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THE PHYSIOLOGICAL RESPONSES OF THE RESPIRATORY DISTRESSED NEONATE TO TWO FORMS OF CHEST PHYSIOTHERAPY

by

© KATHRINE L. PETERS

A THESIS

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Date 26 May 83

DEDICATION

To my family - Mother, Father, Leslie and Rich

who never faltered in their support

nor doubted successful completion of the study

ABSTRACT

This study was undertaken to describe the respiratory distressed neonate's physiological responses to chest physiotherapy (CPT), a procedure consisting of postural drainage, percussions, and endotracheal instillation and suctioning. In addition, the extent and nature of differences of the responses of the neonate to two types of percussions were examined. One form of percussions involved applying a series of rhythmic blows to the external chest wall with the use of a soft silicone Bennett respirator mask (Bennett method). The other involved contact-heel percussions in which the thenar or hypothenar position of the hand remained in contact with the external chest wall throughout the procedure (Boyd Method). The physiological parameters used to describe the neonate's responses were heart rate (H/R), mean arterial pressure (MAP), intracranial pressure (ICP), transcutaneous oxygen ($TcpO_2$) level, alveolar-arterial oxygen gradient (A-a O_2 gradient), transcutaneous carbon dioxide ($TcpCO_2$) level, and arterial carbon dioxide tension ($PaCO_2$).

The clinical, controlled, randomized, experimental, simple cross-over design of the study permitted each neonate to act as his/her own control. The subjects were 30 neonates who met the study criteria of being 28 days of age or younger; weighing more than 750 grams; requiring intubation, less than 91% inspired oxygen concentration, CPT at least once every four hours, and an indwelling arterial line; and not being on short acting sedatives.

Each neonate was randomly assigned to one of two groups. Group one consisted of those infants who received the Bennett percussions first and the Boyd percussions at least one hour later. Group two consisted of those infants who received the percussions in the reverse order. The physiological parameter levels, with the exception of the A-a O_2 gradient and $PaCO_2$, were recorded on a six-channel recorder. Oesophageal pressure was measured to establish equivalency of chest compression. The neonates' responses were recorded during the pre-CPT, postural drainage, percussions, instillation and suctioning, and post-CPT phases.

Analysis of the data revealed that the neonates' mean physiological responses to postural drainage were not significantly different from those observed during the pre-CPT and post-CPT phases. However, the neonates' mean responses to endotracheal instillation and suctioning indicated a significant deterioration in the neonates' condition from that observed during all other phases of CPT except the percussions phase. When the neonates' responses to the Bennett and Boyd percussions were compared, a significantly higher H/R, MAP, and ICP; increased O_2 requirements; longer periods of hypoxia and hyperoxia; and a greater range of H/R were noted during the Bennett percussions. Also, following the Boyd CPT sessions, improvements in the A-a O_2 gradient and $PaCO_2$ level were noted.

The study findings suggest that the endotracheal instillation and suctioning and the increased amount of handling required to deliver the Bennett percussions had a deleterious effect on the neonates. Also, the type of infant handling involved in the Boyd percussions seemed to have a more calming influence on the neonates than the type of handling involved in the Bennett percussions.

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I owe special thanks to Jan Boyd and members of the Physiotherapy Department of the Royal Alexandra Hospitals for helping to ensure each form of chest physiotherapy was done properly; Jim Coward for his help in the early stages of the project; and to the AARN for having enough faith in an idea to provide funding.

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CHAPTER I

INTRODUCTION

Background of the Problem

Over the past twenty years a great number of changes have taken place in the field of neonatology. The term neonatology itself did not exist until 1960 (Schaffer, 1960). Since the premature nursery has become a neonatal intensive care unit (NICU), the survival rate of all infants, especially low birth weight infants, has radically improved. Today, the survival rate of infants weighing as little as 1500 grams is nearly that of full term newborns. The mortality rate among infants with respiratory distress syndrome or hyaline membrane disease (HMD) has been reduced by 90%. These changes can be attributed to the availability of such sophisticated, expensive, and invasive techniques as intra-aortic monitoring of blood pressure and oxygen tension, assisted positive pressure ventilation, total parenteral nutrition with amino acid solutions, and aggressive management of respiratory and surgical problems.

With the advent of continuous monitoring techniques in neonatal intensive care, it has been possible for caregivers to receive immediate feedback regarding the effects of handling and necessary therapeutic treatments on the infant. Tomney (1980) found that nursing care can have a profound effect on the condition of a critically ill preterm neonate. Very little work has been done in the area of responses of critically ill neonates to specific nursing care procedures such as chest physiotherapy (CPT).

Statement of the Problem

A controversy presently exists in the literature about the most efficacious method of CPT for neonates. Several studies have been conducted to investigate the application of percussions to the external chest wall of infants using the clapping method advocated for adult therapy (Curran & Kachoyeanos, 1979; Etches & Scott, 1978; Fox, Schwartz & Schaffer, 1978; Holloway, Adams, Desai & Thambran, 1969; Purohit, 1979; Stern, 1979). Two controlled trials (Finer & Boyd, 1978; Finer, Moriartey & Boyd, 1979) using contact-heel percussions, a new form of CPT for neonates, have been conducted in recent years. The results of these studies have been inconsistent. There is a dearth of conclusive evidence about how neonates respond to CPT and the most efficacious method of CPT for neonates.

Need for the Study

With the rapidly expanding role of the neonatal intensive care nurse, several procedures from other disciplines have been integrated into the routine nursing care of the critically ill neonate (Bellig, 1980; Dunn & Lewis, 1973; Hansen, 1982; Ostra & Schuman, 1974; Peterson & Fisher, 1979; Slovis & Commerci, 1974). Procedures such as starting intravenous (IV) lines, drawing arterial blood samples, manipulating respirator settings and varying oxygen concentrations, and doing CPT now fall within the nurse's domain.

At the present time, in the NICU of the Royal Alexandra Paediatric Pavilion, CPT is ordered for all patients who require mechanical ventilation to keep the artificial airway, i.e. endotracheal tube (ETT), patent, and to improve ventilation through movement of secretions from smaller bronchioles and bronchi to the larger mainstem bronchi. Because the Boyd method of CPT percussions in which contact-heel percussions were used was found to be effective (Finer & Boyd, 1978), it was systematically taught to the neonatal nurses and quickly replaced the Bennett method in which a closed-end Bennett mask for percussion was used. The efficacy of the Bennett method of percussions has remained unproven.

It has been noted that, over the past two years, the staff in the NICU has largely reverted to using the Bennett percussions. This change has been due, in part, to the departure from the unit of the designer of the technique, Mrs. Jan Boyd, D.P.T., as well as to the very high turnover of nursing staff in the NICU since her departure. Thus, to give the best care possible to neonates, it was crucial to study the effectiveness of the Boyd and Bennett methods of CPT.

Purpose of the Study

The purpose of the study was to describe, compare, and evaluate the physiological responses of the respiratory distressed neonate to the Bennett and Boyd methods of CPT.

Research Questions

1. What are the respiratory distressed neonate's responses to the Bennett and Boyd methods of CPT as indicated by the physiological parameters of heart rate (H/R), mean arterial pressure (MAP), intracranial pressure (ICP), transcutaneous oxygen tension level ($TcpO_2$), and transcutaneous carbon dioxide tension level ($TcpCO_2$)?
2. Are there differences in the responses of the respiratory distressed neonate to the Bennett and Boyd methods of CPT as indicated by the physiological parameters of H/R, MAP, ICP, alveolar-arterial oxygen gradient (A-a O_2 gradient), $TcpO_2$, $TcpCO_2$, and arterial carbon dioxide tension ($PaCO_2$)?
3. What is the extent and nature of the differences, if any, in the respiratory distressed neonate's responses to the Bennett and Boyd methods of CPT as indicated by the physiological parameters of H/R, MAP, ICP, A-a O_2 gradient, $TcpO_2$, $TcpCO_2$, and $PaCO_2$?

Research Hypotheses

Research hypotheses related to the second and third research questions were as follows:

1. There is no difference in the H/R during and following the Bennett method of CPT as compared to the Boyd method of CPT.
2. There is no difference in the MAP during and following the Bennett method of CPT as compared to the Boyd method of CPT.
3. There is no difference in the ICP during and following the Bennett method of CPT as compared to the Boyd method of CPT.
4. There is no difference in the change in the $TcpO_2$ level during the Bennett method of CPT as compared to the Boyd method of CPT.
5. There is no difference in the A-a O_2 gradient following the Bennett method of CPT as compared to the Boyd method of CPT.
6. There is no difference in the change in the $TcpCO_2$ level during the Bennett method of CPT as compared to the Boyd method of CPT.
7. There is no difference in the change in the $PaCO_2$ level following the Bennett method of CPT as compared to the Boyd method of CPT.

Definition of Terms

The following definitions were accepted by the investigator for terms utilized in the study.

A neonate is an infant who has not yet reached his/her twenty-eighth day of life (Hasselmeyer, 1964, p.2).

The neonatal period is the period of time from birth to the completion of the twenty-seventh day of life (Hasselmeyer, 1964, p.3).

A preterm or premature infant is any infant born before the end of the thirty-seventh week of gestation, regardless of birth weight (Korones & Lancaster, 1981, p.83).

A term infant is any infant born at or after the end of the thirty-seventh week of gestation, regardless of birth weight (Korones & Lancaster, 1981, p.83).

A respiratory distressed neonate is one who requires endotracheal intubation in order to establish and/or maintain normoxia, normocarbia, a normal pH level, and an unobstructed airway.

Chest physiotherapy is the application of percussions to the neonate's external chest wall following postural drainage and involves instillation and suctioning of the ETT to remove secretions from particular pulmonary lobes.

A neonatal intensive care unit is a specialized nursery which provides facilities and trained personnel for the care of the critically ill neonate.

Assumptions

Six basic assumptions were considered to be essential to the study:

1. CPT is required to help clear pulmonary secretions of the respiratory distressed neonate.

2. Instillation and suctioning of the ETT is required to ensure removal of pulmonary secretions and, hence, patency of the ETT of the respiratory distressed neonate.
3. Handling is necessary to provide care to the respiratory distressed neonate.
4. A state of homeostasis is better for the respiratory distressed neonate than wide variations in physiological parameters.
5. A neonate who is relaxed and quiet has a greater likelihood of achieving or maintaining homeostasis than one who is not.
6. Non-invasive monitoring is in no way harmful to the critically ill neonate.

Summary

Many changes have occurred in neonatology. Procedures which once were performed by non-nursing personnel are being performed by nurses. There is a lack of knowledge about how infants respond to the care they receive. This study was designed to describe, compare, and evaluate the physiological responses of the respiratory distressed neonate to a routine procedure: CPT.

CHAPTER II

REVIEW OF THE LITERATURE

Literature pertaining to chest physiotherapy as well as other related areas is presented in four sections. Studies of neonatal and/or infant CPT as well as adult studies relevant to the present research are presented and evaluated in terms of their methodology, results, and recommendations. Studies and other literature on infant handling are described and evaluated. Studies describing the effects of instillation and suctioning of the ETT on infants are presented. Finally, literature relevant to the instrumentation required by the study protocol for measurement of the selected physiological parameters is discussed.

Chest Physiotherapy

Amidst a relative dearth of available studies, a controversy exists in the literature as to the most efficacious method of performing CPT on the neonate. Chest physiotherapy is felt to be indicated in any condition in which an excess of pulmonary secretions cannot be removed by such normal clearance mechanisms as ciliary action and coughing. It has also been indicated in the treatment of atelectasis, a pathological condition to which neonates are very prone (Schaffer & Avery, 1971).

Holloway, Adams, Desai, and Thambrian (1969) were one of the first groups of researchers to report on the effects of chest physiotherapy on neonates. They attempted to validate results of a preliminary investigation (Holloway, Desai, & Kelly, 1966) in which a fall in arterial oxygen pressure following "standardized chest physiotherapy . . . which took the form of clapping" (Holloway et al, 1966, p.422) was documented. In the 1969 study, Holloway et al studied 51 neonates who were divided into 3 groups. Group 1 consisted of 14 spontaneously breathing, normal babies selected to match the patients in the other two groups with respect to age. Group 2 consisted of 22 curarized and ventilated neonates with tetanus neonatorum. Ten of these infants received percussions and suctioning followed by an increase in ventilatory inflation pressure of 10 centimeters of water (cm H_2O) for 10 minutes. The remaining 12 infants received percussions and suctioning without an increase in inflation pressure. The infants were randomly assigned to these sub-groups. Group 3 was composed of 15 neonates in similar condition to those in Group 2. Through random assignment, 8 neonates received an increase in ventilatory inflation pressure for 30 minutes, while the remainder received no increase. None of the infants in Group 3 received percussions.

The dependent variables in the above mentioned study included the oxygen and carbon dioxide tension levels of arterialized blood obtained from the scalp of all infants and the A-a gradient level for oxygen. Normal standards for resting arterial oxygen tension (PaO_2) and

$PaCO_2$ levels were obtained on Group 1 infants who served as controls. One blood sample was taken from each infant in this group. With Group 2, blood samples were drawn prior to the commencement of the percussions, immediately following the percussions and suctioning, at the end of the ten minute period of hyperinflation, and one hour following the hyperinflation period. A control or baseline blood sample was also drawn from the infants in Group 3, in addition to a sample drawn 30 minutes following the hyperinflation period.

Holloway, et al (1969) reported that the percussions and suctioning did not improve the PaO_2 levels but actually produced a small decrease in the PaO_2 and $PaCO_2$ levels and an increase in the A-a gradient level for oxygen. The $PaCO_2$ levels did return to the pre-CPT levels one hour following the hyperinflation period. This return to normal was accelerated by ventilatory hyperinflation. Moderate hyperinflation (10 cm H_2O) without benefit of percussions produced small increases in the PaO_2 level. Neither percussions nor hyperinflation alone or together produced blood gas levels similar to those of the normal infants in Group 1.

In a retrospective review of 130 charts of neonates with HMD, Remondiere, Relier, Esclapez, and Beaudoin (1976) discovered significant differences in pulmonary complications between those infants who had received percussions by clapping and those who had not. There were fewer incidences of airway obstruction and pulmonary atelectasis in the neonates who had been treated with percussions. The investigators concluded that, "provided it is carried out by an expert, and provided elementary rules of prudence are respected, respiratory physiotherapy is without danger in the premature and newborn. It is thus an essential accessory form of treatment . . . during the neonatal period" (Remondiere et al, 1976, p.622).

In their study, Fox, Schwartz, and Schaffer (1978), randomly selected 13 neonates from an intensive care unit in order to investigate physiological alterations in respiratory function associated with CPT. Arterial blood gas levels, respiratory patterns, lung mechanics, and functional residual capacity were measured during a control period, following 30 seconds of vibrations CPT and suctioning, following hyperventilation, and two hours following suctioning. In all cases, the fraction of inspired oxygen (FiO_2) was maintained at the control period level in order to ascertain the responses of the infants under highly controlled conditions. When comparing test and control measures, the researchers found significant decreases in the PaO_2 levels following suctioning as well as inspiratory resistance and a significant increase in the PaO_2 levels after hyperinflation, and in the respiratory rate following suctioning. There was also a trend in which lung compliance increased as functional residual capacity increased during suctioning.

Etches and Scott (1978) demonstrated that the amount of upper airway secretions removed by suctioning was significantly less than that removed by suctioning following CPT. The CPT used on the six neonates in this study was postural drainage and manual vibration during the expiratory phase as well as "gentle percussion of the chest wall" (Etches & Scott, 1978, p.713). A clapping motion with the cupped hand provided the percussions to the external chest.

A study by Finer and Boyd (1978) and Finer, Boyd, and Grace (1978), comparing the effect of postural drainage to postural drainage accompanied by chest percussions, introduced a new method of performing chest percussions: contact-heel percussions. In the first group of 10 neonates studied, there was no significant alteration in the arterial PaO_2 level following the postural drainage. There was, however, in the second group of 10 neonates, a significant increase in the PaO_2 level, when percussions were added to the postural drainage. The investigators found no difference in the pH or $PaCO_2$ level either prior to or during the treatment or 15 minutes posttreatment in all 20 infants.

In a very poorly controlled study by Curran and Kachoyeanos (1979), six neonates were randomly assigned to one of three CPT groups: 1) vibrations using an electric toothbrush, 2) percussions using a padded nipple, and 3) no CPT. It was not reported if postural drainage was employed. The results indicated that the infants in Group 1 exhibited the highest levels of mean "pO_2 and pCO_2" (Curran & Kachoyeanos, 1979, p.313) as well as the best skin color and clearer breath sounds immediately following CPT. Neonates in all groups had similar significant increases in apical pulse and respiratory rate following CPT.

In a combined retrospective and prospective study, Finer, Moriartey, Boyd, Phillips, Stewart, and Ulan (1979) demonstrated that infants, extubated after 24 hours of intubation, benefitted significantly from CPT which consisted of hourly manual chest vibrations applied to the right upper lobe and postural drainage. Of the 85 neonates evaluated (43 without CPT and 42 with CPT), 17 suffered from right upper lobe (RUL) atelectasis following extubation. Sixteen of the infants with RUL atelectasis were not treated with CPT following extubation, while one infant received CPT following extubation. The investigators concluded that CPT is beneficial in the prevention of RUL atelectasis following prolonged intubation.

In their study, Tudehope and Bagley (1980) added the transcutaneous oxygen factor to the variable of arterial blood gas (ABG) levels studied. Three different techniques of CPT were evaluated in 15 prematures requiring mechanical ventilation: contact-heel percussions, clapping with a Bennett face mask, and vibrations with an electric toothbrush. Each infant received all three treatments two hours apart. Arterial blood gas levels were obtained prior to and 15 minutes following each CPT session. All CPT techniques were accompanied by postural drainage. Significant increases in the PaO_2 levels were demonstrated in the two percussions groups (contact-heel and Bennett mask) with no differences in the pH or $PaCO_2$ levels noted in any of the three groups. The CPT was generally well tolerated by the infants.

In a recent abstract, Duara, Bessard, Keszler, Artes, and Batzer (1983) reported the effects of three different percussion time intervals (0.5, 1.5, and 2.5 minutes) on the neonatal pulmonary function parameters of minute ventilation (V_E), $TcpO_2$, lung compliance (C_L), inspiratory resistance (R_I), and expiratory resistance (R_E). All data were obtained pre-CPT and post-CPT from six intubated neonates with HMD. A cardiorespirograph was obtained throughout the study. The percussion times were tested in three sessions with six postural drainage positions per session done at two hour intervals. For all six infants, after the 2.5 minutes of percussion time per position session, the C_L increased by 74.3%, the R_I increased by 56.4%, and the R_E decreased by 34.1%. Changes following the 0.5 minute session were variable, while changes following the 1.5 minute session indicated a deterioration in the infants' conditions. The H/R stayed consistent throughout all sessions and the V_E showed no significant change following all sessions. In comparision with baseline levels, the $TcpO_2$ decreased by 5.1% after the 0.5 minute session, by 11.5% following the 1.5 minute session, and by 7.7% following the 2.5 minute session. The researchers concluded that the 2.5 minutes of percussions produced the greatest improvement in pulmonary function without any greater decrease in $TcpO_2$ and compromise of the cardiovascular system.

Multiple rib fractures can easily occur in newborn infants with osteogenesis imperfecta congenita, congenital hypophosphatasia, osteoporosis, and pyknodysotosis, and in infants following vigorous resuscitative efforts (Wescenberg, 1973). Also, two cases are reported in the literature in which overforceful hand percussions were implicated as the cause of rib fractures in infants (Purohit, Caldwell, & Levkoff, 1975; Geggel, Periera, & Spackman, 1978).

Purohit, Caldwell, and Levkoff (1975) reported a case of a 75 day old premature infant whose x-rays revealed healing rib fractures of the right sixth and seventh, and left eighth ribs. This infant had received vigorous percussions following the occurrence of postextubation atelectasis on the 53rd day of life. It was felt that the force used in the CPT, despite the "technical expertise of nursing personnel" (Purohit et al, 1975, p.1104), either alone or in conjunction with stress due to respiratory distress, was enough to fracture the rib cage.

Geggel, Periera, and Spackman (1978) also implicated hand percussions (clapping) in the rib fractures of two premature infants. In both cases, as in the previous case, the infant's postnatal age was approximately 2 1/2 months. Both infants suffered from rickets and severe lung disease. Rickets has been implicated in the development of respiratory distress in premature infants, even in the absence of underlying lung disease (Glascow & Thomas, 1977). This respiratory distress has been attributed to softened or fractured ribs and to a myopathy generated by a deficit in 1,25 dihydroxyvitamin D3 (Schott & Wills, 1976). One of the authors of the case study (Pereira, 1982) recommended that chest percussions be avoided entirely and only vibrations and postural drainage be used in babies with poorly mineralized bones. He further recommended that Vitamin D and calcium supplements be added to the nutritional therapy of these infants.

In 1976, Piehl and Brown studied 5 adult patients who required mechanical ventilation for respiratory failure. When the patients were turned from a supine to a prone position using a Circoelectric bed, their PaO_2 levels increased by an average of 47 torr. After the patients were in the prone position for 4 to 8 hours, their PaO_2 levels gradually returned to the levels obtained initially. In this study, arterial blood samples were obtained by radial artery puncture or from indwelling arterial catheters, prior to and 30 - 120 minutes following body position changes.

In a prospective study of 47 adult patients receiving mechanical ventilation, McKenzie, Schinn, and McAsselin (1978) evaluated the changes in the PaO_2 levels which occurred following CPT consisting of postural drainage, clapping or vibrations, encouragement of coughing, and suctioning. The changes in the PaO_2 levels were not found to be significant. Although the PaO_2 levels did not improve, chest x-rays taken within 24 hours of the treatment indicated improved lung status in 68% of the patients. The CPT was most effective in the treatment of unilobar densities and atelectasis of acute onset.

Following the advent, in 1977, of widespread use of transcutaneous oxygen monitoring, Hedstrand, Rooth, and Ogren (1978) attempted to evaluate the effect of individualized therapeutic methods utilized in respiratory physiotherapy. Arterial oxygen tension was estimated by the transcutaneous oxygen tension method. Forty-five postoperative patients cooperated in a study in which the effects of taking 3 deep breaths in a 60 second epoch, assisted by 1 of 3 respiratory therapy devices, were compared to the effects obtained during implementation of a standard physiotherapy programme. A peak increase in the $TcpO_2$ level occurred after 1 minute and significantly increased levels were seen for 2 to 4 minutes following deep breathing with the respiratory devices. The routine physiotherapy programme of verbal and manual assisted deep breathing resulted in an even greater rise in the $TcpO_2$ level and prolongation of this increase to 6 minutes.

Many recommendations have been made regarding CPT techniques. In 1972, Pinney published one of the earliest guides for positioning infants for CPT. The method of CPT recommended was percussions using a cupped hand.

Dunn and Lewis (1973) recommended postural drainage in order to facilitate gravitational drainage of secretions from the smaller bronchi to the larger bronchi. They suggested that the infant be placed in the appropriate drainage positions for lower and middle lobes for up to sixty minutes at a time. They also advocated the use of percussions using a small, padded plastic cup to "provide effective percussion with a suction cup action" (Dunn & Lewis, 1973, p.489). From their clinical experiences and adult studies using bronchoscopy to view movement of secretions in third order bronchi, Dunn and Lewis felt that vibrations using an electric toothbrush was even more effective than percussions for loosening secretions.

Philip (1977) recommended the use of a rubber nipple base for percussion of the neonatal chest wall, with the infant in the appropriate drainage position. Vibrations using an electric toothbrush was also advocated, but no other guidance on technique was offered.

In an article regarding postural drainage positions, percussions, and vibrations techniques (Tecklin, 1979), Tecklin illustrated three types of equipment used in chest wall percussion: an anaesthesia mask for premature infants, a padded medicine cup, and a stethoscope head for term and older infants. The nurse was warned to not "percuss as vigorously as you would for an adult" (Tecklin, 1979, p.68). The vibrations technique was not recommended for infants.

Meier, (1979) while mainly fulfilling a request to evaluate a research study (Curran & Kachoyeanos, 1979), made some conclusions about the safest and most effective form of CPT for all neonates. She recommended 12 appropriate drainage positions without percussions or vibrations.

In their review of CPT techniques, Thibeault and Gregory (1979) recommended that percussions, "a series of blows . . . delivered to the thorax over the distribution of the bronchopulmonary tree" (Thibeault & Gregory, 1979, p.249), be performed prior to each tracheal suctioning and following postural drainage. They also suggested that, following percussions, vibrations, using an electric toothbrush, be administered for a period of thirty seconds.

In one of the most recent comprehensive neonatal nursing text books, it was recommended that CPT should be "expeditious to avoid tiring the infant" (Oehler, 1981, p.203). The author stated that, prior to drainage of the appropriate lobe, percussions using a vibrator, padded medicine cup, or padded toothbrush should be administered to loosen secretions. Vibrations should then be used to assist the movement of secretions from the pulmonary periphery.

Obladen reviewed the major studies undertaken in CPT and described CPT as a "radical measure" (Obladen, 1981, p.98) which, in experienced hands, provided an effective means of removing bronchial secretions and prevention of "wandering atelectasis" (Obladen, 1981, p.98). The method of CPT advocated in the studies was vibrations using an electric massager or toothbrush. It was also advocated that postural drainage be used only in cases of atelectasis.

Meyer (1982) described a series of steps in CPT. Percussions, using a padded bulb syringe cut in half or a padded bottle nipple, directed to the particular area of disease was recommended every two to four hours. Postural drainage was also to be used in conjunction with CPT. Percussions, however, were not to be used on a routine basis but only with those infants whose conditions were relatively stable or who had mild respiratory distress. Meyer cautioned that many complications of CPT could lead to rib fractures (Purhoit et al, 1975; Geggel et al, 1978).

Infant Handling

The ill neonate is almost completely deprived of vestibular and social stimuli. Much of the stimulation the neonate receives is of an intrusive and noxious nature by way of injections, gavage feedings, blood taking, and diagnostic tests. The only time the neonate may experience nonintrusive tactile stimulation or touch is when he self-initiates it through accidental movements, such as moving or squirming against the bedding. Faced with the demands of keeping the ill neonate's biological systems functioning and influenced by the assumption that handling of any kind increases the neonate's energy consumption, nursing personnel usually do not provide the ill neonate with the cuddling, caressing, and holding that the healthier infant usually receives.

Kulka, Fry, and Goldstein (1960) hypothesized the existence of a kinaesthetic phase predating the oral phase of development and the existence of kinaesthetic needs or drives, separate from and of equal importance to the oral, anal, and phallic drives described by Freud (1910). By kinaesthetic is meant all incoming sensory modalities: light, touch, pressure, temperature, visceral, afferent, and their control representations. Kinaesthetic drive refers to tension release or pleasure derived through the above modalities. The kinaesthetic phase of development is never completely left behind but is modified and incorporated into highly complex and sublimated activities throughout life.

The modality of expression of the kinaesthetic drive is motility. In the neonate, motion is the first means of tension discharge. At birth, the myelinization of the pyramidal tracts is incomplete. Also, since the extrapyramidal system is the dominant functioning motor system, cortical control has not yet been established. Therefore, the dominant movement pattern available for tension discharge and the re-establishment of homeostasis is the mass reflex or so-called mass movement. The more premature or immature the infant, the more this mass movement dominates and is only gradually replaced by the less primitive reflexes and coordinated motor activities. With the twenty-eight week old infant, touch results in alertness and slight motor activity, while pain leads to withdrawal. In the gestationally older infant, pain also causes a cry or grimace.

Greenacre (1941) stressed the fact that intrauterine life and early infancy form a continuum, and that the foetus reacts to discomfort with an acceleration of the life movements at its disposal. She stated that these movements are an earlier form of an anxiety-like response. She further postulated that the foetus derives some pleasure from moving and being in contact with the maternal body.

When a baby cries, adults almost instinctively pick up and hold the baby close to them; often the infant quiets at once. The restraint, as much as the human contact, seems to affect the infant's activity level. Greenacre stated:

> "The term restraint is a broad one, but in all forms of restraint there is the common situation that the free response (usually partly motor) of which the subject is capable is not permitted. Restraint may be applied through physical means as in binding the child's body . . ." (Greenacre, 1944, p.204).

In nursing textbooks, swaddling which may be defined as "snug wrapping" was suggested as a means of soothing the irritable infant. Reeder, Mastroianni, Martin, and Fitzpatrick (1977), when discussing the hypertonic infant wrote, "These infants usually respond favorably to being held securely . . . helps to allay tenseness" (Reeder et al, 1977, p.418). Others (Clark & Alfonso, 1979; Jensen, Benson, & Boback, 1977) give similar advice. None of the authors cited nursing research findings as the basis for this procedure.

The research literature presents some contradictions. In an experimental study of infant soothing techniques, Birns, Blank, and Bridger (1966), found no differences among soothing techniques of warm water, rocking, pacifier, and sounds.

Brazelton (1973) found that most fussing or crying newborns seemed to unintentionally initiate several maneuvers to regain control of themselves and move to a lower state of consciousness. The most commonly observed actions used by newborns to quiet themselves were: hand-to-mouth movements, sucking on fingers or fist, sucking with nothing in their mouths, paying attention to voices or faces in the environment, and changes in position. Some newborns, however, made few or very brief attempts to console themselves and always needed outside intervention. Others tried to console themselves; some were successful, while others were not. The newborns were able to calm themselves, at times, at least briefly, while at other times they needed outside help. A few infants were consistently able to console themselves and needed only minimal or occasional intervention. Most infants, however, needed periodic help from others in consoling themselves. Brazelton found some infants became quiet when they were talked to for a few minutes. Not all, however, became quiet at the sound of a voice. Some infants responded to being touched (such as being stroked, having the caretaker's entire hand placed on their chest or abdomen), having their arms restrained, or being swaddled. Finally, one last group of infants quieted when rocked and/or given a pacifier.

In her study of maternal comforting techniques in 30 mother-infant pairs attending a well baby clinic, Dzik (1979) found that, as soon as the infants displayed distress in response to immunizations, maternal comforting in the form of patting, rocking, or cuddling was instituted. The infants soon quieted with these comforting measures.

In her very comprehensive review of the literature, Tomney (1980) concluded that, while infant stimulation programs of tactile, vestibular, and/or auditory input have demonstrated desirable effects of increased weight gain and maturation of neurological processes in the healthy preterm infant, the act of handling the critically ill neonate can have deleterious effects on oxygenation. There is evidence that both hypoxic and hyperoxic episodes, which can result from excessive handling of the infant may result in long-standing negative sequelae with regard to motor and cognitive functioning.

In her study, Tomney continuously recorded neonatal responses to handling in an intensive care unit. Ten critically ill prematures were studied in two twelve hour epochs: while on and off pancuronium, a skeletal muscle relaxant. The study revealed a significantly greater duration of hypoxia and hyperoxia during the non-relaxed period when the infants did not receive pancuronium. As well, durations of ICP elevation 10 cm H_2O above the infants' baseline were significantly less during paralysis as were spikes of ICP to greater than 25 cm H_2O. One of the major conclusions established by Tomney was that "nursing care influences the physiological stability of the critically ill preterm neonate, whether or not he/she is paralyzed" (Tomney, 1980, p.77). Since the completion of Tomney's study (1980), there has been a definite lack of studies evaluating neonatal responses to handling.

In a very recent study, Jay (1982) subjected 13 mechanically ventilated premature infants to 4 to 12 minute periods of touch daily. Dependent variables included: weight gain, temperature stability, oxygen requirement, incidence of apnoea and bradycardia, toleration of oral feedings, haematocrit level, PaO_2 and $PaCO_2$ levels, pH, and length of hospitalization. When the intervention group was compared to a retrospectively matched control group, it differed significantly with regards to two variables: haematocrit level and frequency of apnoea over time. The intervention group had higher haematocrit levels and more apnoeic episodes than the control group.

Norris, Campbell, and Brenkert (1982) evaluated the effects of 3 routine nursing procedures: repositioning, tracheal suctioning, and performing a heelstick, on the $TcpO_2$ levels of 25 ventilated premature infants over a 3 hour period. In comparing mean $TcpO_2$ levels measured during the procedures to those obtained during a three minute baseline period, significant decreases were noted during suctioning and repositioning, with the former resulting in the greatest change. Recovery time (the amount of time required by the $TcpO_2$ level to return to the baseline level) was significantly related to the magnitude of change due to repositioning of the infants. The investigators suggested that the infants' responses were influenced by the type of procedure performed.

A recent textbook on neonatal intensive care contains one very brief chapter entitled "Minimal Handling" (Roberton, 1981, p.30). The text was based on the author's experience and on one reference (Korones, 1976). The main concept of this chapter is embodied in the first sentence "... a basic tenet of neonatal care is that handling and disturbing a sick neonate in any way causes his condition to deteriorate" (Roberton, 1981, p.30).

Tracheal Suctioning

Following any method of CPT, the neonate must be suctioned in order to remove any secretions which may have accumulated in the larger bronchi. A few published research studies with regard to neonatal suctioning techniques and/or its consequences are available for examination. In this section, studies of neonatal and adult responses to tracheal suctioning will be presented first, followed by a review of pertinent literature with recommendations regarding suctioning techniques.

As early as 1963, investigators began looking at the anatomical differences between adults and infants (Bush, 1963). Working with fresh intubated cadavers without obvious chest lesions, Bush found that a straight catheter passed only into the right mainstem bronchus (RMSB). On the other hand, an angled catheter entered the left mainstem bronchus (LMSB) 80% of the time. When live subjects were studied, in 19 out of 22 attempts, a straight catheter entered the RMSB. Using the angled catheter, the investigator was able to reach the LMSB in 29 out of 34 attempts. In all cases, the subject's head was held in the midline position. The author advocated the use of an angled suction catheter to adequately remove secretions from both sides of the bronchial tree.

In assessing adult responses to suctioning, Shin, Fine, Fernandez, and Williams (1969) studied the electrocardiograms of 17 patients during tracheal suctioning. Transient cardiac arrhythmias occurred during 35%

of the suctioning episodes. These arrhythmias did not occur when the patients breathed 100% oxygen for 5 minutes prior to suctioning. Because of this statistically significant finding, the procedure of breathing 100% oxygen prior to and during tracheal suctioning was advocated for all patients to avoid potentially dangerous cardiac arrhythmias.

Brandstater and Muallen (1969) found that atelectasis occurred following tracheal suctioning of six infants who were paralyzed with muscle relaxants and ventilated as treatment for severe tetanus neonatorum. Variables measured included: airway pressure, oesophageal pressure, expired tidal volume, transpulmonary pressure, and pulmonary compliance. Tracheal suctioning consistently produced a marked fall in pulmonary compliance. This fall was even more pronounced when suctioning was prolonged. When the infants were reconnected to the same respirator at the original settings, their lungs remained partially collapsed until a higher pressure or large tidal volume was applied. Partial lung reexpansion occurred commonly and was more complete when initial inflation pressure or stroke volume was high. The authors concluded that, especially in infants, the overzealous use of suctioning to prevent pulmonary atelectasis may, in some cases, be its main cause.

Cordero and Hon (1971) demonstrated the effects of two different suctioning techniques on the neonatal cardiac rate. All neonates were monitored continuously prior to delivery and were considered to be normal. Aspiration of the nasopharynx of 41 neonates with a bulb syringe did not produce any cardiac arrhythmia. On the other hand, 7 of 46 neonates developed severe bradycardia on introduction of a nasogastric tube (deLee suction trap) and suctioning of the oropharynx. In 5 out of the 7 cases, apnoea also occurred. Vagal stimulation was suggested as the underlying cause for this phenomenon.

The results of a preliminary evaluation of the transcutaneous oxygen probe appeared in abstract form in 1976. In the abstract, Dangman, Hehyi, Hiatt, Idnyk, and James (1976) reported very wide variations in the $TcpO_2$ levels. They found endotracheal suctioning resulted in falls of $TcpO_2$ levels of up to 40 torr. The neonates required a recovery period from the suctioning of up to 7 minutes, a much greater period than that required for cardiac recovery from the same procedure.

The study by Fox, et al (1978) has been referred to in an earlier section on CPT techniques. The study results pertinent to this section included a significant decrease in the PaO_2 level and an increase in respiratory rate following suctioning. The investigators recommended that suctioning not be performed on a routine basis in infants recovering from respiratory diseases.

Ravel, Mora, Yeh, and Pildes (1978) studied the effects of percussions and suctioning on seven neonates who required ventilation. The variable measured was the $TcpO_2$ level. While the levels fell significantly during each of the procedures, there was a signifitant increase in the $TcpO_2$ level at the end of the suctioning procedure. The investigators concluded that percussions and suctioning improved oxygenation and that, in order to avoid hypoxic episodes, the infant should be permitted to rest between the two procedures. They also concluded that ventilation, using only a 10% increase in oxygen via the respirator, was a safer procedure than the commonly accepted routine of using 100% oxygen.

In an attempt to overcome the deleterious effects of suctioning, a special suction adapter to enable caretakers to suction neonates without disconnecting them from the respirator, was developed. Cabal, Devastkar, Siassi, Plajstek, Waffarn, Bianco, and Hodgman (1979) reported the responses of a group of premature infants with severe respiratory distress to the new adapter. Each of the eight neonates was continuously monitored during two different methods of suctioning. Variables measured included: arterial oxygen saturation and beat-to-beat H/R. In the first method, the infant was pre-oxygenated and then disconnected from the respirator for each pass of the catheter. In the second method, a special Novametrix C/D suction adapter was used without pre-oxygenation. Although, with both methods, H/R as well as saturation level decreased, both levels fell to significantly lower levels during the first method of suctioning. Also, these decreases were longer in duration.

In 1979, it was thought that the neonate's head position may affect placement of the catheter during ETT suctioning (Fewell, Arrington, & Seibert, 1979). Bronchial catheterization was performed on 8 intubated neonatal cadavers, with the position of the radio-opaque tube being confirmed by x-ray. Each cadaver was catheterized 6 times: twice with the head rotated to the left, twice with the head straight, and twice with the head rotated to the right. In addition, to determine the angle of bifurcation of the trachea, 40 chest x-rays of living neonates were measured and compared. Positioning of the cadavers' head to the right in preparation for suctioning facilitated but did not guarantee catheterization of the LMSB. Positioning the cadavers' head straight or turning it to the left was equally effective in permitting the catheter to enter the RMSB. The mean angles of divergence of the LMSB and the RMSB from the trachea were 44.0° and 24.1° respectively. The investigators concluded that contralateral head turning may change the angle of divergence of the LMSB and thus aid in catheterization during suctioning.

Tudehope and Bagley's (1980) evaluation study of CPT methods has also been mentioned earlier. In examining neonatal responses to ETT suctioning, the investigators found that, when the majority of infants were disconnected from the ventilator and, hence, the oxygen source for suctioning, hypoxia and bradycardia developed. However, by using a suctioning adapter, Tudehope and Bagley found that they were able to reduce the amount of hypoxia and bradycardia.

In order to evaluate the effects of tracheal suctioning on oxygenation, cardiac rate, arterial blood pressure, and pulmonary compliance in neonates, Simbruner, Coradello, Fodor, Havelac, Lubec, and Pollak (1981) assessed 5 infants in each of 2 groups. The first group consisted of neonates weighing less than 1250 grams. The second group included neonates weighing greater than 1750 grams. During tracheal suctioning, the mean $TcpO_2$ level fell 25 torr, while the mean H/R decreased 19 beats per minute (bpm), and the MAP increased 5 torr. All changes, when compared to control values, were statistically significant. No differences were found between the two groups. The investigators, however, raised the possibility that a neonate's negative response to handling could produce similar changes.

Perlman and Volpe (1982) presented, in abstract form, the effect of oral suctioning (OS) and endotracheal suctioning (ES) on cerebral blood flow velocity (CBFV), MAP, and ICP in 15 premature neonates. In each case, the CBFV, MAP, and ICP increased significantly with both types of suctioning. The mean change in MAP during OS was 7.2 millimeters of mercury (mmHg) and during ES was 7.5 mmHg. The mean ICP increase recorded during OS was 7.3 cm H_2O and during ES was 8.0 cm H_2O. The data indicated that both forms of suctioning were associated with a sudden increase in CBFV. The researchers theorized that the increase in MAP (because of impaired autoregulation) led to an increase in CBFV which was then reflected in the ICP increase.

Cunningham, Nelson, and Baun (1983) studied eight premature infants during suctioning of the ETT to determine the effectiveness of oxygen (O_2) concentrations 10% and 20% higher than maintenance, at rates of 5 breaths in 15 seconds or 10 breaths in 30 seconds. The variables studied were $TcpO_2$ and H/R. Data indicated that neonates being ventilated for HMD responded more adversely to ETT suctioning than neonates being ventilated for other respiratory problems. Bradycardia occurred in 5 infants but was more frequent during the use of 10% supplemental O_2 given over 15 seconds in those infants with HMD. Overall, the study, reported in abstract form, indicated that supplemental O_2 20% greater than maintenance at a rate of 5 breaths in 15 seconds prior to and following each pass of the suction catheter resulted in the least frequent occurrence of hypoxia and/or bradycardia.

Vaughan, Menke, and Giacoice (1978) presented a case report of two neonates with pneumothoraces which were directly attributable to ETT suctioning. When chest x-rays of these neonates were taken with a radio-opaque catheter in place, the catheter was assessed as being in the right pleural space. As a result, the authors questioned the recommended suctioning technique of inserting the suction catheter as far into the airway as possible without using force and then withdrawing the catheter 0.5 cm prior to the application of suction (Gregory, 1972).

Several recommendations regarding suctioning techniques are to be found in the literature. Gregory (1971) warned that, due to apnoea and bradycardia, ETT suctioning was a potentially hazardous procedure for the neonate. In order to overcome these problems, he recommended the use of hyperinflation using sighs of pressures 25% greater than normal during the procedure as well as flowing oxygen over the ETT connector during suctioning. Head turning to facilitate catheterization of both mainstem bronchi was also advocated.

According to Dunn and Lewis (1973), two people should be present to expedite endotracheal suctioning. Also, the airway should not be obstructed by the suction catheter longer than ten seconds to limit hypoxia and "bag breathing with an increased oxygen concentration" (Dunn & Lewis, 1973, p.494). In order to increase the likelihood of reaching secretions in both mainstem bronchi, head turning was, again, recommended.

Klaus and Fanaroff (1973) cited four possible complications which could occur with suctioning: a) introduction of infection, b) anoxia, c) atelectasis, and d) production of traumatic lesions. As a result, strict sterile technique was advocated as well as a recovery period between each pass of the catheter. Routine instillation of normal saline prior to suctioning was thought to be not necessary "if adequate nebulization is used" (Klaus & Fanaroff, 1973, p.160).

According to Thibeault and Gregory (1979), suctioning of the airway is particularly important following any method of CPT. After examining the literature, the authors concluded that most of the complications of suctioning could be avoided through the use of a proper technique. According to Thibeault and Gregory, suctioning should occur at least every two hours immediately following CPT. Infants should be ventilated with 10% higher oxygen just prior to and shortly following suctioning and duration of suctioning should not exceed ten seconds. They further stated that instillation of normal saline into the ETT and head rotation ensured maximum removal of secretions and that flowing oxygen over the ETT connector during suctioning aided in avoiding hypoxia.

Stavis and Krauss (1980) suggested that endotracheal intubation inhibits ciliary movement, resulting in the loss of a normal mechanism for clearing mucus. They pointed out that an adequately sized suction catheter should be employed in order to clear the maximum amount of mucus possible and to avoid carbon dioxide (CO_2) retention and ETT blockage. Some complications of inadequate or improper technique cited by Stovis and Krauss included pneumothorax and overhydration due to failure to remove all instilled fluid.

The hazard of introducing infection during suctioning was of utmost concern to Obladen (1980). Besides strict adherence to aseptic technique, he advocated the use of hyperventilation prior to suctioning. Head turning was recommended in order to stretch the contralateral primary bronchus. In order to prevent atelectasis, he stated that the suction catheter should never seal the lumen of the ETT and should be inserted one centimeter beyond the end of the ETT before applying suction.

Oehler (1981) stated that suctioning of the airway should be performed whenever necessary, usually on an hourly basis. Both hyper oxygenation and hyperventilation were recommended prior to initiation of suctioning. Following instillation of the ETT, Oehler pointed out that the suction catheter should be inserted 0.5 to 1 cm beyond the end of the tube. No more than ten seconds of suctioning at one time was recommended. If further passes of the catheter were required, a full minute's rest between each pass was advocated.

Roberton (1981) suggested that suctioning every 4 to 6 hours was sufficient to maintain patency of the airway of a neonate with early respiratory distress. He stated that, following instillation of the ETT, suctioning should commence and that, if the $TcpO_2$ level fell to less than 50 torr, the infant should be reconnected immediately to the ventilator.

Caution was advocated by Schreiner and Kisling (1982) in suctioning via the ETT. They recommended that head turning be used to place the catheter in the desired mainstem bronchus and that, following instillation of normal saline, the ETT should be catheterized for no longer than 10 seconds. They stated that infants who were term or near-term in gestational age should be hyperventilated and hyperoxygenated before and after suctioning. They stressed that the condition of the infant should dictate frequency of suctioning. Careful observation of the infant during suctioning was thought to be imperative.

Instrumentation

Over the past ten years there has been a noticeable shift from monitoring the critically ill neonate using invasive (requiring blood to be drawn or skin to be broken) procedures to using non-invasive monitoring procedures (Finer, 1980; Philip, 1982). The aim of continuously monitoring the neonate is to detect problems as early as possible. In addition, efficient monitoring permits the newborn's caretakers to assess and evaluate the effectiveness of therapy.

Non-invasive monitoring was first used to observe the electrical activity of the heart (EKG). This form of monitoring made it possible to follow the heart beat directly on a screen. Through the use of the EKG, it also became possible to ascertain indirect (albeit imprecise) information reflecting imbalances in the chemical composition of the blood. It soon became apparent, however, that this form of monitoring was not suitable for use with the newborn infant because of the approximate nature of the indirect information and the time which lapsed between the occurrence of actual bradycardia or tachycardia and the signaling of the situation via the monitoring alarm.

The linkage of cardiac monitoring to the monitoring of respiratory movements by impedance measurement (Philip, 1977) was a definite improvement because most disorders in essential functions of the neonate, especially the premature infant, are respiratory in origin. Replacement of simple EKG monitoring by the recording of beat-to-beat H/R also permitted an indirect assessment of neurological distress (Willard, Messer, & Benoit, 1976; Finer, 1980). Cardiac rhythm is, in fact, partly regulated by afferent nerves. While thoracic impedance measurement provides an accurate indication of the mechanical aspects of ventilation, it provides little information as to the efficacy of respirations.

The advent of continuous non-invasive measurement of the PaO_2 level made it possible to detect pathologies in oxygenation of the blood within seconds of a threatening event. It also made it possible to adapt, more exactly, oxygen, as well as other forms of therapy, to the needs of the infant being treated (Finer & Stewart, 1980).

Transcutaneous oxygen monitors, when applied correctly, provide information which, when analyzed, have shown high regression coefficients between the PaO_2 level and the $TcpO_2$ level. These regression coefficients have ranged between 0.94 (Huch, Huch, & Albani, 1976) and 0.98 (Peabody, Willis, Gregory, Tooley, & Lucey, 1978). Tomney (1980) reported a Pearson's r value of 0.93. Such high correlations lend credence to the belief that transcutaneous oxygen monitoring gives an accurate reflection of the neonatal arterial oxygen level.

One of the latest innovations in non-invasive neonatal monitoring is the $TcpCO_2$ monitor. The PaO_2 and $PaCO_2$ levels generally change in a symmetrical and inverse manner as a direct function of the prevailing pathology and administered treatments. Several common neonatal conditions such as HMD and bronchopulmonary dysplasia (BPD) exist in which oxygen and carbon dioxide partial pressure curves are not related to each oth r. It has been established that hypercapnia, in association with acidosis, has a vasoconstrictor effect on the pulmonary circulation and an unfavourable effect on blood oxygenation. However, its role as a cerebral vasodilator is stressed less frequently (Hambleton & Wigglesworth, 1976; Leahy, Sankaran, Cates, McCallum, & Rigatto, 1980). There is a distinct possibility that this vasodilation plays a major, or perhaps, secondary role in the formation of cerebral haemorrhages in the newborn. Hypercapnia leads to cerebral vasoconstriction and hyperlactaemia which, in turn, may also have metabolic consequences.

It is, then, important to monitor the $PaCO_2$ level of the critically ill neonate to try to maintain it within safe limits. There has been a growing interest in the development of a non-invasive $PaCO_2$ probe. It is a relatively new monitoring technique. The applicability and limitations of this technique need to be explored. Clinical trials have been underway since 1979.

Measurement of the $TcpCO_2$ level is based on the chemical reaction of carbon dioxide with water and the formation of bicarbonate and hydrogen ions. The pH potential of the hydrogen ions is converted internally in the $TcpCO_2$ probe to represent a pCO_2 frequency signal. This signal is transmitted to and converted in the amplifier, and finally appears on a digital display at the bedside.

Early reliability and validity reports of the $TcpCO_2$ sensor are promising. Laptook and Oh (1981) were able to establish a correlation coefficient of 0.85 between 191 arterial CO_2 and transcutaneous CO_2 levels of 20 neonates. Monaco and McQuitty's correlation coefficient of $\underline{r} = 0.91$ is even more promising. The investigators measured 106 CO_2 pairs (arterial and transcutaneous) in 15 sick neonates. Bhat, Kim, Shukler, & Vidyasagar (1981) established an overall correlation of $\underline{r} = 0.79$. In this study, 108 samples were taken from 22 critically ill neonates. A study of the reliability and validity of the Roche $TcpCO_2$ probe in the Royal Alexandra NICU indicated a correlation coefficient of 0.78 between the $PaCO_2$ level and the $TcpCO_2$ level on 196 CO_2 (arterial and transcutaneous) pairs.

The final physiological measurement used in the current study was oesophageal pressure. Chest physiotherapy (percussions and vibrations) is based on the principle that pressure is transferred from the external chest wall (striking point) to the lung surface and bronchial tree. This transfer of force may be detected by monitoring the oesophageal pressure. For years, oesophageal pressure has been measured with the use of oesophageal balloons (Agostone, 1959; Cherniak, Farhi, Armstrong, & Proctor, 1959; Avery & Cook, 1961; Daly & Bondurant, 1963; Nightingale & Richards, 1965; Geubelle & Senterre, 1970). In two recent studies, satisfactory oesophageal pressure tracings were obtained through the use of a water-filled feeding catheter or tube.

Gerhardt and Bancalari (1980) determined chest-wall compliance in 26 premature and 10 full term mechanically ventilated infants. The investigators reported that, during mechanical ventilation, the high chest wall compliance and low lung compliance of premature infants prevented a significant rise in intrapleural pressure. The researchers reported that it was possible, via a feeding tube to "transmit esophageal pressure changes with accuracy" (Gerhardt & Bancalari, 1980, p.361).

Asher, Coates, Collinge, and Milic-Emili (1982) assessed the accuracy of the water-filled oesophageal catheter by comparing the changes in oesophageal pressure and airway opening pressure which occurred simultaneously during occluded respiratory efforts in six healthy neonates. They concluded that "the water-filled 8-Fr esophageal catheter gives an accurate measurement of pleural pressure changes" (Asher et al, 1982, p.491).

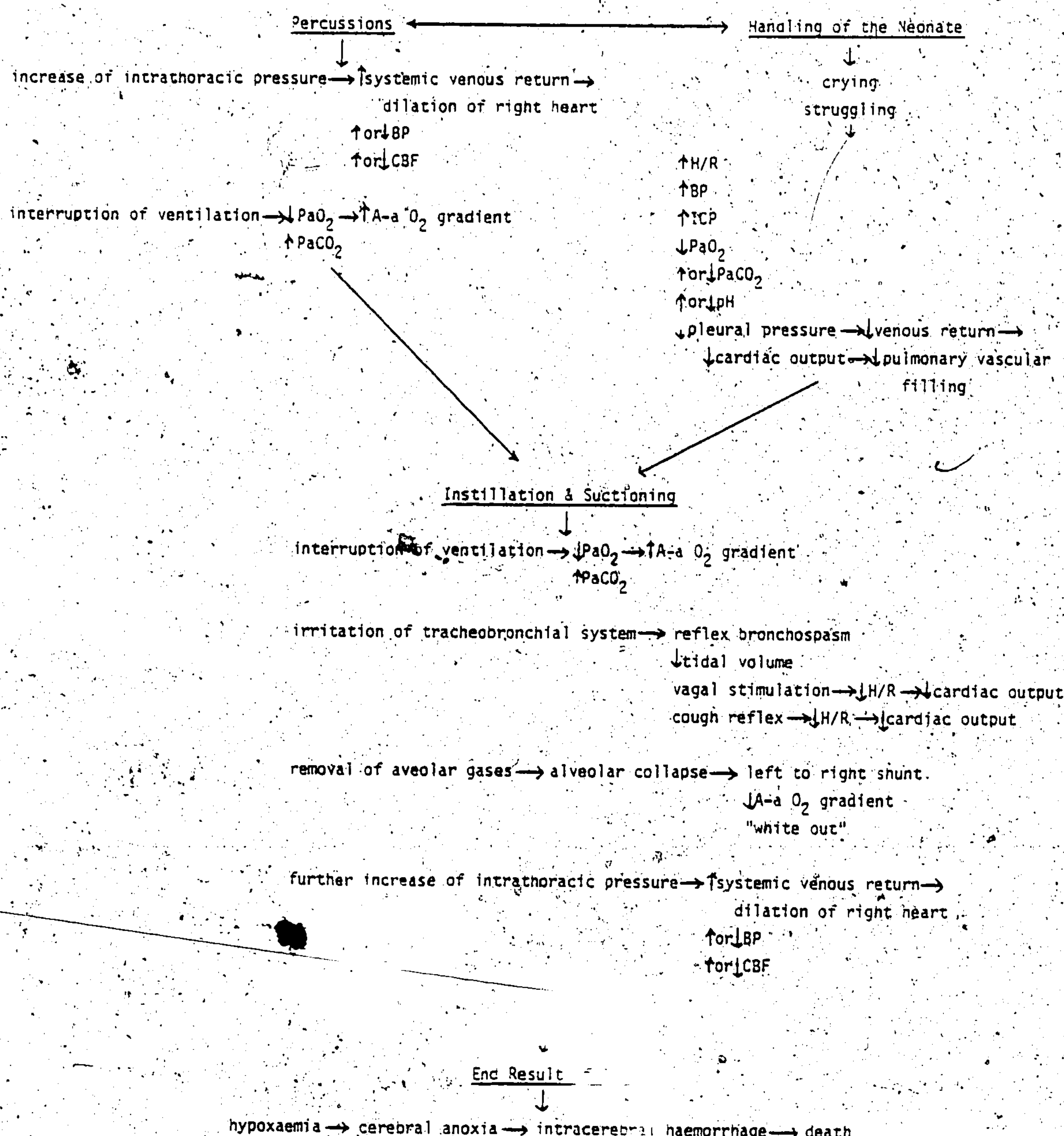
Conceptual Framework of the Study

The conceptual framework used for the study is based on physiological theory. It is a combination of clinical and theoretical knowledge. A graphic representation of the framework appears in Figure 1.

While the effect of deliberate application of pressure to the external chest wall (and thereby increasing intrathoracic pressure) has been minimally examined, studies of the effects of negative pressure ventilation in neonates have shown that an increase in negative pressure leads to an increase in functional residual capacity (FRC) and venous return from those areas of the body to which pressure is not directly applied (Chernick, 1973; Chernick & Vidyasagar, 1972). When one considers that more than 50% of the total neonatal blood volume may be circulated to the brain in very immature infants, shifts in the distribution of only a very small proportion of the circulating volume may

FIGURE 1

Conceptual Framework of the Study



result in major increases in pulmonary vascular volume. This in turn may lead to a decrease in systemic blood pressure, cardiac output, and cerebral blood flow (CBF).

The application of pressure to the external chest wall at a rate other than that of a person's respiratory rate may be disruptive to the normal rhythmic breathing pattern. Such an interruption can lead to apnoea, asynchronous respirations, periodic breathing, crying, and/or struggling. The end result of any disruption in ventilation, no matter how brief, may be a decrease in the PaO_2 level and a concurrent rise in the $PaCO_2$ level.

Tomney (1980) has effectively demonstrated that critically ill premature neonates respond to most handling and/or noxious stimuli in a relatively predictable pattern of increased H/R, MAP, and ICP. In addition, the PaO_2, $PaCO_2$, and pH (which may increase or decrease) levels may decrease. Because of the pathophysiology involved in crying, one can also conclude that an increase in intrathoracic pressure (as in Valsalva's test) may lead to a decrease in venous return, cardiac output, and pulmonary vascular filling. The foramen ovale and the patent ductus arteriosus (PDA) may also contribute to the establishment of great pulmonary shunts (both intrapulmonary and extrapulmonary) during crying.

Instillation and suctioning of the ETT has long been felt to be a noxious but very necessary procedure to ensure patency of the ETT. Normal saline is usually used to dilute the viscosity of the mucus, thereby facilitating its removal by the suction catheter. This procedure requires turning the head to the contralateral side (leading to an increase in ICP) and disconnecting the ETT from the ventilator and, hence, cutting off the oxygen source as well as airway resistance and impetus to breathe. The following may result: a decrease in the PaO_2 level and an increase in the A-a O_2 gradient and the $PaCO_2$ level. Also, the saline and the suction catheter may irritate the tracheobronchial system. This irritation may lead to a reflex bronchospasm, a decrease in tidal volume (V_T), and vagal and/or cough reflex stimulation which may, in turn, decrease the H/R and cardiac output. When the mucus is suctioned, intrapulmonic gases are also aspirated. The sudden removal of these gases may cause a decrease in pressure within the alveoli leading to alveolar collapse. The sudden drop in PaO_2 can result in left to right shunting of blood leading to pulmonary engorgement, increased haemodynamic load on the left ventricle and, if prolonged, pulmonary oedema. Fletcher and Avery (1973) demonstrated that, when a neonate ventilated with an FiO_2 of 1.0 is suctioned, atelectasis of large areas of lung tissue results which may prevail for prolonged periods of time.

Because the neonatal heart cannot increase its own stroke volume, any substantial drop in H/R (40%) may be accompanied by a dangerous fall in cardiac output (Finer & Stewart, 1977). This fall in cardiac output may, in turn, be reflected in a concurrent decrease in arterial blood pressure. Finally, an adequate blood supply to the brain is dependent, for the most part, on the cerebral perfusion pressure which can be defined as "the difference between mean venous and mean arterial pressures" (Reynolds, Evans, Reynolds, Saunders, Durbin, & Wigglesworth, 1979, p.170).

In all phases of the model, a decrease in the PaO_2 level may result. The volume of O_2 poor blood circulating to the brain can quickly lead to cerebral hypoxia or even anoxia. There is clinical and experimental evidence that the brain is relatively resistant to arterial hypoxia (Pape & Wigglesworth, 1979). A pronounced or prolonged lowering of the PaO_2 level may be accompanied by an increase in CBF which may cause irreversible structural damage through focal intracranial haemorrhages. It has been suggested, on the basis of anatomical studies, that disruption of the microcirculation within the subependymal matrix might result from transient increases in arterial pressure associated with apnoea (Hambleton & Wigglesworth, 1976; Wigglesworth & Pape, 1980). This effect may be accentuated by the cerebral vasodilation caused by the hypoxia and hypercapnia of HMD. With the pliable cranium of the neonate, increases in arterial pressure are accompanied by more pronounced changes in transmural pressure than is the case with the fused skull of the adult.

In studies of CBF using the $Xenon^{133}$ method (Low, Lassen, & Frii-Hansen, 1979), a low CBF in asphyxiated premature infants and what appears to be a direct relationship between CBF and blood pressure (BP) in such infants have been demonstrated. It has been suggested that asphyxia results in a loss of autoregulation of CBF in preterm infants and that overperfusion results, when the infant's BP returns to normal or high levels following its decrease. It has yet to be established whether or not the small preterm infant has the ability to autoregulate CBF in the classical manner, that is, to maintain a relatively constant CBF over a wide range of BP. In adults, autoregulation is abolished by extreme hypercapnia or hypoxia. Thus, the lack of autoregulation in infants with asphyxia or HMD may be no more than the expected result of blood gas changes.

A low CBF accompanied by a decrease in BP during asphyxia may impair the neonate's ability to autoregulate the CBF. Whether or not this impairment persists after blood gas tensions return to normal has yet to be proven. Another possibility is that a low CBF causes direct ischaemic damage to the integrity of the capillary bed within the subependymal matrix. In any event, a rise in BP following its decrease may cause haemorrhage due to disruption of the periventricular capillary bed. The major problem, ultimately, is the poor control of CBF in the critically ill neonate. It seems very probable that quite rapid fluctuations between hypoperfusion and hyperperfusion of these infants' brains may lead to haemorrhage. If the haemorrhage is severe enough, death can ensue.

Summary

The objectives of CPT are to remove secretions and improve ventilation. The effectiveness of CPT in removing secretions (Etches & Scott, 1978) has been demonstrated in at least one study. Studies conducted to determine whether CPT improves ventilation and/or oxygenation have produced conflicting findings. The belief that CPT and suctioning are effective in maintaining airway patency is generally accepted but has yet to be scientifically validated. In view of the fact that there are many potential complications associated with CPT and that the neonate must be subjected to handling and noxious stimuli, CPT certainly cannot be considered a benign procedure.

Because of the great advances in modern technology, many aspects of neonatal physiology can be measured fairly accurately through the use of both invasive and non-invasive monitoring procedures. Continuous monitoring techniques can provide information about how the neonate is responding to therapy administered to him/her.

The conceptual framework, based on the review of the literature, graphically depicts the expected results of the various aspects of CPT (percussions, handling of the infant, instillation and suctioning of the ETT) and the expected results, if deleterious responses are not corrected.

CHAPTER III

METHODOLOGY

Research Design

The study was designed to yield a description of the responses of the respiratory distressed neonate to chest physiotherapy in terms of some selected physiological parameters. It was also designed to enable a comparison of the respiratory distressed neonate's responses to two different methods of CPT in terms of some selected physiological parameters.

A clinical, controlled, randomized, experimental, simple cross-over design (Cochran & Cox, 1957) with each neonate acting as his/her own control was used. The cross-over design is very similar to that of the Latin square. However, the cross-over design was used due to the small number of treatments (two) given in each case. The study design may be depicted as follows:

Group I (n = 15)	T_1	X_1	T_2	Group II (n = 15)	T_1	X_2	T_2
	T_1	X_2	T_2		T_1	X_1	T_2

where: X_1 = Bennett CPAP mask percussion method (Bennett method)

X_2 = contact-heel percussion method (Boyd method)

T_1 = pretest

T_2 = posttest

According to Kerlinger (1973), a research design has two main purposes: a) to answer the research question(s) and b) to control variance. The experimental design is considered to be a rigorous research approach as it allows for rigid control of relevant variables that may contribute to variance. In an experimental design the researcher manipulates and controls one or more variables in order to examine the resulting variation. Kerlinger (1973) stated that three sources of variance must be considered and controlled in any effective design: systematic, extraneous, and error.

Systematic variance refers to the variance of the effect of the independent variable(s) on the dependent variable(s). It should be maximized. The independent variables in this study were the two different methods of administering CPT, while the dependent variables included: A-a O_2 gradient, $TcpO_2$, $PaCO_2$, $TcpCO_2$, H/R, ICP, and MAP. In the study, if the two methods of CPT prove to be not substantially different, there will be less chance of separating the effects of the independent variables from the total variance of the dependent variables.

A second source of variance to be controlled is the variance due to extraneous variables. Kerlinger (1973) suggested that the most effective way of controlling these variables is through randomization. Random assignment of patients to treatment groups and then treatments to the groups is the best way to control all possible extraneous variables that might possibly influence the dependent variables. Randomization is also the best method for assuring that groups are statistically equivalent at the beginning of the study. In the study, the subjects were randomly assigned to one of two treatment order groups.

The final source of variance is error variance. Error variance is defined by Kerlinger as:

> variability of measures due to random fluctuations whose basic characteristic is that they are self compensating. . . Random errors tend to balance each other out so that their mean is zero, but systematic variance is in essence predictable. Error variance is unpredictable (Kerlinger, 1973, p.311).

An important source of error variance derives from errors of measurement. These errors can be eliminated, to a large degree, through standardization of the experimental conditions. In the study, all epochs were timed using the same time-piece and a metronome was employed to ensure equivalency in the rate of percussions.

Experimental designs can be threatened by several factors which jeopardize internal and external validity. Internal validity is the degree to which changes in a dependent variable are directly attributable to the independent variable (Campbell & Stanley, 1963). Although eight threats to internal validity have been described in the literature, only four were considered to be applicable to this study: a) history, b) maturation, c) instrumentation, and d) testing.

History refers to "the specific events occurring between the first and second measurement in addition to the experimental variable" (Campbell & Stanley, 1963, p.5). Examples of such possible events in this study included: changes in intravenous infusions, changes in ventilatory settings, and the administration of medical therapy which might have had a direct effect upon the neonate's responses to the CPT. The influence of history becomes more problematic as the time interval between one observation and another in[illegible]. An attempt to minimize this influence was made through trying [illegible] only a maximum of four hours to lapse between CPT sessions [illegible] neonate. The study was, however, conducted on critically ill neonates whose condition and therapy requirements were to take precedence over adherence to the study protocol. As a result, internal invalidity due to historical sources remained a possibility.

Maturation refers to those processes within subjects which operate as a function of time and are not specific to a particular event (Campbell & Stanley, 1963). The majority of subjects in this study suffered from HMD, a disease which, when uncomplicated, has a fairly predictable course. Typically, the condition of an infant with HMD gradually worsens over the first 48 hours of life as the infant tires, stabilizes for 24 hours, and then steadily improves. By the end of the first week of life the infant has usually recovered (Roberton, 1981). In this study, it was thus possible for the internal validity of the study to be threatened by the maturational processes of the infants' stage of disease and by normal physiological changes in the infants. To overcome this problem, in part, neonates with uncomplicated HMD were studied when they were at least 48 hours of age. Also, random assignment to the treatment groups and treatment order was used to overcome maturational threats to internal validity.

Instrumentation refers to the measuring tools (Campbell & Stanley, 1963). In this study, the threat to internal validity through changes in the measuring tool or in the observers over time was reduced by calibrating the instruments prior to each CPT session and by having only the researcher take the measurements. Prior to the start of each data collection period, values determined through transcutaneous monitoring were compared to those of arterial blood samples drawn simultaneously to a digital readout observation from the appropriate non-invasive monitor.

Testing refers to "the effects of taking a test upon the scores of a second testing" (Campbell & Stanley, 1963). In order to decrease the influence of this factor, two procedures were built into the research design. First, all infants were randomly allocated to one of two groups. Group one received the Bennett method of CPT first, followed by the Boyd method of CPT, while Group two received the CPT sessions in reverse order. Secondly, the CPT sessions were given at least one hour apart so that secretions could reaccumulate.

The external validity of a study refers to the degree to which findings can be generalized to other populations, settings, or circumstances (Campbell & Stanley, 1963). If nursing research is to be effective in improving nursing practice, its findings must be applicable to nursing practice. Unfortunately, frequently in nursing research situations, subjects cannot be randomly selected from a defined population.

It is then impossible to generalize from the research findings. In this study, the small number of babies observed in each group (n = 15) and the lack of random selection limit the applicability of the results to the study population. The fact that neonates were randomly assigned to treatment groups and treatment order does aid, in part, in overcoming threats to external validity due to interaction effects of selection biases and the experimental variables.

Sinclair (1966) suggested that researchers use each infant as his/her own control, and measure infant response to a randomized order of test situations to contend with known (or unknown) heterogeneity of the study sample. Many factors remain unknown or uncontrollable and it is a formidable task to select a completely homogeneous sample. The use of an inordinate number of sample delimitations greatly restricts the target population to which the study results can be generalized. To ensure a relatively homogenous sample, a minimum number of delimitations were used in this study.

Criteria for Selection of Subjects

Only neonates were included in the study as it is crucial to learn how to decrease the high mortality rate which characterizes the entire first month of life. The period of greatest risk with regard to survival is the first day following birth due, in part, to the critically ill newborn's inability to adapt physiologically to his/her external environment. For the most part, neonatal respiratory distress manifests itself within twelve hours of birth and is resolved within a two week period. By 28 days of age, the infant is rarely in a state of constant flux.

Only infants whose weight was greater than 750 grams were included in the study for the following reasons. Advances in neonatal medical knowledge and technology have made possible the survival of smaller infants. Aggressive treatment of infants who weigh less than 750 grams at birth is prevalent (Gordon, 1977; Knobloch, Malone, Ellison, Stevens & Zdeb, 1982; Williams & Chen, 1982). However, an infant who weighs less than 750 grams is very immature and poorly equipped to handle the iatrogenic bombardment of neonatal care. Cerebral blood vessels are poorly supported with muscular and adventitial tissue. The very small preterm infant is thus at great risk for incurring an intracranial haemorrhage, the leading cause of death of very premature infants (Ahmann, Lazzara, Dykes, Brann & Schwartz, 1979; Bejar, Curbelo, Coen, Leopold, James & Gluck, 1980; De Courten & Rabinowicz, 1981; Papile, Burstein, Burstein & Koffler, 1978; Shinnar, Molteni, Gammon, D'Souza, Altman & Freeman, 1982; Volpe, 1981). Excessive handling during this critical developmental phase can lead to deleterious results in the neonate (Tomney, 1980). As a result, it was felt the extra handling required for this study may lead to a deterioration in the neonate's condition. In addition, the very small neonate was simply too small to permit placement of the monitoring equipment necessary for the study.

Infants who were intubated were chosen for study to decrease variation with regard to suctioning technique. In addition, the requirement of an FIO_2 of .90 or less permitted the researcher some leeway with regard to resuscitation if the neonate required it during the CPT or post-CPT period.

It was considered necessary for all infants to have an indwelling arterial line to permit easy, unobstructed access to arterial blood for evaluation of blood gas levels (Shapiro, Harrison & Walton, 1977). The arterial line also permitted continuous recording of the mean arterial blood pressure.

The use of short-acting sedation prior to treatment may also decrease the infant's ability to respond to stimuli. Consequently, any infant requiring sedation for irritability and/or restlessness was not included in the study population.

Study Sample

Thirty neonates meeting the study criteria were admitted to the study over a six month period. Twenty-two of the infants were born in the Royal Alexandra Women's Hospital and eight were transported from various hospitals outside of Edmonton. Sixteen of the infants had a diagnosis of HMD; the remainder had a variety of diagnoses. Patent ductus arteriosus (PDA) was a complication of prematurity in four of the neonates. Ten neonates required chest tubes for relief of pneumothoraces. In all cases, the pneumothorax was unilateral and chest tubes were inserted bilaterally to prevent occurrence of a second pneumothorax on the contralateral side. The study sample of 17 males and 13 females ranged in birthweight from 750 to 4030 grams with a mean of 2115 grams (SD + 873.74). The infants' gestational ages varied from 25 to 42 weeks with a mean of 33.60 weeks (SD + 4.01). Twenty-five of these infants were considered to be premature. The 30 infants were studied at a mean age of 2.90 days (range 1 to 10 days, SD + 2.02) and a mean weight of 2168.17 grams (range 750 to 3910, SD + 905.60). The demographic characteristics of all study subjects are presented in Appendix 2 and the respiratory status of all study subjects are presented in Appendix 3.

Group I of the sample consisted of 15 neonates whose birthweight ranged from 760 to 3720 grams with a mean of 2204.70 grams (SD + 1048.86) and gestational age ranged from 25 to 40 weeks with a mean of 34.60 weeks (SD + 4.33). Six of the infants were female and 9 were male. Eight infants suffered from HMD; 2 infants were diagnosed as having a PDA. Four infants were studied while on Pavulon and 2 neonates had chest tubes.

Group II of the sample consisted of 15 neonates who ranged in birthweight from 750 to 4030 grams with a mean of 2203.30 grams (SD + 702.77) and in gestational age from 26 to 42 weeks with a mean of 32.80 weeks (SD + 3.54). Of the 7 females and 8 males, 7 suffered from HMD and 2 suffered from a PDA. Two infants were studied while on Pavulon and 8 neonates had chest tubes.

There were no significant differences at a level of $p \leq 0.05$ between the two groups of neonates, based on non-paired Student's t comparisons of demographic data and pre-CPT status (i.e. FiO_2, PaO_2, peak inspiratory pressure (PIP), positive end-expiratory pressure (PEEP) or continuous positive airway pressure (CPAP), $PaCO_2$, pH, intermittent manditory ventilation (IMV), A-a O_2 gradient, ICP, H/R, MAP, $TcpO_2$, and $TcpCO_2$).

Neonatal Care

All neonates were nursed in overhead radiant warmer beds with their skin or rectal temperature maintained at 36.8°C by servo-control. All infants were intubated nasally by medical staff, using a #2.5 to #3.5 mm Portex tube. Infants received ventilatory support by either a Baby Bird (n = 20), Sechrist (n = 3), or Healthdyne (n = 7) ventilator. All ventilator settings [PIP, PEEP, CPAP, IMV, and inspiratory times (IT)] were determined individually according to the blood gas levels and the clinical condition of each infant.

Intravenous fluids were administered to the neonates by way of the arterial line. Where the arterial line was not an umbilical catheter, a second peripheral vein was used for intravenous perfusion. A peripheral vein was also used to infuse blood or blood products because the line to the arterial blood pressure transducer had to be clamped to prevent contamination by blood products infusing through the arterial line.

Chest Physiotherapy Methods

Each neonate was placed in the appropriate postural drainage position for the affected lobe in accordance with the guidelines of the Royal Alexandra Hospitals Physiotherapy Department (see Appendix 4). Each neonate was kept in this position for five minutes prior to the commencement of the percussions.

The Bennett method of percussions was performed according to the instructions of two physiotherapists who worked in the Royal Alexandra NICU. The Bennett mask used (#5281 Puritan-Bennett, Los Angeles, Ca.) is a doughnut-shaped mask made of translucent silicone rubber. A handle to fit the therapist's first two fingers was made out of a plastic cap of an 18 gauge needle and taped into place on the mask. The neonate's affected lobe was percussed with the prepared mask at a rate of 80 to 120 bpm.

The Boyd method of percussions is also known as contact-heel percussion. In this method, pressure is applied using the thenar-hypothenar eminence of the hand at right angles to the chest wall of the neonate. An attempt to achieve a thoracic displacement of 1 to 2 cm was made. The rate of percussions matched those of the Bennett method.

Each CPT session consisted of five minutes of percussions. Whenever the infant's condition deteriorated to beyond accepted limits for normoxia and H/R, time and corrective measures were taken to return the infant's H/R and/or $TcpO_2$ level to within accepted limits prior to the resumption of the percussions.

Tracheal suctioning was carried out following instillation of 0.5 ml of normal saline into the ETT. As was outlined in the NICU procedure manual, the neonate's head was turned to the contralateral side and the trachea instilled prior to introduction of the suction catheter. The catheters were measured and marked so the catheter would not be passed to greater than one cm beyond the end of the infant's ETT. In each case, the catheter size was dictated by the size of the ETT to ensure free and easy passage. No more than three passes of the catheter on each side was required or employed. Each suctioning session was completed in less than ten seconds while the neonate was normoxic, according to the $TcpO_2$ monitor. Tracheal suctioning was followed by oral suctioning to clear the oropharyngeal area of any accumulated secretions. A mean time of 3.9 minutes (range 1.5 to 5.5 minutes) was required for the entire suctioning procedure.

Measurement Tools

Continuous data were collected on six physiological parameters: H/R, MAP, $TcpO_2$ level, $TcpCO_2$ level, ICP, and oesophageal pressure. In the NICU at the Royal Alexandra Paediatric Pavilion, all monitoring devices, with the exception of the device to measure oesophageal pressure, were used to aid in the care of the critically ill neonate.

Devices to measure the first three parameters were used routinely in the NICU.

Heart rate was measured using adhesive, pre-gelled neonatal cardiac electrodes. The infant's electrocardiogram and mean H/R were recorded on a bedside monitor (Model 78342A, Hewlett Packard, Waltham, Ma.). Alarms were set at 100 bpm (bradycardia) and 200 bpm (tachycardia) for all premature infants and for all fullterm neonates who were not asphyxiated. For the fullterm asphyxiated neonate, the alarm for bradycardia was set at 80 bpm since the sympathetic nervous system of such a neonate is depressed and results in a low resting apical rate.

Mean arterial blood pressure was measured using a #3.5 or #5 umbilical artery catheter, radial artery catheter, or an anterior tibial artery cutdown cannula. When the umbilical catheter was used, it was inserted to the level of the eighth thoracic vertebra. The MAP was monitored using a transducer (Model 4-327-I, Hewlett Packard, Waltham, Ma.) attached to the arterial line. All transducers were flushed and recalibrated at the level of the infant's atrium prior to the commencement of each study session. Values for the MAP were continuously displayed on the cardiac monitor.

Transcutaneous oxygen levels were measured using a neonatal transoxode (Type 33, Module 632, Roche, Basel, Switzerland). The $TcpO_2$ electrode was removed and calibrated prior to each study session. Following application of the electrode onto the infant, no readings were taken for fifteen minutes to allow for increased blood flow to the area and arterialization of the electrode's readings. Values were continuously displayed on a monitor at the bedside. Alarm levels for hypoxia and hyperoxia were set at the discretion of the attending neonatologist according to the gestational age, clinical condition, and post-natal age of the neonate. As a result, hypoxia and hyperoxia limitations differed from neonate to neonate.

Transcutaneous carbon dioxide levels were obtained with the use of a pH glass electrode (Model 341-51, Module 634, Roche, Basel, Switzerland). As with the $TcpO_2$ electrode, the $TcpCO_2$ electrode was removed and calibrated prior to each study session. Values were continuously displayed on a bedside monitor. Alarms levels were set at 10 torr (hypocapnia) and 50 torr (hypercapnia).

Intracranial pressure was measured by a fiberoptic sensor (Model 10004, Ladd Research Industries, Burlington, Vt.). This non-invasive sensor was taped onto the shaved anterior fontanelle of the infant by means of a cotton filled, self-adhesive neonatal cardiac electrode (#01-0110, NDM, Dayton, Oh.). A continuous display of values was available on a bedside monitor (Model M1000, Ladd Research Industries, Burlington, Vt.).

Oesophageal pressure was measured using an 8-FG (2 mm internal diameter) standard infant feeding catheter (#71031, AHS, McGaw Supply Ltd., Mississauga, Ontario). The catheter was attached to a neonatal blood pressure transducer (Type 4-327-I, Bell & Howell, Instrumentation Division, Pasadena, Ca.). The catheter and transducer were filled with water and subsequently kept free of bubbles by flushing them with sterile water between measurements. The catheter was inserted into the infant's stomach through his/her mouth. The catheter was then withdrawn proximally to the cardia and then withdrawn a further 2 - 3 cm into the lower third of the oesophagus. A continuous waveform and digital readout of mean values were displayed on the cardiac monitor.

Levels of all six parameters were continuously recorded throughout all CPT sessions on a six channel recorder at the bedside (Model 3316, Soltec, Sun Valley, Ca.).

Pre-CPT and post-CPT arterial blood gas levels, inspired oxygen concentrations, systolic and diastolic arterial BP, and demographic data as outlined on the data form in Appendix 5 were recorded. Arterial blood for gas analysis was drawn by the researcher and analyzed by an available respiratory technologist (R.T.) on duty in the NICU. This R.T. also recorded ventilatory settings with each blood analysis. Since the NICU R.T. works on a permanent basis in the NICU and blood gas analysis comprises a large portion of his/her required duties, his/her proficiency in blood gas analysis was expected to be uniformly high. All samples were analyzed using one of two blood gas analyzers (Model #813 or #1303, Instrumentation Laboratory Inc., Lexington, Ma.). Each analyzer was calibrated daily to standard solutions. In addition, one analyzer, on which 90% of the gases were run, had a feature of an "autocal" self check between each sample analysis.

Conduct of the Study

Data collection took place over a six month period from 02 August, 1982 to 31 January, 1983 following ethical review and clearance of the study by the Clinical Investigation Committee of the Royal Alexandra Hospitals.

Selection of subjects for inclusion in the study was made on the basis of availability of suitable subjects. Once infants who met the selection criteria were assessed by the researcher as able to withstand application of the monitoring equipment, permission to include them in the study was obtained from the neonatologist in charge of their care.

Informed, verbal consent was obtained by the investigator from one or both parents of all infants who were included in the study. It was emphasized to the parents that their refusal to participate in the study would not affect the care which their baby would receive. The parents who consented to allow their infant to be studied were informed that they were free to withdraw their baby from the study at any time and that, by doing so, they would not jeopardize their infant's care. The parents were also invited to be present during the study and encouraged to ask questions. Only one parent refused admission of her infant to the study as she wished to discuss it with her husband who was out of town for three or four days. By the time consent could be obtained, the infant no longer fit the study criteria.

Once parental consent was obtained, the infant was entered into the study by means of a toss of a coin and a previously constructed schedule of random pairs [i.e. the Bennett method in the first CPT session followed by the Boyd method in the second CPT session (heads), the Boyd method in the first CPT session followed by the Bennett method in the second CPT session (tails)]. The schedule of the study for both groups is depicted in Appendix 6.

Once a CPT session commenced, the investigator took over the nursing care of the infant until the end of the CPT sessions. No other personnel were permitted to handle the infant until completion of the CPT sessions.

All calibration routines, equipment set-up, chest percussion, instillation and suctioning, withdrawal of arterial blood, observations, manipulation of FiO_2, and recording were done by the investigator. Approximately 90 minutes were required to complete each CPT session. The mean time between each CPT session was 1.9[illegible] hours (range 1 to 4 hours). Approximately one hour was required prior to the first CPT session to ensure proper calibration and application of equipment. In all cases, the procedures outlined in Appendix 6 were followed.

Data Analysis

Once data were collected on the 30 study subjects, the recorded tracings of each CPT session [illegible] hand-digitized for relevant information. To avoid bias, a blind analysis of the tracings was done, that is, the method of CPT utilized on the neonate was unknown to the investigator during this period of analysis. Because the data were collected for a dual purpose: for description and hypothesis testing, a variety of analytical methods were used.

Descriptive statistics (mean, SD, and range) were utilized to describe all relevant variables of the study. For hypothesis testing, data that were measured on ordinal or nominal scales were analyzed using the non-parametric test of Chi square, while interval and ratio data analysis employed the following tests: Student's *t*, Pearson's *r*, oneway analysis of variance (ANOVA), and multiple linear regression (Glass & Stanley, 1970). In addition, ANOVA, using a Latin square format (Cochran & Cox, 1958), was employed to ascertain differences between subjects and effect of treatment order. An example of this type of analysis is presented in Appendix 7.

Statistical inference tests are often classified as parametric or non-parametric. Although all inference tests depend on population characteristics to some extent, the requirements for using nonparametric tests are minimal. When the data are nominal or ordinal and there is an extreme violation of an assumption of the parametric test or the investigator believes the scaling of the data makes the parametric test inappropriate, a nonparametric inference test should be employed (Isaac & Michael, 1980).

On the other hand, the requirements for using a parametric inference test entail certain assumptions about population characteristics or parameters. The t tests for two samples or conditions (dependent t or independent t) require that the population scores be normally distributed, when the samples are small. The independent t test further requires that the population variances be equal. The ANOVA has requirements quite similar to those of the independent t test. Despite these requirements, many of the parametric inference tests are robust with regards to violations of underlying assumptions. A test is robust if violations of the assumptions do not greatly disturb the sampling distribution of the statistic. Even though, theoretically, normality in the population is required with small samples, it turns out empirically that, unless the departures from normal are substantial, the sampling distribution of t remains essentially the same. Thus, the t test is robust regarding the violation of normality in the population. As a result, the t test can be used even though the assumptions of normality have been violated.

The paired t test was employed to determine the significance of the difference, if any, between means of all data collected during the baseline period and means of all measurements made during and following CPT.

Where more than one variable was compared to another, the ANOVA (oneway or Latin square model) was used. Like the t test, the ANOVA is a robust test. It is minimally affected by violations of population normality. It is also relatively insensitive to violations of homogeneity of variance provided the samples are of equal size.

Regression models were employed to investigate relationships between methods of CPT and the levels of the physiological parameters and to ascertain the reliability of both transcutaneous monitors ($TcpO_2$ and $TcpCO_2$). Correlation coefficients derived from these analyses were tested for significance using the following formula:

$$t = r\sqrt{\frac{n-2}{1-r^2}}$$

(Armitage, 1974, p.74)

In all cases of inferential testing, a significance level (probability value, p) of equal to or less than 0.05 was used.

Summary

The clinical, controlled, randomized experimental cross-over design of the study permitted each neonate to act as his/her own control but was subject to threats of internal validity due to history, maturation, instrumentation, and testing. The study subjects included thirty neonates who were intubated, had an FiO_2 of 0.9 or less, weighed more than 750 grams, had an indwelling arterial line, and did not require short-acting sedation. Each infant received both types of percussions in randomized order, once parental consent was obtained. The investigator provided all nursing care during the study period. The physiological parameters continuously recorded included H/R, MAP, ICP, oesophageal pressure, $TcpO_2$, and $TcpCO_2$. In addition, pre-test and post-test arterial blood gas levels and O_2 requirement changes were recorded along with pertinent demographic data. Statistical analysis of the data utilized descriptive statistics (mean, SD, and range) for all relevant variables and statistical inferential tests (Chi square, *t* tests, Pearson's *r*, ANOVA) for hypothesis testing. A significance level of ≤ 0.05 was used in all cases of inferential testing.

CHAPTER IV

RESULTS OF THE STUDY

The results suggest that, while the neonates' mean physiological responses during the postural drainage phase of CPT were not significantly different from those observed during the pre-CPT and post-CPT phases, the neonates' mean responses during the instillation and suctioning phase varied significantly from those observed during all other phases of CPT with the exception of the percussions phase. There were significant differences detected in the neonates' responses to the Bennett percussions and the Boyd percussions as measured along the seven physiological parameters of HR, MAP, ICP, $TcpO_2$, $TcpCO_2$, A-a O_2 gradient, and $PaCO_2$.

Neonatal Responses to Chest Physiotherapy

The five phases of CPT referred to in this section include: pre-CPT (baseline), postural drainage, percussions (Bennett or Boyd method), instillation and suctioning of the ETT, and post-CPT. The mean responses of the 30 neonates to all 60 CPT sessions, exclusive of the percussions phase of the sessions, are presented in Table I. Because the neonates' responses to the two different percussion methods were found to be significantly different, the mean values of each phase are presented

Table I Means and Standard Deviations of Responses of Infants along All Parameters: All Chest Physiotherapy Phases except Percussions

Physiological Parameter	Pre-CPT		Postural Drainage		Instillation & Suctioning		Post-CPT		F Value	*P* Value
H/R (bpm)	153.6	(15.69)	154.0	(15.60)	157.5	(15.00)	154.4	(16.45)	0.9	0.456
MAP (torr)	46.9	(10.07)	47.4	(10.63)	51.0	(13.24)	46.8	(9.83)	3.0	0.020
ICP (cm H_2O)	5.3	(2.79)	6.0	(4.24)	8.8	(4.63)	4.9	(2.56)	13.7	0.000
$TcpO_2$ (torr)	66.7	(10.61)	66.8	(10.78)	60.7	(12.04)	67.2	(10.65)	4.6	0.003
$TcpCO_2$ (torr)	35.7	(6.68)	35.8	(7.06)	35.8	(7.19)	35.5	(6.54)	0.0	0.989

__Note:__ Numbers in parentheses = SD

by percussion method in Tables II and III. The mean values of each phase were compared with those of all other phases by one-way ANOVA. The results of this analysis are included in Tables I, II, and III.

The levels of all physiological parameters measured during the pre-CPT phase were all within normal limits for a neonate. Also, these levels returned to within normal limits in the post-CPT phase. With regard to H/R, MAP, ICP, $TcpO_2$, and $TcpCO_2$, there were no significant differences observed between the pre-CPT and post-CPT levels.

The levels of all physiological parameters measured during the postural drainage phase remained within normal limits for each neonate. During postural drainage, the mean H/R and MAP increased by 0.40 bpm and 0.50 torr respectively above the pre-CPT levels. Also, the mean ICP level increased by 0.70 cm H_2O above the pre-CPT level. Both the mean $TcpO_2$ level and the mean $TcpCO_2$ level increased by a very small amount, 1.00 torr and 0.10 torr respectively.

With postural drainage of both upper and lower lobes, no significant changes were noted in the means of this phase as compared to those of the pre-CPT and post-CPT phases. However, a significant increase in ICP was noted when the infants were placed in the head down position for lower lobe drainage [t (9) = 4.04, p = 0.003]. While the majority of the neonates settled quickly following repositioning (in less than 35 seconds), two infants took longer to settle. One infant required ventilation with a Jackson-Reese circuit (a special circuit which permits delivery of an FiO_2 = 1.00, as well as hand bagging) for both

Table II Means and Standard Deviations of Responses of Infants along All Parameters: Bennett Percussions

Physiological Parameter	Pre-CPT	Postural Drainage	Percussions	Instillation Suctioning	Post-CPT	*F* Value	*P* Value
H/R (bpm)	154.1 (19.75)	154.6 (20.21)	170.8 (23.13)	158.4 (19.15)	154.5 (21.92)	5.8	0.000
MAP (torr)	46.4 (10.34)	47.0 (9.92)	51.2 (14.12)	50.1 (14.96)	46.2 (10.82)	2.1	0.040
ICP (cm H_2O)	5.3 (3.28)	6.2 (3.17)	10.0 (11.77)	9.1 (7.54)	5.1 (3.07)	4.7	0.001
$TcpO_2$ (torr)	67.0 (13.70)	67.0 (13.80)	61.2 (18.28)	61.3 (15.33)	67.7 (9.27)	3.4	0.019
$TcpCO_2$ (torr)	34.9 (5.21)	35.0 (5.59)	33.0 (5.69)	34.9 (4.51)	34.8 (5.12)	0.4	0.772

<u>Note:</u> Numbers in parentheses = <u>SD</u>

Table III Means and Standard Deviations of Responses of Infants along All Parameters: Boyd Percussions

Physiological Parameter	Pre-CPT	Postural Drainage	Percussions	Instillation & Suctioning	Post-CPT	*F* Value	*P* Value
H/R (bpm)	153.2 (13.25)	153.5 (13.14)	159.2 (11.98)	156.[illegible] (12.65)	154.4 (11.51)	1.0	0.412
MAP (torr)	47.5 (6.57)	47.8 (6.92)	49.4 (11.71)	52.0 (12.38)	47.3 ([illegible].28)	1.0	0.412
ICP (cm H_2O)	5.4 (0.68)	5.7 (2.38)	7.0 (2.78)	8.5 (2.95)	4.8 (1.47)	3.0	0.033
$TcpO_2$ (torr)	66.3 (6.56)	66.3 (6.72)	60.1 (8.56)	60.2 (15.61)	66.9 (8.36)	2.0	0.104
$TcpCO_2$ (torr)	36.5 (5.47)	36.7 (5.74)	35.0 (5.01)	36.8 (4.08)	36.1 (4.97)	0.4	0.772

<u>Note:</u> Numbers in parentheses = <u>SD</u>

treatment sessions. The other infant required an increase in FiO_2 of 0.35 in order to tolerate the head-down position. Otherwise, all postural drainage positions were well tolerated by the neonates. No infants required termination of the drainage position prior to the five minute limit requirement.

Instillation and suctioning of the ETT affected all infants in a detrimental manner. A total of 12 bradycardia episodes (range 1 to 3, mean 0.2, SD $\pm$ 0.632) and 7 episodes of tachycardia (range 0 to 3, mean 0.12, SD $\pm$ .490) occurred during this phase. Instillation and suctioning of the ETT produced large swings in the various physiological levels. The mean values and the mean ranges included: H/R 32.80 bpm (range 3 to 101 bpm), MAP 12.68 torr (range 3 to 25 torr), ICP 13.24 cm H_2O (range 0.50 to 82 cm H_2O), $TcpO_2$ 24.68 torr (range 3 to 100 torr), and $TcpCO_2$ 4.25 torr (range 0 to 13 torr).

Overall, when, for each physiological parameter, the mean ranges of this phase were compared to the mean ranges of the pre-CPT, postural drainage, and the post-CPT phases, the mean ranges of this phase were found to be significantly greater (p <0.001). Significant differences among all physiological parameters, except for H/R and $TcpCO_2$, were noted, when the means of the instillation and suctioning phase were compared with those of the pre-CPT phase. In comparison to the mean pre-CPT levels, the mean increase in H/R was 3.90 bpm. Both the mean MAP and the mean ICP increased by 4.10 torr and 3.50 cm H_2O respectively. While the mean $TcpO_2$ level decreased by 6 torr, the mean

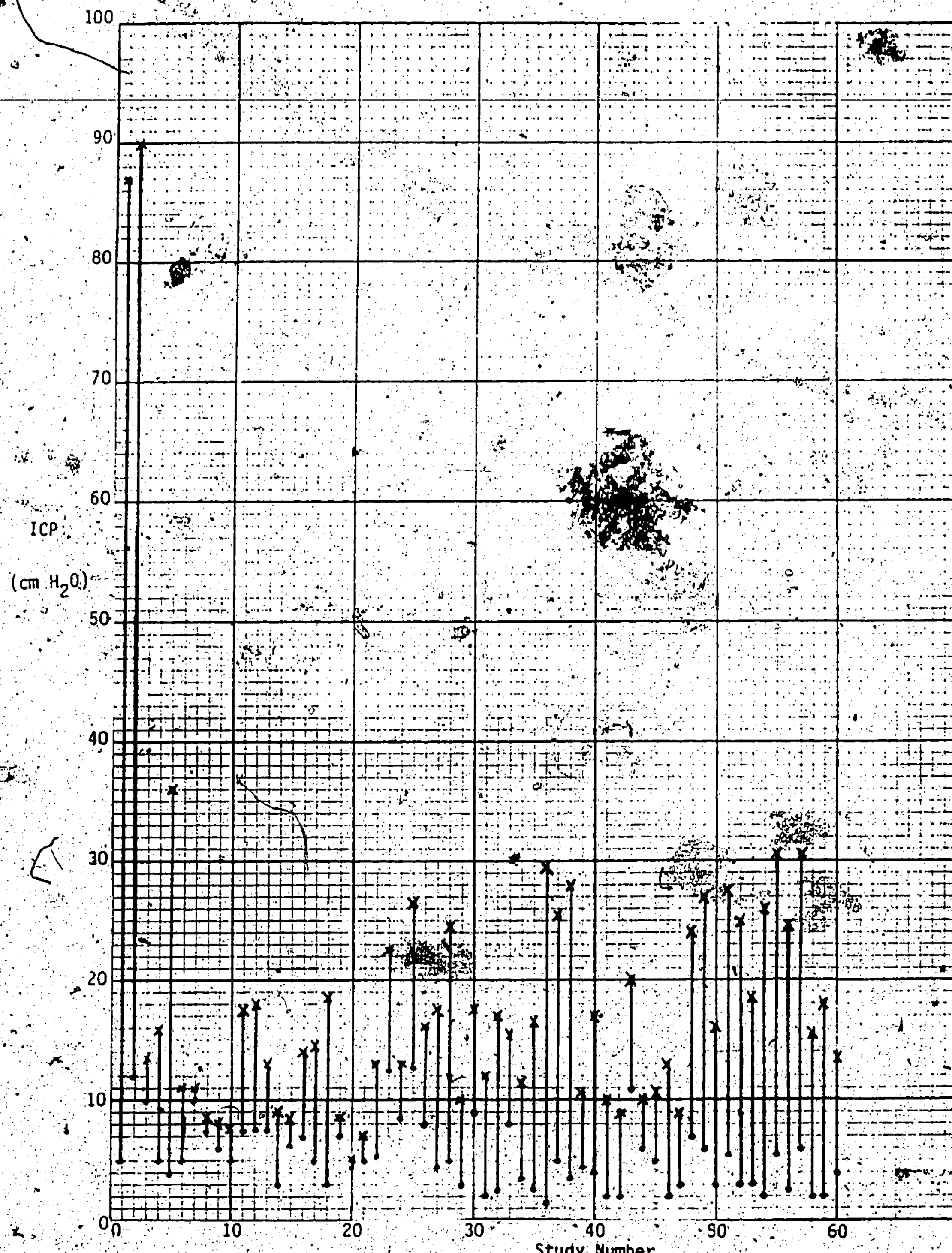
$TcpCO_2$ level rose minimally by 0.10 torr. The lowest mean $TcpO_2$ level detected was 9.88 torr (range 22 to 77 torr, SD + 7.81) indicating a mean maximum decrease of 16.79 torr.

There was an average of 3.23 ICP spikes (range 0 to 17, total 194, SD + 4.82) to greater than 10 cm H_2O above the mean pre-CPT level during instillation and suctioning of the ETT. The large fluctuations in the ICP levels can best be presented by depicting both the highest ICP level reached by each infant during instillation and suctioning and his/her mean [illegible]level (see Figure 2).

During [illegible]odes of instillation and suctioning of the ETT, the neonates [illegible] a mean increase in FiO_2 of 0.15 (range 0 to 0.17, SD + 0.15) above the pre-CPT level. There was a significant correlation (r = 0.47, p = 0.0017) between this increase and the pre-CPT level. The higher the initial FiO_2 requirement, the more the FiO_2 had to be increased to maintain normoxia during instillation and suctioning of the ETT. During 51 (85%) of the sessions, the infants required, at least once during the procedure, extra breaths via the ventilator or a Jackson-Reese circuit. Despite these measures, an hypoxic episode was observed to last an average of 0.45 minutes (range 0 to 3 minutes, SD + 0.587) and an hyperoxia episode an average of 0.33 minutes (range 0 to 3.0 minutes, SD + 0.707).

FIGURE 2

Intracranial Pressure: Pre-Chest Physiotherapy Mean and Highest Level during Instillation and Suctioning



Comparison of Neonatal Responses to the Bennett and Boyd Methods of Percussions

Prior to analysis of the data obtained during the two methods of percussions, all pre-CPT baseline levels were compared to establish equivalency of the two method groups (see Appendices 8 and 9). In all cases there were no significant differences detected. It was therefore assumed that all data from Bennett percussions sessions could be combined and all data from Boyd percussions sessions could be combined to permit comparison by inferential analysis. In addition, all pre-Bennett CPT baseline data were compared to all pre-Boyd CPT baseline data and no significant differences were found.

Oesophageal pressure levels were analyzed using Student's t analysis of paired variates and found to be similar for both methods of percussions [t (29) = 0.571, p >0.5]. The mean pressure due to chest compression was 2.56 cm H_2O (range 0.50 to 3.50 cm H_2O) for the Bennett percussions and 2.63 cm H_2O (range 0.50 to 3.50 cm H_2O) for the Boyd percussions. Thus, any differences between the two methods could be attributed to the inherent differences in the techniques themselves rather than to the amount of chest wall displacement which occurred.

All significant differences detected between the two methods of percussions are presented in Tables IV and V. In all percussions sessions, a mean increase in H/R above the mean pre-CPT H/R level was

Table IV Parametric Test: Significant Differences between Methods of Percussions

Physiological Parameter	Δ Phase of CPT	Bennett	Boyd	Test	Result	Significance
H/R (bpm)	pre-CPT: percussions	16.37	6.51	t F	5.343 28.250	<0.001 <0.001
H/R (bpm)	postural drainage: percussions	15.84	5.70	t F	5.657 26.030	<0.001 <0.001
H/R (bpm) range	percussions	45.50	14.53	t F	5.771 23.340	<0.001 <0.001
MAP (torr)	pre-CPT: percussions	4.81	1.62	t F	2.847 4.580	<0.05 <0.05
MAP (torr)	postural drainage: percussions	4.18	[illegible]	t F	2.197 4.380	<0.05 <0.05
ICP ($cm\ H_2O$)	pre-CPT: percussions	4.74	1.60	t F	2.266 5.060	<0.05 <0.05

Table IV Parametric Test: Significant Differences between Methods of Percussions

Physiological Parameter	Δ Phase of CPT	Bennett	Boyd	Test	Result	Significance
ICP # spikes >10 cm H_2O pre-CPT ICP	percussions	6.00	1.13	t	2.730	<0.02
				F	6.020	<0.02
A-a O_2 gradient	pre-CPT: post-CPT	12.90	-20.37	t	4.837	<0.001
				F	12.280	<0.001
FiO_2	pre-CPT: post-CPT	0.02	-0.03	t	4.590	<0.01
				F	10.050	<0.01
FiO_2	pre-CPT: percussions	0.14	0.07	t	3.619	<0.01
				F	8.012	<0.01
Hypoxia (min)	percussions	0.66	0.16	t	3.456	<0.01
				F	8.539	<0.01
Hyperoxia (min)	percussions	0.21	0.05	t	2.132	<0.05
				F	6.837	<0.05
$PaCO_2$ (torr)	pre-CPT: post-CPT	0.48	-2.53	t	3.460	<0.001
				F	10.530	<0.001

Table V Non-parametric Test: Significant Differences between Methods of Percussions

Physiological Parameter	Phase of CPT	Number of Infants Bennett	Number of Infants Boyd	Test	Result	Significance
H/R # of infants with at least one episode of tachycardia	percussions	9	0	χ^2 Yates correction	8.366	0.004
FiO_2 # of infants requiring additional O_2	percussions	22	13	χ^2	5.554	0.019
Hypoxia # of infants requiring extra breaths	percussions	19	11	χ^2	4.344	0.036

detected. During the Bennett percussions, the mean increase in H/R was 16.37 bpm (range 0 to 35 bpm). During the Boyd percussions, the mean increase in H/R was 6.51 bpm (range 0 to 20.80 bpm). When the mean increase in H/R for the two methods of percussion were compared, the difference was found to be significant ($p < 0.001$). When the mean H/R during percussions was compared to the mean H/R during postural drainage, a significant difference was again evident ($p < 0.001$) with the two methods of percussion. With the Bennett percussions, the mean difference in H/R was 15.84 bpm (range 0 to 35.20 bpm). With the Boyd percussions, the mean difference in H/R was 5.70 bpm (range 0 to 20.80 bpm).

The great amount of fluctuation in H/R which occurred during each session is reflected in the highest and lowest heart rates observed. During the Bennett percussions, this H/R fluctuation ranged from 4 to 101 bpm with a mean range in H/R of 45.50 bpm. During the Boyd percussions, the H/R fluctuation ranged between 4 and 38 bpm with a mean range in H/R of 14.5[illegible] bpm. A significant difference was detected ($p < 0.001$). Nine neo[illegible] at least one episode of tachycardia (>200 bpm) during the Bennett percussions. No infants experienced tachycardia with the Boyd percussions. This difference was found to be statistically significant ($p = 0.004$).

With the Bennett percussions, the MAP ranged from 5 torr below the pre-CPT level to 25.80 torr above the pre-CPT level (mean 4.81 torr). With the Boyd percussions, the MAP ranged from 10 torr below the pre-CPT level to 10 torr above the pre-CPT level (mean 1.62 torr). When the mean increase in the MAP for the two methods of percussions were compared, the difference was found to be significant ($p < 0.05$). When the MAP levels observed during postural drainage were compared to those of the percussions phase, a significant difference was evident with the two methods of percussions ($p < 0.05$). During the Bennett percussions, the MAP ranged from 6 torr below the mean postural drainage level to 20 torr above the mean postural drainage level (mean 4.18 torr). During the Boyd percussions, the MAP ranged from 10 torr below the mean postural drainage level to 19 torr above the mean postural drainage level (mean 1.23 torr).

During the Bennett percussions, the mean increase in ICP above the baseline level was 4.74 cm H_2O (range -0.70 to 39.40 cm H_2O), while the mean increase during the Boyd percussions was 1.60 cm H_2O (range -1.40 to 7.50 cm H_2O). A significant difference was detected ($p < 0.05$). The neonates produced an average of 6.00 spikes of ICP to greater than 10 cm H_2O above the baseline level (range 0 to 32) during the Bennett percussions and only 1.13 spikes of the same nature (range 0 to 9) during the Boyd percussions. This difference was found to be statistically significant ($p < 0.02$).

In order to maintain a normoxic state within the neonate during the percussions, the FiO_2 was increased, as required, and/or the neonate was given extra respirations, either through the respirator or with the use of the Jackson-Reese circuit. Tables VI and VII illustrate the changes in oxygen requirements and the type of bagging required by the

Table VI Changes in Oxygen Requirements: Bennett Percussions

Infant #	Pre-CPT FiO_2	Post-CPT FiO_2	Maximum FiO_2	% Change From Pre-CPT FiO_2	Type of Bagging Required
1	0.25	0.26	0.30	20.0	Ventilator
2	0.44	0.42	0.52	18.2	-
3	0.35	0.35	0.58	65.7	Jackson/Reese circuit
4	0.38	0.38	0.38	0.0	-
5	0.49	0.50	0.60	22.4	Ventilator
6	0.59	0.62	0.69	16.9	Ventilator
7	0.45	0.52	0.50	22.2	Ventilator
8	0.36	0.39	0.45	25.0	Ventilator
9	0.62	0.58	1.00	61.3	Ventilator
10	0.39	0.45	0.80	105.2	Ventilator
11	0.24	0.27	0.24	0.0	-
12	0.43	0.43	0.80	86.0	Ventilator

Table VI Changes in Oxygen Requirements: Bennett Percussions

Infant #	Pre-CPT FiO_2	Post-CPT FiO_2	Maximum FiO_2	% Change From Pre-CPT FiO_2	Type of Bagging Required
13	0.21	0.21	0.21	0.0	-
14	0.21	0.21	0.25	19.0	-
15	0.21	0.21	0.21	0.0	-
16	0.50	0.55	0.65	30.0	Ventilator
17	0.36	0.40	0.36	0.0	-
18	0.28	0.28	0.35	25.0	Ventilator
19	0.24	0.23	0.24	0.0	-
20	0.23	0.21	0.35	52.2	Ventilator
21	0.34	0.38	0.52	52.9	Ventilator
22	0.41	0.40	0.41	0.0	-
23	0.21	0.21	0.35	66.7	Ventilator

Table VI Changes in Oxygen Requirements: Bennett Percussions

Infant #	Pre-CPT FiO_2	Post-CPT FiO_2	Maximum FiO_2	% Change From Pre-CPT FiO_2	Type of Bagging Required
24	0.25	0.31	0.36	44.0	Ventilator
25	0.21	0.21	0.23	9.5	Ventilator
26	0.54	0.58	1.00	85.2	Ventilator
27	0.22	0.29	0.39	77.3	Ventilator
28	0.21	0.21	0.21	0.0	-
29	0.24	0.23	0.65	170.8	Ventilator
30	0.53	0.51	0.90	69.8	Ventilator

Table VII Changes in Oxygen Requirements: Boyd Percussions

Infant #	Pre-CPT FiO_2	Post-CPT FiO_2	Maximum FiO_2	% Change From Pre-CPT FiO_2	Type of Bagging Required
1	0.26	0.21	0.37	42.3	Ventilator
2	0.42	0.41	0.47	11.1	Ventilator
3	0.37	0.37	0.72	94.6	Jackson/Reese circuit
4	0.45	0.45	0.45	0.0	-
5	0.58	0.55	0.58	0.0	-
6	0.58	0.59	0.58	0.0	-
7	0.45	0.45	0.50	11.1	Ventilator
8	0.39	0.36	0.39	0.0	-
9	0.68	0.45	0.78	14.7	Ventilator
10	0.45	0.45	0.45	0.0	Ventilator
11	0.27	0.24	0.32	18.5	Ventilator
12	0.44	0.42	0.47	6.8	-

Table VII Changes in Oxygen Requirements: Boyd Percussions

Infant #	Pre-CPT FiO_2	Post-CPT FiO_2	Maximum FiO_2	% Change From Pre-CPT FiO_2	Type of Bagging Required
13	0.21	0.21	0.21	0.0	-
14	0.23	0.21	0.29	26.1	-
15	0.21	0.21	0.21	0.0	-
16	0.49	0.41	0.55	12.2	-
17	0.29	0.26	0.29	0.0	-
18	0.21	0.21	0.21	0.0	-
19	0.24	0.24	0.24	0.0	-
20	0.21	0.21	0.21	0.0	-
21	0.37	0.37	0.42	13.5	Ventilator
22	0.41	0.32	0.41	0.0	-
23	0.21	0.21	0.21	0.0	-

Table VII Changes in Oxygen Requirements: Boyd Percussions

Infant #	Pre-CPT FiO_2	Post-CPT FiO_2	Maximum FiO_2	% Change From Pre-CPT FiO_2	Type of Bagging Required
24	0.21	0.23	0.21	0.0	-
25	0.21	0.21	0.21	0.0	-
26	0.51	0.41	0.05	9.8	Ventilator
27	0.28	0.24	0.28	0.0	-
28	0.21	0.21	0.21	0.0	-
29	0.23	0.21	0.29	26.0	Ventilator
30	0.56	0.50	0.72	28.6	Ventilator

30 neonates during the Bennett percussions and Boyd percussions, respectively. All extra breaths given were within normal limits of the PIP for each individual neonate. For 22 of the neonates, the FiO_2 had to be increased above the pre-CPT level during the Bennett percussions. In contrast, only 13 neonates required additional oxygen to remain normoxic during the Boyd percussions. This difference was found to be statistically significant ($p = 0.019$).

The mean amount of oxygen increase required by the infants also varied with the particular method of percussions. During the Bennett percussions, the neonates required a mean increase in FiO_2 above the pre-CPT level of 0.14 (range 0 to 0.46). During the Boyd percussions, the neonates required a mean increase in FiO_2 above the pre-CPT level of 0.07 (range 0 to 0.46). A significant difference was noted ($p < 0.01$). In addition to extra oxygen, 19 neonates required additional breaths in order to tolerate the Bennett percussions. Only 11 infants required extra breaths during the Boyd percussions. When this difference was compared, it was found to be significantly different ($p = 0.036$).

Despite all attempts to keep the infants as stable as possible during the percussions, periods of hypoxia and hyperoxia were recorded. Seventeen neonates were judged to be hypoxic according to the $TcpO_2$ record during the Bennett percussions, while only nine were hypoxic during the Boyd percussions. During the Bennett percussions, the neonates remained, on the average, 0.66 minutes (range 0 to 2.5 minutes) below the low $TcpO_2$ level for normoxia. On the other hand, during the Boyd percussions, this time was reduced by 75% to a mean of 0.16 minutes (range 0 to 1.00 minutes). When these means were compared, a significant difference was detected ($p < 0.01$). During the Bennett percussions, the neonates were hyperoxic a mean time of 0.21 minutes (range 0 to 1.50 minutes). During the Boyd percussions, a mean time of 0.05 minutes was spent in hyperoxia (range 0 to 1.50 minutes) by the neonates. A significant difference was evident ($p < 0.05$).

The $TcpCO_2$ data were noted to be similar for both methods of percussions. During the Bennett percussions, the $TcpCO_2$ decreased a mean of 1.90 torr (range 0 - 1.70 torr) below the mean pre-CPT level. During the Boyd percussions, the $TcpCO_2$ fell to a mean of 1.50 torr (range 0 - 8.50 torr) below the mean pre-CPT level. These mean decreases were not found to be significantly different.

Again, there were wide ranges in the levels of the five physiological parameters (H/R, MAP, ICP $TcpO_2$, $TcpCO_2$) during the percussions phase. These ranges are illustrated graphically to demonstrate the differences in individual neonatal responses to the two methods of percussions (see Appendices 10 to 14).

Individual pre-CPT and post-CPT values of H/R, MAP, ICP, A-a O_2 gradient, and $PaCO_2$ for the Bennett percussions group and the Boyd percussions group are presented in Appendices 8 and 9. With the Bennett percussions group, there was a significant difference between the pre-CPT A-a O_2 gradient and the post-CPT A-a O_2 gradient [t (29) =

-3.653, $p = 0.008$]. A significant difference was also detected between pre-CPT and post-CPT A-a O_2 levels with the Boyd method group [t (29) = 2.707, $p = 0.015$]. The mean difference between the pre-CPT A-a O_2 gradient and the post-CPT A-a O_2 gradient for the Bennett percussions group was 12.90 (range -14.00 to 83.50), reflecting a deterioration in respiratory status. For the Boyd percussions group, the mean difference was -20.37 (range -151.90 to 11.00). A significant difference was evident ($p < 0.001$) between these differences.

Pre-CPT and post-CPT FiO_2's were found to be significantly different with each method of percussions [Bennett percussions: t (29) = -2.74, p= 0.01; Boyd percussions: t (29) = 3.68, p= 0.001]. When compared to the mean pre-CPT FiO_2 level, the mean FiO_2 level increased by 0.02 (range -0.04 to 0.07) following the Bennett percussions and decreased by 0.03 (range -0.10 to 0.01) following the Boyd percussions. This difference was found to be statistically significant ($p < 0.01$).

With the Boyd percussions group, the difference between the pre-CPT and post-CPT $PaCO_2$ levels was found to be significant [t (29) = 2.707, $p = 0.015$]. No significant difference was found between the pre-CPT and post-CPT $PaCO_2$ levels with the Bennett percussions group. Changes in the mean $PaCO_2$ levels between the pre-CPT and post-CPT phases were: Bennett percussions: 0.48 torr (range -2.0 to 9.5 torr) and Boyd percussions: -2.53 torr (range -9.0 to 3.5 torr). This difference was noted to be statistically significant ($p < 0.001$).

The physiological responses of the neonates to the two methods of percussions are summarized in Figure 3 and Tables VIII and IX. Figure 3 illustrates the neonates' mean responses as measured along the five physiological parameters of H/R, MAP, ICP, $TcpO_2$, and $TcpCO_2$. Tables VIII and IX contain the nature (direction of response) and extent of the responses of the neonates to the two methods of percussions.

Reliability of the Transcutaneous Monitoring

Finally, the correlation between the PO_2 levels (determined by transcutaneous monitoring) and the PCO_2 levels obtained from arterial blood samples was determined. The Pearson's r value obtained for the O_2 levels was 0.96 (mean PaO_2 64.79 torr, mean $TcpO_2$ 64.02); and 0.92 (mean $PaCO_2$ 35.22 torr, mean $TcpCO_2$ 35.11 torr) for the CO_2 levels. These results indicate that this particular form of monitoring was reliable in this study.

Summary

The neonates did not respond to postural drainage in a significantly negative manner. However, with instillation and suctioning of the ETT, the neonates' condition deteriorated. The two methods of percussions evoked significantly different responses from the neonates. Changes in the levels of the physiological parameters of the Boyd percussions group as compared to those of the Bennett percussions group

FIGURE 3

Mean Physiological Responses of Infants during Each Phase of Chest Physiotherapy

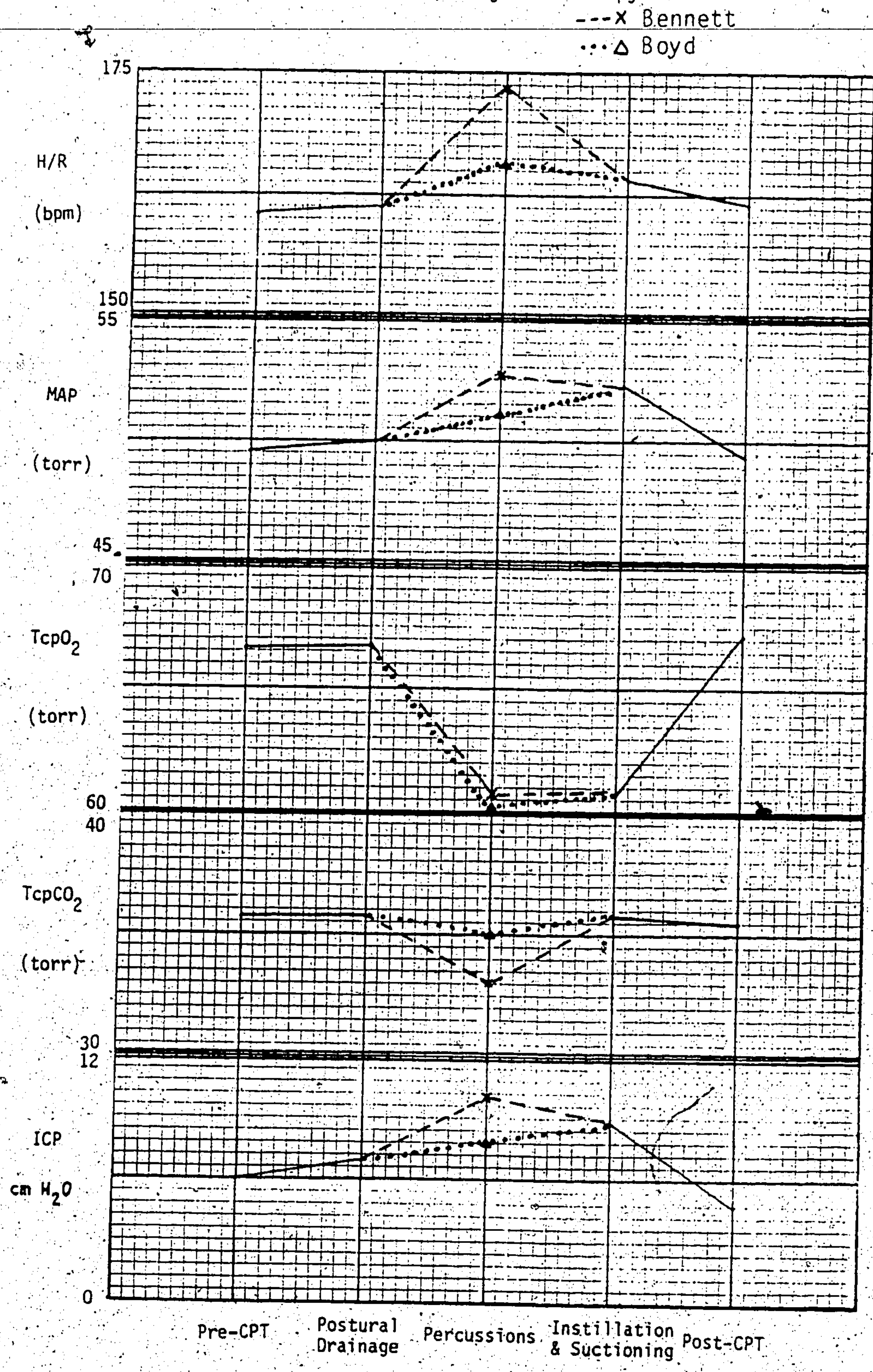


Table VIII Nature and Extent of Change of Mean Responses of Infants to Percussions

Physiological Parameter	Bennett: Nature of Change	Bennett: Extent of Change from Pre-CPT Level	Boyd: Nature of Change	Boyd: Extent of Change from Pre-CPT Level
H/R (bpm)*	Increase	16.37	Increase	6.50
MAP (torr)*	Increase	4.80	Increase	1.90
ICP (cm H_2O)*	Increase	3.80	Increase	1.60
$TcpO_2$ (torr)	Decrease	5.80	Decrease	6.20
$TcpCO_2$ (torr)	Decrease	1.90	Decrease	1.50

Method of Percussion: Bennett, Boyd

* Significant at $p < .05$

Table IX Nature and Extent of Change of Mean Responses of Infants following Percussions

	Method of Percussion			
	Bennett		Boyd	
Physiological Parameter	Nature of Change	Extent of Change from Pre-CPT Level	Nature of Change	Extent of Change from Pre-CPT Level
H/R (bpm)	Increase	0.37	Increase	1.27
MAP (torr)	Decrease	0.33	Decrease	1.00
ICP (cm H_2O)	Decrease	0.22	Decrease	0.60
A-a O_2 gradient*	Increase	12.90	Decrease	20.46
$PaCO_2$ (torr)*	Increase	0.47	Decrease	2.53

* Significant at $p < .05$

were found not to be of the same magnitude nor detrimental to the infants' condition.

Analysis of the data indicated that the observed differences in the direction of neonatal responses were not attributable to the gestational age, condition, or diagnosis of the neonate, or to the location of the percussions (upper vs. lower lobes).

CHAPTER V

DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

In this chapter, the results of the study are discussed and conclusions drawn. Limitations of the study are presented. Finally, implications for nursing care and further nursing research are considered.

Discussion of the Results

The results of the study suggest that tracheal instillation and suctioning and percussions played major roles with regard to the observed neonatal responses to CPT. The postural drainage portion of the CPT did not appear to produce any untoward effects in the neonates in either the head up or head down position. Since the increase in ICP during the lower lobe drainage position was not accompanied by any significant changes in the levels of the other parameters, an overall systemic compensation likely occurred. The amount of time (34.8 seconds) required by the infants to return to prepositioning levels was much less than that (292.0 seconds) reported by Norris, et al (1982).

Tracheal instillation and suctioning produced major changes in the levels of the physiological parameters. While the mean H/R during these procedures increased by only three to four bpm above the pre-CPT level, ($F = 0.9$, $p = N/S$), the wide ranges of H/R which were observed were indicative of the fact that the procedure was not well tolerated by the neonates. Bradycardia occurred at least once during 15% of the procedures. In all cases, the bradycardia was accompanied by a drop in the $TcpO_2$ level. In addition, at least one episode of tachycardia was noted in 8% of the instillation and suctioning episodes. These changes in H/R to beyond normal physiological bounds occurred despite attempts to avoid such responses by permitting recovery periods between each pass of the suction cathether and changing the FiO_2 level in response to the neonates' requirements. These results are worrisome considering that: a change in neonatal H/R directly affects cardiac output due to the neonate's inability to adjust cardiac stroke volume and this effect takes place over a very short period of time.

It is difficult to compare the above mentioned results with those of earlier studies because of the differences in methodology utilized. In all earlier studies, the FiO_2 was not adjusted in response to the infant's condition. However, it is interesting to note that Cabal, et al (1979) found a significant decrease in H/R and O_2 saturation during suctioning, despite pre-oxygenation, as well as a long recovery time following suctioning.

The mean increase in MAP of 4 torr which resulted during instillation and suctioning is very similar to that of 5 torr reported by Simbruner, et al (1981). In addition, as with the H/R, the ranges of the MAP which were observed were wide and occurred within a very short period of time and subsequent to changes in the H/R. Because the actual systolic and diastolic blood pressure waves were not recorded, it is impossible to establish the regulating mechanism for the blood pressure response.

Perlman and Volpe (1982) reported a mean increase in ICP level of 8.0 cm H_2O during suctioning of the ETT of premature infants. It is not stated whether this increase reflected the mean ICP rise during the procedure or the mean peak ICP level observed. In the current study, which included both preterm and full term neonates, the mean ICP level increased 3.50 cm H_2O above the pre-CPT ICP level during instillation and suctioning. The highest mean increase above the pre-CPT ICP level observed was 13.24 cm H_2O.

A decrease in the $TcpO_2$ level was noted in all neonates in response to passage of the suction catheter. In neonates whose FiO_2 requirements were high ($FiO_2 \geq 0.5$), the decrease occurred when they were removed from the ventilator and, hence, their O_2 source. This finding concurs with those reported in earlier studies. Once again, it must be noted that the mean $TcpO_2$ value of this study was influenced by the fact that all neonates were permitted to recover to normal limits between each pass of the suction catheter. There was little difference between the mean instillation and suctioning phase $TcpO_2$ level and the pre-CPT phase level.

With the exception of one case, the act of suctioning produced an initial increase in $TcpCO_2$. Some of these increases were very slight. These increases were mediated by replacing the infant on the respirator. The struggling and crying of the neonates during this procedure produced a decrease in the $TcpCO_2$ as CO_2 was blown off due to hyperventilation and increased respiratory rate. The wide ranges of $TcpCO_2$ recorded during this procedure seemed to be indicative of the noxious effect of the procedure on the neonates. The mean values fail to reflect accurately the wide changes in $TcpCO_2$ which the neonates experienced. Once again, the ranges more accurately reflect the actual threat of instillation and suctioning to neonatal homeostasis.

The struggling and crying of the neonates tended to exacerbate the levels of all the physiological parameters, with the exception of the $TcpCO_2$ level. All episodes of tachycardia were observed while the neonates were struggling and crying. It was only when the neonates were placed back on the ventilator and soothed (usually by placing a hand over the neonates' chest) that they began to settle. With the exception of one neonate, when the infants' initial FiO_2 requirements were low (FiO_2 <0.3), no increase in FiO_2 was required following these manouvers.

The study findings indicate that an abrupt increase in CBF, presumably a direct effect of the increase in MAP (perhaps because of impaired autoregulation) and reflected in an increase in ICP, may occur in an infant during instillation and suctioning of his/her ETT. In the preterm infant, especially, these repeated sudden increases in CBF may play an important role in the pathogenesis of intraventricular haemorrhage. Hambleton and Wigglesworth (1976) and Wigglesworth and Pape (1980) have suggested that, in addition to an increase in CBF, a prolonged lowering of PaO_2 may lead to focal intracranial haemorrhages. Although it is not known exactly how low the PaO_2 must be or for what period of time it must be low to lead to this damage, it seems safe to conclude that repeated episodes of hypoxia, whether for 0.5 minutes or for 5 minutes, are not safe for the neonate.

In summary, the responses of the neonates to instillation and suctioning of the ETT were as postulated in the conceptual framework of the study. Because of the threat to infant homeostasis inherent in the procedure of instillation and suctioning of the ETT, measures must be taken to ensure that the infant does not deteriorate physiologically to the end-point outlined in the model, that is, death through anoxia and intracerebral haemorrhage. The point at which the infant is nonrecoverable, however, is impossible to establish from the study.

The effects of hyperoxia have yet to be investigated by researchers. Aggressive treatment of smaller and smaller neonates has led to increased survival rates among neonates weighing less than 750 grams at birth. These tiny infants, however, are still in the early developmental stage. In many cases, our support measures prove to be toxic and/or detrimental to the neonates' fragile developing systems. Such is the case with oxygen. Hyperoxia has been implicated as a causative agent in retrolental fibroplasia (RLF) and BPD (Kretzner, Hittner, Hunter, et al, 1983; Tomney, 1980). It appears that the younger the neonate, the greater the risk for damage resulting from hyperoxia. Once again, the amount and duration of hyperoxia required for pathology to occur is not known. Tomney (1980) reported that the control infants in her study spent a mean time of 92.5 minutes over a 12 hour period of time in a state of hyperoxia. The use of pancuronium reduced this time to 13 minutes over a 12 hour period of time. In the present study, hyperoxia was observed for a mean time of 0.33 minutes over a 3.9 minute period of time during the instillation and suctioning procedure. Tomney (1980) also found that nurses spent a mean time of 30 minutes over a 12 hour period of time performing this procedure. If one extrapolates from the findings of the current study, it seems that approximately 2.3 minutes of hyperoxia may occur every 12 hours due to this one procedure.

With the exception of the mean ICP, the means of the percussion phase were not statistically significant when compared to the means of all other phases of the study. However, the two methods of percussions had a different effect on the neonates. In general, the neonates responded to the Bennett method of percussions in a negative manner. While the changes in the mean H/R, MAP, mean $TcpO_2$ level, and mean ICP of the Boyd percussions group were in the same direction as those of the Bennett percussions group, they were not of the same magnitude nor considered to be detrimental to the infants' condition.

The neonates' condition was much more stable during the Boyd percussions than during the Bennett percussions. During the Boyd percussions, the fluctuations in H/R, MAP, ICP, $TcpO_2$ and $TcpCO_2$ were much less than those recorded during the Bennett percussions. Thus the neonates had fewer requirements for additional supportive measures in the way of FiO_2, bagging, and soothing. In addition, it was easier to restore their physiological state to within normal limits.

When the neonates' responses to the two percussions methods were compared statistically, significant differences were detected in all variables recorded, with the exception of oesophagoeal pressure. As mentioned earlier, because the changes in oesophageal pressure were not significantly different during both CPT sessions for each infant, it was assumed that differences in variables detected between the two methods was not due to the amount of chest compression delivered to the infant but to another or other factors.

When the mean responses of the neonates were viewed in light of the conceptual framework presented in Chapter II, it appeared that the noxious stimulation of constant application and removal of the altered Bennett mask to and from the external chest wall played a major role. During the Bennett percussions, the neonates responded with significant increases in the mean H/R, MAP, and mean ICP, and a significant decrease in the $TcpO_2$ level. A decrease in the $TcpCO_2$ level was also detected. All of these responses were greatly diminished during the Boyd percussions which involve less handling of the neonate. It is possible that the consistent placement of the hand over the neonate's chest in the Boyd method may have acted as a calming influence, a conclusion suggested by the writings of Brazelton (1973) and Reeder, et al (1977). When the infant was calmer, it seemed that he/she was more able to cope with the effects of the chest wall compressions. In addition, the calm infant seemed to benefit, to a greater extent, from the CPT in terms of movement of pulmonary secretions to the mainstem bronchi for removal by suctioning.

When pre-CPT and post-CPT levels were compared, there were no significant differences detected in mean H/R, MAP, and mean ICP. Thus, it seems that the percussions, regardless of method, had no prolonged effect on the cardiovascular system of the respiratory distressed neonate. The pre-CPT and post-CPT mean A-a O_2 gradient and mean $PaCO_2$ level were, however, significantly different. Following the Bennett percussions, increases in the mean A-a O_2 gradient and mean $PaCO_2$ level were noted, indicating a deterioration in the respiratory status of the neonates. In contrast, the decreases in the mean A-a O_2 gradient and mean $PaCO_2$ level observed following the Boyd percussions indicate that the neonates' respiratory status improved with this method. This improvement in oxygenation and CO_2 exchange seems to indicate that the Boyd percussions might have been more efficacious in moving pulmonary secretions from the smaller bronchioles to the larger ones and facilitating their removal. Such an improvement in oxygenation is in line with that reported by Finer, et al (1978) and Tudehope and Bagley

(1981). However, the significant differences in $PaCO_2$ level noted in the present study have not been reported in earlier studies.

Conclusions

This study provided answers to the three research questions posed at the outset. While no significant differences were detected along the five physiological parameters during postural drainage, a wide range of responses among the neonates was observed during instillation and suctioning of the ETT. During instillation and suctioning of the ETT, the mean H/R, MAP, and mean ICP levels were significantly higher than the pre-CPT means, while the mean $TcpO_2$ level was significantly lower than the pre-CPT mean. Despite measures taken to ensure that the physiological levels remained within the limits accepted to be safe, periods of fluctuation beyond physiological bounds did occur in the way of tachycardia, high ICP levels, hypoxia, and hyperoxia. On the basis of these findings, one can conclude that the neonate tolerates instillation and suctioning poorly and that this procedure needs to be performed in a manner which will enable the neonate to tolerate it without harm.

The study results indicate that the respiratory distressed neonates responded very differently to the Bennett and Boyd method of CPT. As the two methods do not differ in the amount of chest compression delivered, the differences in the responses observed appear to be related to the type of percussions involved in each method. The constant application of blows to the external chest wall results in an increased amount of handling of the infant during the Bennett percussions. Once the hand is applied to the external chest wall for delivery of the Boyd percussions, however, it is not removed until the treatment is finished. While the initial contact may produce a negative response, the infant usually settles quickly. The infants' responses to the two types of handling during the percussions were different. Thus, the differences detected in responses to the two methods of percussions appear to be caused, in part, by the neonates' response to handling.

The Boyd percussions were more efficacious in facilitating the removal of secretions from the lungs and hence improving the ventilatory status of the neonate than the Bennett percussions. If anything, the latter only served to initiate a deterioration in the neonates' status.

Limitations of the Study

One of the major problems of the study was that the study sample was small and chosen on a convenience basis. As a result, the findings of the study cannot be generalized beyond the subjects in the sample.

It was virtually impossible to control for all historical events (eg. method of percussions) that had occurred prior to the neonate's entry into the study. In addition, the possibility of carryover effects from one method of percussions to the other method existed throughout the study. However, the cross-over design and random assignment to treatment order might have minimized the influence of historical events.

In addition, the findings are generated from the responses of the neonates to CPT performed by only one person, the researcher. Had other people been involved, the results may not have been similar to those described due to variation in technique, philosophy of the nurse towards neonatal responses, and observational skills.

Implications of the Study for Nursing Care

The results of the study support the assumption stated earlier that the closer the neonate is to homeostasis, the better equipped he/she is to withstand changes in the environment. Instillation and suctioning of the ETT produced large fluctuations in the levels of the physiological parameters of the neonates. Thus, it is imperative that this procedure be performed as quickly and efficiently as possible. Organization of required equipment prior to commencement of the procedure will decrease the time required to respond to the needs of the infant during the procedure. The use of two people, one to instill and suction the ETT while preserving the sterility of the catheter, and the other to remove the infant from and replace the infant on the ventilator will greatly reduce the amount of time the neonate must function without an enriched oxygen source. The infant's condition should be as stable as possible prior to commencement of the procedure. The mean maximum decrease in $TcpO_2$ during instillation and suctioning in the study was 16.79 torr.

Thus, it seems that the nurse should ensure that the neonate's $TcpO_2$ level is at least 17 torr above the hypoxic level dictated for him/her in order to help him/her cope with the procedure. In addition, the neonate must be permitted to return to as stable a condition as possible between each passage of the suction catheter. It is desirable to keep the neonate as calm as possible during this procedure and to anticipate his/her needs. Prior knowledge of the neonate's responses to handling and constant observation of physiological levels is also imperative.

With regard to the specific question of the efficacy of one method of CPT over the other, other aspects regarding CPT related to this question must be considered. It appears that the Boyd method of percussions is more beneficial for the critically ill neonate than the Bennett method. However, the Boyd percussions are more exacting to perform and require the concentration and observational skills of the nurse. Because of the high compliance of the neonatal chest wall, overzealous use of the Boyd percussions could result in discomfort or even harm. Care must be taken to ensure that the compressions are as even as possible throughout the procedure. For any nurse who does not wish to invest the time to provide the required care and concentration, the Boyd method may not be advisable. If a decision were made to replace the Bennett method entirely with the Boyd method, diligent teaching of the Boyd method must be carried out by those who are well versed in the correct use of the method.

Implications of the Study for Future Nursing Research

It would be helpful if this study were replicated with a number of variations: a greater number of subjects and stricter criteria with regard to birthweight and gestational age, type of pulmonary pathology, and particular lobe percussed. The mean age of the study subjects was three days. Thus, no infant with BPD was included in the sample. These type of infants are usually older, have less compliant chest walls, and tend to become agitated and upset more quickly than other neonates (Oehler, 1981). It would be valuable to describe and evaluate responses of infants with BPD to CPT.

In order to determine the long-term effects of each method of CPT, studies must be done in which only one type of CPT is performed on the neonate throughout his/her stay. The best length of time for and timing of percussions have yet to be established. Early work by Duare, et al (1983) suggests that at least 2.5 minutes of percussions are required to obtain maximally beneficial results. No work has been done and needs to be done to ascertain if CPT will decrease the severity of HMD if it is initiated at birth. Individual differences in CPT technique utilized by nurses must also be addressed in the future as well as efficacy of teaching methods.

Cabal, et al (1979) and Tudehope and Bagley (1980) detected differences in $TcpO_2$ during suctioning with and without ETT adapters. The use of ETT adapters is an area requiring further investigation.

Other nursing procedures, in addition to CPT, such as the starting of IV's, the performing of venipunctures, and the feeding of neonates would benefit from analysis through research. Until nurses become aware of how neonates respond to their care they will be unable to improve the quality of that care and the quality of the neonate's life.

Summary

Instillation and suctioning of the ETT and percussions appear to be the greatest threats to homeostasis of the respiratory distressed neonate. In order to overcome the deleterious effects of instillation and suctioning on the neonate, instillation and suctioning should be performed as quickly and efficiently as possible by two organized people. If the neonate's $TcpO_2$ is within 17 torr of his/her hypoxia level, an increased FiO_2 should be used.

The Boyd method of percussions can overcome most of the neonate's negative responses to percussions. Great care and constant observation of the infant are essential, if the percussions are to be performed properly. While the results of the study were highly significant for the study population, they cannot be generalized beyond the sample due to the selection method and use of a small sample size.

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APPENDIX 1

Glossary of Terms

A-a O_2 gradient	alveolar-arterial oxygen gradient
ABG	arterial blood gases
ANOVA	analysis of variance
BP	blood pressure
BPD	bronchopulmonary dysplasia
bpm	beats per minute
CBF	cerebral blood flow
CBFV	cerebral blood flow velocity
C_L	lung compliance
cm H_2O	centimeters of water
CO_2	carbon dioxide
CPAP	continuous positive airway pressure
CPT	chest physiotherapy
DIC	disseminating intravascular coagulopathy
EKG	electrocardiograph
ES	endotracheal suctioning
ETT	endotracheal tube
FiO_2	fraction of inspired oxygen
FRC	functional residual capacity
HMD	hyaline membrane disease
H/R	heart rate

ICP	intracranial pressure
IMV	intermittent mandatory ventilation (also referred to as ventilator respiratory rate)
IT	inspiratory time
IUGR	intrauterine growth retardation
IV	intravenous
LMSB	left mainstem bronchus
MAP	mean arterial pressure
mmHg	milimeters of mercury
NICU	neonatal intensive care unit
O_2	oxygen
OS	oral suctioning
$PaCO_2$	arterial carbon dioxide tension
PaO_2	arterial oxygen tension
PDA	patent ductus arteriosus
PEEP	positive end-expiratory pressure
PIP	peak inspiratory pressure
R_E	expiratory resistance
R_I	inspiratory resistance
RLF	retrolental fibroplasia
RLL	right lower lobe
RML	right medial lobe
RMSB	right mainstem bronchus

R.T.	respiratory technologist
RUL	right upper lobe
$TcpCO_2$	transcutaneous carbon dioxide tension
$TcpO_2$	transcutaneous oxygen tension
TTNB	transient tachypnoea of the newborn
V_E	minute ventilation
V_T	tidal volume

APPENDIX 2

Demographic Characteristics of Infants

Infant #	Gender	Birthweight (grams)	Study Weight (grams)	Gestational Age (weeks)	Study Age (days)	Clinical Diagnosis(es)
1	F	1070	1250	30	4	Premature, HMD[a]
2	M	2120	2400	36	2	Premature, Pneumonia
3	F	2430	2110	35	3	Premature, HMD
4	M	4030	3910	42	1	Post Mature, Meconium Aspiration
5	M	2580	2780	36	3	HMD, Premature
6	F	1740	1710	34	3	HMD, Premature
7	M	2430	2500	36	1	TTNB[b], Premature
8	F	2975	2920	35	3	Premature, Severe HMD
9	M	3180	3720	35	6	Persistent Foetal Circulation, Premature; HMD
10	F	3380	3580	40	1	Omphalocoele
11	M	1690	1740	32	3	Premature, Twin, HMD, Maternal Talwin Addict
12	M	1560	1580	32	3	Premature, Twin, HMD, Maternal Talwin Addict

Demographic Characteristics of Infants

Infant #	Gender	Birthweight (grams)	Study Weight (grams)	Gestational Age (weeks)	Study Age (days)	Clinical Diagnosis(es)
13	F	0920	0950	31	6	Premature, IUGR[c], Pneumonia, DIC[d]
14	F	2310	2340	36	5	Premature, HMD, Sepsis
15	F	2000	2260	36	5	Premature, Twin, Severe Asphyxia
16	M	1560	1670	30	3	Premature, HMD
17	M	3720	3820	40	10	Persistent Foetal Circulation
18	F	0950	1100	26	3	Extreme Premature, Pneumonia, HMD
19	M	2950	2900	37	2	Omphalocoele
20	F	0760	0760	25	1	Extreme Premature, Pneumonia
21	F	1190	1380	28	3	Premature, Hydrops Foetalis, HMD
22	M	1980	1960	34	3	Premature, HMD

Demographic Characteristics of Infants

Infant #	Gender	Birthweight (grams)	Study Weight (grams)	Gestational Age (weeks)	Study Age (days)	Clinical Diagnosis(es)
23	F	1530	1560	30	1	Premature, TTNB
24	F	2120	1980	33	4	Premature, HMD
25	M	2840	2940	39	1	TTNB
26	M	2280	2370	34	1	Premature, Pneumonia, HMD
27	M	3150	3220	34	1	Premature, TTNB
28	M	1660	1700	33	1	Premature, TTNB, Right Renal Soft Tissue Mass
29	M	0750	0760	27	4	Extreme Premature, TTNB
30	M	1700	1680	33	1	Premature, HMD

a Hyaline Membrane Disease
b Transient Tachypnoea of the Newborn
c Intrauterine Growth Retardation
d Disseminating Intravascular Coagulopathy

APPENDIX 3

Respiratory States of Infants

Infant #	Cause of Respiratory Distress	Most Recent Chest X-ray Result	FiO_2	PIP (cm H_2O)	PEEP or CPAP (cm H_2O)	IMV (breaths/min)	Duration between CPT Sessions (hours)
1	Severe HMD	Bilateral chest tubes Extensive and more severe changes of HMD Extensive bilateral consolidation	0.26	18	4	10	3
2	Pneumonia	Overall consolidation more evident in lower lobes	0.44	32	4	30	3
3	HMD	Changes consistent with mild HMD	0.35	18	2	0	3
4	Meconium aspiration, Right pneumothorax	Pneumothorax improved Diffuse fluffy infiltrates throughout lung fields	0.45	30	4	24	2

Respiratory States of Infants

Infant #	Cause of Respiratory Distress	Most Recent Chest X-ray Result	FiO_2	PIP (cm H_2O)	PEEP or CPAP (cm H_2O)	IMV (breaths/ min)	Duration between CPT Sessions (hours)
5	HMD	Moderately severe HMD Diffuse increased density bilaterally	0.49	26	5	36	2
6	HMD	Extensive ground glass in keeping with moderately severe HMD	0.58	20	4	13	2
7	TTNB[a]	Infiltrates noted in RUL, RML,[b] RLL[c]	0.45	20	2	4	2
8	HMD	Bilateral chest tubes in place Extensive changes of moderately severe HMD	0.39	25	4	30	2

Respiratory States of Infants

Infant #	Cause of Respiratory Distress	Most Recent Chest X-ray Result	FiO_2	PIP (cm H_2O)	PEEP or CPAP (cm H_2O)	IMV (breaths/ min)	Duration between CPT Sessions (hours)
9	HMD	Bilateral pneumothoraces Marked hyper-inflation of lungs Consolidation and interstitial emphysema throughout both lungs	0.60	38	0	20	2
10	Post-operative consolidation	Consolidation of left lung, especially lower lobes associated with patchy consolidation within RUL	0.39	24	6	20	1
11	Severe HMD	Bilateral pneumothoraces drained by chest tubes Severe HMD	0.24	22	4	22	2

Respiratory States of Infants

Infant #	Cause of Respiratory Distress	Most Recent Chest X-ray Result	FiO_2	PIP (cm H_2O)	PEEP or CPAP (cm H_2O)	IMV (breaths/min)	Duration between CPT Sessions (hours)
12	Mild HMD	Bilateral pneumothoraces drained by chest tubes Changes of mild HMD throughout	0.44	26	6	12	2
13	Pneumonia, Pulmonary oedema	Bilateral pulmonary consolidation clearing	0.21	22	4	16	2
14	HMD	Mild to moderate HMD	0.21	0	2	0	1
15	Apnea due to asphyxia	Lung fields well expanded Few areas of increased density in RUL	0.21	16	2	4	3
16	HMD	Changes of HMD Right pneumothorax drained by chest tube Left chest tube in situ	0.49	26	4	20	2

Respiratory States of Infants

Infant #	Cause of Respiratory Distress	Most Recent Chest X-ray Result	FiO_2	PIP (cm H_2O)	PEEP or CPAP (cm H_2O)	IMV (breaths/ min)	Duration between CPT Sessions (hours)
17	HMD	Changes of moderate HMD	0.36	22	4	8	2
18	Pneumonia, HMD	Changes of HMD Bilateral chest tubes	0.21	18	3	16	2
19	Post-operative consolid-ation	Lungs well expanded Small consolid-ation in lower lobes	0.24	22	4	8	2
20	Pneumonia	Bilateral diffuse infiltrates	0.23	15	2	13	2
21	HMD	Bilateral chest tubes draining Right pneumothorax Changes of severe HMD	0.37	24	4	22	2

Respiratory States of Infants

Infant #	Cause of Respiratory Distress	Most Recent Chest X-ray Result	FiO_2	PIP ($cm\ H_2O$)	PEEP or CPAP ($cm\ H_2O$)	IMV (breaths/min)	Duration between CPT Sessions (hours)
22	HMD	Left lung re-expanded Fine granular densities throughout Moderate HMD	0.41	20	2	8	2
23	TTNB	TTNB	0.21	0	2	0	1
24	HMD	Bilateral chest tubes Resolving left pneumothorax Fine granular pattern bilaterally consistent with severe HMD	0.21	24	4	7	2
25	TTNB	TTNB	0.21	20	2	9	1
26	Pneumonia HMD	Early HMD Congenital pneumonia in both lower lobes	0.54	24	4	6	2

Respiratory States of Infants

Infant #	Cause of Respiratory Distress	Most Recent Chest X-ray Result	FiO_2	PIP ($cm\ H_2O$)	PEEP or CPAP ($cm\ H_2O$)	IMV (breaths/ min)	Duration between CPT Sessions (hours)
27	TTNB	TTNB	0.28	0	2	0	1
28	TTNB	TTNB	0.21	16	2	10	1
29	TTNB	Partial clearing Residual consolidation especially on right side	0.23	20	2	14	2
30	HMD	Moderate - severe diffuse granular densities throughout	0.53	20	2	15	1

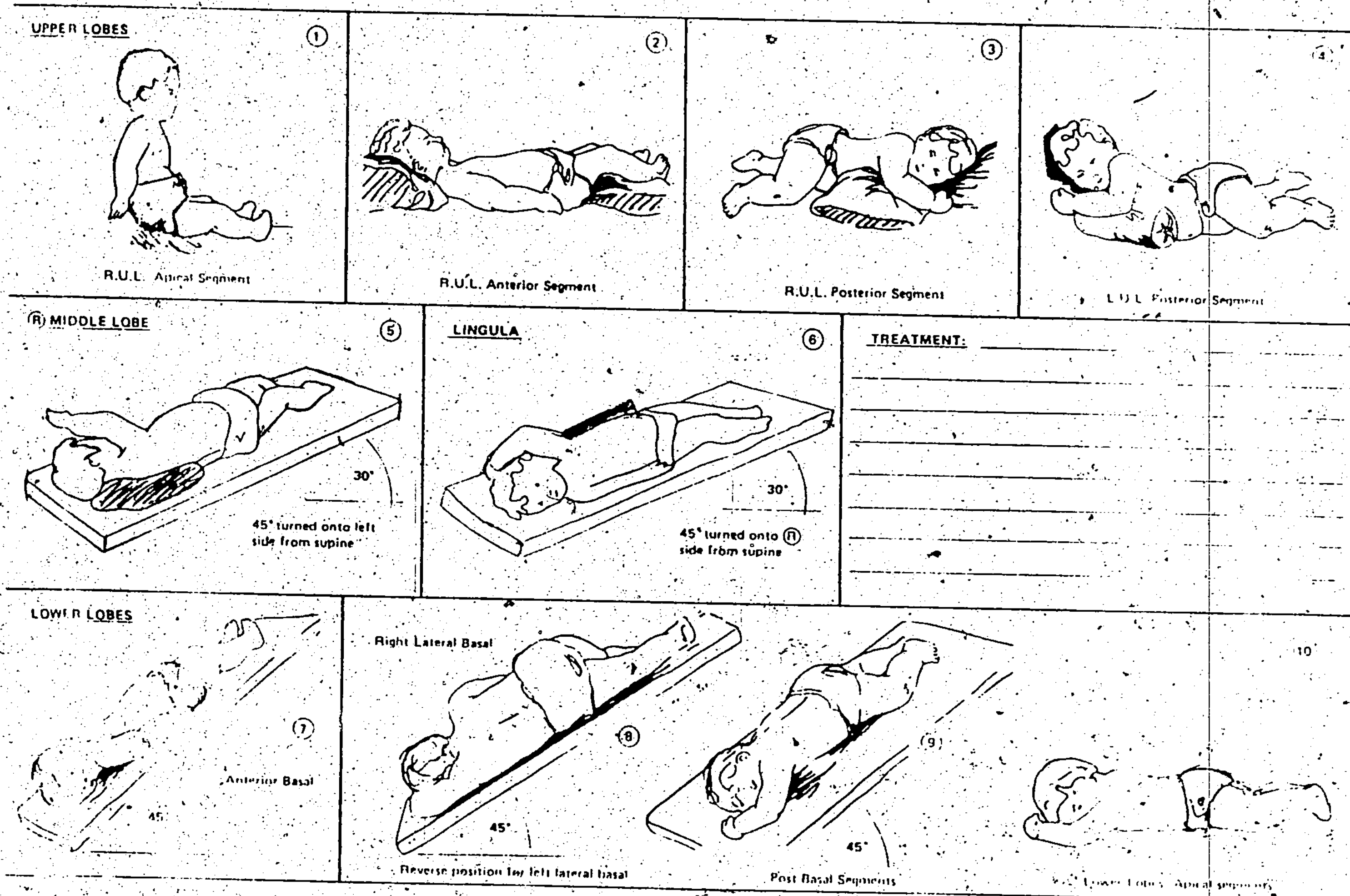
a Transient Tachypnea of the Newborn
b Right Middle Lobe
c Right Lower Lobe

APPENDIX 4

CHEST PHYSIOTHERAPY: POSTURAL DRAINAGE POSITIONS

P.T. EX. #46

ROYAL ALEXANDRA HOSPITAL – PHYSIOTHERAPY DEPT



APPENDIX 5

Study Data Sheet

Infant # ____________________ Method ____________________

Date of Birth ____________________ Time ____________________

Date of Study ____________________ Study Age ____________________

Birth Weight ____________ Mode of Delivery ____________________

Study Weight ____________

Gestational Age ____________ Dubowitz ____________________

Clinical Diagnosis ____

____

Chest x-ray:

Initial ____

Closest to Study ____

Type of Respiratory Distress ____

____

Study FiO_2 ____________

Respiratory or CPAP Setting ____

PDA ____________________ Vitamin E ____________________

Reason for ETT ____

Length of Intubation ____

Total O_2 Exposure .21 - .30 ____________

.31 - .60 ____________

.61 - .90 ____________

MEDICATIONS

TYPE	DOSAGE	TIME GIVEN	REASON	LEVEL (if approp)

NUTRITION

IV

TYPE	SCALP	ARTERIAL CATHETER INFUSION	OTHER

FEEDING

Continuous oro-gastric or naso-gastric tube ______________

Bolus oro-gastric or naso-gastric ______________

None ______________

TEMPERATURE

PRE-CPT ________ DURING CPT ________ POST-CPT ________

PRE-CPT ________ DURING CPT ________ POST-CPT ________

APPENDIX 6

Treatment Order Groups

GROUP 1

Pre-ABG → Post ABG

5 minutes Baseline	5 minutes Postural Drainage	5 minutes Percussions Bennett	Instillation & Suctioning	20 minutes Post-Suctioning

Time Interval at Least 1 Hour

Pre-ABG → Post ABG

5 minutes Baseline	5 minutes Postural Drainage	5 minutes Percussions Boyd	Instillation & Suctioning	20 minutes Post-Suctioning

GROUP 2

Pre-ABG → Post ABG

5 minutes Baseline	5 minutes Postural Drainage	5 minutes Percussions Boyd	Instillation & Suctioning	20 minutes Post-Suctioning

Time Interval at Least 1 Hour

Pre-ABG → Post ABG

5 minutes Baseline	5 minutes Postural Drainage	5 minutes Percussions Bennett	Instillation & Suctioning	20 minutes Post-Suctioning

APPENDIX 7

Example of Latin Square Format of ANOVA

△ H/R Pre-CPT : Percussions

T_1 - 1st CPT session B_1 - Bennett Percussions

T_2 - 2nd CPT session B_2 - Boyd Percussions

Subj - individual subjects

ANOVA

Variation	d.f.	Sums of Squares	Mean Square	F	Significance
$T_1 - T_2$	1	1.067	1.067	0.021	N/S
Subj.	29	2630.397	90.700	1.755	N/S
$B_1 - B_2$	1	1460.270	1460.270	28.250	<0.001
Residual	28	1447.373	51.690		
Total	59	5539.107			

$^{0.05}F^{1}_{28} = 4.20$ $^{0.01}F^{1}_{28} = 7.64$ $^{0.001}F^{1}_{28} = 9.23$ $^{0.05}F^{29}_{28} = 1.87$

APPENDIX 8

Pre-Chest Physiotherapy and Post-Chest Physiotherapy Values: Bennett Percussions

Infant #	H/R (bpm) PRE	H/R (bpm) POST	MAP (torr) PRE	MAP (torr) POST	A-a O_2 Gradient PRE	A-a O_2 Gradient POST	$PaCO_2$ (torr) PRE	$PaCO_2$ (torr) POST	ICP (cm H_2O) PRE	ICP (cm H_2O) POST
1	146	153	41.0	40	119.8	124.8	34	36	12.0	11.5
2	140	138	40.0	40	251.9	258.9	36	33	10.0	10.0
3	150	155	56.0	57	184.8	192.8	38	42	4.0	5.0
4	120	111	21.0	21	195.0	199.0	28	31	7.5	5.0
5	153	150	45.0	43	255.9	261.0	29	31	6.0	6.0
6	138	135	41.0	41	354.6	374.5	36	33	8.5	7.0
7	138	137	48.5	48	253.1	321.7	30	24	7.5	8.0
8	165	161	53.0	53	175.9	203.8	23	24	7.0	7.0
9	150	153	51.5	55	303.7	313.5	27	28	3.0	0
10	144	144	60.0	60	214.0	258.0	38	35	6.5	5.0
11	170	171	40.0	38	112.7	135.8	43	40	5.0	4.0
12	162	165	43.0	44	238.7	259.2	34	35	6.5	7.5

Pre-Chest Physiotherapy and Post-Chest Physiotherapy Values: Bennett Percussions

Infant #	H/R (bpm) PRE	H/R (bpm) POST	MAP (torr) PRE	MAP (torr) POST	A-a O_2 Gradient PRE	A-a O_2 Gradient POST	$PaCO_2$ (torr) PRE	$PaCO_2$ (torr) POST	ICP (cm H_2O) PRE	ICP (cm H_2O) POST
13	190	195	57.0	62	89.4	89.4	34	40	10.0	9.5
14	145	146	53.0	50	91.9	102.9	47	49	4.5	2.5
15	150	151	43.0	44	66.1	66.1	54	63	2.5	3.0
16	180	180	33.0	33	283.0	293.6	30	32	2.5	2.0
17	160	167	75.0	82	169.9	183.4	45	43	5.0	6.5
18	172	175	48.0	48	132.2	134.2	22	22	1.5	2.0
19	140	146	62.0	62	110.5	112.9	35	35	5.0	4.0
20	162	165	29.0	33	102.2	92.3	32	32	3.0	4.0
21	190	190	32.0	35	185.0	208.1	37	37	4.0	4.0
22	159	157	48.0	44	212.8	215.8	41	40	11.0	8.0
23	150	158	43.0	44	77.8	78.9	29	28	2.0	2.0
24	140	145	55.0	47	105.3	150.3	43	40	2.5	3.5

Pre-Chest Physiotherapy and Post-Chest Physiotherapy Values: Bennett Percussions

Infant #	H/R (bpm) PRE	H/R (bpm) POST	MAP (torr) PRE	MAP (torr) POST	A-a O_2 Gradient PRE	A-a O_2 Gradient POST	$PaCO_2$ (torr) PRE	$PaCO_2$ (torr) POST	ICP (cm H_2O) PRE	ICP (cm H_2O) POST
25	145	141	50.0	46	95.1	99.1	35	42	3.0	2.0
26	167	156	44.0	43	321.0	326.5	39	40	5.5	4.0
27	150	142	44.0	43	97.2	149.9	31	30	2.0	2.0
28	137	130	48.0	47	48.9	45.9	26	26	5.5	5.2
29	160	163	44.0	40	109.0	104.0	29	23	2.0	2.0
30	150	154	44.0	43	315.2	305.6	35	36	2.0	1.5

APPENDIX 9

Pre-Chest Physiotherapy and Post-Chest Physiotherapy Values: Boyd Percussions

Infant #	H/R (bpm) PRE	H/R (bpm) POST	MAP (torr) PRE	MAP (torr) POST	A-a O_2 Gradient PRE	A-a O_2 Gradient POST	$PaCO_2$ (torr) PRE	$PaCO_2$ (torr) POST	ICP (cm H_2O) PRE	ICP (cm H_2O) POST
1	147	144	39	36	127.7	99.8	35	34	5.0	[illegible].5
2	148	151	43	43	177.7	166.7	41	38	5.0	5.0
3	151	155	55	57	191.9	202.9	42	40	5.0	4.0
4	148	148	38	38	254.6	244.6	32	32	10.0	8.0
5	152	157	38	38	317.2	304.1	28	27	5.0	4.5
6	135	144	42	47	350.7	330.8	37	34	7.5	5.5
7	132	132	55	53	262.7	266.7	33	30	3.0	3.0
8	162	162	53	51	207.8	180.9	37	35	5.0	5.8
9	142	143	57	65	363.6	211.7	27	27	5.0	5.5
10	150	152	70	63	262.0	260.0	46	45	4.5	4.0
11	170	167	45	43	130.1	113.7	41	39	5.5	6.0
12	165	163	45	47	250.2	241.1	34	33	12.5	14.0

Pre-Chest Physiotherapy and Post-Chest Physiotherapy Values: Boyd Percussions

Infant #	H/R (bpm) PRE	H/R (bpm) POST	MAP (torr) PRE	MAP (torr) POST	A-a O_2 Gradient PRE	A-a O_2 Gradient POST	$PaCO_2$ (torr) PRE	$PaCO_2$ (torr) POST	ICP (cm H_2O) PRE	ICP (cm H_2O) POST
13	180	190	55.0	57	90.4	90.4	41	35	12.5	10.2
14	142	158	50.0	51	102.2	98.9	43	44	5.0	5.0
15	140	146	43.0	39	81.8	61.1	55	46	9.0	7.5
16	172	173	41.0	40	283.1	238.7	28	31	2.0	2.0
17	172	157	80.0	65	141.2	121.9	42	39	3.5	2.5
18	162	165	48.0	52	99.2	98.2	22	21	2.5	2.0
19	120	120	53.0	55	112.5	108.5	39	32	5.0	4.8
20	167	170	31.0	31	75.8	85.3	28	27	4.0	3.0
21	188	190	35.0	35	199.1	196.1	37	39	2.0	2.0
22	155	155	47.5	47	224.8	159.8	37	37	6.0	4.0
23	165	163	42.0	43	83.8	68.8	34	29	5.0	3.5
24	141	146	47.5	48	94.2	94.2	48	40	7.0	6.5

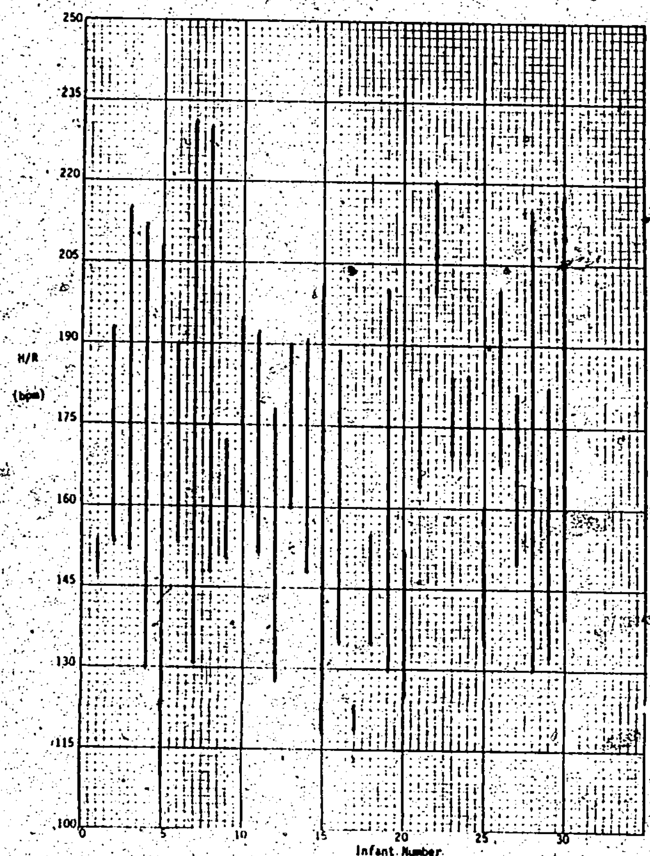
Pre-Chest Physiotherapy and Post-Chest Physiotherapy Values: Boyd Percussions

Infant #	H/R (bpm) PRE	H/R (bpm) POST	MAP (torr) PRE	MAP (torr) POST	A-a O_2 Gradient PRE	A-a O_2 Gradient POST	$PaCO_2$ (torr) PRE	$PaCO_2$ (torr) POST	ICP (cm H_2O) PRE	ICP (cm H_2O) POST
25	161	153	47.0	45	95.1	87.1	42	35	6.0	5.5
26	150	151	46.0	45	308.6	238.3	39	36	3.0	3.0
27	145	141	43.0	43	138.8	103.4	31	30	3.0	3.0
28	125	125	45.0	45	59.9	45.9	25	23	2.5	3.0
29	162	163	47.0	45	101.0	92.0	35	35	6.0	3.5
30	146	152	44.0	43	340.4	303.0	37	31	4.0	4.0

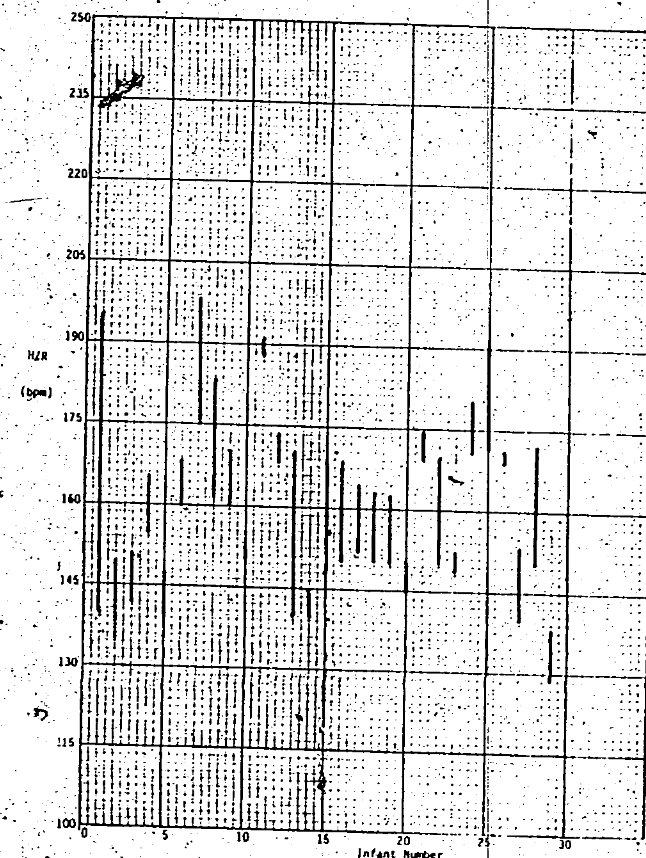
APPENDIX 10

Ranges of Heart Rate during Percussions

Bennett Percussions



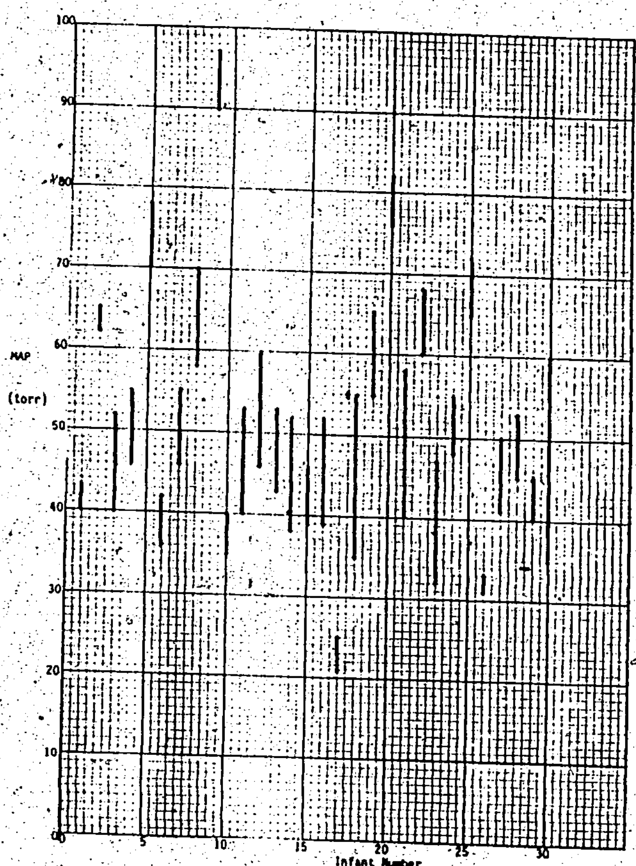
Boyd Percussions



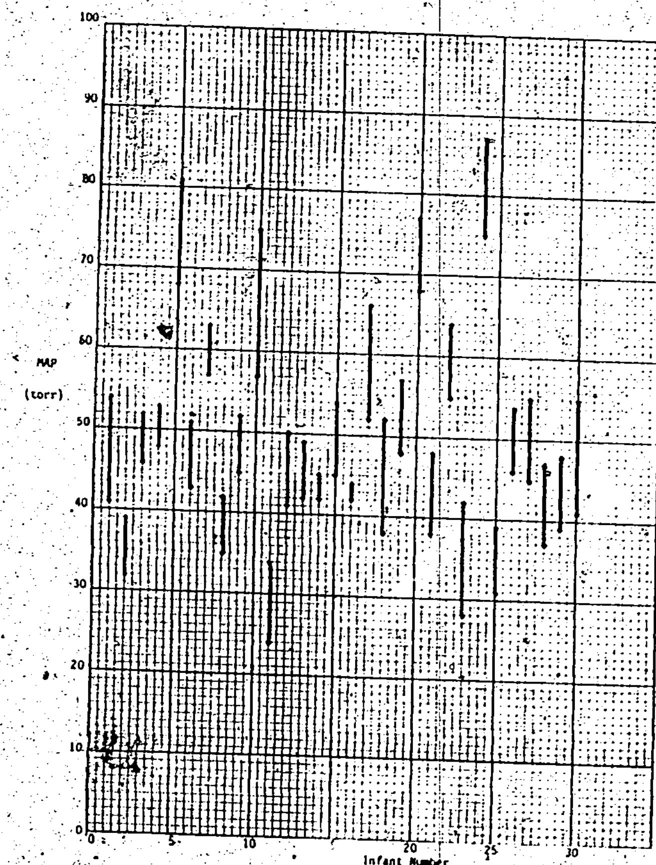
APPENDIX 11

Ranges of Mean Arterial Pressure during Percussions

Bennett Percussions



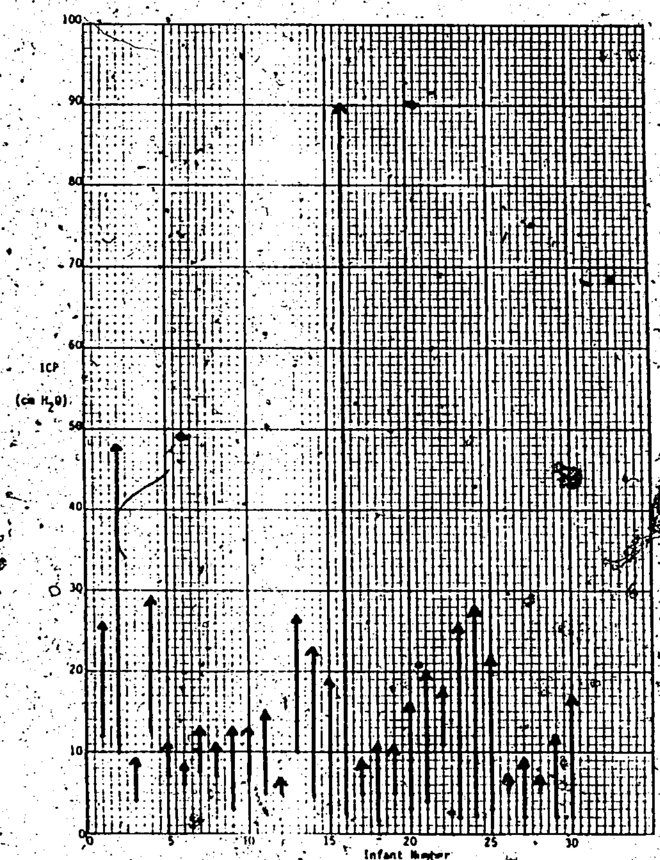
Boyd Percussions



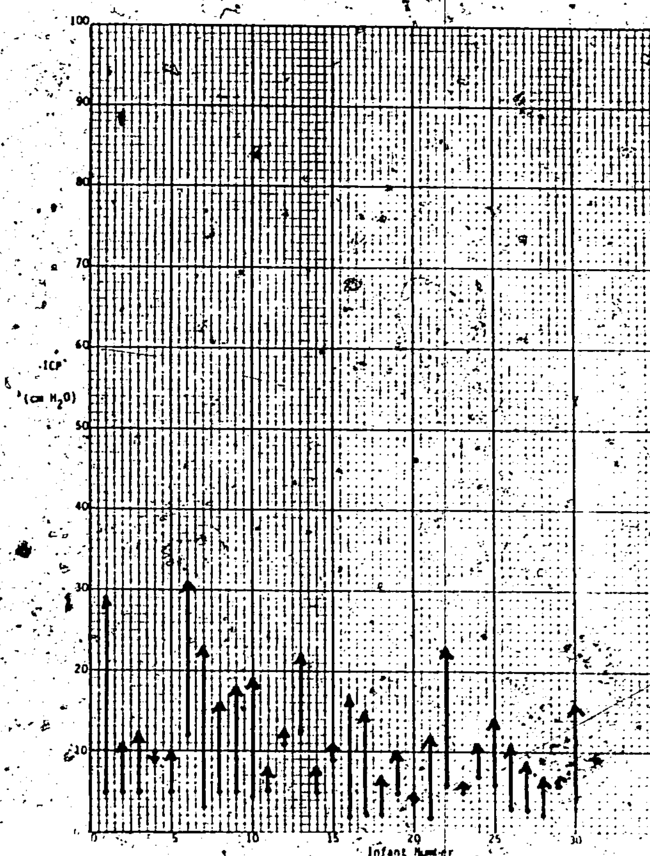
APPENDIX 12

Ranges of Intracranial Pressure during Percussions

Bennett Percussions



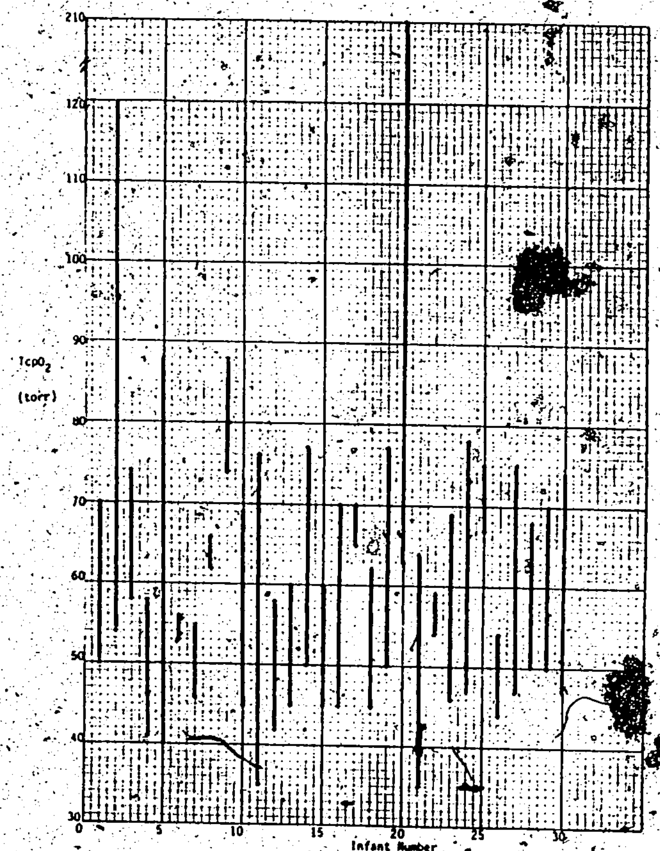
Boyd Percussions



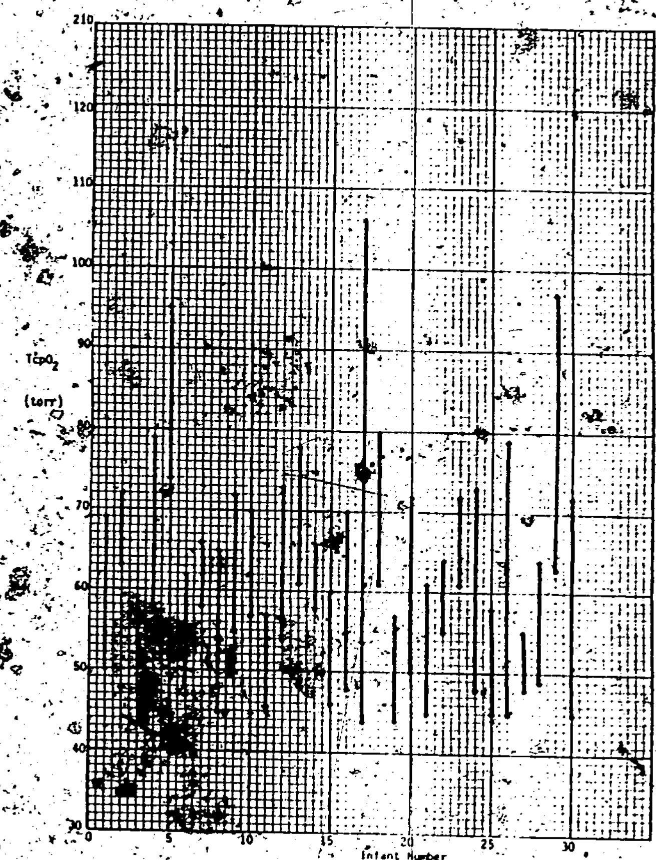
APPENDIX 13

Ranges of Transcutaneous Oxygen Tension during Percussions

Bennett Percussions



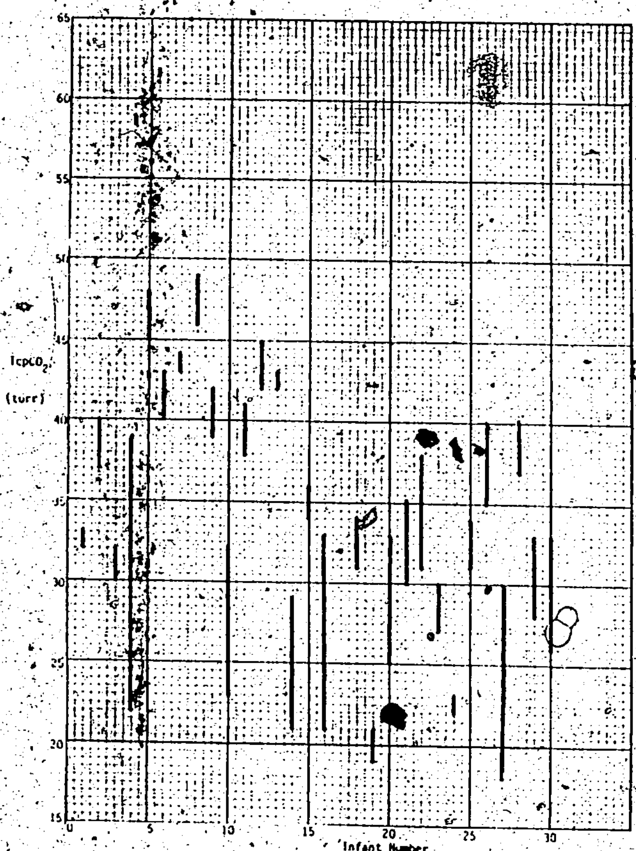
Boyd Percussions



APPENDIX 14

Ranges of Transcutaneous Carbon Dioxide during Percussions

Bennett Percussions



Boyd Percussions