THE UNIVERSITY OF ALBERTA

INFANT RESPONSES TO SALINE INSTILLATIONS

BY

(C) David Russell Shorten

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF NURSING.

FACULTY OF NURSING

EDMONTON, ALBERTA

SPRING 1988

ISBN 0-315-42722-1

THE UNIVERSITY OF ALBERTA

RELEASE FORM

NAME OF AUTHOR: David Russell Shorten

TITLE OF THESIS: Infant Responses to Saline Instillations

DEGREE: Master of Nursing

YEAR THIS DEGREE GRANTED: 1987

.... (Student's signature)

3826 13 St. S.W.
Calgary, Alberta,
T2T 3R3
(Student's permanent address)

Date: November 6, 1987

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled "Infant Responses To Saline Instillations" submitted by David Russell Shorten in partial fulfilment of the requirements for the degree of Master of Nursing.

....
(Supervisor)

....

....

Date: Oct 30th 1987

To my wife Kathleen for her love and support

Infant Responses To Saline Instillations

David Shorten

University of Alberta

ABSTRACT

Endotracheal suctioning of intubated neonates is necessary to maintain airway patency. Possible harmful physiological effects resulting from tracheal suctioning include: hypoxemia, pneumothoraces, changes in heart rate, and increases in blood pressure and intracranial pressure. Instillation of normal saline into the tracheal tube during the suctioning procedure, to facilitate liquifying of secretions, is a common practice in neonatal intensive care units. There is little information known regarding the effects or effectiveness of instillations on neonates. The purpose of this study was to examine the effects of normal saline instillations on neonates with respiratory distress. It is hypothesized that infants undergoing instillation with tracheal suctioning will have greater fluctuations in their physiological parameters than those undergoing tracheal suctioning alone. A completely counterbalanced factorial within subjects design was used for this study to compare two treatment levels (instillations, no instillations) and 13 time periods in 9 phases. A convenience sample of 25 intubated, neonates with respiratory distress were randomly assigned to two orders of presentation of treatment conditions. Half of the infants received " no instillation " first followed by the " instillation " condition. The other half of the infants received the reverse order of conditions. The treatment conditions were separated by a period of two to four hours, depending on the infant's regular schedule. Data were collected on: heart rate, blood pressure, intracranial pressure and blood oxygenation. The tests of hypotheses considered important in determining the effect of saline instillations were the test of the main effect of treatment and especially the interaction of treatment and time. Neither of these hypotheses was supported in the data analysis. Saline instillations did not produce statistical or clinically significant effects on the physiological parameters studied. Thus, the infants tolerated saline instillations of between 0.25 and 0.5 cc without apparent adverse effects. The analysis of changes in physiological parameters over time without regard for treatment condition, indicated significant variations in heart rate and blood pressure over time. These fluctuations were attributed to agitation arising from the tracheal suctioning procedure. The implications of these findings on future research and for nursing were discussed.

ACKNOWLEDGEMENT

Many people were involved in the production of this thesis, to whom I am grateful. I have learned that conducting research involves many disciplines!

A special thanks to the members of my committee, Dr. J. Lander (chairman) for her counsel and patience, Dr. P. Bryne for his enthusiasm and understanding, and Dr. R. L. Jones for his advice and support.

I would also like to thank the behind the scene people who helped to get the practical aspects ironed out. Specifically to Ion Buiciu (computer programming), Alex Sackiw (biomedical technology) and Kathy Peters from the Royal Alexandra's Neonatal Research Lab for the use of the Ladd intracranial pressure monitor.

I would also like to thank Dr. D. Schiff and Mrs B. Hayward for their support of my research in the University of Alberta Hospitals Neonatal Intensive Care Unit. Last, but certainly not least, a big thank you to the neonatal nurses and respiratory technologists who were involved in data collection.

This study was partially funded by the Alberta Foundation For Nursing Research.

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Infant Responses to Saline Instillations

Over the past 25 years, knowledge has expanded greatly in neonatology and has led to a refinement of health care delivery. As a result, the mortality rate among premature infants has decreased significantly. The increase in knowledge has also led to the development of many technological procedures. One of these is the establishment and maintenance of the artificial airway for ventilation purposes. A recent review of endotracheal suctioning literature (Appendix A), revealed that tracheal suctioning of the ill neonate is not a benign procedure. Instillation of normal saline prior to tracheal suctioning has commonly been thought to be necessary to assist in liquifying and facilitating removal of secretions from the tracheobronchial tree. The present study will focus on the physiological effects that intratracheal normal saline instillations have on the neonate with respiratory distress.

Tracheal suctioning is a nursing procedure that is considered necessary in caring for the intubated infant. The positive effect of tracheal suctioning is that it enhances removal of airway secretions. In this way, suctioning helps to prevent airway obstruction and facilitate gas exchange. Unfortunately, several negative effects of tracheal suctioning of the neonate have been documented. These include: hypoxemia and pneumothoraces, changes in heart rate and blood pressure, and increases in intracranial pressure.

Hypoxemia, a decrease of oxygen tension in the blood, is one of the most common negative effects encountered during tracheal suctioning (Cunningham, Baun, & Nelson, 1984; Peters, 1983; Zmora & Merritt, 1980). Throughout the tracheal suctioning procedure there are many potential contributors to the development of hypoxemia. Removal of the infant from the ventilator and hence his oxygen source for suctioning will, in itself, contribute to hypoxemia (Cabal et al., 1979; Cassani, 1984; Norris, Campbell, & Brenkert, 1982; Peters, 1983; Zmora & Merritt, 1980). Another potential contributor to hypoxemia is development of areas of atelectasis within the lungs (Brandstater & Muallem, 1969). Atelectasis may lead to intrapulmonary right to left shunting, a condition which occurs in areas of the lung that are not ventilated but have blood flow. This results in blood returning to the systemic circulation without being oxygenated. Factors related to the procedure, such as the duration of applied suction and suction pressure may also affect the degree of hypoxemia (Fox, Schwartz, & Shaffer, 1978; Simbruner et al., 1981; Thibeault & Gregory, 1979; Young, 1984). Severity of disease (Cunningham et al., 1984; Simbruner et al., 1981) and handling of the infant during suctioning (Murdoch & Darlow, 1984; Norris et al., 1982; Tomney, 1980) may also contribute to hypoxemia.

A second general negative effect of tracheal suctioning is that the procedure may result in cardiovascular changes. There may be a decrease in heart rate (Cabal et al., 1979; Cabal, Siassi, Blanco, Plajstek, & Hodgman, 1984; Cunningham et al., 1984; Fanconi & Duc, 1987; Simbruner et al., 1981; Zmora & Merritt, 1980), sometimes leading to bradycardia (heart rate less than 100 beats per minute). A decrease in heart rate may be the result of vagal stimulation and initiation of the cough reflex. Both of these reactions cause a decrease in cardiac output. Tracheal suctioning may also result in episodes of tachycardia during suctioning (Peters, 1983) due to sympathetic nervous system stimulation which likely is the result of the infant struggling during the procedure.

Another consequence of suctioning is an increase in blood pressure (Fanconi & Duc, 1987; Perlman & Volpe, 1983; Peters, 1983; Simbruner et al., 1981). This effect may be due to hypoxemia (Perlman & Volpe, 1983) and to infant struggling. Associated with increases in blood pressure is a rise in intracranial pressure (Fanconi & Duc, 1987; Perlman & Volpe, 1983; Peters, 1983). The increases in intracranial pressure and blood pressure may play a role in the pathogenesis of intraventricular hemorrhage in the preterm infant (Perlman & Volpe, 1983; Peters, 1983).

Handling of the infant is necessary throughout the suctioning procedure but infants do not tolerate handling well, as indicated by significant drops in transcutaneous oxygen partial pressure tension (TcPO2) readings (Danford, Miske, Headley, & Nelson, 1983; Dangman, Hegyi, Hiatt, Indyk, & James, 1976; Long, Philip, & Lucey, 1980; Murdoch & Darlow, 1984; Norris et al., 1982; Tomney, 1980). Handling may also result in the infant struggling which leads to increases in heart rate, blood pressure and intracranial pressure (Peters, 1983). Handling of the infant throughout the suctioning procedure may be responsible for some of the detrimental effects of suctioning reported in the literature.

As previously mentioned, factors within the suctioning protocol may affect the infant's physiological responses to the procedure. In addition, pneumothoraces resulting from perforation of the lung by the suction catheter have been reported (Anderson & Chandra, 1976; Vaughan, Menke, & Giacoia, 1978). Endotracheal suctioning may also predispose infants to infection (Storm, 1980), despite aseptic technique.

Suctioning protocols differ widely as is evident from those used in research and recommended in textbooks (Appendix B). Areas of difference include: duration of applied suction, suction pressure and strategies to prevent hypoxemia. The duration of applied suction corresponds to the time the infant is disconnected from the oxygen source. Both duration of applied suction and suction pressure will affect the amount of alveolar gases suctioned out of the lungs (Rux & Powaser, 1979) and contribute to atelectasis (Brandstater & Muallem, 1969). Both of these factors may decrease the infant's arterial PO2. The longer the suction is applied and the higher the suction pressure, the more the likelihood of hypoxemia. In order to overcome the negative effects of suctioning, various protocols have employed the use of preoxygenation (Barnes, Asonye, & Vidyasagar, 1981; Cabal et al, 1979; Cabal et al., 1984; Cunningham et al., 1984), hyperinflations (volume) (Brandstater & Muallem, 1969) and hyperventilation (rate) (Cabal et al., 1979; Fox et al., 1978; Raval, Mora, Yeh, & Pildes, 1980; Zmora & Merritt, 1980).

Measurement of physiological parameters are often employed in clinical research, since they provide reliable information of the patient's physical state. Heart rate, blood pressure, TcPO2, and transcutaneous oxygen saturation (TcSaO2) may also be used routinely for monitoring ill infants in the neonatal intensive care unit.

Heart rate and blood pressure are indicators of circulatory system functioning. The circulatory system plays a vital role in physiological homeostasis as it transports food, oxygen and other essential components to the cells. The heart is responsible for pumping sufficient amounts of blood to meet the requirements of cellular metabolism. Blood circulates in the body because of the existence of a blood pressure gradient between arterial and venous areas of the circulatory system (Anthony & Kolthoff, 1971). Blood pressure is determined by arterial blood volume, cardiac output and peripheral resistance.

Cardiac output, the amount of blood pumped out of the left ventricle each minute, depends on heart rate and the amount of blood pumped with each contraction (stroke volume). The premature infant cannot adjust stroke volume as well as adults can, due to immaturity of sympathetic innervation (Teitel, Heymann, & Liebman, 1986). Therefore, the infant increases cardiac output by increasing heart rate.

The heart is controlled by both sympathetic and parasympathetic innervation. Sympathetic (accelerator nerves) increase heart rate, whereas parasympathetic (inhibitory nerves) decrease heart rate. Both systems respond to chemoreceptor and baroreceptor reflexes which are designed to maintain circulatory oxygen pressure and perfusion pressure (Smith & Nelson, 1976). Stimulation of chemoreceptors by hypoxemia and baroreceptors by a decrease in blood pressure, may lead to tachycardia. On the other hand, direct parasympathetic stimulation through the vagus nerve, by oral or endotracheal suctioning or insertion of a gavage tube, may cause bradycardia.

The majority of neonatal problems stem from respiratory distress, so monitoring blood oxygenation is essential in caring for these infants. Arterial blood gases are the most reliable method of assessing oxygenation by direct arterial PO2 measurement. Unfortunately, blood sampling is intermittent and does not allow for continuous monitoring of oxygenation. Additionally, infants do not always have an arterial catheter insitu to provide access for repeated arterial blood gases. Transcutaneous oxygen partial pressure monitoring became a routine procedure in neonatal intensive care units since its development in the early 1970's. The advantage of this form of continuous monitoring is that it is possible to detect any changes in the infant's oxygenation within seconds. It also makes it possible to adjust more exactly, oxygen supply and other forms of therapy (Finer & Stewart, 1980). When applied correctly, TcPO2 monitors have shown high correlation coefficients with PaO2, suggesting that this method yields reliable measures of oxygenation. Correlation coefficients have consistently ranged between 0.86 (Pollitzer, Morgan, Reynolds, Soutter, & Parker, 1979) and 0.98 (Peabody, Willis, Gregory, Tooley, & Lucey, 1978) over a wide range of infants with different diagnoses.

The use of pulse oximetry to measure arterial oxygen saturation is relatively new to neonatology. Pulse oximetry is a noninvasive, transcutaneous method for monitoring arterial oxygen saturation and pulse rate using a sensor on an extremity. Correlation coefficients comparing arterial oxygen saturation and TcSaO2 range from 0.89 (Anderson, Claflin, & Hall, 1985) to 0.95 (Fanconi, Doherty, Edmonds, Barker, & Bohn, 1985).

Monitoring intracranial pressure during tracheal suctioning will assess the infant's intracranial pressure response to the procedure. Elevated intracranial pressure has been reported in preterm infants on the second day of life and may be related to hypoxia (Donn & Philip, 1978). It is possible that increases in intracranial pressure may play a part in causing intraventricular hemorrhages in preterm infants. The etiology of intraventricular hemorrhage has not been fully elucidated but is strongly associated with events causing hypoxemia, such as respiratory distress and asphyxia and since suctioning causes hypoxemia it is possible that the procedure could cause increased intracranial pressure. Intraventricular hemorrhage, a common problem in preterm infants, may lead to death (Milhorat, 1981). Traditionally, clinicians discerned gross changes in intracranial pressure by observing tension in the anterior fontanel. However, variation in the size and fullness of the fontanel makes accurate prediction of intracranial pressure difficult with this method (Philip, 1979). More accurate but invasive methods of measuring intracranial pressure (such as cerebral spinal fluid pressure) are not indicated for routine clinical management of ill infants because the infant is often unstable and does not generally tolerate the lumbar puncture. An accurate but noninvasive method uses a fiberoptic sensor on the anterior fontanel (Ladd Research Industries, Burlington, Va.). This method has yielded a correlation coefficient between cerebral spinal fluid pressure and anterior fontanel pressure of 0.95 (Vidyasagar & Raju, 1977).

The arterial-Alveolar oxygen partial pressure ratio (a/APO2) is a reliable indicator of gas exchange. The Alveolar-arterial oxygen partial pressure difference (A-aDO2) is also widely used as an index of gas exchange but has the disadvantage of changing as percent inspired oxygen concentration changes (Gilbert, Auchincloss, Kuppinger, & Thomas, 1979). In normal lungs and when pulmonary shunting predominates or when ventilation perfusion (V/Q) imbalance predominates, A-aDO2 rises as percent inspired oxygen rises, whereas a/APO2 remains relatively stable. The relative stability of a/APO2 with changing percent inspired oxygen makes it more useful than A-aDO2, when comparing gas exchange in the same patient as percent inspired oxygen levels change (Gilbert, et al. 1979).

In summary, tracheal suctioning is associated with several negative effects. There are interrelated factors which may affect the infant's response to tracheal suctioning.

One factor, overlooked in the literature, which may influence the neonate's responses to endotracheal suction is the common practice of instilling saline during the suction procedure. That instillations are a routine practice in many neonatal intensive care units is supported by the fact that the majority of neonatal researchers who examined tracheal suctioning incorporated instillations into their suctioning procedure (Barnes et al., 1981; Brandstater & Muallem, 1969; Cabal et al., 1979; Cabal et al., 1984; Fanconi & Duc, 1987; Fox et al., 1978; Perlman & Volpe, 1983; Peters, 1983; Simbruner et al., 1981; Zmora & Merritt, 1980). Instillations are thought to aid in the thinning and subsequent removal of secretions. Although instillations are commonly performed, a review of the literature failed to reveal evidence of the effectiveness or effects of this procedure on neonates. It may be that routine instillations are not necessary in order to maintain a patent airway or that instillations exacerbate the infant's temporary negative physiological responses to tracheal suctioning. It is also possible that the irritant effect of normal saline on the tracheobronchial mucosa may increase secretions.

The present investigation will examine the physiological effects of normal saline instillations on neonates with respiratory distress. It is hypothesized that infants undergoing saline instillation with tracheal suctioning will have greater fluctuations in their physiological parameters than those undergoing tracheal suctioning alone. More specific hypotheses will be presented once the procedure has been described.

Methods

<u>Subjects</u>

Based on power analysis, a sample size of 25 to 40 infants was required, assuming medium to small effect sizes. Infants in the neonatal intensive care unit meeting the selection requirements and whose parent/s consented to the infant being included in the study were chosen for the sampl~~e. Criteria for selectio~~n included:

1. having respiratory distress,
2. having endotracheal intubation (oral or nasal),
3. having an indwelling arterial catheter,
4. not requiring sedation,
5. being clinically stable (stable blood pressure and unchanged ventilator settings) and
6. having experienced tracheal suctioning on at least three prior occasions, with the last suctioning having taken place up to 2 to 4 hours earlier.

A sample of the consent form and parent information sheet is located in Appendix C.

Apparatus

Heart rate was measured using a bedside monitor (Hewlett Packard, 78801A Neonatal Monitor, Waltham, Ma) and adhesive pregelled neonatal cardiac electrodes. Mean arterial pressure was measured using a transducer (Model 4-327-I, Hewlett Packard, Waltham, MA) and a number four or five umbilical artery catheter or radial artery catheter. Transcutaneous oxygen tension was measured using a neonatal transoxode electrode (Novametrix Medical Systems Inc., Wallingford, CT.). Pulse oximetry was used to measure transcutaneous arterial oxygen saturation by use of a Nellcor monitor (Model N-100 Hayward, Calif.). Intracranial pressure was measured by a fiberoptic sensor (Model 10004, Ladd Research Industries, Burlington, Vt.) A continuous read out of intracranial pressure was displayed on a bedside monitor (Model M 1000, Ladd Research Ind. Burlington, Vt.). The readings from the equipment were recorded by a 16 channel computer recording instrument (ASM Acquisition System, University of Alberta, Edmonton, Alberta) which was programmed to sample at a rate of 10 times per second. Arterial blood gases were measured using a Corning 178 (Medfield, Mass.) analyzer. The analyzer was auto calibrated every 30 minutes.

Procedure

Infants meeting the selection criteria and whose parents had given consent were assessed during two treatment conditions: (1) tracheal suctioning - no instillation and (2) tracheal suctioning - with instillation. Half of the infants were randomly assigned to receive "no instillation" first followed by the "instillation" condition. The other half of the infants received the reverse order of conditions. The treatment conditions were separated by a period of two to four hours, depending on the infant's regular schedule.

In the neonatal intensive care unit, two people were required to perform tracheal suctioning. One nurse performed the suctioning, while another disconnected and reattached the infant to the ventilator between suctioning passes. The study protocol (including suctioning technique) was reviewed with nurses prior to the study. The protocol included measuring the suction catheter so that the tip of the catheter protruded one centimeter beyond the distal end of the endotracheal tube. Suction pressure was set at 40 mm Hg if the infant was less than 1500 grams or 60 mm Hg if the infant was greater than 1500 grams.

Approximately one hour before each data collection period, the investigator connected the monitors to the data acquisition system. The heart rate leads were checked and changed if necessary in order to obtain a clear pattern on the cardiac monitor. The blood pressure transducer was electronically calibrated at the level of the infant's heart (internal calibration is done every 3 months by a biomedical technician). The TcPO2 electrode was heated to 43.5 C., calibrated (to 0 and 144) and then applied to the skin over the chest or abdomen. If the infant was not already on a transcutaneous saturation monitor a sensor was applied by tape to either the infant's hand or foot. The intracranial pressure monitor was calibrated electronically (to zero) and the probe was attached to the infant's anterior fontannel by a "stockingette" bandage. Lastly, a time marker was connected to the acquisition system.

The two treatment conditions had in common the following sequence: baseline, preparation, suction phase I, treatment, suction phase II , suction phase III, oral suction, recovery phase I and recovery phase II. Immediately prior to the 4 minute baseline phase a pre-suction arterial blood gas was drawn by the researcher. This was analyzed within five minutes by a respiratory technologist. During the one minute preparation phase at the end of the baseline phase, the ventilator rate was increased from maintenance requirements to a maximum of 60 breaths per minute and percent inspired oxygen was increased to a maximum of 100%, both according to infant's past experience with tracheal suctioning. These increases were the same for both treatment conditions. The three identical tracheal suctioning phases which followed the baseline phase consisted of removal of the infant from the ventilator, insertion of the catheter, removal of the suction catheter from the tracheal tube with suction applied and reattachment to the ventilator for a 15 second ventilation period, where the infant was given breaths by the ventilator at the increased rate and oxygen. After suction phase I, the infant was disconnected from the ventilator for 5 seconds and administered a saline instillation or nothing, as determined by the treatment condition. After the second and third suction phase, oral suctioning was performed for 10 seconds to clear secretions. Following oral suctioning, the infant was allowed to settle and data collection continued for two 5 minute recovery phases. A post-suction arterial blood gas was taken by the researcher 20 minutes after the infant had settled and it was analyzed by the same respiratory technologist. Figure 1 illustrates the phases of both conditions.

The two conditions differed at the point of the sequence following the first suction phase, in the treatment phase. During the control condition the infants had a 5 second interval where they were not connected to the ventilator, followed by 15 seconds of ventilation. During the instillation condition, infants were

Figure 1

Sequence of Phases of the Study

P H A S E S

TREATMENT CONDITIONS	Baseline	Prepara-tion	Suction I		Treatment		Suction II		Suction III		Oral Suction	Recov-ery I	Recov-ery II
					CONTROL								
No Instillation Control Condition			suction I	venti-lation I	no venti-lation	venti-lation II	suction II	venti-lation III	suction III	venti-lation IV			
	4 min	1 min	10 sec	15 sec	5 sec	15 sec	10 sec	15 sec	10 sec	15 sec	10 sec	5 min	5 min
					INTERVENTION								
Instillation Condition					instil-lation	venti-lation							
	4 min	1 min	10 sec	15 sec	5 sec	15 sec	10 sec	15 sec	10 sec	15 sec	10 sec	5 min	5 min

disconnected from the ventilator for 5 seconds and administered a saline instillation into the tracheal tube (0.25 mls if they were less than 1500 grams or 0.5 mls if they were greater than 1500 grams), followed by 15 seconds of ventilation. Instillation was performed with a 3 ml syringe and a number five feeding catheter. The depth of insertion of the feeding tube was the same as previously described for catheter insertion. The same nurses performed both treatment conditions. The researcher was present to certify that the treatment protocol was adhered to and that monitors were calibrated and functioning properly. Tape recorded instructions specifying procedure and time of each phase were played during each condition for all subjects. Standardizing the sequence ensured that duration of suction and length of time away from the oxygen source remained constant.

Heart rate, arterial blood pressure, transcutaneous oxygen tension, transcutaneous oxygen saturation and intracranial pressure were recorded continuously during all phases of both conditions.

Design

A completely counterbalanced factorial within subjects design was used to compare two treatment levels (instillations, no instillations) and 13 time periods in 9 phases (baseline, preparation, suction phase I, treatment, suction phase II, suction phase III, oral suction, recovery phase I and recovery phase II).

Hypotheses

Three hypotheses were formulated.

1. Receiving a saline instillation with tracheal suctioning will cause significant changes in heart rate, blood pressure, intracranial pressure, TcPO2, TcSaO2 and a/APO2 compared to receiving tracheal suctioning alone (main effect of condition).
2. There will be significant changes in heart rate, blood pressure, intracranial pressure, TcPO2, TcSaO2 and a/APO2 over the 13 time periods (main effect of time).
3. There will be significant changes in heart rate, blood pressure, intracranial pressure, TcPO2, TcSaO2 at or following the treatment period (interaction effect of condition by time).

Results

Sample Characteristics

Parents of 31 infants were approached to have their infant participate in the study. Consent was obtained for 29 infants. Twenty seven infants were studied; two were excluded by data collection time because their arterial catheters had been removed. Data from two of the infants were lost due to computer failure leaving a study sample size of 25.

Table 1 describes the infants' demographic characteristics. The 25 infants were comprised of one set

Table 1.

Demographic Characteristics of Infants

Variable	Mean	SD	Minumum	Maximum
Gestational age (weeks)	32.5	3.8	25	40
Birthweight (grams)	1879	769	510	3320
Study age (hours)	91.8	47.4	18	198
Baseline oxygen required (%)	32.5	8.8	21	55
Peak Inspiratory pressure (cmH2O)	19.8	2.5	16	26
Positive End Expiratory Pressure (cmH2O)	3.8	0.79	2	6
IMV Rate (breaths/minute)	15.95	11.8	4	55
Oxygen Increase From Baseline (%)	14.28	6.9	4	29
IMV Rate Increase From Baseline (%)	14.36	7.5	0	40
Gender				
Male	14 (56%)			
Female	11 (44%)			
Diagnosis				
Respiratory Distress Syndrome		17 (68%)		
Pneumonia		4 (16%)		
Other Etiologies		4 (16%)		

of triplets, one set of twins and 20 singletons. Fourteen (56%) were male and 11 (44%) were female. Gestational ages ranged from 25 to 40 weeks (mean 32.5 wks, SD 3.8 wks) and weights from 510 to 3320 grams (mean 1879 gms, SD 769 gms). Seventeen (68%) of the infants studied had respiratory distress syndrome. Four (16%) were suffering from pneumonia and four (16%) from respiratory distress of varying etiologies. Of the latter infants', one had a chylothorax with a chest tube insitu, another had bilateral chest tubes and two had pulmonary edema associated with asphyxia.

The infants were studied between 18 and 198 hours of age (mean 91.8 Hrs, SD 47.44 Hrs). Percent inspired oxygen requirements ranged from 21% to 55% (mean 32.5%, S.D. 8.8%). The peak inspiratory pressure ranged from 16 to 26 cm. of water (mean 19.8, SD 2.5) for the 21 infants requiring assisted ventilation. Positive end expiratory pressure ranged from 2 to 6 cm. of water (mean 3.8, SD 0.79). The rate settings of the 21 infants requiring assisted ventilation, ranged from 4 to 55 breaths per minute (mean 15.95, SD 11.8). During the two treatment conditions oxygen settings were increased 4 to 29% from baseline requirements (mean 14.28; SD 6.9) and ventilator rate increases ranged from 0 to 40 breaths per minute (mean 14.36, SD 7.5).

Effect of Saline Instillation

Due to the large amount of information gathered, data were condensed to give several measures (mean, maximum, minimum) for each of the six dependant variables and for each of the 13 time periods. Thus, for each subject there were 234 bits of information (3x6x13) for each of two treatment conditions.

Heart Rate. Factorial analysis of variance (2x13) revealed that the main effect of condition on heart rate was not significant. The interaction effect of condition by time was also not significant. However, the main effect of time was significant (Table 2: F=9.27; df=12, 288; p <.001). Post hoc multiple comparisons (p=.05) indicated that heart rate rose significantly between the baseline phase and each of the following: treatment phase, suctioning phase III, oral suctioning phase and the recovery phase I. Heart rate was significantly higher in the oral suctioning phase compared with each of the following: preparation phase, suction phase I and recovery phase I. It was also revealed that heart rate decreased significantly between the recovery phase I and recovery phase II. Table 3 contains significant post hoc comparisons and Table 4 describes mean heart rates for each time period.

Weight was thought to be a potential covariate but the design and statistical package employed in the study

Table 2.

Analysis of Variance: Effect of Time Period and Condition on Heart Rate

Source	Degrees of Freedom	Mean Square	F	p
Condition	1	436.11	.60	.445
Error	24	722.35		
Time	12	777.05	9.2	<.001
Error	288	83.80		
Condition x Time	12	62.26	1.39	.168
Error	288	44.68		
TOTAL	625	126.25		

n=25

Table 3.

Significant Post Hoc Comparisons for the Effect of Time on Heart Rate *

	Treatment	Vent II	Suction III	Vent IV	Oral Suction	Recovery I
Baseline	9.15	9.83	8.54	10.5	14.5	10.66
Preparation					10.26	
Suction I					9.41	
Vent I					9.17	
Recovery II					12.46	8.62

* all post hoc comparisons significant at p=.05

Table 4.

Mean Heart Rates for the Time Periods *

	No-instillation Condition (n=25)	Instillation Condition n=(25)	Overall Mean (n=50)
Baseline Phase	137.8 (12.2)	138.4 (11.5)	138.1 (11.7)
Preparation Phase	140.5 (15.0)	144.2 (14.0)	142.3 (14.5)
Suction Phase I			
suction period I	142.9 (14.8)	143.4 (15.4)	143.2 (14.9)
vent period I	143.1 (13.3)	143.8 (15.8)	143.4 (14.4)
Treatment Phase			
treatment period	144.9 (19.1)	149.5 (19.4)	147.3 (19.2)
vent period II	146.9 (16.7)	148.9 (18.4)	147.9 (17.4)
Suction Phase II			
suction period II	145.1 (17.9)	143.4 (19.8)	144.3 (18.7)
vent period III	145.4 (15.5)	147.7 (16.9)	146.6 (16.1)
Suction Phase III			
suction period III	145.5 (16.3)	147.8 (17.4)	146.6 (16.7)
vent period IV	146.3 (15.9)	150.9 (16.0)	148.6 (15.9)
Oral Suction Phase	150.7 (14.4)	154.5 (15.0)	152.6 (14.7)
Recovery Phase I	148.7 (12.5)	148.8 (12.7)	148.8 (12.6)
Recovery Phase II	141.2 (12.6)	139.1 (13.8)	140.1 (13.2)

* mean [beats per minute]
(SD)

negated the use of covariate analyses. Hence, weight was treated as a third factor by recoding it into five categories (500 to 1180 grams, 1185 to 1650 grams, 1655 to 1885 grams, 1900 to 2500 grams and 2600 to 3400 grams) for factorial analyses of variance (5x2x13). However, weight was not found to be significantly related to heart rate nor to interact with condition or time.

Multiple regression was also used to determine if weight and diagnosis were covariates when treatment phase heart rate was the dependant variable. The amount of variance in heart rate that was accounted for by weight and diagnosis was not significant.

Discriminant analysis was used to determine what variables would predict change in heart rate from suction phase I to the treatment phase. The change in heart rate allowed infants to be categorized in one of the three groups: drop in heart rate (n=7), no change (n=26) and increase in heart rate (n=17). Two analyses were carried out. The first used the variables: weight, age and diagnosis as possible predictors and the second used the variables: weight, age, diagnosis and treatment condition. In both analyses the variables were not significant predictors of whether the heart rate would increase, drop or remain the same.

When a comparison of heart rate change between ventilation period I and the treatment period was done, it was noted that in the no instillation condition six infants had greater than the 5 beats per minute decrease in heart rate, 13 remained constant and 6 had increases of greater than 5 beats per minute. During the instillation phase only one infant had a decrease in heart rate, 13 remained constant and 11 had greater than the 5 beats per minute increases in heart rate (see Table 5 for ranges of heart rate).

Blood Pressure. A 2x13 factorial analysis of variance of blood pressure revealed no significant difference for the main effect of condition nor the interaction of condition by time. The main effect of time was significant (Table 6: F=17.71; df=12, 204; p <.001). Post hoc multiple comparisons indicated blood pressure rose significantly after the baseline phase for all other phases excluding the two recovery phases (Table 7). There were also significant differences between the preparation phase and every other period except for the first suction period and the two recovery phases. Significant differences were found between the recovery period I and the third and fourth ventilation periods. Recovery phase II blood pressure was significantly lower than all other periods except the baseline phase, preparation phase, first suctioning period, and recovery period I. Mean blood pressures for each time period can be found in Table 8. As described with heart rate, the covariate weight was recoded into five categories

Table 5.

Minimum and Maximum Heart Rates Recorded During Three Phases and Two Conditions

	Condition	
Phases	No-instillation	Instillation
Ventilation Period I	120-170 (mean=143;SD=13.3)	104-168 (mean=144;SD=15.8)
Treatment Period	93-179 (mean=145;SD=19.1)	97-185 (mean=150;SD=19.4)
Ventilation Period II	120-182 (mean=147;SD=16.7)	108-182 (mean=149;SD=18.4)

Table 6.

Analysis of Variance: Effect of Time Period and Condition on Blood Pressure *

Source	Degrees of Freedom	Mean Square	F	p
Condition	1	95.05	0.95	.343
Error	17	99.84		
Time	12	151.03	17.71	<.001
Error	204	8.53		
Condition x Time	12	4.69	0.79	.656
Error	204	5.90		
TOTAL	450	365.04		

*n=18 due to lack of data for some subjects.

Table 7

Significant Post Hoc Comparisons for Effect of Time on Blood Pressure*

	Suction Period I	Vent Period I	Treat-ment Period	Vent Period II	Suction Period II	Vent Period III	Suction Period III	Vent Period IV	Oral Suction Period
Baseline Phase	3.47	4.97	4.68	4.67	4.89	6.35	5.11	6.0	5.29
Preparation Phase		3.98	3.68	3.67	3.90	5.36	4.11	5.0	4.30
Recovery Phase I						3.89		3.54	
Recovery Phase II		3.78	3.48	3.47	3.70	5.16	3.91	4.80	4.09

* all post hoc comparisons significant at p = .05

Table 8.

Mean Blood Pressure for the Time Periods *

	No-instillation Condition (n=18)	Instillation Condition n=(18)	Overall Mean (n=36)
Baseline Phase	42.9 (9.9)	41.2 (9.0)	42.0 (9.4)
Preparation Phase	43.8 (10.2)	42.3 (9.2)	43.0 (9.6)
Suction Phase I			
suction period I	45.9 (10.8)	45.2 (10.0)	45.5 (10.2)
vent period I	47.2 (9.6)	46.8 (10.1)	47.0 (9.8)
Treatment Phase			
treatment period	46.9 (9.2)	46.5 (9.8)	46.7 (9.4)
vent period II	47.2 (9.4)	46.3 (8.9)	46.7 (9.0)
Suction Phase II			
suction period II	47.5 (9.2)	46.3 (8.7)	46.9 (8.9)
vent period III	48.4 (8.4)	48.4 (10.2)	48.4 (9.2)
Suction Phase III			
suction period III	47.1 (8.2)	47.2 (9.2)	47.2 (8.6)
vent period IV	48.3 (8.8)	47.8 (8.8)	48.0 (8.7)
Oral Suction Phase	47.6 (8.6)	47.1 (9.0)	47.3 (8.7)
Recovery Phase I	45.2 (10.0)	43.8 (9.5)	44.5 (9.7)
Recovery Phase II	44.4 (10.8)	42.1 (9.6)	43.2 (10.2)

* mean [mmHg]
(SD)

for further factorial analyses of variance (5x2x13) using blood pressure. No significant differences for the main effects of condition and time, nor the interaction of condition by time were found.

TcPO2. Factorial analysis of variance on TcPO2 showed no significant difference for the main effect of condition nor the interaction of condition by time. There were significant differences for time (Table 9: $F=3.23$; $df=12, 240$; $p < .001$). However, post hoc multiple comparisons did not identify significant differences among the time periods. Mean TcPO2 for the 13 time periods can be found in Table 10. The average arterial PO2 at the beginning of the baseline phase was 62.88 mm.Hg and the TcPO2 reading was 51.5 mmHg, a difference of 11 mmHg.

Alveolar-arterial oxygen gradient. The a/APO2 values were calculated (Appendix D) from the four arterial blood gases taken from each subject (one pre-suction and one post-suction for each treatment condition). The mean a/APO2 can be found in Table 11. When paired t-tests were used to compare the pre and post-suction difference in a/APO2 scores for the two conditions, the findings were not significant.

Other Analyses. Pearson correlations between arterial blood gas PO2 and TcPO2 readings for the four blood gas times ranged between $r=.41$ and $r=.65$ ($p=.071$ and $p=.002$) (Table 12). The correlations between all calculated

Table 9.

Analysis of Variance: Effect of Time Period and Condition on TcPO2 *

Source	Degrees of Freedom	Mean Square	F	p
Condition	1	130.23	0.13	.724
Error	20	1014.02		
Time	12	95.10	3.23	<.001
Error	240	29.47		
Condition x Time	12	20.28	0.87	.577
Error	240	23.28		
TOTAL	525	1312.38		

* n=21 due to lack of data for some subjects.

Table 10.

Mean TcPO2 for the Time Periods *

	No-instillation Condition (n=21)	Instillation Condition n=(21)	Overall Mean (n=42)
Baseline Phase	53.0 (9.7)	49.9 (7.9)	51.5 (9.0)
Preparation Phase	55.1 (11.7)	52.3 (8.5)	53.7 (10.1)
Suction Phase I			
suction period I	57.2 (12.3)	55.6 (9.7)	56.4 (11.0)
vent period I	55.7 (10.6)	56.5 (10.0)	56.1 (10.2)
Treatment Phase			
treatment period	55.3 (10.1)	56.1 (9.4)	55.7 (9.6)
vent period II	57.0 (12.1)	56.2 (9.2)	56.6 (10.7)
Suction Phase II			
suction period II	57.3 (11.8)	56.2 (8.9)	56.7 (10.4)
vent period III	57.1 (11.2)	55.8 (8.6)	56.4 (9.9)
Suction Phase III			
suction period III	57.3 (11.6)	55.1 (8.1)	56.2 (10.0)
vent period IV	57.1 (11.0)	55.1 (8.9)	56.1 (9.9)
Oral Suction Phase	55.3 (9.3)	54.6 (8.1)	54.9 (8.6)
Recovery Phase I	55.3 (8.0)	56.5 (6.8)	55.9 (7.3)
Recovery Phase II	56.7 (8.0)	56.9 (7.9)	56.8 (7.8)

* mean [mmHg]
(SD)

Table 11.

Mean a/APO2 Values

	Time		
Condition	Pre-suction	Post suction	Mean difference
No instillation	.4172	.4096	.0076
Instillation	.3904	.4156	-.0252

Table 12.

Pearson Correlations Between Arterial PO2 and TcPO2 for Two Conditions and Two Time Periods *

	Time	
Condition	Pre	Post
No-instillation	.5230 p=.018	.6214 p=.003
Instillation	.6587 p=.002	.4127 p=.071

* n=20

Table 13.

Pearson Correlations Between Arterial Saturation and Nellcor Saturation for Two Conditions and Two Time Periods When the Heart Rate Values Differ Between Monitors

		Difference Between Monitor Heart Rates		
Condition	Time	All Readings	≤5 beats/min	≤10 beats/min
No Instillation	Pre	.4356 n=25 p=.03	.3997 n=22 p=.065	.4722 n=24 p=.02
	Post	.2149 n=25 p=.302	.3148 n=23 p=.144	.3148 n=23 p=.144
Instillation	Pre	.5178 n=25 p=.01	.4113 n=23 p=.051	.5007 n=24 p=.013
	Post	.7456 n=24 p=.000	.8079 n=22 p=.000	.7436 n=23 p=.000

Table 14.

Pearson Correlations Between ECG Heart Rate and Nellcor Heart Rate for Two Conditions and Two Time Periods When the Heart Rate Values Differ Between Monitors

			Difference Between Monitor Heart Rates	
Condition	Time	All Readings	≤5 beats/min	≤10 beats/min
No Instillation	Pre	.9114 n=25 p=.000	.9775 n=22 p=.000	.9584 n=24 p=.000
	Post	.3037 n=25 p=.14	.9926 n=23 p=.000	.9926 n=23 p=.000
Instillation	Pre	.6213 n=25 p=.001	.9870 n=23 p=.000	.9793 n=24 p=.000
	Post	.95 n=24 p=.000	.9831 n=22 p=.000	.9742 n=23 p=.000

saturations and Nellcor saturation readings ranged from r=.215 to r=.75 (p=.302 and p <.001) (Table 13). Correlations of calculated saturations and Nellcor saturations when the two heart rate readings were not greater than 10 beats apart ranged between r=.47 and r=.74 (p=.02 and p <.001). The correlations between all ECG heart rates and Nellcor heart rates ranged between r=.30 and r=.95 (p=.14 and p <.001). ECG and Nellcor heart rates that were more than 10 beats different (those considered clinically unreliable) were removed from the analysis. Then the correlations ranged from r=.96 and r=.99 (p <.001 and p <.001) (Table 14).

The continuous saturation readings could not be analyzed due to the large amount of artifact (caused by the infants' moving during the procedures). In addition, the intracranial pressure readings were compromised because of an incorrect and inconsistent conversion factor in data transfer and could not be analyzed.

Discussion

Effect of Saline Instillations

The purpose of this study was to evaluate the immediate effects of a saline instillation on selected physiological parameters of respiratory distressed infants. The results of this study indicated that physiological parameters were not influenced significantly by a saline instillation, as shown by the failure to support hypotheses of a main effect of condition and, importantly, an interaction effect for condition and time.

One reason for the failure to obtain significant findings is that the sample size of 25 may have been too small. The data suggest that a small effect size would be observed in this study. From computations done after the study, statistical power was likely about .26. Since power is low, results must be interpreted cautiously because there is an increased chance of failing to reject the null hypothesis when it should be rejected (Type II error). In order to be more confident that saline instillations do not have a statistically significant effect on any of the physiological parameters, power would have to be increased considerably by using a larger sample size (for 1-beta of .80 n=100).

Even if statistical significance was obtained in a study with a larger sample size, the clinical significance of changes in physiological parameters must be questioned. The infants in this study were sampled over a five month period and were typical of infants requiring ventilatory care in this neonatal unit. It is likely then, that with a sample of 100 infants the effect on heart rate, blood pressure and TcPO2 would be in the same range but would be found to be statistically significant. The change in heart rate during instillation was an average of five beats per minute and blood pressure and TcPO2 changed slightly. For most infants a change in heart rate of this magnitude is not clinically significant. Eleven of the infants in this study experienced increases in heart rate ranging between 5 and 21 beats per minute after the instillation. One infant had a 13 beat per minute decrease in heart rate and the remaining infants' heart rates did not change. Given the observed changes in heart rate and lack of change in blood pressure and TcPO2, it can be concluded that a saline instillation does not produce clinically significant changes. It may be that saline instillations could produce clinically significant effects in unstable infants or in infants with different diagnoses. However, the use of unstable infants would pose a problem when interpreting results, since any effects seen would be clouded by simultaneous changes in clinical condition.

There was also no statistically significant effect from instillations on a/APO2. There are several possible explanations for this finding. First, since power was low, future studies could perhaps obtain statistical significance by increasing the sample size. However, the same question about clinical significance could be raised in view of the small changes observed in this study in a/APO2 after instillations. Secondly, in infants with other illnesses, different results may be observed as two thirds of subjects had hyaline membrane disease and were period when infants were studied, there may not have been enough tracheal secretions for saline to loosen, thus contributing to the a/APO2 findings of this study. Thirdly, since the a/APO2 was calculated from an arterial blood gas taken 20 minutes after the study, any a/APO2 change resulting from the instillation could have been missed because of the time that had elapsed. Possibly, taking an arterial blood gas one minute after the treatment condition would have revealed a significant change in a/APO2.

Effect of Tracheal Suctioning

It is not surprising that the main effect of time on the physiological parameters was significant given the various intrusive events which occurred over time. Mean heart rate rose significantly following the second ventilation period and although it approached baseline values in suction phase II, the overall pattern suggests that infants become increasingly agitated and heart rate peaks in the oral suctioning phase. Whether the increase in heart rate in the oral suctioning phase is a result of a cumulative effect or that oral suctioning itself causes this elevation in heart rate is not known. Heart rate varied significantly between the first and second recovery phases indicating that infants' heart rates remained elevated up to 5 minutes following the procedure.

values and remained elevated throughout both procedures returning to baseline in recovery phase I. This finding concurs with several studies cited earlier demonstrating that blood pressure generally rises during the tracheal suctioning procedure. Unlike Perlman and Volpes' (1983) findings, hypoxemia does not seem to have been a factor for the increase in blood pressure as there were no significant differences between baseline PO2 and the other periods. If increased systemic blood pressure is associated with increases in intracranial pressure and if increases in intracranial pressure play a role in the pathogenesis of intraventricular hemorrhage in the preterm infant, then the length of time blood pressure is elevated should be kept to a minimum.

Transcutaneous oxygen tension values increased slightly during the preparation phase where oxygen and ventilator rates were increased. Surprisingly, TcPO2 values did not vary significantly over the various phases. The most likely explanation for this finding is that the full effect of each period on TcPO2 was not seen. This may be the case because the TcPO2 probe takes approximately 15 seconds for values to change, and since the periods were of short duration (5 to 15 seconds), the true effect may not have been shown. Several of the infant's had intra arterial oxygen catheters attached to Searle monitors. These catheters react quickly to changes in oxygenation.

During the treatment conditions, the Searle readings of these infant's were observed to have wider fluctuations in their PO2 readings than TcPO2. Unfortunately, not all of the infants' had these catheters, nor could the data be recorded on the acquisition system at the time of study.

It is also possible that, as in other studies, the combination of preoxygenation and hyperventilation reduced the amount of suction induced hypoxemia in infants. In this study the oxygen and ventilation rates were increased, based on the infants' previous suctioning experience. Generally, oxygen was increased 14% and rates were increased 14 beats per minute higher than individual baseline values. The 15 second length of ventilation period between suctioning passes (allowing the infant to rest) and limiting the depth of catheter insertion (decreasing vagal response) may be other reasons the TcPO2 values did not change significantly.

<u>Weight</u>

It is interesting that when the infants were subdivided into different weight categories, there were no significant differences for heart rate, blood pressure, or TcPO2. In neonatology, it is often assumed that the smaller infants under 1500 grams cannot tolerate procedures as well as larger infants. It is possible that the analysis used to examine weight, may not have adequately shown the true effect. Additionally, it may also be that the current suctioning practice in this neonatal intensive care unit minimizes the harmful effects of tracheal suctioning.

<u>Reliability of Oxygen Monitoring Devices</u>

Reliability of TcPO2 monitoring has been reported in the range of r=.86 and r=.98. In this study TcPO2 readings were not reliable. One reason for the low reliability in this study, other than improper placement, may be that the probe was heated to 43.5 degrees Celcius and other researchers used 44 degrees. While higher heat may produce more reliable readings, by increasing arterialization of blood in the skin under the probe, higher heat may also result in burns to the probe sites.

Reliability of Nellcor saturation monitoring has been reported to be r=.89 to r=.95. In this study, even when the heart rates of both monitors were no greater than 10 beats apart, Nellcor saturations were not reliable. Studies like Fanconi et al. (1985) who reported a correlation of r=.95, have led clinicians to believe this form of monitoring is reliable. However, it should be pointed out that the correlation of r=.95, was obtained only after further adjustment for infant temperature and hemoglobin. In this study no further adjustment was made to the readings because in this clinical setting saturation readings are taken to be reliable if the ECG and Nellcor monitor heart rates are no greater than 10 beats apart.

[illegible]sults of this study suggest that (assuming the calculated saturations are accurate) saturation monitoring may not be as reliable in practice as other authors suggest.

Implications for Nursing Practice

Instillation of normal saline during tracheal suctioning is a common practice in neonatal intensive care units. The results from this study indicate that infants generally tolerate instillations of between 0.25 and 0.5 cc in the short term. Since the findings also added further evidence that tracheal suctioning stresses infants, suctioning should be only carried out as necessary. Each infant should be assessed individually to determine whether or not the infant requires instillations and how often suctioning should be performed.

The present practice of preoxygenation and hyperventilation should be continued with the addition of the fifteen second ventilation period which allowed the infants to rest and recover adequately between suction periods. TcPO2 readings should not be relied upon during the suctioning procedure to monitor the infant's oxygenation because of the TcPO2 monitors delay in indicating changes in oxygenation. Lastly, every effort should be made to reduce the length of the tracheal suctioning procedure. One way is to limit the number of suctioning periods.

Recommendations for Future Research

Although instillations may not affect infants in the short term, the long term implication of this practice needs to be researched. Specifically, would there be a higher incidence of blocked tracheal tubes if instillations were not performed? What are the long term effects of saline instillations on the lungs?

Individual infants may respond differently to tracheal suctioning. It would be beneficial to be able to predict those infants who would experience clinically significant decreases or increases in heart rate, blood pressure, and TcPO2. Since tracheal suctioning stresses infants, it would be worthwhile to know how often it needs to be performed in order to keep the airway patent.

Although oxygen saturation monitoring is gaining popularity in neonatology, the reliability of this form of monitoring should be investigated further. Researchers requiring oxygen monitoring for evaluation of procedures done repeatedly over short duration should use monitors that react more quickly to changes in oxygenation than TcPO2 monitors do. Finally, since appropriate covariate analysis could not be carried out, the assumption that low birth weight infants do not tolerate procedures also requires further study.

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APPENDIX A

A Paper Titled "Negative Effects of Tracheal Suctioning"

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Negative Effects of Tracheal Suctioning

Endotracheal suctioning of the intubated patient is a necessary procedure because suctioning facilitates gas exchange by removing airway secretions which may obstruct the airway. On the other hand, researchers and clinicians recognize that this procedure may be harmful to the patient's physical well being. They have identified many factors that may contribute negatively to the patients' physiological status when tracheal suctioning is performed.

This paper describes potential negative effects associated with tracheal suctioning and identifies contributing factors. Specifically, the negative effects of hypoxemia, changes in heart rate and rhythm, blood pressure and intracranial pressure, and sepsis will be examined. Possible contributing factors to infants' responses to suctioning include suctioning procedure variables, infant handling and instillation of normal saline.

Effects of Tracheal Suctioning

Hypoxemia

Hypoxemia, a decrease of oxygen tension in the blood, is a common negative effect encountered during tracheal suctioning. Although some of the findings from animal and adult human research are comparable, they are reported separately since researchers used animals with normal lungs in controlled laboratory settings, while studies using humans involved ill patients in less controlled clinical settings.

Strategies to Reduce Hypoxemia in Animals. Researchers have demonstrated decreases in PaO2 during and following tracheal suctioning in animals with normal lungs who did not receive intervention aimed at preventing hypoxemia (Baun & Flones, 1984; Buggy, Hanson, Flynn, & Baum, 1980; Langrehr, Washburn, & Powaser-Guthrie, 1981; Naigow & Powaser, 1977; Rindfleisch & Tyler, 1981; Skelley, Deeren, & Powaser, 1980; Woodburne & Powaser, 1980). The fall in PaO2 is sometimes prolonged, lasting up to five minutes after suctioning (Langrehr et al., 1981; Naigow & Powaser, 1977; Skelley et al., 1980). Preventing dangerously low PaO2 has been accomplished by using a combination of preoxygenation (O2 of 100%) and hyperinflation (Baun & Flones, 1984; Naigow & Powaser, 1977; Powaser & Converse, 1980; Skelley et al., 1980). Preoxygenation, without hyperinflation, with inspired oxygen of 100% prior to tracheal suctioning did not prevent a significant fall in PaO2 below control levels (room air breathing) at three and five minutes following suctioning (Naigow & Powaser, 1977). However, continuous insufflation of oxygen without hyperinflation during tracheal suctioning has maintained PaO2 above control (room air) levels (Fell & Cheney, 1971). It should be noted that while PaO2 dropped significantly, it remained above control values. It may be that continuous insufflation of oxygen is most effective when spontaneous ventilatory efforts are made by the animal and insufflation rates are great enough to minimize suction induced negative airway pressure (Langrehr, et al., 1981; Powaser-Guthrie, Langrehr, Washburn, & Rux, 1981).

Strategies to Reduce Hypoxemia in Human Adults. The protocols used in animal studies have been used in studies involving human adults. As in animal research, it has been found that tracheal suctioning of humans precipitates a decrease in PaO2 when no attempts are made to prevent hypoxemia (Adlkofer & Powaser, 1978; Boutros, 1970; Fell & Cheney, 1971; Gonzalez, Erchowsky, & Ahmed, 1983; Jung & Newman, 1982; Skelley et al., 1980; Urban & Weitzner, 1969).

Various strategies have been used to reduce suction induced hypoxemia in adults. One of these strategies is a combination of preoxygenation and hyperinflation. This combination has been effective in minimizing and even eliminating decreases in PaO2 due to suctioning (Fell & Cheney, 1971; Langrehr et al., 1981; MacKinnon-Kesler, 1983; Skelley et al., 1980). However, hyperinflations should be used with caution in patients who have severe respiratory disease requiring large tidal volumes, as they are at risk of developing barotrauma and a decrease in cardiac output (Barnes & Kirchhoff, 1986; Goodnough, 1985; Skelley et al., 1980).

Another method used to reduce suction induced hypoxemia in adults is continuous insufflation of oxygen during the suctioning procedure. Presently, insufflation is accomplished by using either a double lumen suction catheter or a sidehole endotracheal tube adaptor. The double lumen catheter has two openings, one to deliver a continuous flow of oxygen and the other to suction secretions. A sidehole adaptor allows the endotracheal tube to be suctioned through a sidehole without disconnecting the patient from the ventilator. Results of studies using insufflation vary. The majority of researchers using insufflation have found this technique to be beneficial in minimizing suction induced hypoxemia (Bodai, 1982; Bodai et al., 1987; Gonzalez et al., 1983; Jung & Newman, 1982; Langrehr et al., 1981; Urban & Weitzner, 1969).

With regard to the rate of oxygen flow, Fell and Cheney (1971), found that insufflation of oxygen at 5 l/minute was not successful in controlling the fall in PaO2. On the other hand, insufflation of oxygen at 10 and 15 l/minute prevented significant changes in PaO2 throughout suctioning (Langrehr et al. 1981). One possible reason for the difference in the findings of these researchers is that Fell and Cheneys' (1971), 5 litre per minute (l/min.) oxygen flow rate was well below the suction catheter flow rate of 18 l/min.. Langrehr et als' (1981) oxygen flow rates of 10 to 15 l/min., met or exceeded the suction flow rate of 10.8 l/min. The oxygen fow rate used in Fell and Cheneys' study may have been too low to minimize the amount of negative pressure in the lungs. It should also be noted that the two studies had patients with different health problems: respiratory failure (Fell & Cheney, 1971) compared to postoperative cardiac surgery (Langrehr et al., 1981). Lung function may have been better in the cardiac surgery patients than patients in respiratory failure.

A third method employed to reduce suction induced hypoxemia in adults is preoxygenation alone. Preoxygenation, by increasing the percent inspired oxygen to 100% while the patient is on a ventilator, thus keeping the rate and tidal volumes constant, has been found to be effective in preventing a decrease in PaO2 in 75% of the subjects (Goodnough, 1985). Other investigators recommend preoxygenation with a percent inspired oxygen of 100% while hand bagging, rather than using ventilator "sighs" (Belknap, Kirilloff, & Zullo, 1980; Harken, 1975). Lucke (1982), on the other hand, suggested that preoxygenation by ventilator at 100% inspired oxygen is more effective than hand bagging. These studies fail to report the rate of handbagging. It may be that Harken (1975) and Belknap et al. (1980) bagged the patient at a faster rate than the initial ventilator rate. If this is so, the benefit attributed to preoxygenation may be partially due to hyperventilation (rate).

Factors Contributing to Hypoxemia in Infants. Neonates are also prone to developing hypoxemia during tracheal suctioning (Barnes, Asonye, & Vidyasagar, 1981; Cabal et al., 1979; Cunningham, Nelson, & Baun, 1984; Fox, Schwartz & Shaffer, 1978; Norris, Campbell, & Brenkert, 1982; Peters, 1983; Simbruner, Coradello, Fodor, Havelec, Lubec, & Pollack, 1981; Young, 1984; Zmora & Merritt, 1980). The majority of intubated infants suffer from respiratory diseases and are dependant on mechanical ventilation for survival. Dependency on mechanical ventilation implies the infant would be hypoxemic without ventilation, so removal of the infant from the ventilator (and therefore his oxygen source) for the purpose of suctioning will in itself cause hypoxemia (Cabal et al., 1979; Cassani, 1984; Norris et al., 1982; Peters, 1983; Zmora & Merritt, 1980). Tracheal suctioning may also contribute to hypoxemia through development of areas of atelectasis within the lungs, a result of the negative pressure applied by the suction catheter (Brandstater and Muallem, 1969). Atelectasis then contributes to hypoxemia by decreasing the oxygen diffusion area and facilitating intrapulmonary right to left shunting in areas of the lung that are not ventilated but have blood flow. The result is that blood leaves these areas of the lung with the same oxygen content as blood entering the lung.

Another factor which contributes to the amount of hypoxemia resulting from tracheal suctioning is the severity of lung disease (Cunningham et al. 1984; Simbruner et al., 1981). Those infants with severe lung disease requiring high inspired oxygen values, airway pressure and ventilator rate will have decreased tolerance to a procedure which removes them from the ventilator. Other possible contributors to hypoxemia are those related to infant handling and variables within the suctioning procedure, such as suction pressure and time of applied suction. These topics are addressed later in this review.

Strategies to Minimize Infant Hypoxemia during Suctioning. Neonatal researchers have concentrated on developing a suction procedure that minimizes hypoxemia. Hyperinflations (increasing peak ventilation pressures from baseline pressures) have been recommended for neonates (Brandstater & Muallem, 1969; Thibeault & Gregory, 1979). It is relevant to note that in Brandstater and Muallem's (1969) study, the subjects were not premature and they had normal lungs, as indicated by clinical and radiologic examinations. These infants likely were better able to tolerate hyperinflations, compared to respiratory distressed infants. The cautious use of hyperinflations during suctioning of infants is recommended (McFadden, 1981) especially with premature infants who may be susceptible to pneumothoraces (Stahlman, 1981). Since hyperinflations may lead to the development of pneumothoraces in infants, the majority of neonatal researchers have primarily concentrated on the use of preoxygenation, hyperventilation (increased rate) and continuous insufflation of oxygen in their protocols.

Preoxygenation with hyperventilation has been employed successfully in order to reduce suction induced hypoxemia in infants (Barnes et al., 1981; Cabal et al., 1979; Cunningham et al., 1984; Raval, Mora, Yeh, Pildes, 1980). However, it is not clear if the improved results were due to the preoxygenation, increased rate or a combination of both. The combination of increasing the oxygen to 100% and increasing ventilation rate by 50% with different sequences of bagging leads to hyperoxemia in some infants (Barnes et al., 1981). Hyperoxia may have adverse effects for the infant, such as the development of retrolental fibroplasia (Friendly, 1981). The use of 100% oxygen then, may not be indicated for tracheal suctioning in all infants. One recommendation is bagging with 10% higher oxygen than baseline requirements (Raval et al., 1980). One hundred percent oxygen should be avoided unless the baseline oxygen is already very high. This recommendation is supported by Cunningham et al. (1984), who used percent inspired oxygen of 10 and 20% higher than maintenance requirements, combined with two different ventilation rates to minimize hypoxemia. Of interest in this study is that the infants with hyaline membrane disease still had decreases in TcPO2 readings below baseline values despite the increase in inspired oxygen. It may be that the infants with hyaline membrane disease required higher rates than the two rates assessed (20 or 40 breaths/minute).

Another way of decreasing hypoxemia in infants during the tracheal suctioning procedure is the use of continuous insufflation of oxygen. Cabal et al.(1979) and Zmora & Merritt (1980) reported decreases in PaO2 for both the endhole adaptor (conventional technique) and side hole adaptor but the decreases were less with the side hole adaptor. One explanation for the findings is that airway pressure is partially maintained throughout the side hole suctioning procedure because the infant is not removed from the ventilator (Zmora & Merritt, 1980). There is a decrease in airway pressure with the end hole procedure, since the infant is removed from the ventilator. Airway pressure assists in providing distending pressure to the alveoli and thus assists in preventing atelectasis and facilitates gas exchange.

Changes in Heart Rate and Rhythm

Alterations in heart rate during tracheal suctioning have been reported in animals, adults and infants. Ehrhart, Hofman and Loveland (1981) found that 45 seconds of apnea or tracheal suctioning with animals led to significant decreases in heart rate.

In adults severe cardiac arrythmias and cardiac arrests have been reported in association with tracheal suctioning (Bodai, 1982; Jung & Newman, 1982; Shim, Fine, Fernandez, & Williams, 1969). Factors thought to be involved in causing these events in adults are hypoxemia (Bodai, 1982; Jacquette, 1971; Jung & Newman, 1982; McKenzie, 1981; Shim et al., 1969;) and stimulation of vagal receptors by the suction catheter (Jacquette, 1971; McKenzie, 1981; Shim et al, 1969). Arrythmias may be eliminated by preoxygenating the patient for five minutes prior to tracheal suctioning (Shim et al., 1969) or by maintaining continuous insufflation of oxygen throughout the procedure by use of a side hole adaptor on the endotracheal tube (Bodai, 1982; Jung & Newman, 1982).

Changes in heart rate have also been reported in infants undergoing tracheal suctioning. There may be a decrease in heart rate (Cabal et al., 1979; Cabal, Siassi, Blanco, Plajstek, & Hodgman, 1984; Cunningham et al., 1984; Peters, 1983; Simbruner et al, 1981; Zmora & Merritt, 1980), sometimes leading to bradycardia (heart rate less than 100 beats/minute). A decrease in heart rate may be the result of indirect stimulation of the vagal receptors by hypoxemia and direct vagal stimulation by the suction catheter. Tracheal suctioning may also result in struggling and crying during the procedure (Peters, 1983). Maintenance of heart rate is essential in all humans for survival, but in infants, heart rate is the major determinant of cardiac output. Since infants are unable to increase their stroke volume, cardiac output is increased by raising the heart rate. Prevention of low heart rate may be facilitated by decreasing the amount of hypoxemia associated with suctioning (Cabal et al., 1984) and perhaps decreasing the amount of direct vagal stimulation by limiting the depth of suction catheter insertion.

Changes In Blood Pressure

Evaluation of blood pressure during tracheal suctioning has led to different findings in animal studies compared to human studies. Some researchers using dogs have reported no significant changes in blood pressure with tracheal suctioning compared to baseline values (Baun & Flones, 1984) while others have documented significant increases in blood pressure (Ehrhart et al., 1981). Differences in procedures may be the source of discrepancies in the findings. The dogs in which blood pressure did not change had normal lungs while the dogs which increased their bood pressure with suctioning had respiratory distress and were therefore less able to tolerate the suctioning procedure. In addition, Ehrhart et al. (1981) suctioned their respiratory distressed dogs for normal dogs for only 15 seconds.

Changes in blood pressure have also been reported during suctioning of adults (Goodnough, 1985) and children (Fisher, Frewen, & Swedlow, 1982). Goodnough (1985) found that 71% of her adult patients had increases and 29% had decreases in blood pressure associated with hyperinflation. In the study, preoxygenation with 100% oxygen and hyperinflations of 1.5 times the baseline tidal volume were evaluated. Two patients developed extreme hypotension but the blood pressure returned to normal as soon as hyperinflations were discontinued.

Infants, like dogs with respiratory distress, generally respond to tracheal suctioning with increases in blood pressure (Perlman & Volpe, 1983; Peters, 1983; Simbruner et al., 1981). The increases in blood pressure may be associated with the occurrence of hypoxemia and the physical stimulation of the infant throughout the suctioning procedure (Perlman & Volpe, 1983).

<u>Changes in Intracranial Pressure</u>

Significant increases in intracranial pressure during tracheal suctioning have been reported in adults (Parson & Shogan, 1984), children (Fisher et al., 1982) and infants (Fanconi & Duc, 1987; Perlman & Volpe, 1983; Peters, 1983). In adults and children with head trauma, a major goal in providing care is to prevent cerebral ischemia and acute

1986) as recurrent elevations in intracranial pressure are associated with poor neurologic outcomes (Miller J. D., Butterworth, & Gudeman, 1981; Shapiro, 1975). Therefore, increases in intracranial pressure from tracheal suctioning may compromise neurological status.

As previously mentioned, infants also respond to tracheal suctioning with increases in intracranial pressure which probably results from increases in systemic blood pressure (Perlman & Volpe, 1983). Increased intracranial pressure may also play a role in the pathogenesis of intraventricular hemorrhage in the preterm infant (Perlman & Volpe, 1983; Peters, 1983). Intraventricular hemorrhage is strongly associated with prematurity, probably due to immaturity of the germinal matrix and to perinatal asphyxia (Volpe, 1981). Infants who survive an intraventricular hemorrhage may go on to develop major neurological problems, the most common sequelae being hydrocephalus and cerebral palsy.

Sepsis

The importance of aseptic technique during tracheal suctioning is generally recognized. The placement of an endotracheal tube bypasses the respiratory system's defense mechanisms against invasive organisms. Introduction of organisms into the lung with suctioning is a possibility, even when aseptic technique is used (Storm, 1980). However, equipment may introduce bacteria into the tracheobronchial tree (McKenzie, 1981).

Sepsis is a significant cause of neonatal morbidity and mortality (McCraken, 1981). The premature infant is particulararily prone to infection due to immaturity of the immune system. Storm (1980) reported evidence of transient bacteremia as early as one minute following tracheal suctioning in infants. Although sepsis may not be an immediate effect of tracheal suctioning, it must be considered a potential threat in the days following suctioning.

<u>Suctioning Procedure Variables</u>

As previously discussed there can be several negative effects of tracheal suctioning. This section of the review examines variables within the suctioning procedure which may affect the patient's responses to the procedure. These variables include: depth of catheter insertion, duration of applied suction, suction pressure and the ratio of the diameters of suction catheter to tracheal tube.

Suctioning protocols vary widely as is evident from descriptions in the literature and standard textbooks (see Appendix B which lists the parameters previously used). Insertion of suction catheters into the lungs without applied suction have been associated with mucosal trauma in kittens (Thambiran & Ripley, 1966). Pneumothoraces catheter have been reported in infants (Anderson & Chandra, 1976; Vaughan, Menke, & Giacoia, 1978). Direct stimulation of the tracheal mucosa may trigger a vagal response in infants leading to bradycardia. Most authors of current neonatal texts recommend insertion of the catheter until slight resistance is met. Some authors recommend measuring the required depth of catheter insertion in order that the catheter protrudes one centimeter beyond the distal end of the tracheal tube (Abrams & Johnson, 1984) or the carina (Anderson & Chandra, 1976). They suggest that measurement of the suction catheter length will minimize mucosal trauma due to catheter insertion.

Both the duration and magnitude of applied suction will affect the amount of alveolar gases suctioned out of the lungs, facilitating hypoxemia (Rux & Powaser, 1979). These factors, along with the ratio of suction catheter diameter to endotracheal tube, will affect the amount of negative pressure within the lungs. Large negative pressures facilitate atelectasis (Fox et al., 1978; Hipenbecker & Guthrie, 1981; Polacek & Powaser-Guthrie, 1981) and therefore hypoxemia. The ratio of diameters of suction catheter to tracheal tube is a concern in neonates because of the small size of endotracheal tubes. Most researchers have used a 1:2 ratio in their studies although Brandstater and Muallem (1969) used a 1.8:2 ratio for some the amount of atelectasis found in the infants, for with a 1:2 ratio atelectasis has not been reported (Fox et al., 1978).

Suction pressure contributes to tracheal mucosa trauma (Kuzenski 1978; Plum & Dunning, 1956; Sackner, Landa, Greenelтch, & Robinson, 1973; Thambiran & Ripley, 1966). Infants have developed right lung emphysema as a result of obstructive granulation tissue (Grylack & Anderson, 1984; Miller, K. E. et al., 1981) and the authors suggest that these lesions may develop from repeated tracheal suctionings. They recommended the catheter be passed just beyond the distal end of the tracheal tube.

Infant Handling

Research has demonstrated that ill infants do not tolerate handling well, as indicated by significant drops in TcPO2 and PaO2 readings during handling (Danford, Miske, Headley & Nelson, 1983; Dangman, Hegyi, Hiatt, Indyk & James, 1976; Long, Philip & Lucey, 1980; Murdoch & Darlow, 1984; Norris et al., 1982; Tomney, 1980). These findings support the concept that ill infants should be handled as little as possible. Unfortunately, it is the ill neonate who requires more handling in order to perform many therapeutic procedures, such as tracheal suctioning. Although tracheal suctioning is one of the most potentially feedings, diaper changes and weighing also lead to significant decreases in TcPO2 (Danford et al., 1983).

Hypoxemia, associated with infant handling has been decreased by the use of pancuronium (Pavalon) (Tomney, 1980) or Phenobarbital (Ninan, O'Donnell, Hamilton, & Sankaran, 1985). Pancuroni[illegible]omplete muscle relaxant and infants receiving this dru[illegible] move and therefore cannnot expend energy and co[illegible]ygen excessively by fighting and crying during procedures. Phenobarbital is a sedative and anticonvulsant. Infants receiving this drug are usually more calm and settled. Since hypoxemia may result from infant handling alone, the detrimental effects of suctioning reported in the literature may be in part due to handling during the procedure.

Instillations

Instillation of normal saline into the artificial airway is thought to aid in the thinning and subsequent removal of secretions with suctioning. Use of instillations is a common practice in many neonatal intensive care units as evidenced by the fact that the majority of neonatal researchers who examined the effects of tracheal suctioning, have incorporated instillation of normal saline into their suctioning procedure (Barnes et al., 1981; Brandstater & Muallem, 1969; Cabal et al., 1979;

Merritt, 1980). The majority of authors of textbooks on neonatology and respiratory care recommend that instillations should be part of routine tracheal suctioning. Many advocate instillations ranging in quantity from 0.25 milliliters (mls) to 0.5 mls. (Oehler, 1981; Robertson, 1981; Schreiner & Kisling, 1982; Thibeault & Gregory, 1979).

A review of the literature did not reveal any research on the effects of normal saline instillations on adults or neonates. However, related research has been conducted on the effects of introducing substances into the tracheobronchial tree.

Pulmonary lavage involves introducing a large volume of normal saline into an obstructed lobe of the lung for irrigation purposes. The volume inserted into the left lungs of 10 dogs in one study was 100 mls on 5 separate occasions for a total of 500 mls (Huber, Edmunds, & Finley, 1971). Although only small amounts of saline were absorbed, perivascular, peribronchial, and interstitial spaces were expanded and appeared edematous under electron microscopy. The researchers mentioned that intracellular and interstitial edema could result from saline lavage and concluded that instillations into the lung in large volume is not a benign procedure.

The effects of aspiration on the large airways of mice showed that under electron microscopy, the tracheas of all those mice who aspirated normal saline were found to be normal (Wynne, Ramphal, & Hood, 1981). The site of deposition of normal saline instillations was of interest to Hanley, Rudd and Butler (1978). Normal saline labelled with radioactive material was injected into the opening of the tracheal tubes of anesthetized dogs and of two intubated adult patients. Images of the distribution of radioactivity in the chest were recorded during instillation and for 30 minutes after. The labelled normal saline was seen in the trachea and mainstem bronchi in both the dogs and patients. Only traces were seen in the lung periphery. The distribution pattern of normal saline was not affected by hyperinflations and suctionings. Suctioning recovered only 18.7% in the adults. Airway clearance of the saline due to mucociliary clearance and absorption required from 28 to more than 30 minutes in the adult patients. The investigators suggested that instillation, as done in their study, will not affect secretions beyond the mainstem bronchi.

Instillations have not been considered by researchers to be a factor which may affect the infant's physiological status. Yet, instilling infants with normal saline may directly stimulate vagal responses, leading to further hypoxemia and bradycardia. It may be that routine instillations are not necessary to maintain airway patency.

Conclusions

Endotracheal suctioning is not a benign procedure. Immediate negative effects associated with tracheal suctioning include: hypoxemia, changes in heart rate and rhythm, blood pressure and intracranial pressure. Interrelated factors thought to influence the patient's reponse to suctioning include: removal of the patient from their oxygen source, the severity of the patient's disease, depth of catheter insertion, the length and magnitude of applied suction pressure and the diameter of the suction catheter relative to the endotracheal tube. In addition, handling may exacerabate the infant's responses to tracheal suctioning.

Several strategies have been used to minimize suction induced hypoxemia in adults and infants. In adults, the use of preoxygenation and hyperinflations, continuous insufflation of oxygen and preoxygenation have been successful in minimizing hypoxemia. Hyperinflation should be used with caution in patients with severe respiratory disease requiring large tidal volumes. These patients are at risk of developing barotrauma and decreases in blood pressure and cardiac output. Continuous insufflation of oxygen may be more beneficial if patients are making respiratory efforts and when flow rates approximate the suction flow.

The use of hyperinflations with infants is not generally recommended because of the possibility of developing pneumothoraces. Both preoxygenation with hyperventilation and continuous insufflation of oxygen have been successful in minimizing suction induced hypoxemia in infants.

The practice of instilling saline before tracheal suctioning is often used in clinical practice. However, the effect or effectiveness of instillations has not been examined. Research should be undertaken to evaluate the contribution of instillations to the negative effects of tracheal suctioning.

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APPENDIX B

Values For Suctioning Procedure Variables Used By Other Researchers

APPENDIX B *

Duration of Applied Suction(seconds)	Subjects	Source
45	Animal	Ehrhart et al.,1981
15	Animal	Skelley et al.,1980 Baun & Flones,1984 Langrehr et al.,1981 Naigow & Powaser,1977 Powaser-Guthrie et al. 1981
5,10, and 15	Animal	Rindfleisch & Tyler, 1981
10,15, or 30	Animal	Woodburne & Powaser, 1980
45	Animal	Ehrhart et al.,1981
60	Animal	Fell & Cheney,1971
<15	Adults	Plum & Dunning,1956
5	Adults	MacKinnon-Kesler,1983
8	Adults	Goodnough,1985
15	Adults	Urban & Weitzner,1969 Fell & Cheney,1971 Langrehr et al.,1981 Gonzalez et al.,1983
3	Infants	Cunningham et al., 1984
5	Infants	Cabal et al.,1979 Cabal et al.,1984
10	Infants	Barnes et al.,1981
<10	Infants	Thibeault & Gregory, 1979
<15	Infants	Fox et al.,1978
15 to 40	Infants	Fanconi & Duc,1987

* References in Appendix A

Diameter of Suction Catheter to ETT(Ratio)	Subject	Source
1:2	Animal	Ehrhart et al.,1981 Fell & Cheney,1971
1:1.8	Animal	Naigow & Powaser, 1977
1:2	Adults	McKenzie,1981
1:2	Infants	Fox et al.,1978 McKenzie,1981 Cunningham et al., 1984 Barnes et al.,1981
[illegible] or 1.8:2	Infants	Brandstater & Muallem,1969 Perlman & Volpe, 1983

Hyperinflations(volume)	Subjects	Source
1.5 times the baseline tidal volume	Animal	Skelley et al.,1980 Baun & Flones,1984
	Adults	Skelley et al.,1980 Langrehr et al.,1981 MacKinnon-Kesler, 1983 Goodnough,1985
300-400 ml. more than baseline tidal volume	Animal	Naigow and Powaser,1977
27 ml/kg	Animal	Powaser & Converse,1980
0.25 times the baseline peak pressure for two breaths during ventilation phase between suction catheter passes	Infants	Thibeault & Gregory,1979
25 cmH_2O(pressure)	Infants	Brandstater & Muallem,1969

Continuous insufflation of O2 during suctioning (sidehole adaptor or double lumen catheter	Subjects	Source
5 litres of O2/min	Animals	Fell & Cheney, 1971
6 or 15 litres O2/min.	Animals	Powaser-Guthrie et al., 1981
inspiratory minute volume increased by amount determined for suction employed. O2 increased to keep inspiratory O2 concentration close to baseline	Adults	Urban & Weitzner, 1969
ventilator settings unchanged during procedure	Adults	Jung & Newman, 1982 Gonzalez et al., 1983
	Infants	Cabal et al., 1979 Zmora & Merritt, 1980

Hyperventilations (rate)	Subjects	Source
50% > baseline rate	Infants	Barnes et al., 1981
5 breaths in 15 secs. or 10 breaths in 30 secs.	Infants	Cunningham et al., 1984
20 breaths/min. above baseline rate to a maximum of 60 breaths per min. for 1 min.	Infants	McFadden, 1981

Suction Pressure (mmHg)	Subjects	Source
60	Animal	Fell & Cheney, 1971
40-200	Animal	Sackner et al., 1973
50,100,200,300	Animal	Thambiran & Ripley, 1966
100	Animal	Ehrhart et al., 1981
100-200	Animal	Kuzenski, 1978
150	Animal	Skelley et al., 1980
170	Animal	Naigow & Powaser, 1977 Woodburne & Powaser, 1980
483	Animal	Baun & Flones, 1984
60	Adult	Fell & Cheney, 1971
140	Adult	Goodnough, 1985
<150	Adult	Jung & Newman, 1982
100-200	Adult	McKenzie, 1981
200	Adult	Plum & Dunning, 1956 Gonzalez et al., 1983
8	Infants	Barnes et al., 1981
30	Infants	Fox et al., 1978
<35	Infants	Brandstater & Muallem, 1969
40-50	Infants	Zmora & Merritt, 1980
60-80	Infants	McFadden, 1981 Cunningham et al., 1984
80-120	Infants	Perlman & Volpe, 1983
154	Infants	Simbruner et al., 1981

Preoxygenation (Prior to and during suctioning)	Subjects	Source
FiO2 increased to 1.0, for either 1 or 3 breaths	Animals	Skelley et al., 1980
FiO2 increased to 1.0 for 3 min. (spontaneous breathing or hyperinflations)	Animal	Naigow & Powaser, 1977
FiO2 increased to 1.0 for 1 min.	Animal	Fell & Cheney, 1971
FiO2 increased to 1.0 for 3 breaths	Animal	Baun & Flones, 1984
FiO2 increased to 1.0, for either 1 or 3 breaths	Adults	Skelley et al., 1980
FiO2 increased to 1.0 for 1 min.	Adults	Goodnough, 1985
FiO2 increased to 1.0 for 5 min. (Spontaneous breathing)	Adults	Shim et al., 1969
FiO2 increased 0.2 for 14 min.	Adults	MacKinnon-Kesler, 1983
FiO2 increased 0.1 if baseline FiO2 < 0.5 FiO2 increased 0.2 if baseline FiO2 > 0.5	Infants	Cabal et al., 1979 Cabal et al., 1984
FiO2 increased to 1.0 for 1 min.	Infants	Barnes et al., 1981
FiO2 increased 0.1 or 0.2 > baseline	Infants	Cunningham et al., 1984 Fanconi & Duc, 1987
FiO2 increased to 1.0 if baseline FiO2 > 0.5 if baseline <0.5 increase PRN	Infants	McFadden, 1981

FiO2 increased 0.1 > than baseline for 15 secs.	Infants.	Thibeault & Gregory, 1979
FiO2 increased 0.1 or to 1.0	Infants	Raval et al., 1980

APPENDIX C

Samples of Parent Information Sheet and Consent Form

PARENT INFORMATION SHEET

INFANT RESPONSES TO TWO ENDOTRACHEAL SUCTIONING METHODS

David Shorten RN BSCN (Investigator)

Infants requiring neonatal intensive care often require the placement of a tube into their windpipes to help them breathe. Every two to four hours, mucous is suctioned from the tube so that the tube will not block. There are two variations of this procedure. One variation involves placing a little water (less than one quarter of a teaspoon) into the tube prior to suctioning to help soften crusty secretions. The other variation involves suctioning alone. Although both forms of this procedure are normally used in caring for these infants, we do not know if one is better than the other. The objective then of this study is to find out if the infant responds differently to the placement of water with suctioning compared to suctioning alone.

Your baby's condition is being routinely monitored with a variety of equipment. This routine monitoring is not felt by the baby and will be used to measure the effects of the two suctioning variations. We know that any form of airway suctioning causes changes in pressure on the baby's brain. To examine this we will attach a small pad to the skin on top of the head. While most babies' hair will already have been shaved for intravenous treatment, it may be necessary to shave a small patch of hair in order to attach the pad. The hair will grow back. Samples of blood totalling one quarter of a teaspoon will be drawn from the arterial catheter (which your baby already has). Your baby's responses will be recorded during the two variations of suctioning. The study time will be two, half hour sessions with two to four hours between the sessions.

Participation of your infant in this study is totally voluntary, withholding your consent will not affect any present or future treatment your child may require.

If you have any questions or would like to find out the results of the study when completed, please feel free to contact

David Shorten RN BSCN or Dr. Paul Byrne
452-0691 432-6187

CONSENT FORM

INFANT RESPONSES TO TWO ENDOTRACHEAL SUCTIONING METHODS

DAVID SHORTEN RN, BSCN, MN CANDIDATE
FACULTY OF NURSING, UNIVERSITY OF ALBERTA

I have been told that the purpose of this study is to compare the effects of two variations of suctioning procedures which my infant normally undergoes while he/she has a breathing tube.

I understand that my baby's responses will be monitored by the use of equipment routinely in place.

I understand that an additional small pad will be attached to the skin on top of the head to measure pressure on the baby's brain (as indicated in the Parent Information Sheet).

I understand samples of blood totalling one quarter of a teaspoon will be drawn from my baby, without causing him/her any harm.

I have been assured that participation of my infant in this study is totally voluntary and that I may withdraw my baby from the study at any time witout affecting any present or future treatment my child may require.

I have been assured of confidentiality and anonymity with respect to the information gathered throughout the study.

Before giving my consent by signing this form, I have been sufficiently informed about the purpose of this study, the nature of the investigations, the methods of assessment, and the duration of the study.

I have read and understand the information sheet above and I sign this consent form willingly.

Signature of Parent/Guardian	Relationship to Infant	Date

Signature of Witness	Date

APPENDIX D

Formula Used To Determine a/APO2

Formula Used To Determine a/PO2 *

$$a/APO2 = \frac{PaO2}{PAO2}$$

Where:- $PAO2 = PIO2 - \frac{PaCO2}{R}$

And:- $PIO2 = FIO2\ (PB - PH2O)$

* KEY

PAO2= Alveolar Oxygen Tension

PaO2= Arterial Oxygen Tension

PIO2= Inspired Oxygen Tension

FIO2= Fraction of Inspired Oxygen

PaCO2= Arterial Carbon Dioxide Tension

R= Respiratory Exchange Ratio (assumed to be 1.0)

PB= Barometric Pressure

PH2O= Water tension in lungs (assumed to be 47 at 37 deg.C & relative humidity 100%).