LIMB BLOOD PRESSURE MEASUREMENTS IN INFANTS TWELVE HUNDRED GRAMS OR LESS

by

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ABSTRACT

Mean arterial blood pressures were measured peripherally in the upper and lower positions of the right leg, right arm, and left arm by a neonate oscillometric blood pressure machine. They also were compared to the mean arterial pressures measured centrally by an umbilical artery catheter or radial arterial line. The study consisted of 10 infants (3 males, 7 females) 1,200 grams or less. Measurements were obtained in each infant for 3 consecutive days. The data collected were analyzed by computer statistical analysis. The analysis revealed that day and day by location were significant. However, the standard deviations were so great that further analysis was not continued. The physiological significance of these findings was discussed. In order to obtain a correct clinical evaluation, the importance of knowing these physiological variances of blood pressure in infants was stressed.

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CHAPTER I

INTRODUCTION

In the newborn intensive care unit, blood pressure monitoring is a useful diagnostic tool for management of critically ill neonates. Blood pressure is used to determine perfusion and heart function by measuring the force exerted by the blood against any unit area of the vessel wall (Guyton, 1991). The measurement consists of three different parts: (a) systolic blood pressure, (b) diastolic blood pressure, and (c) mean blood pressure. The systolic blood pressure is the pressure at the height of a pulse energized by the heart (Guyton, 1991). In full-term neonates, this measurement is approximately 65 to 85 mm Hg (National Heart, Lung, and Blood Institute, 1987). The lowest point of a pulse energized by the heart is the diastolic blood pressure (Guyton, 1991). The mean arterial blood pressure equals the diastolic blood pressure plus one third of the pulse pressure (Guyton, 1991).

These blood pressure measurements, when low, suggest a decrease in intravascular volume and, when accompanied by an elevated heart rate, suggest an increased workload on the heart. When blood pressure measurements are low, urine output and oxygenation can be affected because of decreased blood flow. Hypovolemia can be treated effectively with volume such as blood, colloid (albumin or plasmanate), or normal saline. If pressures remain low after reestablishing intravascular volume, with decreased urine output, vasopressors can be helpful. Vasopressors are medications that stimulate contraction of capillary and arterial musculature, resulting in increased resistance to blood flow and elevation of blood pressure (Guyton, 1991). This increase in blood pressure will improve renal perfusion, resulting in increased urine output. For these reasons and because blood pressure can be altered by many different disease states, accurate blood pressures are important in caring for the critically ill neonate.

In neonates, central blood pressure tends to be more accurate. This pressure is measured in neonates by two methods: (a) umbilical artery catheters or (b) radial arterial lines. In addition to being more accurate, implementation of these two methods results in decreased discomfort in the critically ill neonate by decreasing the amount of needle sticks required to monitor their laboratory values. These two methods can be hazardous, and they also can be associated with complications such as acute blood loss if the line becomes dislodged, thrombosis, or hypertension. For these reasons, an accurate peripheral noninvasive blood pressure must be identified.

There has been substantial research on peripheral blood pressures of term infants and infants greater than 1,000 grams. However, until recently, little research has been conducted concerning very low birth weight infants of 1,000 grams or less because they rarely survived. A large part of their survival is secondary to the discovery of surfactant, a phospholipid found in Type II pneumocytes of the lung that increase compliance. Lack of lung compliance (respiratory distress syndrome) in these smaller infants was the main reason for failure to survive. Researchers have found a method to provide surfactant to these infants, thus supplying them with a biological replacement that increases survival.

The discovery and use of surfactant also has decreased the critical phase of illness in these infants, resulting in a decreased length of time in which an umbilical artery catheter or radial arterial line is required. Loss of a central blood pressure monitoring capability makes the need for an accurate peripheral blood pressure in these smaller and younger infants even more compelling. It was the hope of this investigator that this research would find an accurate peripheral blood pressure for this population of neonates.

The accepted and studied locations for peripheral blood pressures are the upper arm and thigh. In larger-term infants, at least one of these locations is typically free of leads and intravenous catheters, thus permitting acquisition of a blood pressure reading. Unfortunately, with smaller, more premature infants, this task is not easy. The difficulty in obtaining a blood pressure is that these infants require different equipment to monitor and care for them. For example, these infants are smaller and more immature, with skin that easily tears. For this reason, limb leads are used. Limb leads are plastic strips containing electrode wires in the center of the strip that wrap around the infant's extremities, adhering to themselves rather than the infant's skin. This procedure is different from the traditional leads for cardiac and respiratory monitoring that stick to the skin of the chest and legs.

Smaller, premature infants require intravenous therapy for longer periods of time. Prolonged intravenous therapy is a problem because these infants have smaller peripheral veins; thus, silastic lines are frequently placed in the larger veins of the arms. This placement prevents use of these sites for monitoring blood pressure. For these reasons, alternative blood pressure locations are used.

The staff of many newborn intensive care units, as an alternative, take blood pressures in alternate peripheral locations. Taking peripheral blood pressures in these locations is a problem because blood pressure ranges have not been studied from these locations nor have they been compared to the ranges of other accepted blood pressure locations. Thus, no norms have been established for peripheral blood pressures. The lack of information pertaining to alternative blood pressure locations makes the interpretation of these blood pressures difficult. For these reasons, this investigator believed that the current study would find an accurate peripheral blood pressure range that would correlate with central blood pressures for this population of lower birth weight, premature infants.

Problem Statement

The focus of this study was to (a) identify a peripheral blood pressure range for infants 1,200 grams or less and (b) identify if any specific limb pressure is more accurate than others by comparing these pressures with a central arterial blood pressure.

Purpose

The purpose of this study was to determine if infants less than 1,200 grams have a different blood pressure range compared to higher birth weight infants. A specific peripheral blood pressure location was identified as the immediate correlate to the central blood pressure as well as a blood pressure range for this population of infants. If an accurate peripheral blood pressure site is identified, it will assist with medical management of these smaller, critically ill infants.

CHAPTER II

REVIEW OF LITERATURE

The review of literature covers a brief overview of surfactant, umbilical artery catheters, radial arterial lines, and critikron blood pressure monitors. It also includes a more extensive review of blood pressures of neonates.

Surfactant

In 1959, Avery and Mead demonstrated that lungs from infants who died from respiratory distress syndrome were deficient in surfactant (Avery & Mead, 1959). Since that time, many physicians have worked to develop a replacement for this deficiency. In the early 1970s, morphological and surface physical studies were conducted on lamb and rabbit lungs showing changes in lung morphology, surface activity, and mechanical properties (Clements, 1977). These changes were correlated with increased amounts of phospholipid. Once phospholipid was identified as the main component of surfactant, research was conducted to determine methods to effectively deliver it to immature lungs. Initial attempts to aerosolize these into the airways of infants did not show a sufficient effect (Clements, 1977). However, a surfactant suspension placed in the airway prior to the initiation of breathing increased survival and aeration of the lung (Enhoming, Shennan, & Possmayer, 1985).

Approximately 30 years after Avery and Mead (1959) identified surfactant deficiency as the cause for respiratory distress, the first use of surfactant in human subjects was performed (Rooney, 1985). Since 1987, the use of surfactant has been shown to decrease duration of mechanical ventilation, incidence of bronchopulmonary dysplasia, and mortality (Takahashi, Amirkhanian, & Taeusch, 1988). Surfactant also has increased the survival rate for 24- to 29-week gestation infants to more than 90%. Surfactant also has decreased the number of infants who have severe respiratory distress, i.e., those who require more than 60% oxygen or inspiratory pressures greater than 20 cm H2O (Shapiro, Notter, & Morin, 1985). In addition to the decrease in respiratory disease syndrome, there also is a decreased need for umbilical artery catheters and radial artery lines.

Umbilical Artery Catheters

Umbilical artery catheters are small polyethylene or silastic catheters that are placed in the umbilical artery of critically ill neonates. These umbilical artery catheters are placed in infants for the following reasons: (a) frequent blood gas monitoring, (b) infusion of maintenance glucose and electrolyte solutions, and (c) respiratory distress requiring more than 40% oxygen (Fletcher, MacDonald, & Avery, 1983; Gomella, 1988). Umbilical artery catheter placement is critical and controversial. At present, there are two accepted positions: (a) The "high" line is positioned between thoracic vertebrae 6 to 10, and (b) the "low" line is placed between lumbar vertebrae 3 to 4 (Fletcher et al., 1983; Stringel, Mercer, Richler, & McMurray, 1985). Umbilical artery catheters provide immediate access and decrease the amount of needle sticks an infant might receive; however, complications may occur (Bergqvist, Bergentz, Hermansson, Lundberg, & Troeng, 1987).

Complications that may occur include hemorrhage, ischemic damage to organs and skin, infection, thrombus formation with distal embolization, refractory hypoglycemia, and hypertension (Stringel et al., 1985). The incidence of major complications has been reported from 1.5% to 30% (Stringel et al., 1985). However, the incidence of clot formation is 95% for all catheters placed, with the risk of serious complications from 2% to 5% (Behrman, 1987). Due to the risk and severity of complications of umbilical artery catheters, all providers agree that removal should occur as soon as possible (Bergqvist et al., 1987; Fletcher et al., 1983; Gomella, 1988).

Radial Arterial Lines

Historically, radial arterial lines have been used when umbilical artery lines have not been available, either secondary to complications, congenital anomalies, or older infants who no longer have umbilical access (Barr, Sumners, Wirtschafter, Porter, & Cassady, 1977). Indications for placement of radial arterial lines are similar to umbilical artery catheters, including frequent blood pressure monitoring (Barr et al., 1977; MacDonald & Eichelberger, 1983).

Complications of radial arterial lines include infection, arteriospasm, embolism or thrombosis, hematoma, and nerve damage (Barr et al., 1977; MacDonald & Eichelberger, 1983). The incidence of complications from radial arterial lines is from 0.6% to 25.4% (Adams, Speer, & Rudolph, 1980). The severity of complications, however, is much less than those of umbilical artery catheters (Adams et al., 1980; Barr et al., 1977). Duration of these lines, in general, is less than umbilical artery catheters, ranging from 48 hours to 10 days ($\overline{X} = 4$ days) (Adams et al., 1980; Todres, Rogers, Shannon, Moylan, & Ryan, 1975). Peripheral arterial lines are an alternative to umbilical artery catheters, but potential for complication requires their removal as soon as possible (Adams et al., 1980; Todres et al., 1975).

Critikron Blood Pressure Monitoring

The critikron automatic blood pressure machine is designed to noninvasively and automatically measure systolic and diastolic pressure, mean arterial pressure, and pulse rate. The machine is capable of measuring these parameters for neonates, adults, and pediatric patients. When taking peripheral blood pressure, the critikron uses the oscillometric technique. The oscillometric technique consists of a recording apparatus that can register pulsations in a lightly inflated blood pressure cuff around the forearm (Guyton, 1991).

Kimble, Darnall, Yelderman, Ariagno, and Ream (1981) demonstrated that the oscillometric method of blood pressure measurement was within 0.0 ± 2.1 torr of the intraarterial blood pressures when the appropriate cuff size was used. Baker, Maisels, and Marks (1984) studied 19 patients with 206 indirect measurements from upper extremities and 50 from lower extremities. They found a significant correlation between the automated oscillometer and intraarterial catheters. Similar results were found by Sonesson and Broberger (1987). However, there is controversy as to the accuracy of the oscillometric technique for blood pressure monitoring as evidenced by studies performed by Diprose, Evans, Archer, and Levene (1986) and Wareham, Haugh, Yeager, and Horbar (1987). Both of these studies suggested that, even though there is a statistically significant correlation between oscillometric and intraarterial blood pressure values, there is still a wide range of intraarterial values that correspond to each individual oscillometric reading (Wareham et al., 1987). Because of this discrepancy, these authors stated that statistically significant correlation does not equal clinically acceptable agreement.

Chia et al. (1990) demonstrated that blood pressure measurements by the Dinamap monitor were reasonably close in agreement to those obtained by intraarterial mean arterial pressure ranges more than 40 mm Hg. For mean arterial pressure of 40 mm Hg and lower, the Dinamap readings tended to be higher than those obtained by the intraarterial methods. Despite this controversy, many units throughout the United States use automated oscillometric blood pressure monitoring devices. Two units from which data were collected in this study use this type of blood pressure device; thus, this instrument was used in the present study.

Blood Pressure in Neonates

Versmold, Kitterman, Phibbs, Gregory, and Tooley (1981) reported that the mean, systolic, and diastolic blood pressures increased with increasing birth weight for average gestational age infants and small for gestational age infants of compatible weights. Versmold et al.

demonstrated this increase by using low-lying umbilical artery catheters and measuring blood pressures every 15 minutes for the first 12 hours of life. This study used infants with birth weights from 610 to 4,220 grams. In closer review, only 16 infants < 1,000 grams were obtained.

In another study, Park and Guntheroth (1970) measured direct blood pressure of the brachial and femoral arteries in children 3 to 15 years old. They found that the average auscultatory systolic pressure in the arm was identical to the average direct systolic pressure in the brachial and femoral arteries. They obtained their data during cardiac catheterization using cuffs 20% wider than both limbs. They also found leg auscultatory systolic pressures to be 11 mm Hg higher than direct pressures. From the data obtained, they concluded that a cuff 25% larger for the lower limb is required.

The differences between upper and lower extremity blood pressures in newborns have been studied by several researchers with different conclusions. De Swiet, Peto, and Shinebourne (1974) studied 20 healthy full-term infants using the upper arm and calf. They found that the upper extremity blood pressure was consistently higher than the lower extremity blood pressure by as much as 30 mm Hg. De Swiet et al. also suggested that all healthy full-term infants have some degree of coarctation during their first week of life. However, Uhari, Isotalo, Kauppenin, and Kouvalainen (1981) found no difference when studying 38 healthy full-term infants as long as the appropriate cuff size was used for both extremities using the Doppler method. They used a cuff size for the arm of 4 cm x 10 cm and a cuff size for the leg of 5.5 cm x 14 cm.

Piazza et al. (1985) studied 100 normal full-term infants, finding the same result as De Swiet et al. (1974). In 66%, of all infants tested, the systolic blood pressure was higher in the upper extremity than the lower extremity, whereas 28% had higher blood pressures in their lower extremities. Bucci, Scalamandre, and Savignoni (1972), in a study of 186 symptom-free infants from 3 to 96 hours old, showed that the systolic blood pressure was independently related to weight, gestation, and postnatal age. Systolic blood pressure increased linearly with weight and gestational age and nonlinearly with postnatal age.

Levison, Kidd, Gemmell, and Swyer (1966) measured peripheral blood pressures on 21, 27- to 34-week-old infants and 15 full-term infants, with gestational ages from 37 to 40 weeks old. The weights of the 27- to 34-week-old infants ranged from 960 to 1,984 grams, and the weights of the 37- to 40-week-old infants ranged from 2,750 to 4,240 grams. Using the modified Whitney mercury rubber strain gauge, Levison et al. found that systolic pressure in premature infants was related to weight and postnatal age, but not gestational age. Systolic blood pressure in full-term infants increased to a high of 76 mm Hg by the end of the 5th day. Neither groups' systolic pressure varied with thermal conditions. Spinazzola, Harper, de Soler, and Lesser (1991) also found that blood pressure was more closely related to the size of the baby than gestational age. They also found feedings caused an increase in blood pressure.

In 1986, Briassoulis reported that oscillometric devices were as much as 10 mm Hg different when compared with arterial lines in preterm infants. This difference was significant since neonatal hypotension has been associated with fluid overload, patent ductus arteriosus, necrotizing enterocolitis, and bronchopulmonary dysplasia. Unlike Briassoulis, Kimble et al. (1981), Baker et al. (1984), and Sonesson and Broberger (1987) showed that the oscillometric measurements were within ±2.5 mm Hg as long as the cuff size was at least 50% of the limb circumference. In addition, Baker et al. found both upper and lower extremities correlated to the aortic measurement.

Diprose et al. (1986) and Wareham et al. (1987) found that even though there is statistical significance, there also is a wide range of intraarterial values that correspond to each individual oscillometric reading. They also reported that the Dinamap consistently overreads blood pressures in very low birth weight infants when hypotension occurs.

Based on recommendations of the British Hypertension Society (De Swiet et al., 1974), blood pressures in children less than 1 year old should be measured by Doppler ultrasound or oscillometry. This type of measurement is necessary because korotkoff sounds cannot be heard reliably using sphygmomanometry. De Swiet et al. also reported that the median systolic blood pressure at 4 days old is 75 mm Hg.

Gemelli, Manganaro, Mami, Rando, and DeLuca (1989) reported that newborn infants have a circadian rhythm influencing blood pressure but not heart rate. They also described an hour-by-hour significant fluctuation in male infants but not female infants. Gemelli et al. believed this significance was important for a correct clinical evaluation of blood pressure measurement.

In 1990, Gemelli, Manganaro, Mami, and DeLuca demonstrated in a longitudinal study of blood pressure during the first year of life that blood pressure increases significantly in both sexes during the first 6 months of life. They also showed that boys have higher systolic blood pressures than girls after the first 4 days of life. This difference persists during the first year of life. Only at 12 months of age do boys and girls have the same mean values of systolic blood pressure.

Park and Guntheroth (1970) measured blood pressure and heart rate in 1,554 healthy infants and children aged 2 weeks old to 5 years old, using an oscillometric device. They found that the average blood pressure value increased rapidly from the 2- to 3-week value to the 1- to 5-month value. No subsequent blood pressure change occurred until 2 years old, when it increased by an average annual rate of 2 mm Hg for systolic and 1 mm Hg for diastolic. From these data, Park and Guntheroth concluded that blood pressure should be determined at each routine physical examination.

In a study of the influence of behavioral state on blood pressure in preterm infants through the 5th day of life, Van Ravenswaaig-Arts, Hopman, and Kollee (1989) measured blood pressures every 3 hours. The behavioral state was scored, with each blood pressure showing a slightly higher blood pressure and heart rate when the infant was awake than when asleep.

Spinazzola et al. (1991) reported a trend toward increasing blood pressure with increasing gestational age for the first week of life. They obtained blood pressure values from 44 charts of infants with birth weights of 500 to 750 grams in this retrospective study. The blood pressure readings were taken from umbilical artery catheters and oscillometer. These readings showed no statistical difference. The investigators also reported from these data that the blood pressure range of this size infant is extremely wide and that it may be necessary to use other clinical criteria, in conjunction with blood pressure, to assess the infants' hemodynamic state.

In conclusion, the review of literature has revealed that, with the use of surfactant, smaller infants are surviving and respiratory distress syndrome (the most common illness) is less severe. The decrease in severity of this illness reduced the length of time and, in some cases, even the need for an umbilical artery or radial arterial catheter. The benefits of these two lines no longer outweigh the risks.

The review of literature also has shown that peripheral blood pressure is close to arterial blood pressure if the appropriate size blood pressure cuff is used. Peripheral blood pressure in upper and lower extremities also is similar if the cuff is 20% larger than the arm and 50% larger than the leg. The critikron blood pressure machine, if calibrated correctly and monthly, can be as accurate as ±2.5 mm Hg from the central blood pressure. All of these findings have been considered in developing the methods and procedures for this study. This information also has led the investigator to ask the following research questions:

1. Is there a significant difference in blood pressure between the right upper arm and right lower arm and the right upper leg and right lower leg?
2. Is there a significant difference between the upper arm, lower arm, upper leg, and lower leg blood pressure and central arterial blood pressure?

CHAPTER III

METHODOLOGY

Design

The design of this study was a descriptive survey (Wilson, 1985) used to determine an accurate peripheral blood pressure for infants 1,200 grams or less. Blood pressures were correlated to the "gold standard" (i.e., umbilical artery catheter and peripheral radial arterial lines) central arterial blood pressures. The setting was in two, level three, newborn intensive care units located in the Intermountain region: (a) Primary Children's Medical Center and (b) University Hospital.

Sample

The sample size consisted of 10 premature infants who had birth weight at 1,200 grams or less. The only infants excluded from this study were those with major congenital defects that would alter blood pressure, e.g., coarctation, tetralogy of fallot, aortic stenosis, pulmonary stenosis, atrial septal, ventricular septal, gastroschisis, and omphaloceles. Because the subjects were their own control, they were not excluded if they were receiving any blood pressure medications.

Instruments

The instruments included an (a) Oscillomate automatic blood pressure machine, (b) an Oscillomate blood pressure cuffs, and (c) either an umbilical artery catheter or a peripheral arterial line--whichever the infant currently had in place. Standardized data collection forms (see Appendix A) and consent forms from one parent of each infant (see Appendix B) also were utilized.

Procedure

Infants were selected after parental permission was obtained. In order to answer the first research question, peripheral blood pressure measurements were obtained on the proximal and distal parts of the right arm and right leg. The left upper arm was added to these previous measurements to answer the second research question of significant difference between peripheral blood pressures and the central blood pressure. These measurements were obtained on 3 consecutive days during the first week of life. The size of the cuff used was determined by the circumference of each limb. The width of the cuff for all extremities was at least 50% the circumference of that extremity, as determined by previous studies (Baker et al., 1984; Kimble et al., 1981; Sonesson & Broberger, 1987). Measurements were taken in the same sequence, starting with the right upper arm, left upper arm, right forearm, right thigh, and right calf. Measurements were taken within 2 hours of the same time each day for 3 consecutive days. This standard time was used to decrease the effect of extraneous variables on blood pressure. Each measurement was taken twice at 1-minute intervals. As discussed in the instruction manual for appropriate use, the first measurement was used for calibration and the second measurement was recorded for actual blood pressure measurement.

In order to increase validity of measurement, only one investigator and one machine were used. The Oscillomate machine was used and calibrated every 2 weeks throughout the study. The umbilical artery catheters and peripheral arterial lines were calibrated prior to the beginning of each consecutive day's measurements.

Analysis

Statistical analyses were performed using a completely crossed analysis of variance (ANOVA), followed by an intraclass correlation coefficient, regression analysis, and clinical criteria. Three consecutive, daily blood pressure results were treated as a separate group, and they also served as replications of each other.

ANOVA is an inferential statistical procedure that is used to compare the mean scores of two or more groups (Wilson, 1985). In this study, the ANOVA was used to compare each blood pressure separately and together. Importantly, the ANOVA sample size was 10, with three separate measurements.

Intraclass correlation coefficients are measures of the relative similarity of quantities that share the same observational units of a sampling and/or measurement process (Kotz & Johnson, 1983). In this study, intraclass correlation coefficients were used to measure the relative similarity of all collected blood pressures.

Simple linear regression is a technique that utilizes the correlation between variables to develop a prediction equation (Munro, Visintainer, & Page, 1986). The higher the correlation, the more accurate the prediction (Munro et al., 1986). This type of regression analysis was used between the gold standard and each set of separate limb pressures. With regression analysis, the sample size was considered to be 30 since each measurement was compared to the gold standard.

CHAPTER IV

RESULTS

The sample for this study consisted of 10 infants. Data describing these infants are presented in Table 1. Nine subjects' blood pressures were measured by an umbilical artery catheter during the first week of life, and 1 infant's blood pressure was measured by a radial arterial line during the first week of life.

Raw data included mean arterial blood pressures, as measured by the Oscillomate blood pressure machine and the umbilical artery catheter/arterial line; then, these blood pressures were compared. Table 2 displays the Oscillomate blood pressures for each infant for each of the 3 consecutive days. Table 3 displays the blood pressures from the umbilical artery catheter/radial arterial line for each infant for each of the 3 consecutive days. Table 4 displays the comparison of the Oscillomate peripheral blood pressures and the umbilical artery catheter/radial arterial line blood pressures.

The statistical analysis was conducted using the SPSS/PC+ computer program at the University of Utah. Data were analyzed to determine if there was a difference between the right upper arm and lower arm, the right upper

Table 1

Demographics

Sample size: 10 patients

Age at study: 1 to 7 days of life for all but one, which was conducted on Day 63 of life

Type of arterial line: Umbilical artery catheter = 9 patients, radial arterial line = 1 patient

Sex: females = 7 patients, males = 3 patients

Diagnoses: Prematurity = 10 patients
Respiratory distress syndrome = 8 patients
Rule out sepsis = 9 patients
Patent ductus arteriosus = 2 patients
Bronchopulmonary dysplasia = 1 patient
Airway obstruction = 1 patient

Infant's state: Sleeping

Gestational age: 22 weeks = 1 patient
26 weeks = 1 patient
27 weeks = 4 patients
28 weeks = 1 patient
29 weeks = 3 patients

Actual weight:	Range	Mean
	Day 1 = 835-1,180 grams	956 grams
	Day 2 = 790-1,160 grams	934 grams
	Day 3 = 600-1,126 grams	907 grams

Drugs received: Fentanyl = 3 patients
Phenobarb = 1 patient
Versed = 1 patient
Nembutal = 2 patients
Lasix = 1 patient
Ampicillin = 8 patients
Vancomycin = 1 patient
Erythropoietin = 3 patients
Morphine = 1 patient
Dopamine = 1 patient
Indocin = 2 patients
Albumen = 1 patient
Decadron = 1 patient
Gentamicin = 8 patients
Claforan = 1 patient

Table 2

Oscillomate Blood Pressure Machine Raw Data

Variable	$\overline{X}$	*SD*	Minimum blood pressure	Maximum blood pressure
RUA1	33.60	7.18	20	47
RLA1	33.50	7.86	21	49
LUA1	34.20	9.24	20	50
RUL1	33.70	8.10	20	46
RLL1	33.40	8.44	18	46
RUA2	38.90	7.53	24	49
RLA2	41.40	8.24	32	54
LUA2	43.50	8.07	32	54
RUL2	39.10	7.82	30	51
RLL2	39.10	8.28	29	53
RUA3	39.10	5.22	33	48
RLA3	39.10	6.06	29	48
LUA3	40.50	8.67	28	56
RUL3	38.80	7.41	32	56
RLL3	38.40	5.82	30	50
RUA	37.20	5.77	28.67	48.00
RLA	38.00	5.61	30.00	48.33
LUA	39.40	6.67	32.00	51.00
RUL	37.20	6.95	30.00	50.00
RLL	36.97	6.45	28.33	49.67

Note. RUA = right upper arm, LUA = left upper arm, RUL = right upper leg, RLL = right lower leg, and RLA = right lower arm. 1 = Day 1, 2 = Day 2, and 3 = Day 3.

Table 3

Umbilical Artery Catheter/Artline Raw Data

Variable	$\overline{X}$	*SD*	Minimum blood pressure	Maximum blood pressure
RUA1	41.00	10.28	23	59
RLA1	38.50	10.68	24	60
LUA1	40.70	8.69	23	54
RUL1	32.20	12.85	21	67
RLL1	34.30	9.67	21	57
RUA2	42.20	10.59	27	57
RLA2	37.40	10.32	20	55
LUA2	47.40	9.98	29	60
RUL2	34.30	10.61	22	59
RLL2	40.20	9.04	29	56
RUA3	45.80	9.19	29	62
RLA3	40.10	6.59	28	47
LUA3	40.90	10.73	25	60
RUL3	32.60	5.95	24	41
RLL3	39.60	4.77	30	45
RUA	43.00	7.96	26.33	54.33
RLA	38.67	7.48	27.33	53.33
LUA	43.00	7.86	34.33	58.00
RUL	33.03	8.78	24.00	55.00
RLL	38.03	6.93	29.00	51.00

Note. RUA = right upper arm, LUA = left upper arm, RUL = right upper leg, RLL = right lower leg, and RLA = right lower arm. 1 = Day 1, 2 = Day 2, and 3 = Day 3.

Table 4

Oscillomate Blood Pressures Compared with Umbilical Artery Catheter/Artline Blood Pressures Raw Data

Variable	$\overline{X}$	SD	Minimum blood pressure	Maximum blood pressure
RUA1	-7.40	8.36	-22	8
RLA1	-5.00	9.23	-21	8
LUA1	-6.50	5.08	-12	3
RUL1	1.50	9.28	-21	11
RLL1	- .90	8.28	-11	12
RUA2	-3.30	7.86	-14	8
RLA2	4.00	11.87	-10	31
LUA2	-3.90	5.38	-13	5
RUL2	4.80	6.92	-11	13
RLL2	-1.10	9.34	-20	10
RUA3	-6.70	10.79	-27	9
RLA3	-1.00	6.51	-16	10
LUA3	- .40	7.82	-11	11
RUL3	6.20	6.27	- 4	17
RLL3	-1.20	7.13	-14	9
RUA	-5.80	7.22	-16.33	4.67
RLA	- .67	5.28	-11.00	6.33
LUA	-3.60	3.23	- 8.67	1.67
RUL	4.17	4.65	- 5.00	11.33
RLL	-1.07	6.95	- 9.67	10.33

Note. RUA = right upper arm, LUA = left upper arm, RUL = right upper leg, RLL = right lower leg, and RLA = right lower arm. 1 = Day 1, 2 = Day 2, and 3 = Day 3.

leg and lower leg, and the left upper arm blood pressures and central arterial blood pressure. The mixed model ANOVA with repeated measures was used for the difference between groups of means of the upper and lower extremity blood pressures and the central arterial blood pressure. With this type of analysis, there are fixed effects, random effects, within subject factors, between subject factors, dependent variables, and independent variables (see Table 5).

The fixed effects in this study are the day and location that the blood pressure was obtained. The random effects are the 10 infants. There were no between-subject factors in this study. The within-subject factors have the dependent variable of mean arterial pressures. These blood pressures were obtained from the Oscillomate blood pressure monitor for the peripheral blood pressures and the Hewlett Packard Cardiorespiratory Monitors for the central blood pressures. The independent variables included the day and location. The day consisted of three levels. Each level is equivalent to 1 of the 3 different days data were obtained. Location consisted of five levels for the five different peripheral sites used to obtain blood pressures.

The results showed that the day and the day by location were not significant. However, location did show some significance. Standard deviations were high; thus,

Table 5

Mixed Model Analysis of Variance

Fixed effects: Day and blood pressure locations

Random effects: Patients = 10

Between subject factors: None

Within subject factors:
- Dependent variable: Mean arterial blood pressure
- Independent variable: Day 1, Day 2, and Day 3
  - Location = Right upper arm
    - Right lower arm
    - Right upper leg
    - Right lower leg
    - Left upper arm

comparison tests of the means were not conducted.

Intraclass correlation coefficients were conducted comparing the umbilical artery catheter/radial arterial line coincident with each peripheral blood pressure site for each of the 3 consecutive days. These data are displayed in Table 6. The classical intraclass correlation coefficient is the (a) mean square of between people, (b) minus the within-people mean square, (c) divided by the mean square of between people, (d) plus twice the mean square of within people.

Table 6

Intraclass Correlations

UAC-RUA1 Day 1: UAC - coincident right upper arm
UAC-RUA2 Day 2: UAC - coincident right upper arm
UAC-RUA3 Day 3: UAC - coincident right upper arm
Intraclass correlation coefficient = 0.4434

UAC-RLA1 Day 1: UAC - coincident right lower arm
UAC-RLA2 Day 2: UAC - coincident right lower arm
UAC-RLA3 Day 3: UAC - coincident right lower arm
Intraclass correlation coefficient = -0.0676

UAC-LUA1 Day 1: UAC - coincident left upper arm
UAC-LUA2 Day 2: UAC - coincident left upper arm
UAC-LUA3 Day 3: UAC - coincident left upper arm
Intraclass correlation coefficient = -0.2527

UAC-RUL1 Day 1: UAC - coincident right upper leg
UAC-RUL2 Day 2: UAC - coincident right upper leg
UAC-RUL3 Day 3: UAC - coincident right upper leg
Intraclass correlation coefficient = 0.0592

UAC-RLL1 Day 1: UAC - coincident right lower leg
UAC-RLL2 Day 2: UAC - coincident right lower leg
UAC-RLL3 Day 3: UAC - coincident right lower leg
Intraclass correlation coefficient = 0.5829

Note. UAC = umbilical artery catheter, RUA = right upper arm, LUA = left upper arm, RUL = right upper leg, RLL = right lower leg, and RLA = right lower arm. 1 = Day 1, 2 = Day 2, and 3 = Day 3.

CHAPTER V

DISCUSSION AND RECOMMENDATIONS

The purpose of this study was to answer two questions: (a) Is there a difference in blood pressure between the right upper arm and lower arm, and the right upper leg and right lower leg? and (b) Is there a significant difference among upper arm, lower arm, upper leg, lower leg, and central arterial blood pressures? The difference was defined as significant between the peripheral blood pressure and the central arterial blood pressure.

Ten infants were included in the sample. The data indicated a homogeneous sample. All infants who comprised the sample were representative of the population of very low birth weight infants, as defined by infants weighing less than 1,250 grams (Kopelman, 1990). Their weight range for 3 consecutive days was from 600 to 1,180 grams, with means for 3 days from 907 to 956 grams.
These infants were representative of the population of premature infants, as defined by infants less than 38 weeks gestation (Phibbs, 1991). These infants also were in a sleeping state for all 3 days of measurement. Nine infants had an umbilical artery catheter in place for the

duration of the study, and 1 infant had an arterial line in place for the duration of the study. Also, 90% of the data were collected within the first week of life. Of that 90%, 60% were started on Day 2 of life, 20% on Day 1 of life, and 10% on Day 7 of life.

The individual raw blood pressure data from the oscillometer, as well as from the umbilical artery catheter, had significant variability; thus, no congruency could be identified. These data are evidenced by standard deviations ranging from 4.77 to 10.68. When the two types of measures were compared again, the standard deviations were significant, ranging from 3.23 to 11.87; thus, comparisons of means tests were not performed.

The raw blood pressure data of the umbilical artery catheter were significant when compared to the various peripheral blood pressure sites. The means for the umbilical artery catheter ranged from 32.20 to 47.40, and the means for the peripheral blood pressure sites ranged from 33.50 to 43.50. The higher umbilical artery catheter blood pressure is most likely because the umbilical artery catheter is located in one of the main arteries of the circulatory system; therefore, it is believed to be more stable and accurate when functioning properly. Consequently, most health professionals consider the umbilical artery catheter the gold standard for blood pressure measurement.

The mixed model ANOVA supported the day and the day by location to be insignificant. However, location showed significance with the simultaneous right forearm and umbilical artery catheter blood pressures ($\overline{X}$ = -.67) and with the simultaneous right calf and umbilical artery catheter blood pressures ($\overline{X}$ = -1.07). These locations had the highest correlation. Again, no comparison tests were performed because the standard deviations were 5.28 for the right forearm and 6.95 for the right calf. However, location is important for the clinician to consider when taking peripheral blood pressures.

The intraclass correlations were conducted comparing the umbilical artery catheter/artline mean arterial blood pressure coincident with each peripheral blood pressure site for each of the 3 consecutive days. The results supported the intraclass correlation coefficients, ranging from -0.2527 to 0.4434, suggesting little similarity between the different peripheral blood pressure sites and the umbilical artery catheter/artline. The significant range for intraclass correlation coefficients was -0.5 and 1, respectively. The variability of these data may be a result of the inability to control the monitor and the transducer used to obtain the arterial blood pressures.

The analysis of data showed no statistical significance for one particular site for blood pressure in any one infant on any particular day at this gestational age and weight range. When comparing peripheral blood pressure with central blood pressure, there also was no statistical significance. The most likely reason that there is variability among the different types and locations of blood pressures in these smaller infants is because they do not have a stable hemodynamic state. Their peripheral vasculature is so small in diameter that any change will affect it, such as temperature, intravenous sites, and even the blood pressure cuff. However, the central vasculature in which the umbilical artery catheter is located is not affected as much by these changes. These results do not support the information gathered in the Review of Literature; that is, peripheral blood pressure is close to arterial blood pressure if the appropriate cuff size is used (Baker et al., 1984; Kimble et al., 1981; Sonesson & Broberger, 1987). These data support the Diprose et al. (1986) and Wareham et al. (1987) studies. Even though there is statistical significance, there also is a wide range of intraarterial values that correspond to each individual oscillometric reading. Data also support the Spinazzola et al. (1991) study; that is, the blood pressure range of very low birth weight infants is extremely wide, and it may be necessary to use other clinical criteria in conjunction with blood pressure to assess the infants' hemodynamic state. Spinazzola et al. also discussed the role that the autonomic nervous system is believed to play in the maintenance of peripheral vascular resistance, thus affecting blood pressure and the relative immaturity of the autonomic nervous system in premature infants. The immaturity of the autonomic nervous system in this population might help to explain the wide variation seen in the peripheral blood pressure values. The immaturity of the autonomic nervous system may affect the central blood pressure (i.e., the wide range of umbilical artery catheter readings); however, it does not affect the central blood pressure as much as the peripheral blood pressure.

Limitations

Due to the small sample size and limited data collection period, even though sufficient to conduct a statistical analysis, this study may have prevented the appearance of statistical significance in the peripheral blood pressure compared with the arterial blood pressure. An additional limitation that may have affected the pressure readings is the inability to control the monitor and transducer used to obtain arterial blood pressures. The transducers were changed daily, which could have altered the readings. Each infant had his or her own monitor calibrated to a specific standard. However, because an identical monitor was not used for each infant, the investigator questions the variability that one monitor might have compared to another. The position and location of the umbilical artery catheter, high or low in the right or left umbilical artery, might explain the difference in the findings for the right forearm and right calf appearing to be more accurate. The accuracy might be explained by the central catheter being located closer to that particular peripheral site, thus having a similar reading.

Benefits

However limited this study, it may still benefit very low birth weight infants in several ways. By being aware of the variability between each individual infant as well as the group, health professionals can be more discerning in the choice of treatments used for hemodynamic stability. This study also may encourage researchers to use a better method of blood pressure analysis for these smaller infants.

Recommendations for Future Research

Further research is recommended to substantiate the findings of this study. Duplication using larger groups and longer collection periods will provide support. Noting the placement of the umbilical artery catheter position also may prove to be helpful in explaining differences in the peripheral blood pressure measurements. Research also should be undertaken that assesses individually the reliability and validity of the utilized indicators of peripheral and arterial blood pressures. Because heart rate and blood volume contribute to the stability of an infant's hemodynamic state, it would be helpful to monitor heart rate and hematocrit during the data collection period.

APPENDIX A

STANDARDIZED DATA COLLECTION FORM

	Weight	Gestational Age	Drugs	Calibration	Date of Labor/Time	Infant's State	UAC Blood Pressure S D M	Right Upper Arm S D M	Left Upper Arm S D M	Right Forearm S D M	Right Thigh S D M	Right Calf S D M
Day 1												

	Weight	Gestational Age	Drugs	Calibration	Date of Labor/Time	Infant's State	UAC Blood Pressure S D M	Right Upper Arm S D M	Left Upper Arm S D M	Right Forearm S D M	Right Thigh S D M	Right Calf S D M
Day 2												

	Weight	Gestational Age	Drugs	Calibration	Date of Labor/Time	Infant's State	UAC Blood Pressure S D M	Right Upper Arm S D M	Left Upper Arm S D M	Right Forearm S D M	Right Thigh S D M	Right Calf S D M
Day 3												

APPENDIX B

CONSENT FOR PARTICIPATION IN INVESTIGATIONAL STUDY

At the present time, the most accurate measurement of blood pressure in the neonate is the one obtained centrally by an umbilical artery catheter or peripheral arterial catheter. I am conducting a research project looking at blood pressures in infants 1,200 grams or less to evaluate and compare the peripheral blood pressure (i.e., blood pressure taken by a blood pressure cuff around the arm or leg) with the central blood pressure (i.e., blood pressure taken by a line that is placed in an artery either in the arm, leg, or umbilical artery that gives a continuous central blood pressure measurement).

I am requesting that your child participate in this study because he or she is in the appropriate weight range and currently has a central line in place. This will help me to identify if any peripheral blood pressure is consistently closer to the central blood pressure.

If you decide to have your child participate in this study, he or she will have his or her blood pressure taken once each day for 3 days. The blood pressure will be taken peripherally on the right upper arm and forearm, left upper arm, and right thigh and calf. A blood pressure machine (i.e., "Oscillomate") will be used. It is the same type of machine that is used daily for blood pressures as part of routine care for your child. These blood pressures will be compared to the blood pressure reading on the monitor from the central line your infant currently has in place.

By agreeing to participate in this study, you should realize that a total of 30 extra peripheral blood pressures will be taken during the entire study. These blood pressures are not part of your child's ordinary care.

There will be no immediate benefit and almost no risk to your child by participating in this study. The potential risks include minor discomfort from the blood pressure cuffs and a minimal increase in handling during the time periods the blood pressures are being obtained. There will be no additional charge for participating in the study. Your participation in this study is voluntary. Your decision to withdraw from this study, at any time, will be honored. Should any abnormality be found in the blood pressures, you will be notified. Approximately 10 infants will be studied.

If you have any questions or concerns regarding this study, please contact Yvonne Raymond at 588-3800 or an operator at 588-2000. The operator can page me 24 hours a day. If you have any questions concerning your child's rights as a research subject, you may contact J. Ross Milley, MD, PhD, Chairman of the Research and Human Subjects Committee at Primary Children's Medical Center at 581-7052 or the Institutional Review Board at 581-3655. Your decision to participate in this study will not affect your child's care.

Considering the possible benefits and risks of the study as outlined, I voluntarily agree to allow my child to participate in the study.

My questions regarding participation in this study have been answered and I understand the explanation.

I give permission for the information gathered in this study and pertinent information from my child's medical records to be released to Yvonne Raymond, with the understanding that they may be published for scientific purposes. My child's identity will not be publicly revealed by the investigator without my written consent.

I acknowledge receipt of a copy of this consent document.

Child's name: ______________________________

Signature of parent: ______________________________

Date: ______________________________

Signature of witness: ______________________________

Date: ______________________________

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