rater reliability of 0.89 (range 0.83-0.95). It has been utilized in two studies reported in the literature. Gill, et al. (1984) reported an inter-rater reliability for seven observers of 0.71; and Burroughs, et al. (1978) utilized the scale but did not report an inter-rater reliability assessment.

Infant Digital Scale. The digital scale available in the NICU was used for prefeeding and postfeeding weights. The scale weighs to an accuracy of five grams and was easily calibrated prior to each weight. The prefeeding weight subtracted from the postfeeding weight provided a gross estimate of intake. The measurement of weight was not intended to obtain an accurate volume of milk taken. Rather it was intended to assure that there was intake of milk during breastfeeding, which indicated nutritive sucking of the PTI. It was recognized that the method of pre and post weighing may not reflect actual volume taken.

In addition to the above measures once the mother and infant were enrolled as participants in the study, a log book was kept where information obtained from the patient's charts (mother and infant) and summary of interviews/interventions with the mother was recorded (see Appendices B-E). Information recorded included maternal and infant demographic characteristics, infant nutritional and weight information, and information obtained during contacts with the mother.

Procedure for Data Collection

Mothers and infants meeting the inclusion criteria were asked to participate in the study during the first week of their baby's life. As part of the study the mother was loaned an electric breast pump and given a milk collection system for "double-pumping". Double-pumping is a method of using an electric pump and collecting milk from both breasts simultaneously. Data reported by Neifert and Seacat (1987) demonstrated greater milk production in mothers of PTIs when using a double-pump system.

The investigator provided educational information about the initiation and maintenance of lactation and used guidelines from the NICU in which the study was completed for the collection, storage and transport of breast milk. The investigator maintained close contact (at least weekly) with the mothers for support and counseling about milk expression. The mothers also had access to the investigator for lactation/breastfeeding questions.

Because of continuous data collection the investigator knew when the PTI was near the point of progressing to suckled feedings. At the time the decision was made by the infant's physician to begin suckled feedings, the two week study period began. The initial breastfeeding began within 48 hours of the initial order to begin suckled feedings for all but one of the PTIs. The physician of that PTI felt the baby was not "strong enough" and refused to allow the infant to be put to breast until day 5 following the first bottlefeeding.

The protocol for data collection during feedings included preparation of the infant, a ten minute prefeeding period, the feeding period, a ten minute postfeeding period, and return of the infant to the isolette/crib. Prior to moving the infant from the isolette/crib the investigator applied the skin temperature probe and oxisensor as described earlier. The PTI was dressed in a standard "NICU-issue" tee-shirt and diaper with a stockinette-type cap placed on her/his head. Occasionally the mother brought special clothes from home to dress her infant and the "NICU-issue" tee-shirt was not used. The PTI was then swaddled in two receiving blankets, transferred to the mother or nurse at the bedside, or carried to the feeding room by either the mother, father, or the investigator.

In transit to the feeding, the infant was weighed while fully clothed and swaddled, and then placed in the arms/lap of the person to do the feeding. All of the monitors were connected for recording of data. Pulse oximetry measurements of oxygen saturation and heart rate were recorded automatically every minute throughout the observation. A ten minute prefeed period was recorded initially. The infant's temperature was recorded during the first minute of the prefeed period and then every five minutes throughout the observation. During the last minute of the prefeed period the infant was observed for 30 seconds and the infant state recorded. At the completion of the ten minute prefeed period, the feeding period began.

The feeding period continued until either the prescribed amount had been taken during bottlefeeding or the infant voluntarily stopped sucking during breastfeeding. There were instances during the feeding period of the breastfeeding observations when the investigator was unable to obtain the infant's temperature at the prescribed five minute interval because of involvement with the feeding. Infant temperature was recorded as close to the five minute interval as clinically feasible. Following the feeding the infant was held for the ten minute postfeeding period. The infant's state was again assessed for 30 seconds during the last minute of the postfeeding period. All the monitoring equipment was then disconnected and the PTI was carried back to the bedside. The infant was returned to the isolette/crib after being weighed on the same scale used for the prefeed weight. The data were collected during a minimum of 6 study periods, three breastfeedings and three bottlefeedings, during the first two weeks of suckled feedings. The investigator was present during all study feedings. No infant had difficulty with any of the feedings requiring discontinuation of the observation.

Data Analysis

The major variable of interest was the physiologic response, pulse oximetry measurement of oxygen saturation, of the PTI during feeding. The actual pulse oximetry measurement was recorded for each one-minute period. The values were averaged for each study period, i.e., prefeeding, feeding, and postfeeding periods. Data was analyzed using a 2 X 3 within subjects design to determine any difference of the means occurring by time period, as well as, by feeding method. In addition, means for infant temperature, heart rate, and infant state were analyzed for any difference by time period and feeding method. Infant weight gain was analyzed using a paired t-test. The CRUNCH Statistical package was used for data analysis.

Protection of Human Subjects

Mothers were approached by the investigator regarding their willingness to participate in the study. Each mother received a full explanation of the study and the procedures involved. She had time to ask questions of the investigator, and review the consent form without the investigator present. The investigator explained the potential risks and benefits to her and to her baby as described in the consent (see Appendix F). The mother was told the study was voluntary and that she could refuse to participate without concern for her own care or the care of her baby. She was informed that all information collected as part of the study would be kept in strict confidence. Written consent was obtained and filed separately from the data for analysis in order to assure confidentiality. All data for analysis had code numbers in order to maintain subject confidentiality.

CHAPTER FIVE

Findings

This chapter will describe the sample of mother-infant pairs and report the findings with respect to the research hypothesis. Additional findings will conclude the chapter.

A 2 X 3 within-subjects analysis of variance (ANOVA) was computed to test the hypothesis: The physiologic response of pulse oximetry measurement will not be significantly different during the early initiation of breastfeeding versus bottlefeeding in the small PTI. A within subjects format was used since each infant was observed during both methods of feeding, breastfeeding and bottlefeeding. The analysis provided a technique to determine any differences that may be present in PTIs based on their method of feeding.

Sample Characteristics

The total sample consisted of 10 mother-infant pairs. Characteristics of the mothers in the sample are displayed in Table 2. The mothers' average age was 30.5 years; 9 were Caucasian and 1 was Black. Seven of the mothers were primiparas and three were multiparas. Three of the mothers reported having previous experience breastfeeding. Seven of the mothers were married, one was living with the father of the baby, and two were not partnered. Eight of the mothers had been transported to the tertiary hospitals because of complications of their pregnancies.

The primary pregnancy complication identified on hospital admission included preterm labor (n = 4), premature rupture of the membranes (n = 4), pregnancy induced hypertension (n = 1), and placental abruption (n = 1). All but one of the mothers had some combination of pregnancy complications. The exception was the mother with an abruption, whose pregnancy had been uncomplicated to that point. Intrapartum complications were encountered by 5 of the mothers. Two of the mothers had complications due to fetal distress in labor, and 3 of the mothers had complications due to the fetus presenting breech. The average number of contacts the investigator had with the mothers prior to the beginning of the feeding observations was 7.3 (range 2 - 19). After the feeding observations had begun the investigator had an average of 4.3 contacts with the mothers (range 3 - 5).

Table 2

Descriptive Characteristics of the Mothers

Marital Status	
Single, not living with FOB	2
Single, living with FOB	1
Married	7
Parity	
Primiparous	7
Multiparous	3
Primary Pregnancy Complication	
Pregnancy-induced hypertension	1
Preterm labor	4
Premature rupture of membranes	4
Placental abruption	1
Intrapartum Complications	
None	5
Fetal Distress	2
Breech presentation	3
Previous experience breastfeeding	
No	7
Yes	3

Characteristics of the study infants are displayed in Table 3. The infants in this study included 4 females and 6 males with an average gestational age at birth of 30.3 weeks and an average birth weight of 1431.5 grams. Four of the infants were born vaginally and six were delivered by Cesarean section. Seven of the infants had been ventilator dependent within the first 24 hours of life. The average age at enrollment to the study was 4.6 days with a range of 2 to 15 days. The average weight of the infants at enrollment was 1300.4 grams with a range of 810-1570.

The infants were able to begin suckled feedings by a mean age of 25.8 days, with a range of 8 to 73 days. The median age to begin suckled feedings was 18.0 days. The average age of PTIs at the initial breastfeeding observation was 27.5 days with a range of 10-73 days. The mean weight of the infants at the initiation of feeding observations was 1612.5 grams with a range of 1370 to 1800 grams. Eight of the infants were evaluated by occupational/physical therapy for sucking coordination prior to routine suckled feedings being ordered. Two of the infants were not evaluated by a therapist because of transfer to affiliated hospitals where the practice was not routine. Other than a therapist evaluation, which included a partial bottlefeeding, five of the infants had received one bottlefeeding prior to the initial breastfeeding, one infant had received two bottlefeedings, and four of the infants had received no bottlefeedings prior to the initial breastfeeding.

Table 3

Characteristics of the Infants

	Mean	SD	Range
Birth Weight (grams)	1431.5	247.35	975-1750
Gestational age by exam	30.5	1.42	27-32
Age at enrollment (days)	4.6	3.8	2-15
Weight at enrollment (gms)	1300.4	255.92	810-1570
Age began suckled feeds (da)	25.8	19.26	8-73
Age at initial breastfeeding	27.5	18.58	10-73
Infant wt - first obs	1612.5	136.18	1370-1800

Average feeding time was analyzed using a paired t-test. Feeding time excluded the prefeeding and postfeeding periods of the observations. Feeding time was found to be significantly different between breast and bottlefeeding. The mean feeding time for breastfeedings was 32.23 minutes compared to a mean bottlefeeding time of 15.77 minutes ($t = -5.018$, $df = 9$, $p = 0.0008$).

In addition, infant behavioral state before and after feedings was analyzed using a within-subjects analysis of variance (ANOVA). The analysis demonstrated a significant difference from the prefeeding to postfeeding period under both conditions. Infant behavioral state decreased significantly from a prefeeding mean of 5.6 to a postfeeding mean of 3.9 ($F = 23.301$, $df = 1,9$, $p = 0.001$).

Research Hypothesis

The research hypothesis, that the physiologic response of pulse oximetry measurement will not be significantly different during the early initiation of breastfeeding versus bottlefeeding in the small PTI, was supported.

In this within subjects design, there were two factors for analysis. Factor 1 (Time) was the time periods within each observation. This factor had three levels for analysis, prefeeding, feeding, and postfeeding periods. The second factor (Method) was the method of feeding used during the observations. This factor had two levels, breastfeeding and bottlefeeding. Pulse oximetry measurements were recorded every 60 seconds during the study observations. The measurements were averaged for the prefeeding, feeding, and postfeeding periods. Pulse oximetry data was then analyzed using a within subjects, repeated measures (ANOVA). Results of the analysis, as shown in Table 4, failed to demonstrate any significant interaction effect (F = 1.328, df = 2,18, p = 0.2787) nor any difference in the measurements by time period or feeding method.

Table 4

Repeated Measures ANOVA for Time Periods by Feeding Condition - Pulse Oximetry Measurements

Source	df	SS	MS	F	p
Within Subj	50	207.0956			
Time	2	35.8079	17.9039	3.717	0.0860
T X SwGps	18	86.6930	4.8163		
Method	1	1.1298	1.1298	0.426	0.5300
M X SwGps	9	23.8611	2.6512		
TM	2	7.6625	3.8312	1.328	0.2787
TM X SwGps	18	51.9405	2.8856		

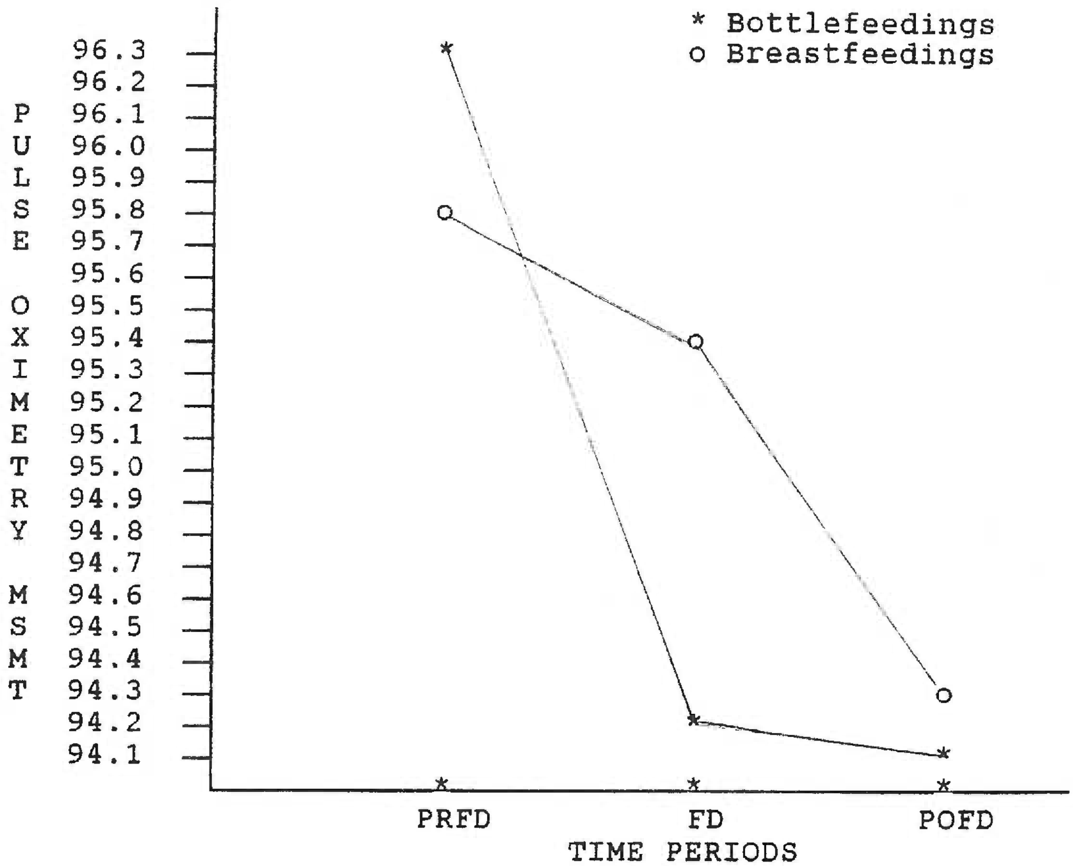
Note. SwGps = Subjects within groups; T = time periods; M = methods of feeding; TM = time periods and methods

There was no significant difference found between time periods for subjects within groups (SwGps). In this instance the mean pulse oximetry measurements were computed for each time period by the group of subjects within each method of feeding ($F = 3.717$, $df = 2,18$, $p = 0.086$). In other words, there was no difference in mean pulse oximetry values between prefeeding, feeding, and postfeeding periods for either breastfeeding or bottlefeeding method.

There was also no significant difference found between method of feeding for SwGps. In this instance, mean pulse oximetry measurements for each method were compared by the group of subjects within each time period ($F = 0.426$, $df = 1,9$, $p = 0.53$). In other words, there was no difference in mean pulse oximetry measurements between breastfeeding or bottlefeeding method for the prefeeding, feeding, or postfeeding time periods. The decline in pulse oximetry from the prefeeding to feeding period, however, was more pronounced during bottlefeeding than during breastfeeding (see figure 1). The mean pulse oximetry measurement during bottlefeedings declined from 96.3 in the prefeeding period to 94.2 in the feeding period. During breastfeedings the decline from prefeeding to feeding periods was less dramatic decreasing from 95.7 to 95.5, respectively.

Figure 1

Comparison of Pulse Oximetry during Prefeed, Feed, and Postfeed Periods



In summary, there were no significant differences found in mean pulse oximetry measurements between time periods or method of feeding. These findings support the original hypothesis that physiologic response will be similar regardless of method of feeding.

Other Findings

In addition to pulse oximetry measurements, data were analyzed for infant temperature, heart rate, and amount of weight gain with feedings. Infant temperature and heart rate were analyzed using a within subjects, repeated measures ANOVA. The amount of weight gain with feedings was analyzed using a paired t-test.

Infant Temperature

Infant temperature was measured every 5 minutes and a mean value was computed for each of the time periods, prefeeding, feeding, and postfeeding. Table 5 displays the results of the within subjects, repeated measures ANOVA for infant temperature.

Table 5

Repeated Measures ANOVA for Time Period by Feeding Condition - Infant Temperature

Source	df	SS	MS	F	p
Within Subj	50	5.9473			
Time	2	1.4653	0.7327	17.518	0.0024
T X SwGps	18	0.7528	0.0418		
Method	1	1.4107	1.4107	9.297	0.0139
M X SwGps	9	1.3655	0.1517		
TM	2	0.5841	0.2921	14.252	0.0044
TM X SwGps	18	0.3689	0.0205		

Note. SwGps = Subjects within groups; T = time periods; M = method of feeding; TM = time periods and methods

There was a significant difference found in mean infant temperature with a significant interaction effect between time period and feeding condition ($F = 14.252$, $df = 2,18$, $p = 0.0044$). Because of the significant interaction between time period and feeding condition, a simple effects analysis was computed. Table 6 displays the results of the simple effects analysis for method by time period. Results demonstrate that infant temperature was not different during the prefeeding period for method of feeding. However, there was a significant difference in infant temperature demonstrated for the feeding period ($F = 14.64$, $p < 0.01$) and the postfeeding period ($F = 20.06$, $p < 0.01$). This analysis indicates there was no significant difference between method of feeding during the prefeeding period with a significant difference demonstrated at the feeding and postfeeding periods in the direction of the breastfeeding method.

Further analysis demonstrated a significant difference in temperature during the time periods for the breastfeeding condition but no significant difference during the time periods for the bottlefeeding condition. To further understand the difference during breastfeeding a Tukey test was computed. The Tukey value obtained for the prefeeding versus feeding period was 10.25 with $df = 9$, which is significant at $p < 0.01$. The prefeeding versus postfeeding period also demonstrated a significant Tukey value of 8.13 with $df = 9$, which is significant at $p < 0.01$).

Table 6

Simple effects analysis - Method by Time Period for Temperature

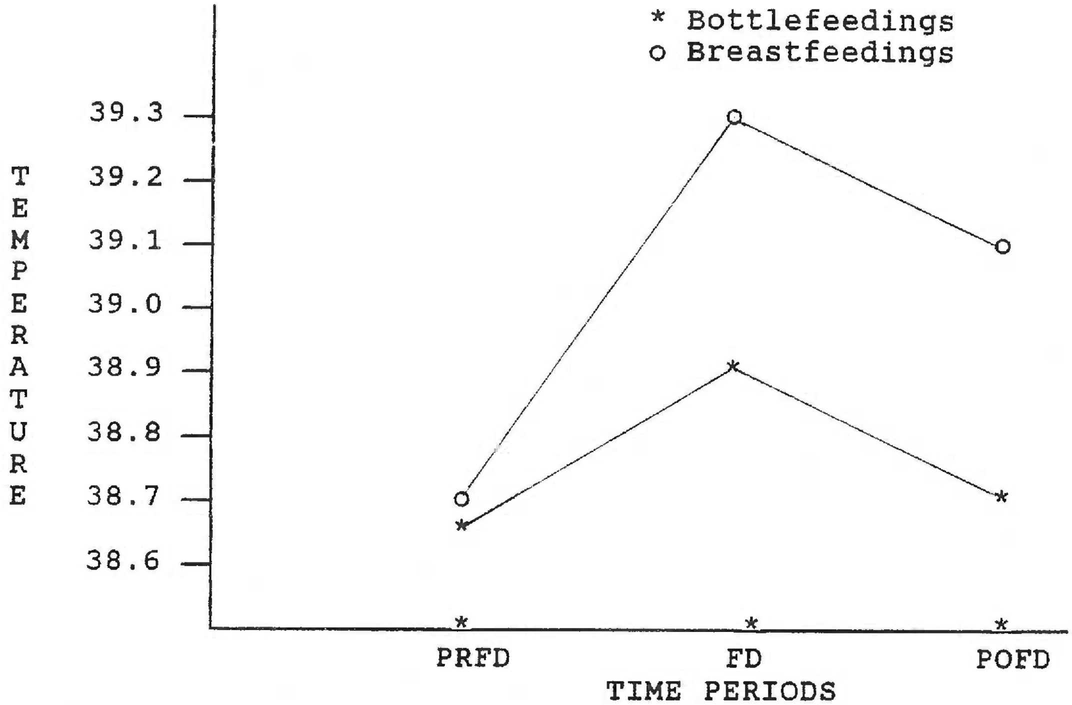
Source	F	p
SS_m at Time 1 (prefeeding)	.122	>.10
SS_m at Time 2 (feeding)	14.640	<.01
SS_m at Time 3 (postfeeding)	20.060	<.01

Note. SSm = sum of squares for method

The changes in infant temperature during feedings are displayed in Figure 2. The mean temperature during breastfeeding increased sharply from prefeeding to feeding periods, 38.7 to 39.3, respectively. In addition, the mean temperature remained significantly elevated from prefeeding to postfeeding periods, 38.7 to 39.1, respectively. In contrast mean temperature did not increase significantly from prefeeding to feeding periods, 38.7 to 38.9, respectively, and returneds to prefeeding mean temperature during the postfeeding period.

Figure 2

Comparison of Temperature during Prefeed, Feed, and Postfeed Periods



In summary, results demonstrated there was no temperature difference in the prefeeding period by feeding condition. However, there was a significant difference shown at both the feeding and postfeeding periods during breastfeeding. The results demonstrated that during breastfeeding infants' temperature increased significantly and remained at a significantly higher level during the postfeeding period. This significant increase was not demonstrated when the infants were bottlefeeding.

Infant Heart Rate

Infant heart rate was recorded every 60 seconds and mean values were computed for the prefeeding, feeding, and postfeeding periods. A within subjects, repeated measures ANOVA was computed for heart rate (see Table 7). No significant difference was demonstrated in either time period or method of feeding and no interaction between the factors was seen.

Table 7

Repeated Measures ANOVA for Time Period by Feeding Condition - Heart Rate

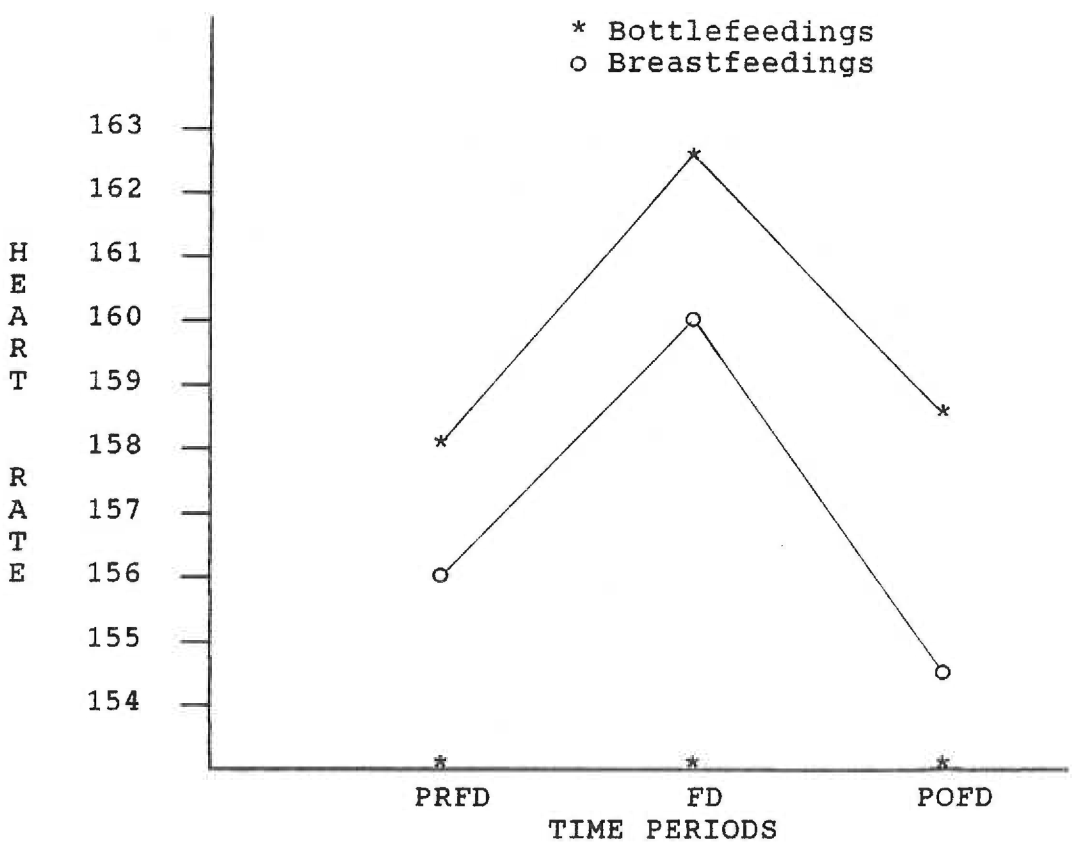
Source	df	SS	MS	F	p
Within Subj	50	1870.8721			
Time	2	253.6065	126.8033	3.365	0.0999
T X SwGps	18	678.3792	37.6877		
Method	1	124.2241	124.2241	2.649	0.1381
M X SwGps	9	422.0463	46.8940		
TM	2	11.8480	5.9240	0.280	0.6093
TM X SwGps	18	380.7637	21.1535		

Note. SwGps = Subjects within groups; T = time period; M = method of feeding; TM = time periods and methods

The results of this analysis failed to demonstrate a difference in the heart rate for the PTI between time periods or method of feeding. The heart rate displayed a similar pattern for both feeding conditions. As seen in figure 3, there was a similar rise in heart rate with feedings and a return to near prefeeding level during the postfeeding period in both breast and bottle feedings.

Figure 3

Comparison of Heart Rate During Prefeed, Feed, and Postfeed Periods



Infant Weight Gain

Infant weight was recorded prior to the initiation of the observation and at the conclusion of the observation. The prefeeding weight was subtracted from the postfeeding weight to obtain infant weight gain. The mean weight gain of all observed feedings was computed. When the breastfeeding and bottlefeeding weight gain was compared using a paired t-test the analysis failed to demonstrate a significant difference between the two feeding conditions ($t = 1.893$, $df = 9$, $p = 0.091$). The lack of significant difference indicates that the PTIs gained a similar amount of weight when breastfeeding and bottlefeeding.

In summary, additional analyses were completed for infant temperature, heart rate, and infant weight gain. The results demonstrated a significant increase in infant temperature from prefeeding to feeding temperature and from prefeeding to postfeeding temperature. Further analysis revealed the difference was only significant during the breastfeeding method. Analysis of infant heart rate failed to demonstrate any difference by time periods or method of feeding. Finally, there was no significant difference in infant weight gain between the methods of feeding.

Additional Findings

During the feeding observations, notations were made by the investigator to describe behaviors of the infant and the person providing the feeding. Two differences were noted which "seemed to be different" between breastfeeding and bottlefeeding observations. It is not uncommon for PTIs to become dusky (pale with circumoral cyanosis) during feedings. During breastfeeding observations none of the PTIs were noted to be dusky. In contrast, five of the PTIs were noted to have become dusky during bottlefeeding observations. In addition, the investigator noted the frequency that the feeding was interrupted by either taking the bottle out of the infant's mouth or removing the infant from the breast. The average number of times that the bottle was removed from the infant's mouth during bottlefeeding was 3.933. The average number of times the infant's were removed from the breast during feeding was 2.433.

All but one of the mother-infant pairs required assistance for the first breastfeeding. All but two of the mothers were able to position and achieve latch-on of the PTIs by the end of the study. Daily infant weight was recorded in order to identify if the feeding observations had any untoward effect on weight gain.

Mean daily weight gain was calculated for the infants by feeding method. For the three breastfeeding observations, infants gained a mean daily weight of 17.5, 25.5, and 27.0 grams. Mean daily weight gain for the three bottlefeeding observations were 30.5, 21.5, and 26.0 grams.

Chapter Summary

The research hypothesis, that the physiologic response of pulse oximetry measurement will not be significantly different during the early initiation of breastfeeding versus bottlefeeding in the small PTI, was supported. In addition, no significant differences were found in heart rate, weight gain, nor infant state when breastfeeding and bottlefeeding were compared. Infant temperature increased significantly during feeding and remained elevated into the postfeeding period for breastfeeding observations. The same rise in temperature was not demonstrated during the bottlefeeding observations. These results will be further discussed in the following chapter.

CHAPTER SIX

Discussion

This study examined the physiologic response of small preterm infants (PTI) during the early initiation of breastfeeding versus bottlefeeding. The convenience sample included 10 mother-infant pairs. The PTIs were born less than 32 weeks gestation and their mothers planned to breast feed. Using an alternating treatment, repeated measures design, each infant was observed for a total of 6 feedings, 3 breastfeedings and 3 bottlefeedings during the first two weeks of suckled feedings. Physiologic response was measured by pulse oximetry during three time periods; prefeeding, feeding, and postfeeding periods. Heart rate and skin temperature were also measured during prefeeding, feeding, and postfeeding periods. Behavioral state was assessed before and after feedings using the Anderson Behavioral State Scale. Finally, the infants were weighed before and after feedings.

There was no statistically significant difference found in the primary dependent variable, pulse oximetry, when breast and bottlefeedings were compared using a repeated measures analysis of variance (ANOVA). In addition, there were no significant differences found in mean heart rate or weight gain when breast and bottlefeedings were analyzed.

Analysis of infant temperature demonstrated a significant interaction effect between time periods and feeding methods. Further analysis demonstrated a significant increase in temperature during breastfeeding observations from prefeeding to feeding, and prefeeding to postfeeding periods. There was no difference in infant temperature found during bottlefeeding observations. Mean infant behavioral state decreased significantly from prefeeding to postfeeding periods for both breast and bottlefeedings.

In summary, the findings suggest that early breastfeeding does not place an increased demand for energy on the preterm infant when compared to early bottlefeeding. Further, PTIs engaged in nutritive sucking during early breastfeeding as evidenced by sufficient weight gain with feeding. It appears that breastfeeding keeps infants warmer both during feeding and the period immediately after feeding. The current practice of delaying breastfeeding based on the assumption that it may result in physiologic destabilization is not supported by this research.

This chapter will discuss the procedures used in data collection and the findings. In addition, implications for clinical practice and future research will be suggested. Limitations of the research will conclude the chapter.

Procedures

Data Collection Protocol

The protocol developed for use during feeding observations assumed that all babies in the study would be able to be moved to a private room adjacent to the neonatal intensive care unit (NICU). This assumption was not realistic for three of the study infants. One of the infants was considered to be too fragile to move to the feeding room for observations and two of the infants were in NICU's where an adjacent room was not available. For these infants the protocol was adapted so that all of the feeding observations occurred at the infant's bedside with screens used to provide privacy for the mothers and infants. The other steps in the protocol were followed for all infants as described in the methods section.

Potential Influence of the Investigator

The investigator's clinical expertise was a clinically significant factor in this research. The investigator was involved in the education of the mother about the initiation and maintenance of milk production. In addition, the investigator provided hands-on assistance during breastfeeding.

It was assumed that providing the mother with the equipment and education for milk expression would prevent the decreased milk supply phenomenon commonly reported for mothers of PTIs. In this sample, mothers were provided with the pumping equipment, instructions for pumping which included an every 3 hour milk expression routine, and with continued close supervision by the investigator for the first 2-3 weeks following recruitment. As a result, all 10 of the mothers in this study maintained an adequate supply of breast milk prior to and after initiation of breastfeeding.

During breastfeeding observations, the investigator directly assisted the infant to latch-on and provided continued assistance during the breastfeeding observations. Each mother had expressed concerns about her ability to breastfeed. Concerns seemed to center around the mechanics of breastfeeding, such as how to hold the baby, the infant's ability to breastfeed, and whether the baby would be able to get enough milk. During the breastfeeding observations the investigator was able to demonstrate positioning techniques that had been discussed prior to the initiation of feedings, provide encouragement to the mother as the infant nursed, and describe the normal pattern of sucking and swallowing for the PTI during the breastfeedings.

In addition, the study observations occurred during the regularly scheduled feeding routine for the PTI. In other words, the feeding observations were completed during the scheduled feeding time set by the NICU routine. There was no attempt to manipulate feeding times or extend feeding intervals to allow the PTI to awaken on his/her own. The study infants were able to suckle effectively from both the breast and the bottle with assistance. Since the investigator assisted the infants to latch-on and maintain breastfeeding it is unknown whether they would have suckled as well without this assistance.

Breastfeeding in these infants may have been related to two factors. The first factor was the assistance provided by the investigator to achieve adequate latch-on. The process of latching-on involves simultaneously positioning the breast correctly, encouraging the infant to open its mouth widely, and bringing the infant toward the breast smoothly and rapidly. In clinical practice the majority of mothers and PTIs need assistance to achieve adequate latch-on.

The second factor related to the PTI's

effectiveness with breastfeeding was the adequacy of the mother's milk supply. Once the infant achieved adequate latch-on, the flow of milk provided continued stimulus for the infant to sustain sucking until satiated. All of the mothers in this study maintained an adequate supply of breast milk. These findings suggest that the PTI may require assistance with latch-on and an adequate milk supply in order to initiate and sustain nutritive sucking during early breastfeeding.

Findings

The results provide support for this study's conceptual framework, which proposed that physiologic response would remain stable as long as energy expenditure did not exceed energy reserves of the PTI. The rationale used by clinicians to delay breastfeeding has included three principle concerns. The first is that physiologic destabilization will result because breastfeeding is believed to require more energy expenditure than bottlefeeding. Second, there is a concern that the PTI will become hypothermic because of the increased length of time spent breastfeeding compared to bottlefeeding. Finally, there is a concern that the PTI would not be able to obtain sufficient milk during breastfeeding. None of these concerns were apparent in this study.

Physiologic response

In this study the breastfeeding observations lasted twice as long as the bottlefeeding observations ($p < 0.0008$). However, there was no difference in physiologic response as measured by pulse oximetry when breast and bottlefeeding were compared. This finding supports the premise that PTI's do not increase energy expenditure during breastfeeding in comparison to bottlefeeding even though the length of time spent feeding is longer.

In the present study, the results of pulse oximetry measurements were not significantly different for either breast or bottlefeeding. Yet, there was a decline in pulse oximetry from prefeeding to feeding periods, which continued through the postfeeding period for both breast and bottlefeeding methods. The decline in pulse oximetry measurements from the prefeeding to feeding period appears to be more dramatic during bottlefeeding observations than during breastfeeding observations.

Decline in pulse oximetry measurements from prefeeding to feeding periods might be explained by a decrease in respiratory rate and, therefore, oxygenation during infant feeding as reported by

Shivpuri, et al. (1983). It could be speculated that instinctually the infant stops sucking to prevent the flow of milk. This would allow for intermittent bursts of respirations during feedings. However, since milk flow from a bottle is largely gravity regulated, milk will continue to flow until the PTI either learns to obstruct the flow, or the bottle is removed from its mouth. The PTI who is unable to obstruct milk flow cannot initiate bursts of respirations without choking. The infant therefore does not initiate respiratory bursts and subsequently pulse oximetry measurements decline. When the infant demonstrates a lack of breathing the person doing the feeding removes the nipple and stimulates the PTI to initiate a respiratory burst.

The pattern of milk flow from the breast is largely infant regulated. When the infant stops sucking the flow of milk also stops, allowing spontaneous bursts of respirations to occur without obstruction. In this fashion, the PTI can regulate the feeding without decreasing pulse oximetry measurements.

Stable physiologic response may have been due to non-nutritive sucking by PTIs during breastfeeding. Burroughs, et al. (1978) and Paludetto, et al. (1984)

demonstrated that PTIs could maintain or increase tcPO2 levels during non-nutritive sucking observations. Non-nutritive sucking during breastfeeding may be a mechanism used by the infant to stabilize physiologic response. It is unclear, however, why the pulse oximetry measurements continued to decline during the postfeeding period in this group of PTIs.

Infant Temperature

There was a significant increase in infant temperature during breastfeeding from prefeeding to feeding periods. In addition, the significant increase in temperature continued into the postfeeding period. There was not a significant rise in temperature during bottlefeeding observations. The maximal temperature change from prefeeding to feeding periods during bottlefeeding was +0.15°C and the maximal temperature change during breastfeeding was +0.55°C. Meier (1988) found a similar increase in infant temperature during breastfeeding observations. Her results demonstrated a +0.20°C maximal temperature change from prefeeding to feeding periods for bottlefeeding sessions and a +0.49°C maximal temperature change during breastfeeding sessions.

There may be two explanations for the significant increase in infant temperature during breastfeeding, which was not observed with bottlefeeding. First, the position of the PTI during bottlefeeding is very different than during breastfeeding. During bottlefeeding the infant was placed in a semi-sitting position with his/her head supported by one hand. While held in the lap of the person doing the feeding, the PTI was usually facing the 'feeder' but not held close to the chest. Even though the PTI was clothed and swaddled with blankets there would be little opportunity for heat exchange to the infant held in this position. During breastfeeding the infant was held firmly in a cradle position next to the mother's chest while suckling. It was evident from the mothers' comments that they became very warm during nursing.

In addition to infant positioning, the temperature of the milk being fed may have affected the infant's temperatures. The milk suckled from the breast can be assumed to be comparable to maternal body temperature, whereas, milk fed from a bottle would be comparable to room temperature. When preparing a bottle of breast milk for feeding the milk was warmed and then allowed to remain at room temperature until fed to the PTI. There was no measure of milk temperature, however, it is assumed that the milk fed in the bottle was cooler than that from the breast. Holt, et al. (1962)

demonstrated that cold formula could significantly lower body temperature in the PTI. The significant rise in temperature of PTIs during breastfeeding is likely a combination of close contact with the mother as well as the warmer temperature of the milk being suckled by the infant.

Weight Gain

This study documents that PTIs can obtain sufficient volume of milk during early breastfeeding. There was no significant difference found in weight gain by feeding method indicating that the healthy PTI can suckle effectively to obtain milk during both breast and bottlefeedings. Because the sucking pattern of the PTI is immature the length of the breastfeeding may be necessary so that the infant can obtain an adequate amount of milk.

In summary, this study supports the hypothesis that small PTIs can breastfeed effectively without negative physiologic response. The concern about physiologic destabilization and/or hypothermia was not experienced in the subjects studied despite breastfeeding observations that were twice as long as bottlefeeding observations. In contrast, during breastfeeding, the PTIs were kept significantly warmer. The concern that the PTIs would not be able to obtain sufficient milk was also not warranted. Furthermore, mean weight gain was not significantly different between breastfeedings and bottlefeedings for this sample.

Implications for Nursing

Clinical Practice

Nurses should be aware that the rationale for delaying breastfeeding based on physiologic concerns is not empirically based. The results of this study demonstrate that the small, healthy PTI can breastfeed effectively using the described protocol. Nurses should be aware that the type of positioning of the infant close to the mothers chest during breastfeeding prevents a decrease in infant temperature, and in fact may raise their temperature during breastfeeding. In addition, nurses can be assured that the increased length of time a PTI spends breastfeeding effectively may be necessary to obtain an adequate amount of breast milk, and is not detrimental to the infant.

In order for nurses to improve their ability to help mothers breastfeed they must assess the mother soon after the PTI is admitted to identify those who desire to breastfeed. They must provide assistance and education about the initiation of milk production and maintenance of milk supply. In addition, assistance during breastfeeding and assessment of efficacy of feeding is necessary. Additional training of nurses in NICU's would be necessary for adequate assessment and assistance with breastfeeding the PTI to become standard practice. Nurses must be prepared to assist with breastfeeding conceptually, educationally, and technically. Lactation protocols should be developed so that consistent education of mothers is ensured and assessment of effective breastfeeding is evaluated.

Another alternative is to have a breastfeeding specialist on staff in the NICU. This specialist would evaluate and educate the mothers, and provide technical assistance during early initiation of breastfeeding. The disadvantage of having only one specialist is that mothers may require assistance at varying times and days when the specialist is not available.

In addition, physicians need to be provided with the information that PTIs can breastfeed effectively and safely at a much earlier time than is generally considered. With this information, physicians should be more supportive of providing earlier breastfeeding opportunities for PTI's.

Daily weight gain should be used as an overall indicator of the infant's ability to breastfeed effectively. Before and after weights in general practice may not be realistic and may cause unnecessary concern because of the insensitivity of common weight scales to identify small weight changes.

Pulse oximetry could be utilized to monitor physiologic response if the nurse is concerned about physiologic stability during feedings. The results of this study, however, suggest the decline in pulse oximetry was more pronounced during bottlefeeding than during breastfeeding. With the assistance of a nurse experienced in managing breastfeeding, these results support the ability of small, healthy PTI's to initiate breastfeeding earlier than is currently practiced.

Future Research

Documentation of the ability of PTIs to breastfeed effectively continues to mount. Replication of this study with a larger number of subjects is suggested along with expansion of the study protocol to PTI's who did not meet the eligibility criteria for this study, e.g., non-English speaking mothers, infants with congenital anomalies or neurological deficit, and multiple births. In addition, there needs to be further research to document whether assistance, such as that provided by the investigator in this study, is required for PTI's to breastfeed effectively.

Additional information is necessary to identify why the decrease in pulse oximetry measurements found during feedings continued into the postfeeding period. Further research is also warranted to investigate if there is a change in feeding behavior when breast milk fortifiers are used. Sucking patterns during breastfeeding are not well described in the PTI. Description of physiologic response in the PTI during nutritive and non-nutritive sucking patterns with breastfeeding would supplement the literature.

Studies should be developed to focus on how the mother feels about her breastfeeding experience, when breastfeeding patterns can be changed to demand versus scheduled feedings, and if the early initiation of breastfeeding would improve the mother's ability to care for her PTI after discharge. In addition, studies are needed to determine if the early initiation of breastfeeding is more cost effective, or would reduce the length of stay of the small PTI.

Limitations

There are always limitations to research. This study utilized a small number of PTIs and it is obvious that a larger sample could provide broader generalizability of the findings. Subjects were predominantly healthy, stable PTIs without congenital anomalies or neurological defects. The study sample is limited both racially and culturally. All but one infant was Caucasian. Culturally, in this sample, there was a predominance of families from the white, American culture. One family had immigrated from Hungary, and one family was of Lebanese descent. It is unclear whether these findings could be generalized to families of other ethnic backgrounds or cultures, or with infants who do not meet the same eligibility criteria.

Caution is also advised with regard to utilizing the findings to promote the early initiation of breastfeeding in PTIs without recognizing the contributions of the investigator. The effective breastfeeding of the PTIs may have been mediated by the assistance provided. It is unknown whether these PTIs would have been as effective breastfeeding without this intervention.

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APPENDIX A
ANDERSON BEHAVIORAL STATE SCALE (ABSS)

EYES OPEN OR CLOSED

12 Hard crying: very red face; clenched fists; very prolonged exhalation; audible or silent cry; entire body very tense

11 Crying: prolonged exhalation; audible or silent cry; general body tension; (red face)

10 Fussing: normal color; single or frequent slightly prolonged exhalations; whimper (precry grimace; snorts)

EYES OPEN

9 Very Active: total body movement; (twisting or lifting head or trunk; turning head side to side)

8 Active: whole limb movement; (twisting or lifting trunk or head slowly or slightly)

7 Awake, Quiet: eyes don't fix and follow; no movement or slight slow movement of head, face, hand, forearm, foot, or lower leg

6 Alert Inactivity: eyes are wide open, quiet, luminous, fixated; no or slight, slow movement of head, face, hand, forearm, foot, or lower leg; (eye contact; eyes follow)

EYES OPENING AND CLOSING SLOWLY

5 Drowsy: quiet or some movement; eyes dull or glazed; heavy lidded; (drowsy waking tends to be more active)

EYES CLOSED

4 Very Active Sleep: total body movement (twisting or lifting head or trunk; turning head side to side)

3 Active Sleep: irregular respirations; whole limb movement; (twisting or lifting trunk or head slowly or slightly; facial grimaces)

2 Irregular Quiet Sleep: irregular respirations; no movement or slight, slow movement of face, head, hand, forearm, foot, or lower leg; (brief apnea)

1 Regular Quiet Sleep: regular respirations; faint or no movement; (slight mouthing or movement of fingers and toes)

Items in parentheses need not be present. Infant must rest 2 minutes before first behavioral state. Score the highest prone state attained during the 30 seconds. If State 6 occurs, score as a 6 even if a higher number occurs. If eye patches are on, assume eyes are closed unless seen to be open. Score 5 State if one eye open and one eye closed and little movement.

APPENDIX B
INITIAL ENROLLMENT DEMOGRAPHICS

SUBJECT NUMBER__________

MATERNAL DEMOGRAPHICS

1. Maternal age ____________
2. Marital status
   a. Single, not living with FOB
   b. Single, living with FOB
   c. Married, living with husband
   d. Married, not living with husband
3. Gravida _________
4. Parity _________
5. Living Children__________
6. Complications of pregnancy
   a. PIH
   b. PTL
   c. PROM
   d. sepsis
   e. diabetes
   f. previa
   g. abruption
   h. IUGR
   i. other, ________________________________
7. Intrapartum complications
   a. fetal distress
   b. breech
   c. PIH
   d. sepsis
   e. vaginal bleeding
   f. other, ________________________________
8. Method of delivery
   a. NSVD
   b. operative vaginal delivery
   c. C/section
9. Reason for C/section where applicable

____
10. Previous experience breastfeeding
    a. yes
    b. no
    c. not apply
11. Problems with previous breastfeeding
    a. yes, describe__________________________________
12. Maternal transport
    a. yes
    b. no

INFANT DEMOGRAPHICS

1. Birth date ______________
2. Birth weight ______________
3. Gestational age at birth by exam ______________
4. Infant sex
   a. male
   b. female

6. Age at enrollment ______________
7. Weight at enrollment ______________
8. Ventilator dependent within first 24 hours
   a. yes
   b. no

CONTINUING PROBLEM LIST

DATE	PROBLEM	RESOLVED

APPENDIX C

DAILY INFANT LOG

SUBJECT NUMBER______

DATE	WEIGHT	NUTRITIONAL METHOD	PROCEDURES	COMMENTS

APPENDIX D

MATERNAL LOG

SUBJECT NUMBER ________

DATE	CONTACT METHOD	PUMPING FREQ	AMOUNT PUMPED	PROBLEMS PUMPING	COMMENTS

APPENDIX E

STUDY FEEDING LOG

SUBJECT NUMBER ___________

DATE	FDG MTHD	TIME PREP BGNS	TIME WT	PRFD WT	TIME PRFD BGNS	PRFD TEMP	PRFD ABSS	TIME FDG BGNS	TIME FDG ENDS	POFD ABSS	POFD TEMP	TIME POFD ENDS	TIME POFD WT	POFD WT

APPENDIX F

OREGON HEALTH SCIENCES UNIVERSITY

CONSENT FORM

PHYSIOLOGIC RESPONSE OF THE PRETERM INFANT DURING THE EARLY INITIATION OF BREASTFEEDING VERSUS BOTTLEFEEDING
B. J. SNELL, RN, MSN, DOCTORAL STUDENT, SCHOOL OF NURSING (714)634-5344

The main purpose of this study is to find out if preterm babies have to work harder when they breast feed than when they bottle feed.

This study is experimental because usually preterm babies do not have the opportunity to breastfeed when they begin feedings by mouth. The procedures in the study will be as follows: After I agree to participate, B. J. Snell will provide me with instructions and equipment to assist me with establishing and maintaining my breast milk. The equipment will be on loan to me for the length of my participation in the study. This educational instruction and counseling will continue through the time that my baby and I participate in the study. Once it is determined by my baby's physician that he/she can take feedings by mouth I will be allowed to breastfeed once per day.

I understand that my baby will be studied during breastfeedings and bottlefeedings. For all the feeding sessions, my baby will be taken to a room next to the intensive care nursery for privacy and monitoring. I understand that my baby will be weighed before and after the feeding. My baby's temperature and blood oxygen level will be recorded during the feeding sessions. In addition, B. J. Snell will observe my baby's level of alertness during the feeding sessions. The feeding sessions will include a ten minute period before the feeding begins, the time for the baby to feed, and a ten minute period after the feeding has ended. I understand that I will be able to hold my baby during all portions of the feeding sessions when I breastfeed and that a nurse that is caring for my baby will hold the baby and feed him or her during the bottlefeeding sessions.

I understand that there are possible risks involved including that my baby may slow down his or her heart rate and decrease the blood oxygen level. I understand that if that happens the usual measures of stopping the feeding until the baby returns his heart rate and blood oxygen level to its usual range will occur. I understand that all the feedings will take place within the neonatal intensive care unit feeding room so that staff is available immediately if any complications occur.

I understand there are potential benefits to me including early beginning of breastfeeding which may increase my ability to breastfeed after my baby goes home from the hospital. In addition, I will be loaned an electric breast pump and the equipment necessary to collect my milk efficiently. Also, I will have free consultation with B. J. Snell about my breastfeeding while I am involved in the study.

I understand that all of the information collected during the course of the feeding study will be confidential. I understand that neither my name nor my babys name will be on any of the forms or monitor paper. I further understand that the information will only be available to B. J. Snell, and her committee of advisors, of which there are three. I understand that neither my name nor my identity will be used for publication or publicity purposes.

I understand that there will be no costs to me for participation in this study.

The Oregon Health Sciences University, as an agency of the state is covered by the State Liability Fund. If you or your baby suffer any injury from the research project, compensation would be available to you only if you establish that the injury occurred through the fault of the University, its officers or employees. If you have further questions, please call Dr. Michael Baird at (503)279-8014.

B. J. Snell, RN, MSN, has offered to answer any questions that I might have about the study now or at any time during the study. I understand that I may refuse to participate or withdraw from this study at any time without affecting my relationship with or treatment at the Oregon Health Sciences University. If I decide to withdraw from the study, I understand that I must return the equipment loaned to me for the study.

I understand that I will receive a copy of this consent form after agreeing to participate in the feeding study.

Your signature below indicates that you have read the foregoing and agree to participate in this study.

____ _______________
Signature Date

____ _______________
Witness Date

ABSTRACT

Title: Physiologic Response of the Preterm Infant During the Early Initiation of Breastfeeding versus Bottlefeeding

Author: B. J. Snell, RN, MSN, CNM

Approved: ______________________________

Mary Ann Curry, DNSc, FAAN, Dissertation Advisor

The clinical assumption that breastfeeding, in comparison to bottlefeeding, places an increased demand for energy on the preterm infant has not been substantiated in the literature. This study tested the hypothesis, the physiologic response of pulse oximetry measurement will not be significantly different during the early initiation of breastfeeding versus bottlefeeding in the small PTI.

The convenience sample consisted of 10 preterm infants hospitalized in a neonatal intensive care unit, whose mothers planned to breastfeed. Following recruitment the mothers were loaned an electric breast pump and had frequent contacts with the investigator while maintaining their milk supply prior to initiating actual breastfeeding. The infants' mean age at birth was 30.3 weeks (SD=1.418, range=27-32 weeks) with a mean birth weight of 1431.5 grams (SD=247.353, range 975-1750 grams). Four were female and six were male. Four infants were delivered vaginally and six by cesarean section. Seven of the infants were

ventilator dependent in the first 24 hours of life.

The methodology involved an alternating treatment, repeated measures design. Each infant was observed for a total of 6 feedings, 3 breastfeedings and 3 bottlefeedings, during the first two weeks of suckled feedings. For purposes of this study, breastfeeding was initiated within 48 hours of the initial order to bottlefeed. Infants were monitored for pulse oximetry, heart rate, and skin temperature during prefeeding, feeding, and postfeeding periods. Behavioral state was assessed before and after the feedings using the Anderson Behavioral State Scale. In addition, the infants were weighed before and after the feedings.

The hypothesis was supported. No statistically significant differences were found in pulse oximetry measurements when feedings were analyzed using a repeated measures ANOVA. In addition, there was no significant difference found in mean heart rate between feeding conditions. Analysis of infant temperature demonstrated a significant interaction effect between time periods and methods ($F=14.252$, df 2,18, $p=0.0044$). Further analysis demonstrated a significant difference from prefeeding to feeding, and prefeeding to postfeeding periods during breastfeedings. Mean infant behavioral state decreased significantly from prefeeding to postfeeding periods

($F=23.301$, df 1,9, $p < 0.001$).

In summary, the findings suggest that early breastfeeding does not place an increased demand for energy on the preterm infant. It appears that breastfeeding keeps PTI's warmer during and immediately after breastfeeding. Finally, these preterm infants engaged in nutritive sucking during the early initiation of breastfeeding. The current practice of delaying breastfeeding based on the assumption of physiologic destabilization is not supported by this research.