Title
Hyperinflation, hyperventilation and hyperoxygenation prior to tracheal suctioning in children requiring long-term respiratory care

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Publication Date
1984

Peer reviewed|Thesis/dissertation

HYPERINFLATION, HYPERVENTILATION AND HYPEROXYGENATION PRIOR TO TRACHEAL SUCTIONING IN CHILDREN REQUIRING LONG-TERM RESPIRATORY CARE

by

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THESIS

Submitted in partial satisfaction of the requirements for the degree of

MASTER OF SCIENCE

in

Nursing

in the

GRADUATE DIVISION

of the

UNIVERSITY OF CALIFORNIA

San Francisco

[redacted]

Date JUN 17 1984 University Librarian

Degree Conferred: . . . .

ABSTRACT

The purpose of this study was to determine if a specific combination of hyperinflation (HI), hyperventilation (HV) and hyperoxygenation (HO) before and immediately after tracheal suctioning will minimize oxygen desaturation in children requiring chronic respiratory support.

Eleven trials were performed on seven children between the ages of 11 months and two years. All required respiratory support via a tracheostomy tube. All children were receiving chest physiotherapy followed by tracheal suctioning. Suction technique was standardized for all trials. HI, HV and HO in various trial sequences were performed prior to and immediately after tracheal suctioning. Oxygen saturation was recorded from a non-invasive pulse-oximeter before chest physiotherapy, before tracheal suctioning and at 30 seconds, one, five, 10, and 20 minutes after tracheal suctioning.

Means for each trial were calculated along with standard deviations. No significant difference was noted between any of the trials. A statistically significant desaturation occured following chest physiotherapy in some trials ($p \leq 0.05$). It was concluded that no pre-suctioning technique studied was superior to another in preventing arterial desaturation during and after tracheal suctioning.

SUMMARY

The purpose of this study was to determine if there is a combination of hyperinflation, hyperoxygenation and hyperventilation that will minimize oxygen desaturation in children two years of age or less who require chronic respiratory support. According to this study, the effects of tracheal suctioning on this population of children are unpredictable and variable. All trials utilizing pre- and post-suctioning treatments with hyperinflation alone or in some combination with hyperventilation and/or hyperoxygenation prevented significant oxygen desaturation following tracheal suctioning. No technique could be shown to be superior to another, or in fact, could even be repeated with consistent results.

ACKNOWLEDGEMENTS

I would like to thank: (1) my thesis committee, Sandra Ferketech, Claudia West and Kit Newth for their support and guidance; (2) the nurses at Children's Hospital of Philadelphia PICI and PICA for their participation, cooperation, and enthusiasm during this study; (3) David Swedlow, M.D. and Jack Downes, M.D. for their ideas and recommendations during the study; (4) Audrey Clarke for her wonderful graphics; (5) Barb von der Groeben for her support and editorial assistance; and (6) to Nellcor, Inc. for the use of a pulse oximeter and technical support when I needed it. A special thank you goes to my loving husband Bill for his emotional, financial, and editorial support throughout my graduate education.

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CHAPTER ONE

THE STUDY PROBLEM

Introduction

Nurses working in a Pediatric Intensive Care Unit (PICU) are responsible for tracheal (endotracheal and tracheostomy) suctioning of their patients according to procedures outlined by their institution. As there are no definitive guidelines for tracheal suctioning, the procedures recommended vary widely (Turner, 1983).

When any clinical procedure is established, a major component of the procedure must be the avoidance of adverse effects on the patient. With tracheal suctioning, the introduction of a catheter and negative pressure into the tracheobronchial tree cause alterations in cardiopulmonary physiology and atelectasis. This may result in hypoxemia which, when severe, can lead to arrhythmias and death (Bodai, 1982; Boutros, 1970; Taylor & Waters, 1971; Brandstater & Muallem, 1969).

Hypoxemia may be minimized by several different methods used prior to, during, and after endotracheal suctioning. Some of these are hyperoxygenation, hyperinflation, hyperventilation, high frequency jet ventilation, oxygen insufflation, and the use of adaptors with side ports for suctioning the tracheal tube while maintaining the patient on the ventilator (Boutros, 1970; Fell & Cheney, 1971; Holladay, Deeren & Powaser, 1980; Keszler & Miroslau, 1980; Brown, Stansbuty, Merrill, Linden & Light, 1983).

There is a paucity of information about tracheal suctioning in the young child two years of age or less who requires long term respiratory support for chronic lung disease. As a result of chronic lung disease which is characterized by decreased dynamic compliance, increased airway resistance, increased physiologic deadspace, and an increase in pulmonary venous admixture, these children are particularly sensitive to alterations in oxygenation (Crone, 1981). Without well controlled research studies to support a particular suctioning technique, these patients may be unnecessarily subjected to the harmful effects of tracheal suctioning.

Statement of the Problem

Is there a specific combination of the three commonly employed methods of hyperinflation, hyperventilation, and hyperoxygenation before and immediately after endotracheal suctioning that will minimize oxygen desaturation in children two years of age or less that require chronic respiratory support?

Purpose of the Study

The purpose of this study is to determine if there is a combination of hyperinflation, hyperoxygenation, and hyperventilation that will minimize oxygen desaturation in children two years of age or less who require chronic respiratory support.

Significance of the Study

This study may significantly benefit children who require chronic respiratory support by obtaining baseline data on how these children respond to suctioning with hyperinflation, hyperoxygenation, and hyperventilation as pre- and post-suctioning treatment. It may also identify the best method of minimizing oxygen desaturation during tracheal suctioning.

There have been no studies performed on children who require chronic respiratory support that demonstrate the effect of hyperinflation, hyperventilation, or hyperoxygenation prior to and immediately after tracheal suctioning on oxygenation. The detection of hypoxemia in this group of patients is difficult. One indicator of hypoxemia is cyanosis.

Often cyanosis is not detected even by the trained observer until the oxygen saturation (SaO_2) of hemoglobin is markedly decreased, i.e. a SaO_2 of less than 70% (Nunn, 1978). Blood gas analysis is presently the standard measurement of oxygenation. Its intermittent nature places limitations on the ability to detect sudden or transient changes. It is painful and the procedure itself may alter oxygenation. Recently, non-invasive monitoring has been developed to measure levels of oxygenation accurately and on a continuous basis. This technique can provide an objective assessment of oxygenation without altering the patient's steady state.

The problem of ventilator-dependent children will probably increase in the years to come. Neonatologists have improved the survival of critically ill premature infants at the expense of chronic lung disease (bronchopulmonary dysplasia) following a period of severe respiratory distress. Surgeons are improving their techniques for palliating congenital thoracic anomalies. Bellows dysfunction, however, may occur requiring chronic continuous respiratory support for the child. These patients, and others, form a growing population of ventilator dependent children (Kettrick, 1983). This population requires tracheal suctioning as long as an artificial airway is required; therefore, it is critical that health care providers who perform endotracheal suctioning be aware of the possible complications of tracheal suctioning and the techniques that may prevent oxygen desaturation.

Objectives of the Study

1. To describe the pattern of and quantitate oxygen desaturation that may occur with hyperinflation, hyperventilation, and hyperoxygenation before and after endotracheal suctioning.
2. To identify the interacting effects of hyperinflation, hyperventilation, and hyperoxygenation in minimizing oxygen desaturation.

Definition of the terms

Chest physiotherapy - Chest percussion to all lung segments followed by tracheal suctioning.

Chronic Respiratory Support - Delivery of intermittent mandatory ventilation, continuous positive airway pressure, or oxygen mist therapy via a tracheostomy tube for a period of greater than one month.

Hyperinflation (HI) - Delivery of ten centimeters of water pressure greater than peak inspiratory pressure if the subject is ventilated and the delivery of 20 centimeters of water pressure above end expiratory pressure if the subject is breathing spontaneously.

Hyperoxygenation (HO) - The application of a fraction of inspired oxygen to equal 1.0.

Hyperventilation (HV) - The increase in ventilatory frequency by 50 percent above the subject's baseline frequency.

Oxygen Saturation - The fraction of hemoglobin bound to oxygen. The hemoglobin measured is only that hemoglobin available for reversible binding with oxygen. Irreversibly bound hemoglobin (eg. carboxyhemoglobin, methemoglobin) is thus excluded.

Tracheal Suctioning - The procedure of inserting a suction catheter into the tracheal tube and application of negative pressure for no longer than five seconds while withdrawing the suction catheter out of the tracheal tube.

Limitations

This study will be performed in the clinical area where it is often difficult to meet the strict requirements of a research protocol. The protocol will be designed so that the operator can carry out the procedure with little difficulty. The procedure will be designed to closely follow the tracheal suctioning procedure outlined by the Children's Hospital of Philadelphia (Appendix A). It would be preferable to have one person perform each of the trials, but this is not possible due to staffing patterns. It is therefore difficult to control for consistency of techniques.

The population of children being studied is very unique. These patients have variable severity of lung disease. There is also only a small available patient population at any given institution. Unlike an ill adult, these children are often mobile in their bed or as far as their ventilator apparatus will allow them to travel. It is impossible to control for the populations level of mobility. Some days the children are more active than others and this may also affect their oxygenation status (Schonfeld, Sargent, Bautista, Walters, O'Neal, Platzker, & Keens, 1980). It is equally not feasible to control for changes in clinical status which may affect oxygenation such as respiratory infections, gastrointestional disturbances, or other illnesses that may occur during the course of the study.

Summary

Tracheal suctioning is performed routinely on children under two years of age who require chronic respiratory support. Tracheal suctioning is known to cause alterations in pulmonary and cardiac functions which at times can be life threatening (Bodai, 1982; Boutros, 1970; Taylor & Waters, 1971; Brandstater & Muallem, 1969). Various methods have been suggested to minimize these effects.

There is little information on the effects of these methods on the young child, and therefore, no best method has been described. This study may be beneficial to these patients by describing an optimal pre- and post-suctioning technique that prevents oxygen desaturation and will additionally provide baseline data on suctioning in this age group.

CHAPTER TWO

REVIEW OF THE LITERATURE

Conceptual Framework

Tracheal suctioning of the intubated or tracheostomized patient is necessary to maintain a patent airway, however, the procedure is accompanied by many undesired physiologic effects. These deleterious effects are caused by the introduction of a catheter into, and negative pressure exerted on the lung. The resultant hypoxemia, as well as reflexive stimulation may cause arrythmias and cardiac arrest.

Pre and post-suctioning treatments described in Chapter One have been shown to lessen these adverse effects. The conceptual framework illustrates the relationship of three treatments and patient oxygenation during tracheal suctioning (Figure 2.1). Figure 2.1 illustrates the relationship between the nursing intervention (tracheal suctioning alone or in combination with hyperinflation, hyperventilation and hyperoxygenation) and the oxygenation status of the subject. Combinations of hyperinflation with hyperventilation and hyperoxygenation will be explored to determine which has the best, if any, positive effect on oxygenation. It cannot be ruled out that

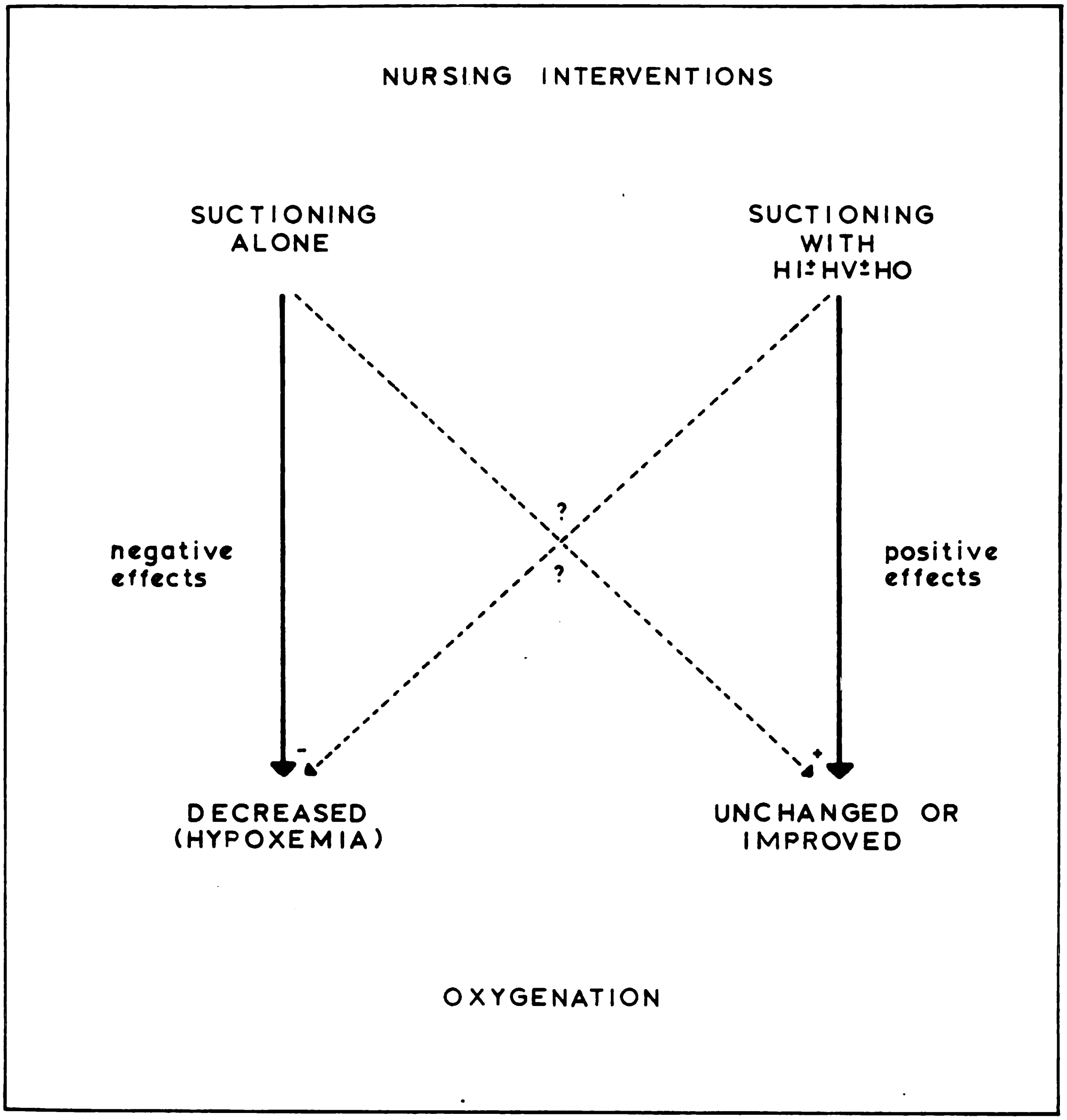

Figure 2.1. Conceptual Framework

suctioning alone (dotted line) may actually have a positive effect or that the use of hyperinflation, hyperventilation and hyperoxygenation (dotted line) may have a negative effect on oxygenation.

Factors Contributing to Hypoxemia

Several aspects of the suctioning technique can influence the occurence of hypoxemia. The major factors are the negative pressure exerted by the suction apparatus, suction flow, the external diameter of the suction catheter relative to the lumen of the tracheal tube and the mechanical stimulation of the airway by the catheter.

Negative Pressure. The negative pressure exerted on the lung is partly governed by the pressure exerted on the suction apparatus. Absolute numbers for acceptable negative pressure are difficult to establish. Limiting the negative pressure to approximately -100 cm water is felt to decrease mucosal damage in the trachea without reducing aspiration efficiency (Kuzenski, 1978; Shapiro, Harrison & Trout, 1982).

Negative pressure produces a sharp decrease in lung volume due to alveolar collapse with a resultant decrease in pulmonary compliance (Nunn, 1978). The measurement of compliance has often been used to indicate alveolar collapse in patient populations (Nunn, 1978). Tracheal suctioning in neonates consistently produced a fall in pulmonary compliance (Brandstater amd Muallem, 1969). The effects on the lungs were greater when the suction was prolonged and when larger suction catheters were used. Allowing negative pressure to develop slowly in the suction apparatus will reduce the negative pressure transmitted to the lungs, however, secretions will also be removed slowly which will increase the likelihood of hypoxemia (Rosen & Hillard, 1962).

Suction Flow. The flow of air through the suction catheter is determined by the pressure applied to the catheter and its resistance to flow. The resistance increases proportionately to the length of the catheter and inversely by the fourth power of the internal radius (Nunn, 1978). Theoretically, if suction flow rates are greater than the gas flow delivered to the patient, all gas delivered will be removed along with the gas in the patient's airway. Clinical studies of suction flow and its relationship to hypoxemia involve the insufflation of oxygen via a side port or a double lumen catheter and do not isolate the effects of flow from hyperoxygenation (see below).

<u>Catheter Size</u>. In addition to the actual negative suction pressure applied, the external diameter of the catheter affects the amount of negative pressure the lung experiences during suctioning. The negative pressure in the lung increases as the outside diameter of the suction catheter increases relative to the internal diameter of the airway. As a result, alveolar air is aspirated into the suction catheter instead of atmospheric air. Rosen and Hillard (1962) used mock lungs to show that negative pressures in the lungs may be avoided if the outside diameter (O.D.) of suction catheter is one-half or less of the inside diameter (I.D.) of the tracheal tube (O.D./I.D.$\leq$0.5).

Fox, Schwartz and Shaffer (1978) studied 13 newborn infants recovering from respiratory disease. Functional residual capacity (FRC) was measured as an indication of atelectasis. The authors found no decrease in FRC when the subjects were tracheally suctioned. It was the investigators' belief that the absence of atelectasis was due to the use of a smaller suction catheter (6 Fr.) inside an endotracheal tube measuring 3.0 mm I.D. to 3.5 mm I.D. In fact, the 6 Fr. catheter had an outside diameter of 1.9 mm. and for the 3.5 mm I.D.tracheal tube the O.D./I.D. was 0.54.

For the 3.0 mm I.D. tracheal tube the O.D./I.D. increased to 0.63, larger than the recommendations of Rosen and Hillard (1962). The patients studied by Fox, et al. (1978) maintained their FRC despite this large ratio. This may be attributed to their use of continuous positive airway pressure (CPAP) and high transpulmonary pressures during the study.

Airway Stimulation. Woodburne and Powaser (1980) compared the effects of inserting a suction catheter into the airway of spontaneously breathing and mechanically ventilated dogs with and without suction applied. The oxygen tension dropped in all cases by nearly equal amounts providing support for the concept that the physical presence of the catheter in the airway may lead to hypoxemia. This was felt to be due to reflexive bronchoconstriction as a result of mechanical stimulation of the suction catheter, and pre-treatment with isoproterenol aerosol did not eliminate this effect.

Summary. Tracheal suctioning can cause an increase in negative pressure exerted in the lungs by two means. These are that the apparatus itself can be set at a high negative pressure or the suction catheter may be too large in relationship to the tracheal tube.

Several investigators have suggested various means of preventing this high negative pressure. Fox, et al. (1978) as well as Rosen and Hillard (1962) suggested the use of smaller suction catheters for suctioning. Rosen and Hillard (1962) recommended that the outside diameter of the suction catheter be no greater than half the size of the inside diameter of the tracheal tube. The use of smaller suction catheters must be approached with caution. The effectiveness of clearing secretions with small catheters must be considered as only thin secretions may be able to be removed. This is an important consideration when dealing with the small child who requires a small tracheostomy tube (Turner, 1983).

Cardiovascula Effects

Cardiac depression may occur during prolonged suctioning. There are several reasons hypothesized for this depression. It is felt that vagal stimulation by the suction catheter causes bradycardia (Berman & Stahl, 1968). Children are especially sensitive to vagal stimulation (Slota & Beerman, 1983). Arterial oxygen desaturation is responsible for a decreased supply of oxygen to the cardiac muscle. This increases cardiac irritability with resultant cardiac arrhythmias (Keszler & Klain, 1980). Shim, Fine, Fernandez, and Williams (1969) studied patients with various lung diseases. Those who were breathing room air prior to tracheal suctioning developed arrhythmias whereas those who were breathing 100% oxygen for five minutes prior to tracheal suctioning had no arrhythmias. The disruption of mechanical ventilation for suctioning, especially when high positive end expiratory pressure (PEEP) is used, caused a decrease in FRC in this study population. The hypoxemia induced may lead to cardiac arrhythmias and possibly asystole (Bodai,1982).

Simbruner, Coradello, Fodor, Havelec, Lubec, and Pollak (1981) studied ten newborn infants with respiratory distress syndrome. Heart rate, transcutaneous oxygen levels, and blood pressure after suctioning was recorded. The authors observed that the heart rate decreased, blood pressure increased, and transcutaneous oxygen levels decreased significantly ($p \leq 0.05$) during tracheal suctioning.

Relevant Literature Directly Related to the Problem

Hyperoxygenation and Oxygen Insufflation

Many authors recommend the use of some form of oxygen administration prior to tracheal suctioning. Shapiro, et al. (1981) recommend that the patient be preoxygenated with 100% oxygen prior to suctioning. The authors did not present specific guidelines for the amount of preoxygenation time necessary to avoid hypoxemia.

Boba, Cincotti, Piazza and Landmeser (1959) studied the effects of apnea, endotracheal suctioning, and oxygen insufflation on oxygen saturation in fifteen men with no cardiovascular or pulmonary disease. The authors observed that suctioning (negative flow rate approximately 13 Liters per minute [L/min.]) resulted in oxygen desaturation as noted by color changes in the mucosa or nailbed and documented by blood gas analysis. During this study, apnea of one minute caused an average drop of 15% in oxygen saturation. Endotracheal suctioning did not significantly alter this degree of hypoxia. It was noted that oxygen insufflation at 4 L/min. would prevent hypoxemia that occurred during apnea, as well as apnea with endotracheal suctioning. The average drop for these two procedures was 1.8% and

5% respectively. The authors concluded that small amounts of oxygen will maintain adequate arterial oxygen saturation. It must be considered, however, that the subjects did not have cardiovascular or pulmonary pathology. In these subjects, the admininstration of a small amount of oxygen may have been enough to prevent hypoxemia; but in the patient with pulmonary or cardiac abnormalities, a compromised oxygenation state may already exist and the patient may become seriously desaturated under the same conditions.

Urban and Weitzner (1969) utilized a modified side arm port with the catheter being introduced through a sterile adaptor without disconnecting the ventilator to allow increased oxygen flow to equal the flow from the suction catheter and apparatus. This was believed to prevent the hypoxemia that occurs when alveolar air is removed. Berman and Stahl (1968) found that the use of a double lumen suction catheter with an oxygen flow rate of 5 L/min. applied to the one lumen and suction pressure applied to the second lumen will prevent suction-induced hypoxemia. Arterial oxygen tension level in the subjects increased.

Fell and Cheney (1971) found conflicting results. Five L/min of oxygen was administered via a sidearm port during suctioning with 18 L/min. negative flow. The authors found that insufflation did not make a difference in the oxygenation of the patient. This differed from the results of Boba et al. (1959) who used a negative suction flow of 13 L/min. with a 4 L/min. oxygen flow. This difference in suction flow could alter the results obtained.

Langrehr, Washburn and Guthrie (1981) performed a similar study on animals and patients. The authors concluded that the use of oxygen insufflation was most effective when the oxygen insufflation flow rates (10 to 15 L/min.) approximated the suction flow rates (10.8 L/min.). This was maximized when the subjects made some ventilatory effort during either insufflation or suctioning. There was not much difference in the oxygen tension level between the control level and the 300 second time measurement of all the studies performed. Recovery time for arterial oxygen tension was better than for others studied.

Naigow and Powaser (1977) studied the use of suction alone, 100% oxygen administration for three minutes prior to suctioning, hyperinflation with room air after suctioning, hyperinflation with 100% oxygen for three minutes prior to suctioning, and hyperinflation with 100% oxygen before, during, and after suctioning. The authors demonstrated that oxygen desaturation after suctioning was reversed by lung hyperinflation post suctioning. The best rise of oxygen tension occurred when dogs were hyperinflated with 100% oxygen before, during, and after 15 seconds of tracheal suction. The authors concluded that hyperinflation alone, after suctioning, quickly raised arterial oxygen tension above control values. When this method was combined with 100% oxygen before, during and after tracheal suctioning, oxygen tension remained elevated at all times. The authors concluded that hyperoxygenation combined with hyperinflation produced favorable results. The study was well controlled for negative flow of the suction apparatus as well as for the ratio of the internal diameter of the tracheal tube in relation to the outside diameter of the suction catheter.

Skelly, Deeren, and Powaser (1980) studied preoxygenation techniques and found that without preoxygenation a fall in oxygen tension ocurred. This fall in oxygen tension occurred despite the patient making a ventilatory effort. The patients returned to the control oxygen tension value after 180 seconds.

The preoxygenation techniques that were performed will be discussed in the hyperinflation section because they were performed concurrently.

Hyperventilation

Downes, Wilson, and Goodson (1961) described trials in anesthesized men to determine the amount of oxygen desaturation that occurred when patients were subjected to one minute of apnea both with and without suctioning or prior hyperventilation for 15 seconds with oxygen. Arterial oxygen desaturation at or below 93% occurred in 25 of 30 trials in which one minute of apnea was not preceeded by hyperventilation with oxygen. Those subjects who received hyperventilation had very little change in oxygen saturation either during the period of apnea or during apnea in combination with suctioning. Downes, et. al. (1961) concluded that hyperventilation would prevent oxygen desaturation from occurring. It is unclear, however, if hyperventilation or the fraction of inspired oxygen (FiO2) of 100% made the difference in the results of the study.

Hyperinflation

Many of the studies mentioned previously used hyperinflation in addition to oxygen administration. A respiratory rate was often not discussed in these studies and a possibility that the subject was hyperventilated existed.

Brandstater and Muallem (1968) noted that endotracheal suctioning in infants caused atelectasis which remained until a distending pressure was administered to open the closed alveoli. Tidal volume was measured as well as transpulmonary pressures to determine when full re-expansion of the lungs occurred. The authors concluded that full re-inflation could be achieved consistently by giving three deep breaths (25 cm) over a two second period. One problem with this study was the fact that with a 3mm I.D. tracheal tube, the investigators used either a size 8 Fr. or 5 Fr.(2.5 and 1.6 mm O.D., respectively) suction catheter for suctioning. According to Rosen and Hillard (1969) a suction catheter with an outside diameter that is over half the size of the inside diameter of the tracheal tube can significantly contribute to increases in negative pressure exerted in the lungs. Although neither addressed, nor controlled, this factor may have caused increases in atelectasis in the patients who were suctioned with the larger suction catheter versus the patients suctioned with the smaller suction catheter. This could not be examined from the data presented.

Woodburne and Powaser (1980) performed animal studies to test various procedures utilizing eight protocols for suctioning. Mechanically and spontaneously breathing dogs were observed in their response to suction duration, catheter stimulus, hyperinflation, and administration of isoproterenol mist. Only the hyperinflation results will be discussed in this section. The dogs were given one hyperinflation breath with room air at 170 seconds after tracheal suctioning was performed. This produced a small transient increase in the oxygen tension (5 mmHg) which then returned to the prehyperinflation level. In another trial the authors used hyperinflation for three breaths in mechanically ventilated dogs prior to tracheal suctioning. The oxygen tension remained depressed below the control values throughout a five minute time period. The volumes and pressures administered were not reported and no comparison could be made between the one hyperinflation and the three hyperinflation breath trial. The purpose of this study was not to compare hyperinflation methods but rather to compare bronchoconstriction secondary to mechanical stimulation of the airways to reduction in the airway pressure as two factors contributing to suction-induced hypoxemia.

Naigow and Powaser (1977) studied various suction procedures in dogs. As discussed earlier, hyperinflation was found to be beneficial in preventing post-suctioning hypoxemia. When combined with 100% oxygen, arterial oxygen tension improved dramatically.

Summary

There have been many studies performed on dogs and humans to explore the various effects of hyperinflation, hyperoxygenation and hyperventilation in preventing oxygen desaturation. Many of the studies varied in methodology and may not be generalizable or capable of being reproduced without further information from the authors. In addition to the difference in methodology, there were major differences in subjects sampled. Some subjects had healthy lungs, while other had cardiac or pulmonary pathology. Some subjects were neonates, some were adults, and others were dogs. It is therefore difficult to generalize findings from these studies to all patient populations, or to the population two years of age or less with chronic lung disease.

CHAPTER THREE

METHODOLOGY

This quasi-experimental study was designed to explore the effects of hyperinflation combined with hyperventilation and/or hyperoxygenation prior to, during, and after tracheal suctioning on children requiring long term respiratory support. Permission to perform this study was obtained from the Committees on Human Research at the University of California, San Francisco and the Children's Hospital of Philadelphia as well as the child's attending physician prior to the study. No parental consent was required by the Committees on Human Research (Appendix B).

Setting

This study was performed at the Children's Hospital of Philadelphia (CHOP) in the Pediatric Intensive Care Unit Complex. The complex consists of 14 beds of Acute, five beds of Isolation, and eight beds of Intermediate Care. CHOP is affiliated with the University of Pennsylvania. This setting was chosen because of its large population of children requiring chronic respiratory support due to bronchopulmonary dysplasia, chronic respiratory failure, etc. The usual age range of the children is three months to three years.

Sample

A convenience sample of seven children between the ages of 11 months and two years and nine months was chosen for this study. The criteria established for inclusion into this study were:

1. A tracheostomy tube for suctioning access.
2. Respiratory support (i.e. ventilator, continuous positive airway pressure [CPAP], or varying amounts of FiO_2) via tracheostomy tube.
3. Tracheal suctioning for removal of secretions at least every six hours.
4. An adequate arterial pulse for successful application of the pulse oximeter as determined by the amplitude of the pulse wave on the oximeter.
5. Chest physiotherapy being performed on a routine basis.

There were ten children in the Intensive Care Complex that required chronic respiratory support. Three of these children were excluded from this study for various reasons. These reasons were: (1) one child would be decannulated before all four studies could be completed, (2) another child required 100% oxygen administration throughout chest physiotherapy and suctioning, and (3) the last child did not receive chest physiotherapy because of a pulmonary thrombosis.

Procedure

All nursing personnel interested in participating in the study were trained according to the protocol. The standard suctioning procedure at CHOP was used (Appendix A). Each child was randomly assigned an order of hyperinflation alone or with hyperventilation and/or hyperoxygenation (Table 3.1).

Table 3.1

Trial Combinations

Trial	Combination
1	Hyperinflation alone
2	Hyperinflation + Hyperoxygenation
3	Hyperinflation + Hyperventilation
4	Hyperinflation + Hyperoxygenation + Hyperventilation

Hyperinflation

The procedure for hyperinflation during suctioning at CHOP was not standardized for pressure or volume.

This investigator however, did standardize hyperinflation to consist of a 10 cm water pressure greater than peak inspiratory pressure if the subject was being mechanically ventilated, or 20 cm water pressure above end expiratory pressure if the subject was receiving no mechanical ventilation. All subjects were hyperinflated for 10 breaths via a Mapleson anesthesia bag with a pressure manometer inserted into the system to document hyperinflation measurements. Hyperinflation using pressure instead of volume was considered standard as the children are intubated with uncuffed tracheal tubes that have variable leakage. This leak makes volume measurement unreliable (Crone, 1981).

Hyperventilation

Hyperventilation was standardized by this investigator to consist of an increased ventilatory frequency of 50% over the baseline frequency (ventilated and spontaneous respiratory rate) for ten breaths. The respiratory rate was counted by the investigator prior to commencement of the study and a hyperventilation rate was calculated. The nurse performing the procedure was told the rate prior to beginning the suctioning procedure and a practice count for timing was performed. This investigator counted out the ventilations required for the proper hyperventilation rate to the nurse while the procedure was actually being performed.

Hyperoxygenation

Hyperoxygenation consisted of 100% oxygen administration for ten breaths. Oxygen delivery was via a wall flow meter or an oxygen blender. The oxygen level was checked prior to the study with a Bennett Oxygen Analyzer. This instrument was used routinely by the Respiratory Therapy Department at CHOP for analyzing oxygen delivery.

Sequence of Events in the Study

Table 3.2 provides a chronicle of the events in the study. The pulse oximeter was applied to the child's great toe approximately five to 15 minutes prior to commencement of the study (Appendix C). An oxygen saturation reading was obtained five to 10 seconds prior to chest physiotherapy. Chest physiotherapy was then performed by the nurse. After chest physiotherapy was completed and pre-suctioning oxygen saturation (SaO2) readings were obtained hyperinflation alone or in combination with hyperoxygenation and/or hyperventilation was performed. The time it took to prepare for suctioning after chest physiotherapy and to begin the trial was variable but did not exceeded one minute. After chest physiotherapy and before suctioning, sodium chloride solution was instilled into the tracheal tube. This was standardized to 0.05 milliters per kilogram of body weight. Disposable sodium chloride containers were used for the study and the exact amount required per patient was withdrawn into a syringe immediately before the trial.

The subjects were then suctioned with an 8 French (Fr.) suction catheter. These suction catheters are used clinically on the children at CHOP. Maximum suction time allowed per pass was no greater than five seconds; however, repeated suctioning passes were permitted until the nurse performing the suctioning judged that secretion removal was complete. This was usually when secretions were no longer obtained. If more than one suctioning pass was required, the patient was re-treated according to the trial protocol for ten breaths. Negative suction pressure was applied only during withdrawal of the suction catheter.

Table 3.2

Sequence of Events

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1. A pulse oximeter was applied at least five minutes prior to chest physiotherapy.
2. Suction pressure was calibrated and suction flow was measured.
3. An oxygen saturation reading was obtained five to 10 seconds prior to commencement of chest physiotherapy.
4. Chest physiotherapy was performed.
5. Pre-suctioning SaO_2 was recorded approximately one minute after chest physiotherapy and 15 seconds prior to beginning the experimental technique.
6. The experimental technique was initiated (see Table 3.1).
7. Tracheal suctioning was performed until the patient was secretion free.
8. Oxygen saturation readings were recorded at 30 seconds, 1 minute, 5 minutes, 10 minutes, and 20 minutes post suctioning.
9. Suction pressure and suction flow were rechecked.

Data Collection

The pulse oximeter sensor was applied to a distal extremity five minutes prior to commencement of chest physiotherapy (which preceded suctioning) to obtain a baseline measurement and ensure proper placement of the sensor. The value of the digital display of oxygen saturation was recorded on the data sheet (Appendix D) by the investigator and any desaturation that occurred was documented. The sensor was left in place for 20 minutes after suctioning to observe the trajectory of desaturation and recovery time. Oxygen saturation was continuously observed by the investigator during the entire study. Any unusual responses (movement artifact, cardiac arrhythmias, etc.) were noted and recorded. Oxygen saturation measurements were documented five to 10 seconds prior to chest physiotherapy, 15 seconds prior to suctioning as well as 30 seconds, 1, 5, 10, and 20 minutes after suctioning. At no time did the oxygen saturation drop below 75%.

Instrumentation

The suction catheter used was Superior Safety Suction Catheter R distrubuted by Superior Plastic Products. The suction catheter had a bevelled opening as well as two side holes. The flow rate of the suction catheter was established by attaching the catheter to a Wright Respirometer and a portable pneumatic calibrator (Wallace and Tiernan) that was attached to the wall suction. In addition to calibrating the negative pressure from the wall suction, the researcher was able to determine the flow of the suction catheter prior to and after all studies.

The Nellcor Pulse-Oximeter (N - 100) was used to measure oxygen saturation non-invasively and on a continuous basis.

CHAPTER FOUR

RESULTS OF THE STUDY

Selected Study Sample

The sample population for this study consisted of seven children studied over a one month period in the Pediatric Intensive Care Complex, all of whom required long term respiratory support. Each child selected for the study met the following criteria so that all children: (1) had a tracheostomy tube in place; (2) required respiratory support (i.e. ventilator, continuous positive airway pressure [CPAP], or varying amounts of FiO2) via tracheostomy tube; (3) required endotracheal suctioning for removal of secretions; (4) had an adequate arterial pulse for successful application of the pulse oximeter as determined by a pulse beat on the oximeter; and (5) received chest physiotherapy no less than three times per day.

Age and Sex

Six males and one female comprised the sample. The age of the children ranged from eight and one-half months to two years and nine months of age.

Diagnoses

All but one child had some degree of bronchopulmonary dysplasia as documented in the patient's chart. The other child had a congenital myopathy. All of the children studied required chronic respiratory support. Many of these children also had other problems in addition to their bronchopulmonary dysplasia such as tracheomalasia, a small ventricular septal defect, etc. (Table 4.1). These children were stable and did not have any major change in their condition or therapy prior to the study. All of the children required chest physiotherapy followed by tracheal suctioning via their tracheostomy tube every four to eight hours.

Respiratory Support

Respiratory support varied from child to child, as did the method of delivering this support (Table 4.1). Subjects 1, 3, 5, 6, and 7 were ventilated with the Health Dyne 105 ventilator for the duration of the study. Subject 2 received an FiO2 of .21 via mist collar for the duration of the study. Attempts were made, unsuccessfully, during the month long study period to permanently decannulate Subject 2. Subject 4 was a child with a congenital myopathy. He was being weaned from ventilatory support during the day at various time intervals. Several of his suctioning studies were performed off ventilatory support as well as on assisted ventilation.

All suction catheters used in the study were 8 Fr. The outside diameter of the catheter was 2.5 mm. The ratio of the outside diameter of the suction catheters to the inside diameter of the various tracheostomy tubes (O.D./I.D.) were between .42 to .71 (Table 4.2). Subject 6 was the only subject that deviated substantially from the recommendations of Rosen and Hillard (1962) that the O.D./I.D. be less than 0.5. The investigator honored the practice of the institution by using an 8 Fr. suction catheter for that particular patient.

The suction flow rate within the catheter was measured by a Wright Spirometer and portable pneumatic calibrator (Wallace and Tiernan). The exact millimeter of suction pressure, in addition to suction flow (L/min.) was also measured. The flows calculated were between 7.0 L/min. to 7.4 L/min (Table 4.2) consistantly for all subjects studied. No drift of pressure occurred during the study period.

The pulse oximeter was placed on the great toe of all children. Good pulsatile readings were established for a minimum of five minutes prior to beginning the procedure. In a few instances the sensor was kicked off by the child, but was easily reapplied by the investigator. As more studies were performed the children better tolerated the sensor. A hard copy of oxygen saturation was not available for the model N - 100 oximeter, therefore, the investigator had to record all saturations manually as well as observe the saturation continuously for any changes in oxygenation.

Table 4.1

Descriptive Data on the Subjects

Subject	Age	Sex	Diagnosis	Respiratory Support Ventilator FiO2/ IMV/ PIP/PEEP
1	8.5 mos	M	BPD	Health Dyne 105 .4/ 25/ 38/4
2	2 yrs	M	BPD, tracheo-bronchial malasia	None .21
* 3	11 mos	M	BPD	Health Dyne 105 .4/ 40/ 38/3
* 4	2 yr 9 mos	M	Congenital Myopathy	Seimans - Servo .21/ 16/ 24/0 being weaned with .21 mist T-piece
* 5	11 mos	F	BPD Esophogeal Atresia	Health Dyne 105 .25/ 12/ 28/10
* 6	1 yr 7 mos	M	BPD Tetralogy of Fallot (with shunt)	Health Dyne 105 .30/ 5/ 40/5
7	1 yr	M	BPD cor pulmonale VSD	Health Dyne 105 .40/ 30/ 35/9

* Trials were repeated on these 4 subjects.

Table 4.2

Trachal Tube Size, Suction Catheter O.D./Tracheal Tube I.D. and Suction Flow

Subject	Tracheal Tube Size (mm. I.D.)	O.D./I.D.	Suction Flow Rates (L/min.) averaged over 4 trials
1	6.0	0.42	7.1
2	6.0	0.42	7.1
3	4.5	0.55	7.0
4	4.5	0.55	7.1
5	4.5	0.55	7.1
6	3.5	0.71	7.3
7	4.5	0.55	7.4

(All Suction Catheter tubes were 8 Fr. [2.5 mm O.D.])

Data Analysis

Descriptive Analysis

Mean, minimum, and maximum scores as well as standard deviations were calculated for the seven subjects (Table 4.3). They were also calculated for the four subjects who were studied twice. All trials were very close in their arterial saturation as noted by the graphic representation (Figure 4.1). Graphically all studies returned to baseline saturation or above after the twenty minute time period. No subject ever desaturated below 75% during any portion of the study.

Hyperinflation alone. Figure 4.2 demonstrated little change in the mean scores from the baseline oxygen saturation of pre chest physiotherapy which was 93.7% (pre-CPT) until the 20 minute post suctioning time period which was 94.8%. Graphically this trial appeared the most consistent of the four trials.

Hyperinflation and Hyperoxygenation. This trial graphically depicted a small decrease in the oxygen saturation between the beginning of chest physiotherapy (93.5% saturation) and just before beginning the study protocol with tracheal suctioning (92.6% saturation) (Figure 4.1). This is not likely to be clinically

Table 4.3

Descriptive Statistics of Oxygen Saturation (N = 7)

Trials and Times	Mean	Standard Deviation	Minimum Score	Maximum Score
HI (pre CPT)	92.857	2.268	90	95
HI (pre sx)	93.143	4.259	85	98
HI (30 sec)	93.571	4.504	87	99
HI (1 min)	92.845	4.845	84	98
HI (5 min)	93.429	3.780	86	97
HI (10 min)	92.571	4.158	84	96
HI (20 min)	94.571	1.988	92	97
HI/HO (pre CPT)	94.714	1.976	92	97
HI/HO (pre sx)	92.143	3.436	85	95
HI/HO (30 sec)	95.000	3.162	91	100
HI/HO (1 min)	94.571	1.272	93	96
HI/HO (5 min)	93.857	2.410	90	96
HI/HO (10 min)	94.143	3.579	87	97
HI/HO (20 min)	95.429	2.507	91	98
HI/HV (pre CPT)	92.286	3.729	85	96
HI/HV (pre sx)	90.429	3.155	87	96
HI/HV (30 sec)	91.143	5.146	85	98
HI/HV (1 min)	91.143	4.525	85	98
HI/HV (5 min)	92.714	2.498	90	98
HI/HV (10 min)	92.571	2.225	90	96
HI/HV (20 min)	92.429	3.359	87	98
HI/HO/HV (pre CPT)	92.857	3.185	88	96
HI/HO/HV (pre sx)	90.429	3.309	86	94
HI/HO/HV (30 sec)	95.286	1.976	93	99
HI/HO/HV (1 min)	95.000	2.582	90	98
HI/HO/HV (5 min)	92.857	3.237	88	98
HI/HO/HV (10 min)	94.287	2.870	91	99
HI/HO/HV (20 min)	94.571	2.440	90	97

Note: HI = Hyperinflation
HO = Hyperoxygenation
HV = Hyperventilation
pre CPT = pre chest physiotherapy (5 - 10 sec.)
pre sx = pre tracheal suctioning (15 sec.)

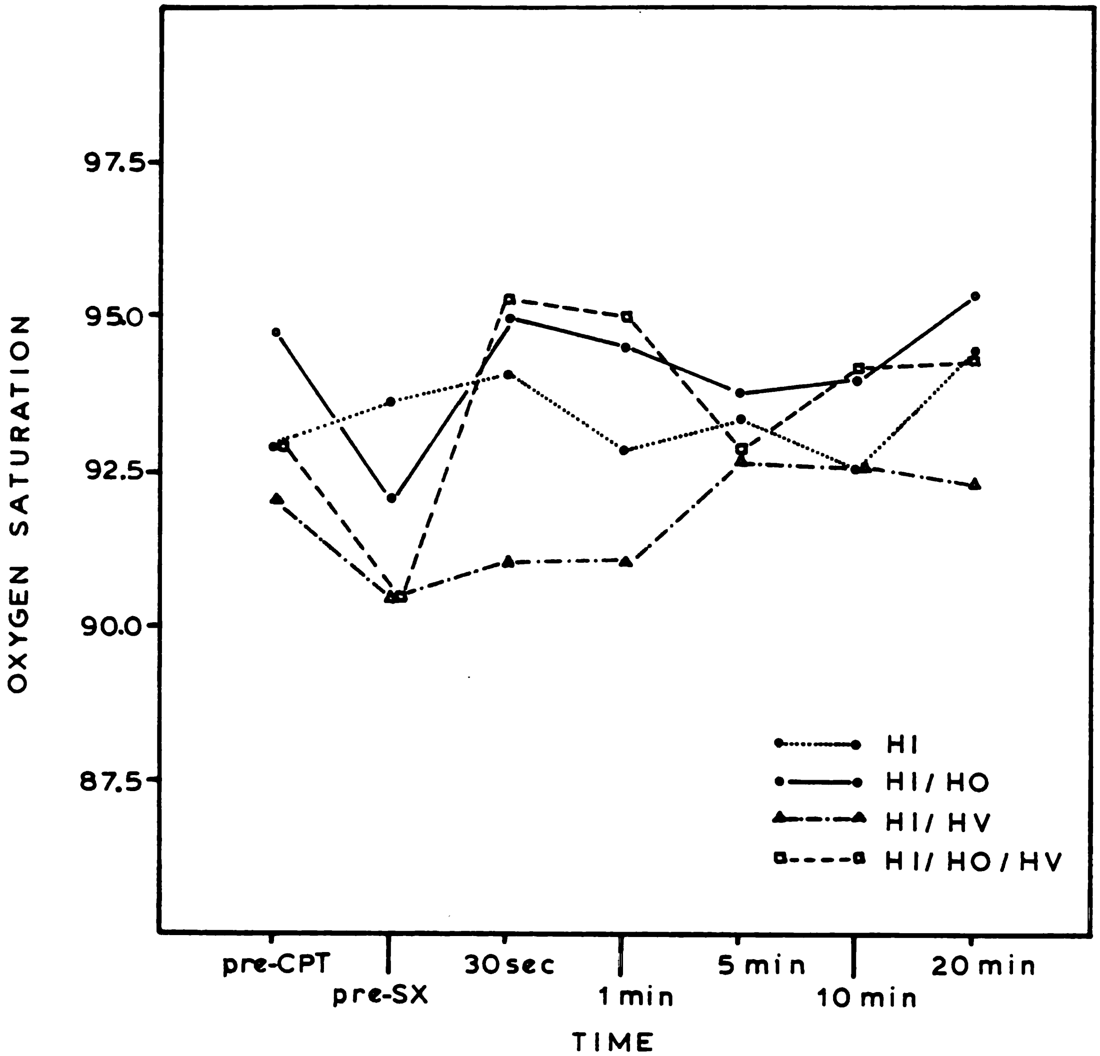

Figure 4.1

Mean Scores for all Trials (N = 7)
HI = Hyperinflation
HI/HO = Hyperinflation & Hyperoxygenation
HI/HV = Hyperinflation & Hyperventilation
HI/HO/HV = Hyperinflation & Hyperoxygenation & Hyperventilation

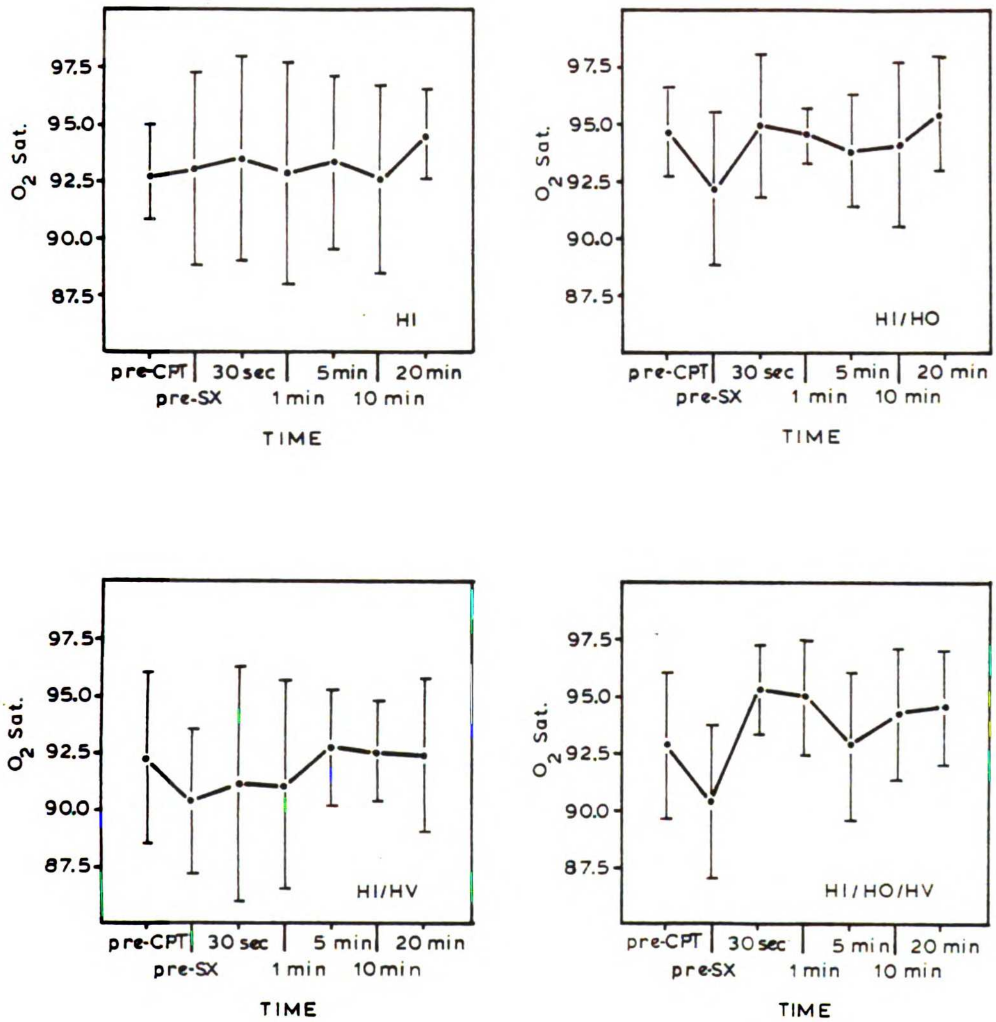

Figure 4.2

Mean Scores and Standard Deviations (N =7) significant as Sa02 did not fall below 90%. Again, the oxygen saturation returned to the baseline by the 20 minute time period.

Hyperinflation and Hyperventilation. This trial showed consistantly lower oxygen saturation levels (92.7%, 90.6%, 90.7%, 91.0% respectively) until the five minute time period after tracheal suctioning when saturation rose to 92.7%. The oxygen saturation did return to slightly above the baseline saturation (92.8%) by the 20 minute time period (Figure 4.2). It must be noted that the lowest oxygen saturation represented less than a five percent decrease in oxygen saturation.

Hyperinflation, Hyperoxygenation, and Hyperventilation. Again, this trial had a decrease in oxygen saturation after chest physiotherapy from 93.3% to 91.6%. It also had the most graphic rise in saturation after the treatment protocol and tracheal suctioning (Figure 4.1 & 4.2). The oxygen saturation rose back to above the baseline saturation (94.6%) by the 20 minute time period.

Summary of the Data Analysis. The data collected varied among different pre-suctioning techniques (Figure 4.1 & 4.2). Some interesting patterns were noted. Chest physiotherapy caused a decrease in oxygen saturation as seen in Figure 4.2. Although the mean values remained above 90% saturation, individual subjects desaturated to the mid 80% range after chest physiotherapy (Table 4.3). In most instances, recovery from desaturation occurred after the 30 second post-suctioning time period and remained above 90% for the remainder of the study (Figure 4.1 & 4.2).

Non-Parametric Statistical Analysis

A Wilcoxon signed ranks test was performed to determine if there was a statistically significant difference between pre and post-chest physiotherapy oxygen saturation (Don Chambers, personal communication, April 20, 1984; Spence, Cotton, Underwood, Duncan, 1976). The two groups were found to have a statistically significant ($p \leq .05$) decrease in oxygen saturation after chest physiotherapy. These groups were hyperinflation with hyperoxygenation as well as hyperinflation with hyperoxygenation and hyperventilation (Table 4.4). This is a statistically significant drop in saturation, however, it is not a clinically significant drop with the saturation staying above 90%. There was a statistically significant increase ($p \leq .05$) in oxygen saturation after the trial of hyperinflation, hyperoxygenation and hyperventilation at the 30 second post suctioning time period.

Pre-suctioning saturation was compared with the 30 second time period to determine if oxygen saturation was improved by the study technique. The only statistically significant ($p \leq .05$) improvement was that of the trial of hyperinflation, hyperoxygenation and hyperventilation (Table 4.5).

Table 4.4

Comparison of Pre CPT to Pre SX Times

Trial	P value
Hyperinflation alone	.833
Hyperinflation + Hyperoxygenation	.027 *
Hyperinflation + Hyperventilation	.461
Hyperinflation + Hyperventilation + Hyperoxygenation	.027 *

* statistically significant ($p \leq .05$)

Table 4.5

Comparison of Pre Sx to 30 Seconds after Suctioning

Trial	P value
Hyperinflation alone	.75
Hyperinflation + Hyperoxygenation	.14
Hyperinflation + Hyperventilation	.83
Hyperinflation + Hyperoxygenation + Hyperventilation	.03 *

* statistically significant ($p \leq .05$)

Comparison of Trial 1 and Trial 2

It was observed that the results of one trial were not consistently reproducable in a second trial (Figure 4.3, 4.4, 4.5, 4.6). The time between trials on all patients was between two and four weeks.

Other Findings

During the course of the study, notes were taken by the investigator if any unusual changes occurred. Chest physiotherapy appeared to produce the most dramatic changes in oxygen saturation. Subject 2, in one trial, desaturated during chest physiotherapy to 76% for a few seconds and then remained in the 80's throughout chest physiotherapy. Subjects 1, 4, and 5 also desaturated into the 80's with chest physiotherapy.

Summary

The findings reported failed to support a best way of pretreating the subjects prior to tracheal suctioning to minimize oxygen desaturation. Conversely, all methods prevented significant desaturation. No subject desaturated during the study to such a point that they did not subsequently recover after thirty seconds and return to baseline by the end of the twenty minutes. Several subjects had oxygen saturations in the high 70's to low 80's as reported with chest physiotherapy. After recovery from chest physiotherapy (in most cases a 30 second time period), there was no clinically significant desaturation noted from the 30 second time period to the end of the study. When the trials were repeated on four subjects, the results could not be reproduced.

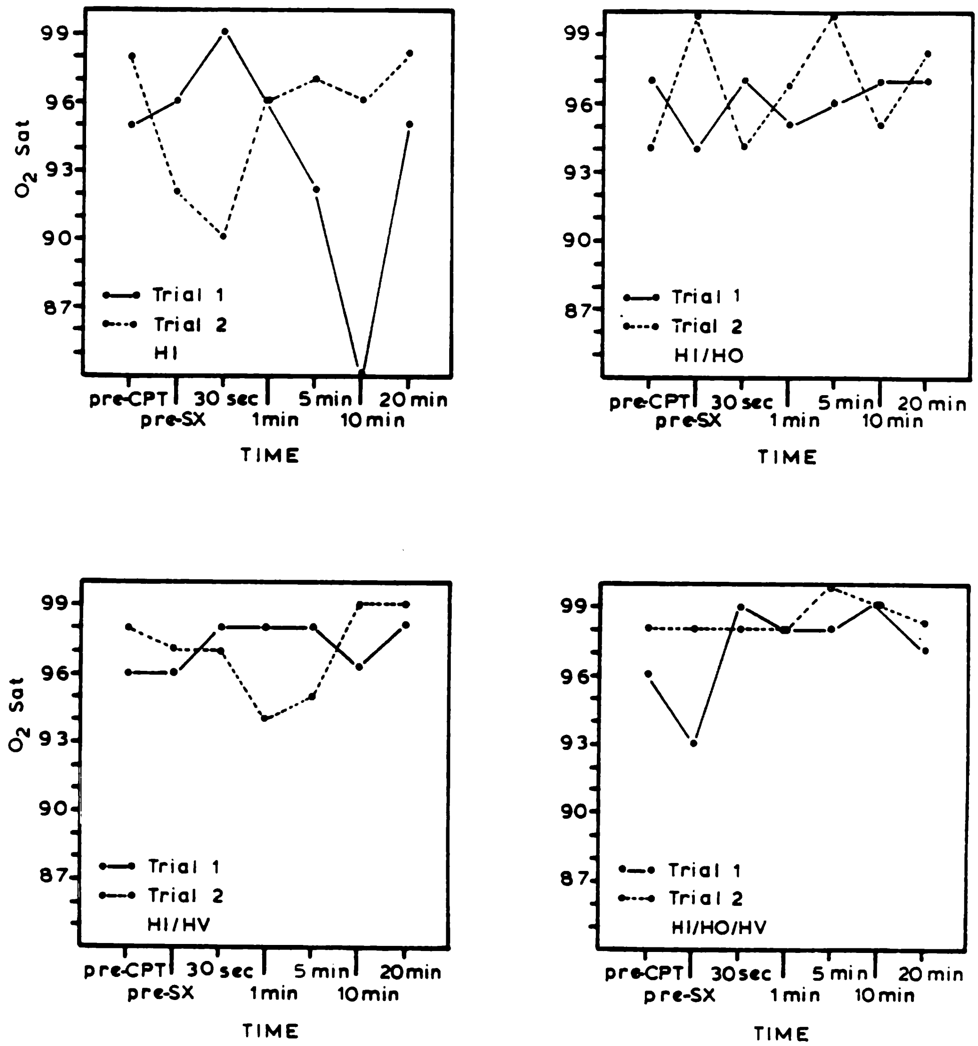

Figure 4.3

Comparison of Trial 1 and Trial 2 (subject 3)

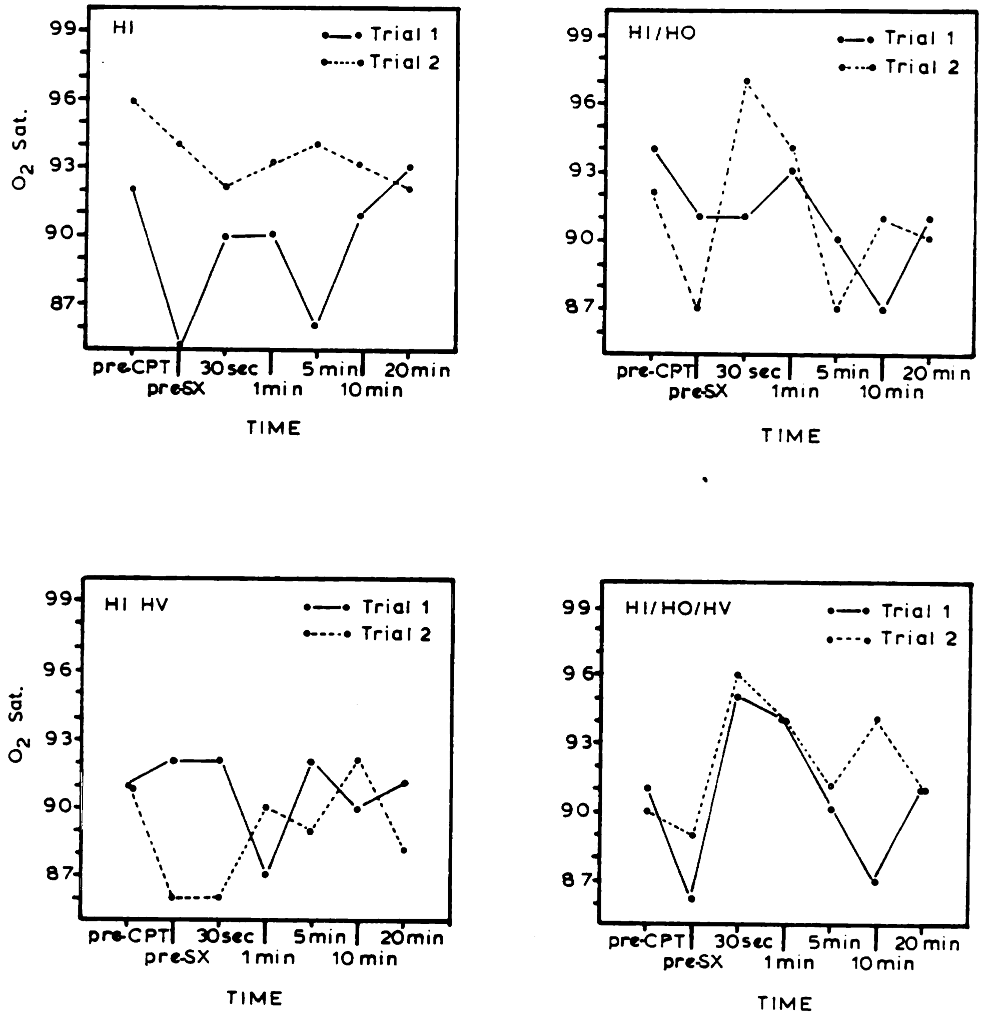

Figure 4.4

Comparison of Trial 1 & 2 (Subject 4)

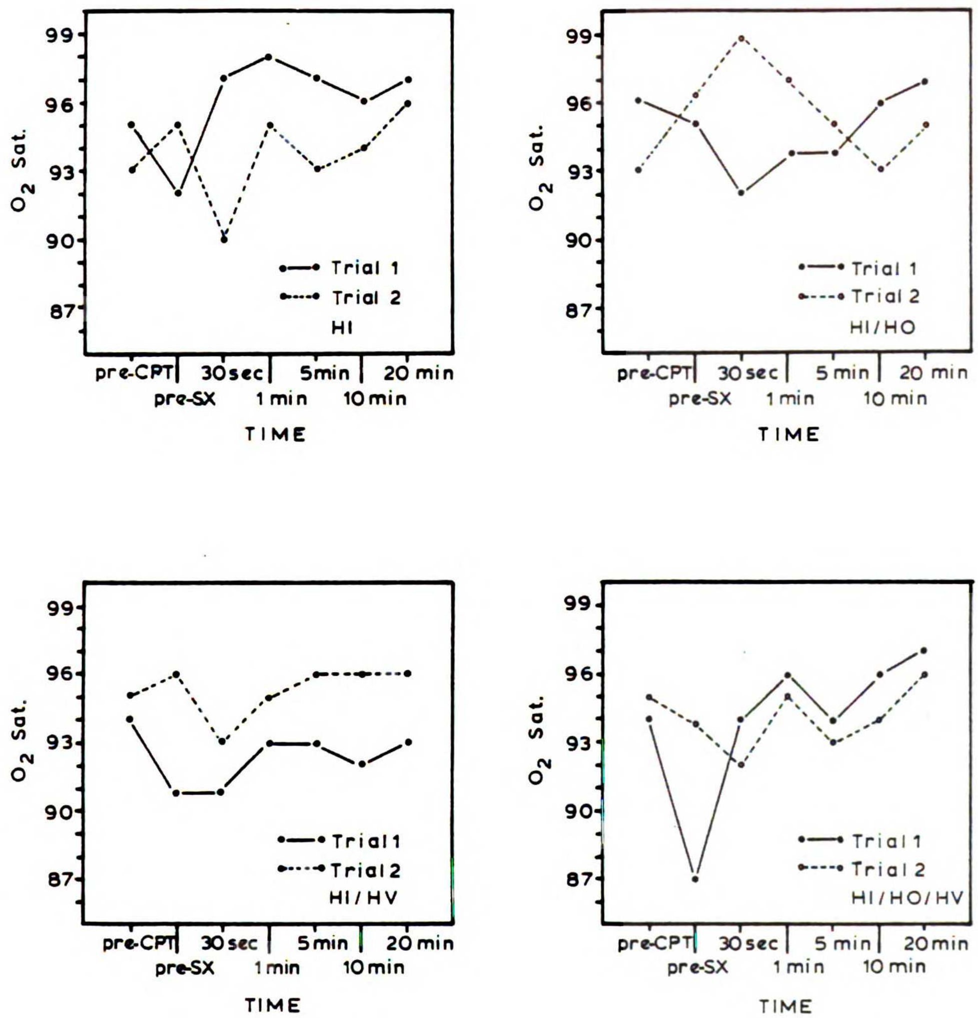

Figure 4.5

Comparison of Trial 1 & 2 (Subject 5)

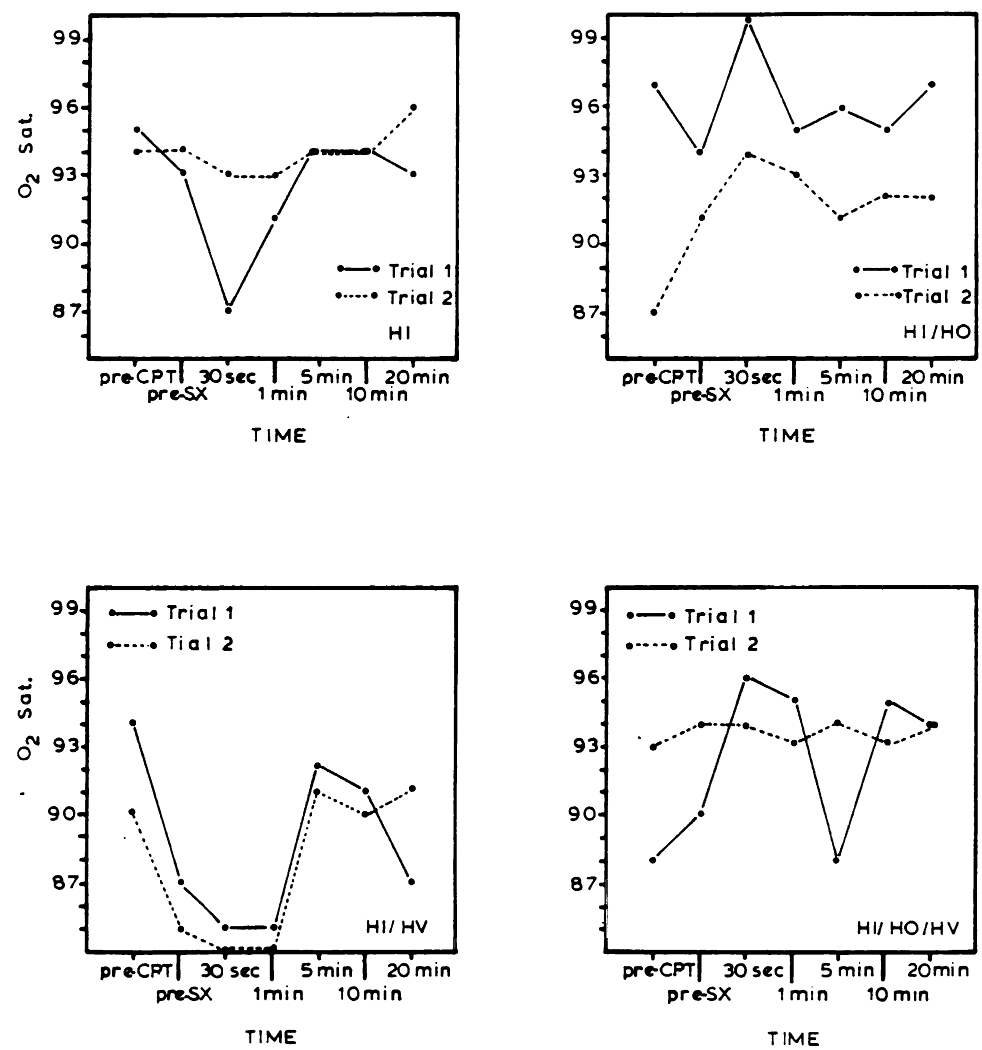

Figure 4.6

Comparison of Trial 1 & 2 (Subject 6)

CHAPTER FIVE

DISCUSSION

The purpose of this study was to determine if there is a combination of hyperinflation, hyperoxygenation and/or hyperventilation that will minimize oxygen desaturation in children two years of age or less who require chronic respiratory support. According to this study, the effects of tracheal suctioning on this population of children are unpredictable and variable. All trials utilizing pre- and post-suctioning treatments with hyperinflation alone or in some combination with hyperventilation and/or hyperoxygenation prevented significant oxygen desaturation following tracheal suctioning. No technique could be shown to be superior to another, or in fact, could even be repeated with consistent results. This is the first study which has attempted to repeat study trials on the same subjects. A change in the subject's clinical status between individual trials may have altered study results. Other similar studies did not include repeated trials and there is a possibility that their results would have been variable as well.

There are several factors in this patient population which may help to explain these results. The study was conducted at the Children's Hospital of Philadelphia and hyperinflation is the standard of care as a pre-suctioning technique, therefore, it was performed on all subjects. This may have prevented serious desaturation. Hyperinflation has been shown to improve oxygenation in subjects that had some degree of atelectasis (Brandstater and Mullam, 1968).

Morray, Fox, Kettrick and Downes (1982) studied nine patients with severe bronchopulmonary dysplasia and found that patients who were seven months of age or older and in the resolution phase of their disease had improved lung compliance, pulmonary resistances, and increased chest wall strength. As lung function improved there was less dependency on respiratory care and perhaps less sensitivity to suctioning as in those who were more acutely ill. This could explain the overall lack of significant desaturation with suctioning observed, as most of the children in this study were in the stage of resolution described by Morray et al. (1982).

The lack of reproducibility in this study may be explained by the many changes in any one patient's clinical condition over the one month period of time that the study was performed. Many of the children contracted a viral respiratory infection during the study. This may have affected their lower respiratory tract and affected secretions and oxygenation. Many were febrile from these infections as well as from a breakdown in the air conditioning system in the Intermediate Intensive Care Unit when the outside temperatures were in the 90's. Increased body temperature will cause a shift to the right in the oxyhemoglobin dissociation curve. At a given oxygen tension the saturation will be lower (Mines, 1982). Increased body temperature will lead to increased oxygen consumption due to an increased metabolic rate further stressing a child with compromised cardiopulmonary function (Guyton, 1981).

Desaturation to approximately 75% was observed during chest physiotherapy in some patients. Much of the literature supports the fact that chest physiotherapy is necessary in those populations that have increased secretions such as cystic fibrosis, atelectesis or pneumonia (Walters, 1979; MacKensie, Shin,& McAslan, 1978; Hammon & Martin, 1981). Connors, Hammon, Martin, and Rogers (1980) observed that those patients who did not produce sputum and did receive chest physiotherapy had a significant decrease in arterial oxygenation. This investigator did not record the amount of secretions retrieved during suctioning for the subjects studied. Thus, while a lack of significant secretions may have contributed to the desaturation that occurred during chest physiotherapy, the data is not available to substantiate this.

A major flaw in the conceptual perspective of this study was the omission of chest physiotherapy as a major intervening variable. The most appreciable change in oxygenation was observed after chest physiotherapy and this was a variable that should have been better controlled. The investigator recommends that if this study were to be repeated or any similar study that the protocol be performed by only one person and this person be reassessed periodically for standardization.

Hypoxemia is often associated with chest physiotherapy, possibly due to ventilation - perfusion mismatch. Events leading to ventilation - perfusion mismatch may be: (1)secretions once in the small airways converging in the large central airways thus reducing ventilation, (2) bronchospasm, and (3) lung compression with chest percussion that may cause the airways to narrow or even closure of the small airways (Connors, et al.,1980). These effects are superimposed on small airway closure already present due to the patient's diagnosis and presence of an additional infectious process (Tecklin, 1981). Prolongation of chest physiotherapy certainly could aggrivate these factors mentioned above. All nurses performed the technique of percussing all lobes of the lungs, but the time element was different for each operator. Operator performance time for chest physiotherapy ranged from approximately three to ten minutes.

Finer and Boyd (1978) in their study of 20 newborns with respiratory distress found a significant increase in oxygenation after postural drainage and percussion. Their analysis of oxygenation was made midway through and fifteen minutes after the completion of postural drainage and percussion. It is possible that desaturation was not detected because of the intermittent nature of blood gas analysis.

It was difficult to generalize from the subject population used in this study (N = 7). It was a small population, and inferential statistics were limited. There were also no other studies that dealt with this particular population for comparison. The investigator recommends that a larger population be used from several institutions to obtain more cases and increase the power of statistical tests used for analysis.

It must also be noted that one subject did not have pulmonary disease as did the other six subjects, but required chronic respiratory support for a congenital myopathy. The manuevers performed may have affected this subject differently from the others, and elimination of this subject from the data analysis may have changed the results statistically. One example of this would be the administration of positive pressure during hyperinflation. The extent to which positive transpulmonary pressure is transmitted to the heart and great vessels depends on lung and thoracic compliance. (Cassidy, Eschenbacher, Robertson, Nixon, Blomqvist, & Johnson, 1979; Qvist, Pontoppidan, Wilson, Lowenstein, & Laver, 1975). The child with the myopathy would have had the most compliant chest wall and lungs in the group and thus the greatest transmitted pressure with hyperinflation. Positive pressure transmitted to the heart and great vessels may decrease cardiac output and venous return. The extent of this effect would again be variable as the children with lung disease may have had some degree of pre-existing cor pulmonale which would cause an increase in right ventricular filling pressure and volume (Cassidy, et al., 1979; Downs & Douglas, 1980). In addition, hyperinflation may cause a reflex cardiac depression mediated by the stimulation of lung stretch receptors (Robotham, Lixfeld, Holland, Macgregor, Bromberger-Barnea, Permatt, & Robinson, 1980).

There were technical problems that prevented the study from being as tightly controlled as the investigator would have liked. Different nurses performed the suctioning, the study techniques, as well as the chest physiotherapy. It was difficult to change the operator performance to meet the study protocol. Hinshaw (1981) validated this difficulty in the clinical area.

It was difficult to control for the pressure and rate exerted on the the Mapleson anesthesia bag by the operator during the study trial. On occasion, the pressures were exceeded for one breath and the nurse needed to be reminded of the pressure limits. The investigator had to count each breath for the nurse performing the trial to ensure that proper ventilatory rate was administered.

Two ways of preventing the above variables would be to have a preoxygenated ventilator attached to a three way stopcock set. When the trial was ready to begin the investigator would only have to turn the stopcock on and off at the appropriate times. If a ventilator was not available the investigator suggests that a metronome be used for respiratory rate counting and a pressure limiting device be placed on the pressure manometer to prevent pressure limits from being exceeded.

The ratio of the suction catheter size to tracheostomy size in one patient exceeded the recommendations by Rosen and Hillard (1962). These recommendations have been discussed in a previous chapter. Turner (1983) stated that it is common practice in the neonatal population to use a larger catheter for adequate suction removal. To control the study more effectively, future investigators could choose only patients with the same O.D./I.D. ratio. This investigator opted to utilize the larger catheter for more efficient secretion removal because the subject occassionally was cyanotic during suctioning and the goal was to remove secretions quickly and efficiently.

The objective measure of oxygenation in this study was the determination of oxygen saturation by a recently developed pulse-oximeter. Oximetry, however, is not a new concept and dates back to 1934 when arterial oxygen content measurement utilizing a photoelectric technique was devised. It was adapted during World War II to advise high altitude pilots that supplemental oxygen was necessary to maintain their arterial oxygenation (Stephen, Slater, Johnson, & Sekelj, 1951).

The pulse oximeter contains two low intensity light emitting diodes and a photocell detector (Appendix C). The absorbances of two wavelengths of light are used to calculate the percentage of oxygenated hemoglobin, and the oxygen saturation is displayed via a digital readout (Wood, Sutterer, & Cronin, 1960). The sensor is wrapped over a distal extremity like a bandaid dressing. Because the sensor contains no heat, the possibility of a heat burn on the patient is eliminated.

The reliability and validity was tested by Swedlow and Stern (1982). Repeated measures from 23 children (who were hospitalized for various reasons) ages one day to 16 years of age were obtained. These measures were compared to data obtained from simultaneous blood samples analyzed for oxyhemoglobin concentrations with an Instrumentation Laboratory (IL) 282 Co-oximeter. They found a linear correlation between the two readings (r = 0.95). Yelderman and New (1983) also performed clinical trials on 79 pooled data points from five healthy adolescent subjects. A significant correlation (r = 0.98) was found between the oximeter oxygen saturation and oxyhemoglobin concentration measured by an IL 282 Co-oximeter.

The oximeter posed some technical difficulties for data collection. At the time of the study, it was not possible to obtain a continuous hardcopy paper readout. The digital display had to be read by the investigator at time intervals designated in the study as well as monitored visually at all times. The sensor was, on occassion, difficult to keep on a particularly active child.

The activity of the children must be taken into account. Several children were relatively immobile such as the child with congenital myopathy. Four other children were tethered to feeding tubes and intravenous lines in addition to the ventilator tubing and rendered immobile in the bed except to kick and turn their heads. The remaining two children in the study population were quite active. They could move freely in bed and had rolling chairs to move about when out of bed. Activity level should be controlled in future studies to see if activity influences oxygenation.

Technical skills, due to their complexity, often take priority over the patient's clinical status. Some individuals performing the skill are so involved in the skill itself that patient observation may be neglected (i.e. the presence of cyanosis or arrhythmias). In the specific example of tracheal suctioning, oximetry can act as an objective clinical indicator of the patient's oxygenation status. This may alert the caregiver to an early deterioration in the patients oxygen saturation so that the appropriate intervention may be instituted, possibly averting a serious complication.

On the negative side, monitoring leads to another step in the suctioning procedure. This increases the demand on nursing time and knowlege. This complexity of care must be looked at closely in view of reimbursement under the Diagnostic Related Group (DRG) payment scale. The current trend appears to be toward nurses performing the function that was once the role of the respiratory therapist. Any increased burden on the nurse must be justified (E.D. Lafferty, personal communication March 13,1984).

Improved technology is the trend of the future. Nurses will be expected to be proficient in its use as well as allow for the time necessary for its application and maintainence. We must look at these technologies very carefully to determine if they are useful, time- worthy and cost-effective.

Physiological parameters are important for assessing our therapies. Chest physiotherapy and tracheal suctioning have great impact on physiological parameters and have the potential for life threatening complications. Non - invasive monitoring allows researchers to study these parameters in the clinical area and make recommendations for the best care that we can provide to our patients. Despite the fact that there were no "best method" conclusions from this study, the data presented can provide a baseline for future studies.

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APPENDIX A

THE CHILDREN'S HOSPITAL OF PHILADELPHIA
NURSING PROCEDURE MANUAL

STERILE SUCTIONING PROCEDURE

I. INDICATION:

To be performed when suctioning a tracheostomy, nasotracheal tube or orotracheal tube.

II. PURPOSE:

A. To maintain a patent airway.

B. To maintain sterility of the tracheo-bronchial tract.

C. To remove secretions.

D. To promote adequate oxygenation.

III. EQUIPMENT:

A. Wall suction unit with container and connecting tubing.

B. Sterile tracheo-bronchial suction catheters of appropriate size (infants 6F - 8F, children 8F - 14F).

C. Sterile disposable gloves.

D. Normal saline in disposa-vials.

E. Dixie cups

F. 1000 ml bottle of normal saline.

IV. NURSING RESPONSIBILITIES:

A. Explain the procedure to the patient and/or family.

B. Request assistance to restrain child, if necessary.

C. Ensure all necessary equipment is functioning and at the bedside.

D. Be familiar with the hyperinflation procedure, 5:4:f.

E. Perform the procedure using aseptic technique.

IV. NURSING RESPONSIBILITIES: (cont'd)

F. Suction the patient when necessary.

G. Record observations in the nursing progress notes.

V. PROCEDURE:

A. Wash hands.

B. Assemble necessary equipment at bedside.

C. Turn tracheal suction on. Pressure should range from 80 mmHg for neonates to 120 mmHg for older patients.

D. Pour saline from 1000 ml. bottle into one dixie cup.

E. Attach sterile suction catheter to connecting tubing of tracheal suction bottle, leaving wrapper on the catheter without contaminating catheter.

F. Open sterile disposable glove package.

G. Auscultate breath sounds.

H. Instill normal saline solution from disposa-vial into artificial airway - hyperinflate as ordered.

I. Put on sterile glove. Remove sterile catheter from wrapper, grasping sterile suction catheter with gloved hand.

J. Insert tracheal suction catheter into artificial airway until resistance met. Pull back 1-2 cm. and then apply suction. Suction with a rotating movement of the catheter, not up and down while removing the catheter.

K. Allow patient to take several deep breaths between suctioning attempts or place on appropriate respiratory equipment. Each suctioning attempt should last only 5 to 10 seconds.

L. After suctioning, remove and discard sterile glove and suction catheter.

M. Rinse connecting tube in dixie cup with saline until clear of secretions.

N. Discard dixie cup with saline after single use.

O. Turn suction off (In the Intensive Care and Infant Transitional Units, the suction will remain on).

V. PROCEDURE: (cont'd)

P. Auscultate for breath sounds.

Q. Wash hands.

VI. DOCUMENTATION:

A. Record the number of times suctioning required; the amount, color, odor, and consistency of secretions.

B. Record how procedure was tolerated by the patient; notify physician if patient does not tolerate the procedure.

VII. SPECIAL NOTES:

A. The suction catheter should be no larger than one-half the diameter of the artificial airway.

B. Tracheal suction pressure should never exceed 120 mmHg.

C. Suction should only be applied upon withdrawal of catheter, not upon insertion.

D. Suction bottles and connecting tubing must be changed every 24 hours. Glass suction bottles are to be cleaned out and then sent to Supply Purchasing and Distribution Department for further cleaning and sterilization. Plastic suction bottles must be changed and discarded in the dirty utility room.

E. Connecting tube should be kept clean at the bedside and secured so it will not fall onto the floor. Never open the suction catheter package and connect to tubing after suctioning in preparation for future suctioning. Suction catheter package should only be opened immediately prior to suctioning.

APPROVED BY: Charlotte C. Welch

TITLE: DIRECTOR OF NURSING

DATE: May 1, 1981

Nursing
Written: 3/77
Revised: 7/78
4/81

THE CHILDREN'S HOSPITAL OF PHILADELPHIA

Nursing Procedure Manual

PROCEDURE FOR HYPERINFLATION

I. PURPOSE:

A. To increase the oxygen concentration in the alveoli.

B. To increase inspiratory airway pressure and aid in expansion of collapsed alveoli.

C. To enhance the distribution of saline in the airway prior to chest physiotherapy.

II. EQUIPMENT:

A. Mapleson connected to oxygen flow meter via rubber tubing.

B. Stethoscope

C. Swivel and swivel stopper for the patient with a tracheostomy.

III. PHYSICIAN RESPONSIBILITIES:

A. Write order for frequency that procedure is to be done.

B. Write order for concentration of oxygen if blender is being used.

IV. NURSING RESPONSIBILITIES:

A. Eligibility to attend required classes to learn Hyperinflation procedure.

1. Registered Nurses assigned to the Intensive Care Units will learn and be supervised in carrying out this procedure during their orientation to the unit.

2. Registered Nurses assigned to the Infant Transitional Unit will be eligible three months after employment or as determined by Head Nurse.

3. All Registered Nurses employed on remaining units will be eligible for classes six months after employment.

B. Attend Required Classes:

Anatomy and Physiology of Respiratory Tract

Acid-Base Balance

Practice Sessions and Supervision of Procedure Using Mannequins.

C. The first time this procedure is done on a patient the Registered Nurse must be supervised by a Staff Education Instructor, Supervisor, or Head Nurse.

V. Procedure for Hyperinflation

A. Have Mapleson attached to oxygen at correct flow rate.

Flow rate for Mapleson: 500 ml bag - 5 liters
1000 ml bag - 10 liters
2000 ml bag - 15 liters

B. Disconnect all respiratory therapy equipment in use from the patient.

C. Check Expiratory Valve on Mapleson to make sure it is open and attach Mapleson to endotracheal tube.

or

If patient has a tracheostomy place swivel stopper in opening of swivel, attach Mapleson to end of the corregated tubing attached to swivel.

D. Adjust expiratory valve on Mapleson to allow for adequate ventilation of patient and proper filling of reservoir bag. Expiratory valve of Mapleson is never to be completely closed.

E. Ventilate patient for five to ten breaths at his normal respiratory rate.

F. Evaluate breath sounds with stethoscope during hyperinflation to check for adequate aeration.

G. Instill appropriate amount of saline into artificial airway.

H. Ventilate patient for five to ten breaths at his normal respiratory rate to distribute saline.

I. Suction artificial airway.

J. Ventilate patient for five to ten breaths at his normal respiratory rate to increase oxygen concentration.

K. Listen to breath sounds with stethoscope during hyperinflation to evaluate for effectiveness of procedure.

L. Disconnect Mapleson from endotracheal tube

or

If patient has a tracheostomy tube disconnect Mapleson from tubing attached to swivel and remove swivel stopper.

M. Reconnect patient to respiratory therapy equipment.

N. Cover Mapleson with clean glove wrapper from glove used in suctioning or wrapper from sterile 4 x 4.

VI. Procedure for Hyperinflation with Percussion and Postural Drainage.

A. Follow steps A through H from the above procedure.

B. Disconnect Mapleson from endotracheal tube or from the swivel on a patient with a tracheostomy and remove swivel stopper. Reconnect patient to respiratory therapy equipment.

C. Begin Percussion and Postural Drainage (see Procedure 5:4:d).

D. After Percussion and Postural Drainage and suctioning, disconnect patient from respiratory equipment and attach Mapleson.

E. Follow steps J through N from the above procedure.

VII. Special Notes

A. Signs to determine proper technique for Hyperinflation:

1. Breath sounds will be audible in lung fields (this is most important.)

2. Expansion of thoracic cavity will be visible.

3. Child will be relaxed during procedure.

4. Color of child will remain constant or improve.

B. If Mapleson becomes contaminated, e.g., falls on floor, obtain replacement from Respiratory Therapy Department.

C. Mapleson's should be changed by Respiratory Therapy Department once a week.

VIII. Charting is to include:

A. Evaluation of breath sounds before and after the procedure.

B. Reactions of child to procedure.

C. Color, odor, amount and consistency of secretions obtained.

Nursing Service
Written: 6/75
Revised: 1/79

APPROVED BY: [illegible] RN

TITLE: Associate Pres. for Patient

DATE: 8-[illegible]-79

THE CHILDREN'S HOSPITAL OF PHILADELPHIA FOUNDED 1855
ONE CHILDREN'S CENTER, 34th STREET & CIVIC CENTER BOULEVARD, PHILADELPHIA, PA. 19104 • (215) 596-9400

THE JOSEPH STOKES, JR. RESEARCH INSTITUTE

KLAUS HUMMELER, M.D.
Director

June 24, 1983

Sandra Feaster, R. N., B. S. N.
712 Harbor Road
Alameda, CA 94501

Dear Mrs. Feaster:

Your protocol entitled "What is the Effect of Hyperinflation, Hyperventilation, and Hyperoxygenation on Minimizing Oxygen Desatūration Following Endotracheal Suctioning as Measured by a Continuous Non-Invasive Pulse-Oximeter?" was reviewed by the Committee for Protection of Human Subjects on Wednesday, June 15, 1983.

The Committee voted, unanimously, for approval with no consent form necessary.

Thank you for your cooperation with this Committee.

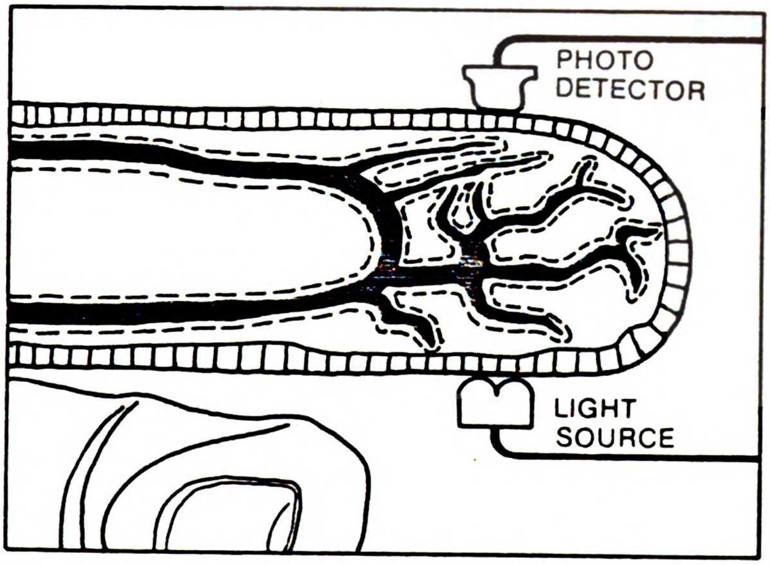
Yours sincerely,

Dolly Saget

Dolly Saget, Coordinator
Committee for Protection
of Human Subjects
Office of Research Administration

cc: David B. Swedlow, M. D.

APPENDIX C



Pulse - Oximeter Sensor

APPENDIX D

Pt. code # Date:
Dx: Unit:
Age: RN Suctioning:
Wt:
Ht: Hb:
Meds:

Tracheostomy _____ mm. ______ Fr.
Suction Catheter Size: _______ Fr.
Amount of NSS instilled _________cc (0.05ml/kg)

RESPIRATORY SUPPORT

How long has pt. required support: _____days _____weeks _____ > 1 month

Ventilator Settings:
FiO2: IMV: PEEP: PIP: TV:

Activity: _____active ______sleeping _____crying _____paralyzed _____other

Suction pressure:_________mmHg
Suction flow: ___________L/min.
Mapleson Bag (Size & flow):_________

TRIAL

Trial #
Trial method: HI; HI/HO; HI/HV; HI/HO/HV

Times	SaO2	Heart Rate
Pre CPT		
Pre Method (15 sec before sx)		
Post sx: 30 sec		
1 min		
5 min		
10 min		
20 min		

Adverse effects:

Heart rhythm:

Site of oximeter:

Other comments: