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The Effect Prone Positioning Has upon the Oxygen Ratio of Ventilated Children

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**THE EFFECT PRONE POSITIONING HAS UPON THE
OXYGEN RATIO OF VENTILATED CHILDREN**

by

Mary Schira

A THESIS

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in partial fulfillment of the requirements
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ABSTRACT

THE EFFECT PRONE POSITIONING HAS UPON THE OXYGEN RATIO OF VENTILATED CHILDREN

**By
Mary Schira**

The purpose of this study was to examine the effect of prone positioning on oxygen ratios for ventilated children. A retrospective research design was implemented to study the effect that changing ventilated children from the supine position to the prone position had upon their oxygen ratio two hours after the intervention. Twenty-three ventilated children admitted to an eight bed Pediatric Intensive Care Unit (PICU) in Southwest Michigan between January 1998 and July 1998 and were prone, had their medical records reviewed. Data analysis using a T-test for paired samples was performed to compare oxygen ratios just prior to proning and two hours after the intervention. T-tests for independent samples were used to investigate the influence that age, gender, admitting diagnosis, hours from initial ventilation to proning, and lung status prior to admission had upon the oxygen ratios. No statistical differences were found in any of the variables analyzed that may have influenced the findings when oxygen ratios were compared. A significant difference was found between oxygen ratios prior to proning and two hours after the intervention. The findings of this study indicated that proning ventilated children had a favorable impact upon their oxygenation.

DEDICATION

This work is dedicated to Chuck, Lauren, and Sam for all of the patience, encouragement, understanding, and willingness to let “Mom” go back to school.

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inconvenient intervention, many of you were willing to try it for the benefit of the children in our unit. Your efforts will hopefully impact future pediatric patients!

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CHAPTER 1

INTRODUCTION

In the United States the incidence of acute respiratory distress syndrome (ARDS) has been estimated from 250,000 to 400,000 cases per year. Mortality rates remain in the 40-60 percentile (Vollman, 1997). Studies have shown that in the pediatric population, ARDS accounts for 1-4% of Pediatric Intensive Care admissions (Heulitt, Moss, Walker, & Fiser, 1993, Pfenninger, Gerber, Tschappeler, & Zimmermann, 1982; Timmons, Dean, & Vernon, 1991).

A major goal in treating patients with ARDS is to correct life threatening hypoxia. An approach that is gaining interest in research to achieve this goal is prone positioning of the ARDS patient. The mechanism to produce improved oxygenation is still not clear, however Lamm, Graham, and Albert (1994) have shown that prone positioning improved ventilation/perfusion matching. Broccard, Shapiro, Schmitz, Ravenscraft, and Marini (1977) have shown through animal studies that prone positioning in comparison to supine positioning provide a number of positive results which include: 1) less lung damage as indicated by histologic abnormalities, 2) less time for evolution of lung compliance, 3) greater distribution of lung water into dependent regions of the lungs, 4) higher PaO₂, 5) lower venous admixture, and 6) increased cardiac output and mean airway pressure.

There is limited research available on the effect that prone positioning has on oxygenation in the pediatric population. One study by Hader and Sorenson (1988),

showed that positioning a child in supine, prone or a Fowler's position had no significant effect on transcutaneous oxygen tension. The actual means between the groups however showed improved oxygenation in the prone position, which led the authors to believe there was the possibility of a Type II error. In another study, Murdoch and Storman (1994) examined seven children with ARDS when positioned prone and supine. No significant differences were found upon heart rate, mean systemic arterial blood pressure and cardiac output between the two positions. Arterial oxygen saturation, however, significantly improved in the prone position.

Statement of the Problem

This study built upon findings in both pediatric and adult research that explored the effects prone positioning had upon the ventilated pediatric population. Data were collected through medical record audits that enabled the calculation of children's oxygenation ratios (Patient oxygen saturation/FIO₂) for the effect that prone positioning had upon this population.

The investigator, with assistance from physicians and nurses at an eight bed Pediatric Intensive Care Regional Center in Southwest Michigan, investigated the effect that prone positioning had on ventilated children in this facility. All children admitted requiring mechanical ventilation were considered for inclusion into the study. A goal of this study was to incorporate prone positioning into a standard of care at the above mentioned institution if favorable results were found.

CHAPTER 2

THEORETICAL FRAMEWORK AND LITERATURE REVIEW

Theoretical Framework: Levine's Conservation Model

Levine's Conservation Model was used as a conceptual framework to guide this research project. Levine's theory focuses on one person, in the present or near future, and in an altered or impaired state of health in need of nursing intervention (Leonard, 1990). Although this theory has limitations because of its narrow focus on the illness and dependency of a patient, it suited the nature of this study. One intervention was examined for its effect upon critically ill children and the subsequent response. The role of registered nurses in this study was to observe children to determine if they would qualify for the intervention, provide the intervention, and evaluate the response.

Nursing process as described by Levine consists of three phases: trophicognosis, intervention, and evaluation. Trophicognosis is defined as a nursing care judgment arrived at by the scientific method (Levine, 1966). This process replaces the traditional nursing diagnosis. The first step of trophicognosis involves observation of the patient and gathering of data. Upon data collection, provocative facts are identified and a testable hypothesis is formulated. This results in the trophicognosis which forms the basis for the second phase of the nursing process, intervention (Fawcett, 1995).

The goal for nursing interventions is to maintain the unity and integrity of the patient. In order to meet this goal, the nurse has a responsibility to recognize the patient's

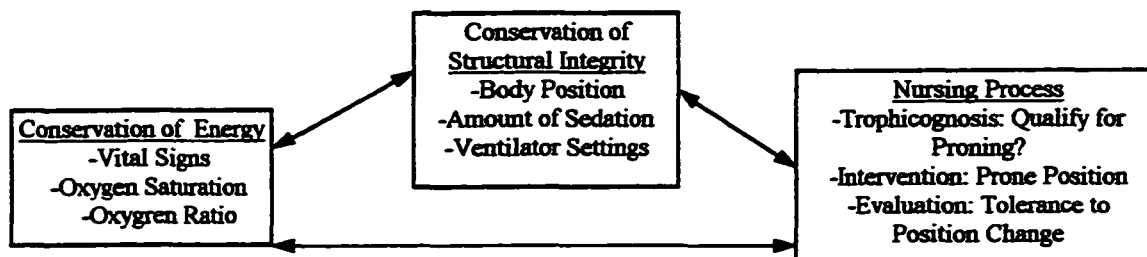
organismic response to an altered state of health. This organismic response is a change in behavior or levels of functioning as the patient tries to adapt to the environment. This response has been identified in four levels: response to fear, inflammatory response, response to stress, and sensory response (Leonard, 1990). Interventions can be supportive or therapeutic, and are developed within the four conservation principles. These are conservation of energy, conservation of structural integrity, conservation of personal integrity, and conservation of social integrity (Leonard, 1990). For the purpose of this study, the concepts of conservation of energy and structural integrity were used.

Conservation of energy refers to balancing energy output and energy input to avoid excessive fatigue. Energy is not observable but the consequences of its exchange are predictable, manageable, and quantifiable. Instruments can be used to monitor, measure, produce, or capture energy (Fawcett, 1995). In this project, examples of this energy that were measured included the child's oxygen saturation, heart rate, respiratory rate, and blood pressure. Conservation of energy assures that energy is naturally spent carefully by the body with essential priorities served first (Levine, 1991).

Conservation of structural integrity addresses the principle that the body attempts to maintain or restore itself by preventing physical breakdown and promoting healing (Fawcett, 1995). Conservation of structural integrity emphasizes that the individual's defense against the hazards of the environment are achieved with the most economical expense of effort. It results in repair and healing to sustain the wholeness of structure and function (Levine, 1991). Nurses can affect a person's conservation of structural integrity through early recognition of functional changes and nursing intervention (Artigue, Foli, &

Johnson, 1994). In this study, attempts were made to minimize threats to structural integrity through position changes, ventilatory support, and medications to promote sedation and pain control (see Table 1).

Table 1
Concept Diagram: Concepts and Study Variables



The final phase of the nursing process is the evaluation stage. It is in this phase that the trophicognosis is reviewed and revised in light of the patient's responses to various interventions and new information gathered (Fawcett, 1995). The patient's response to the condition requiring ventilation and to prone positioning were evaluated in this study.

Review of the Literature

Acute Respiratory Distress Syndrome. Acute respiratory distress syndrome has been attributed to a mortality rate that remains as high as 74% in childhood despite advances in patient care techniques (Timmons, Dean, & Vernon, 1991). ARDS is characterized by severe ventilation-perfusion mismatch with pulmonary hypertension, causing severe hypoxemia and decreased cardiac performance (Katz, Pollack, & Spady, 1984). In a 1992 Consensus Conference, the American Thoracic and the European Society of Intensive Care Medicine developed a definition for acute lung injury (ALI) and ARDS.

"ALI is defined as a syndrome of inflammation and increasing permeability that is associated with a constellation of clinical, radiologic, and physiologic abnormalities that cannot be explained by, but may coexist with left arterial or pulmonary capillary hypertension, and that ARDS be defined simply as a more severe form of ALI."

Schuster (1995) offers a further summary of the Consensus statement. Lung injury is present when characteristic pathologic abnormalities in the lungs' normal underlying structure result in a deterioration of normal lung function: ARDS is a specific form of lung injury with diverse causes, characterized pathologically by diffuse alveolar damage, and pathophysiologically by a breakdown in both the barrier and gas exchange functions of the lung. The results of ARDS lung injury are proteinaceous alveolar edema and hypoxemia.

Correcting life threatening hypoxia is one of the main goals in the treatment of ARDS. A range of possible approaches has been suggested including high airway pressures, jet ventilation, nitric oxide inhalation, and extracorporeal membrane oxygenation. None of these approaches has yet proved definitive (Ryan & Pelosi, 1996). Heulitt, Anders, & Benham (1994) in their critical exam of current ventilatory management of patients with ARDS, also found that there may be important lung injury caused specifically by mechanical ventilation.

Several studies have been conducted that support the relatively simple procedure of positioning a ventilated patient in the prone position to improve oxygenation with decreased lung trauma (Broccard, Shapiro, Schmitz, Ravenscraft, & Marini, 1997; Gattinoni, Pelosi, Vitale, Pesenti, D'Andrea, & Mascheroni, 1991; Langer, Mascheroni, & Gattinoni, 1988; Mutoh et al., 1992). The majority of studies reviewed on prone positioning ventilated patients focused on the neonatal and adult populations.

Lung Physiology. The rationale for prone positioning stems from basic lung physiology. Effective gas exchange depends on an approximately even distribution of gas (ventilation) and blood (perfusion) in all portions of the lungs. Gravitational forces pull the lungs down toward the diaphragm and compress the bases. As a result, the alveoli in the apices contain a greater residual volume, are larger, and less numerous than those in the bases. Because surface tension increases as the alveoli become larger, those in the apices are less compliant than those in the bases. Therefore, during ventilation most of the tidal volume is distributed to the bases of the lungs, where compliance is greater (McCance & Huether, 1994).

Numerous factors determine the gravitational pleural pressure gradients and include: 1) the shape and mechanical priorities of the chest wall, 2) the inherent stress free shape of the lung, 3) the weight of the lung, 4) the mechanical properties of the lung, and 5) possible friction between the two pleural surfaces (Milic-Emili, 1986). The relatively steep pleural pressure gradient in the supine position is thought to result from the effects of the force-balance relationship required for the lung and thoracic cavity to conform to one another. This relationship is affected by gravity acting on the rib cage, the diaphragm, the abdomen, the heart, and on other mediastinal content. At forced residual capacity, the heart and diaphragm extend farther dorsally in the supine position compared to the prone position that squeezes the lungs beneath them and expands the lung located in nondependent regions (Lai-Fook & Rodarte, 1991). Although gravity still influences regional pleural pressure in the prone position, its effect is offset by positional differences in the forces generated in the thoracic cavity (Lieu, Margulies, & Wilson, 1990). The

prone position differs from the supine position in having smaller gradients of pleural pressures and blood flow along the vertical axis (Mutoh, Guest, Lamm, & Albert, 1992).

History of Proning. The use of prone positioning for ventilated patients was first suggested by Bryan in 1974. He proposed prone positioning after studies done by Froese and himself (1974) demonstrated that mechanical ventilation of patients aggravates further the loss of dependent lung volume. Bryan suggested that the prone position is best suited to expand dependent portions of the lung by placement of the body in such a position that ventilation of the normally dependent lung is facilitated.

Prone positioning was also described in studies by Piehl and Brown (1976) and Douglas, Rehder, Beynen, Sessler, and Marsh (1977). However, it did not become a very popular treatment modality until years later.

Neonatal Studies. In 1989, Fox and Molesky studied 25 neonates with a range of gestational ages from 26-34 weeks. Each infant was his own control when positioned in the supine and prone positions. Arterial PaO₂ was measured in each position beginning at 5 minutes after positioning and every 30 seconds for the next 15 minutes. Prone positioning was found to significantly increase the infant's PaO₂ ($p=0.005$). There were several limitations to this study. Special beds were used that may not be practical for use in other clinical situations, infants were only studied if they were in deep sleep, and the study period was brief. Its utility is also questionable in older neonates.

Bjornson et al. (1992) also studied oxygenation of neonates. Four preterm infants were studied during nine sessions of prone, Fowler's, and supine positioning. Statistical analyses were not performed, however data points were graphed for

visual interpretation. Consistent differences in oxygen saturation were found for each infant when prone, however inconsistent findings were found when the infants were placed in Fowler's and supine positions. A strength of this study was that by using a single-subject alternating-treatment design, level differences between three positions used clinically with ventilated preterm infants were clarified. A small sample size, however, limited the power of this study.

Pediatric Studies. Hader and Sorenson (1988) investigated prone effects in 12 infants aged 2 months to 24 months. A quasi-experimental design was used in which the infant was his/her own control and was positioned in the prone, supine, and Fowler's positions. Transcutaneous oxygenation tension was used as the dependent variable. No statistical differences were found in transcutaneous oxygen tension between the three positions ($p=0.088$). Authors questioned a Type II error because means showed improvement in oxygenation with the prone position. Limitations included a small sample size, convenience sampling, use of one facility, and variability of external and confounding variables, such as: 1) patient disease process, 2) the amount of subcutaneous fat and/or accumulation of subcutaneous fluid, 3) circulatory and/or peripheral blood perfusion, 4) anatomic abnormalities, 5) temperature of the patient, 6) environmental temperature, 7) parental interaction, and 7) medications the patient was receiving.

Murdoch and Storman (1994) studied seven ventilated children aged 3 months to 6.8 years with ARDS. Baseline data of heart rate, systemic and arterial blood pressure,

cardiac output, oxygen saturation, and arterial blood gases were obtained in the supine position. Each child was then positioned prone and data collected after 30 minutes in this position. Changing the child's position had no significant effects on any of the hemodynamic variables with the exception of oxygen saturation. A significant increase ($p<0.02$) in oxygenation saturation was found when the children were in prone positions, while a significant decrease occurred when repositioned supine ($p<0.02$). Limitations of this study were the small sample size and limited time spent in the prone position.

Numa, Hammer and Newth (1997) suggest that they are the first investigators to study the effect that prone positioning has upon the functional residual capacity (FRC) in children with severe lung disease or in those under neuromuscular blockade. Thirty patients, aged three years to 7.6 years, were studied after being prospectively classified as having normal, restrictive, or obstructive lung disease based upon diagnosis and physical examination. Pulmonary function tests were performed and arterial blood gases analyzed before prone positioning, ten minutes and sixty minutes after proning, and finally ten minutes after the patient was returned supine. Although impressive individual results were obtained, no significant change in FRC in any group was found when patients were moved from supine to prone. An increase in oxygenation following prone positioning was found only in patients with obstructive lung disease ($P=0.009$). Limitations to this study include the inconsistent duration that patients in this study were ventilated prior to inclusion into the study, the investigators' dismissal of proning when FRC was not found to be significant as a mechanism for oxygenation improvement, and the lack of an unrestricted abdomen in paralyzed subjects.

Adult Studies. Piehl and Brown (1976) were the first investigators documented to study the actual use of prone positioning. The authors studied five patients with respiratory insufficiency positioned prone through the use of a CircOlectric Bed. All patients showed improved PaO₂ values and secretion mobilization. Obvious limitations were the small sample, the use of equipment that was unavailable to many, and lack of consistent data collection between patients.

Douglas et al. (1977) studied six patients that were turned from supine to prone to confirm the findings of Piehl and Brown (1976). One reported difference in the procedure used by Douglas et al. was that the patients were positioned with their abdomens unrestricted. Measurements of arterial blood gas tensions were obtained at no specific time interval after the position change. Five of the six patients had a pronounced increase in PaO₂ after the initial turn from the supine to prone position, the sixth had similar increases when position changes were performed in both positions. All six had PaO₂ levels that increased consistently in subsequent positioning. Limitations in this study were small sample size and no consistent time interval for measurements.

Langer, Mascheroni, and Gattinoni (1988) studied 13 patients aged 1 year to 74 years with moderate to severe ARDS in an experimental repeated measures design. Gas exchange and hemodynamics were evaluated before, during, and after a two hour period of prone positioning. Arterial and venous blood samples were analyzed for hemoglobin, oxygen saturation, carboxyhemoglobin content, and venous admixture. Other variables measured were cardiac output, pulmonary wedge pressures, cardiac index, and central

venous pressure. A significant increase in PaO_2 ($p < 0.01$) was found after prone positioning at 30 minutes and 120 minutes, while PaCO_2 and hemodynamic parameters were unaffected. Eight of the patients were considered responders and five were non-responders. Patients were considered responders if their PaO_2 showed an increase after 30 minutes in the prone position. Non-responders were those that did not experience any PaO_2 improvement at any time after proning. A limitation to this study was because there were responders and nonresponders, investigators were unable to discriminate which mechanism of respiration attributed to improved oxygenation.

Gattinoni et al. (1991) reported that lung density as shown through CT scan increased, and regional inflation decreased from ventral to dorsal regions. This suggested progressive deflation of gas-containing alveoli along the gravity gradient when subjects were in the supine position. Ten patients with ARDS and 14 volunteers without a history of lung disease were compared through CT. Lung mass distribution between the two groups were similar in both the supine and prone positions. Tissue distribution between the supine and prone positions, however were different. Tissue content in prone subjects was significantly increased in ventral lung levels compared with those in the supine position ($p < 0.01$), and significantly decreased in the dorsal levels ($p < 0.01$). The investigators believed that the most likely explanation of the density redistribution was a redistribution of intrapulmonary gas. In patients with ARDS, the gravitational pressure gradients were greater because of increased tissue mass and the overall gas content was reduced causing decreased transpulmonary pressure. A secondary effect of the phenomenon was that decreased transpulmonary pressure could also induce collapse of

potential recruitable lung units. When gravitational force was applied by turning patients from supine to prone, decompressed atelectatic regions reopened while new regions of compression atelectasis developed. This could explain varying degrees of response in oxygenation observed during positional changes. Yet, limitations with this study were found. First, the 14 volunteers used did not undergo CT in both positions so intersubject differences were not controlled. Lack of control between subjects was also evident by having the healthy volunteers unsedated while the patients with ARDS were anesthetized and paralyzed. This made it unclear whether the differences found were due to the lung status of the subjects, the effect of paralytics and anesthetic agents on those with ARDS, or the position change.

In 1994, twelve patients with severe ARDS were evaluated by Pappert, Rossaint, Slama, Gruning, and Falke in a prospective randomized study. Pulmonary gas exchange and hemodynamics were measured through a multiple inert gas elimination technique (MIGET) before, during, and after a two hour period of pressure controlled mechanical ventilation. Data were measured on patients in the prone position for the effect upon continuous ventilation-perfusion distribution in the lung. Findings included a marked, but not significant ($p=0.06$) increase in PaO_2 after 30 minutes of proning. A significant increase in arterial oxygenation was found however at 120 minutes ($p=0.027$). When the patient was returned to the supine position, a significant drop ($p=0.005$) in PaO_2 to nearly baseline was found after 120 minutes. Eight of the patients were considered responders, while four were classified as non-responders. Analysis of the data in the responder group showed that 44% of the blood flow in the supine position was distributed to unventilated

areas and that no areas with a low ventilation-perfusion ratio were apparent. Fifty four percent of this blood flow was demonstrable in areas with normal ventilation-perfusion ratios. The prone position resulted in a significant reduction of blood flow to unventilated areas to 34% after 30 minutes, whereas blood flow to areas with good ventilation perfusion increased from 54% to 66%. Areas that had low ventilation-perfusion were not affected by positioning. These changes were almost reversible by returning the patient to supine after 120 minutes. Pulmonary oxygenation was found to be nondependent upon the procedure of positioning, but from the posture itself because of the timing when the improvements were noted, and when they were lost. Findings supported the theory of Langer et al. (1988) that ventilation redistribution is probably the main factor influencing oxygenation when patients are in the prone position.

Similar findings were found by Vollman and Bander (1996) using a prospective controlled trial without blinding design with 15 adult patients with ARDS. Each patient was his/her own control and was randomly assigned to begin in either the supine or prone position. Two sessions of data collection were performed to assess reproducibility. After 20 minutes in the assigned position, data were collected on gas exchange, pulmonary mechanics, and hemodynamics. The patient was then turned to the alternate position and data collected after an additional 20 minutes. This study differed from other clinical studies mentioned because a positioning aid was used that had been developed by the investigators to aid in proning. In the overall population, the PaO_2 increased and the oxygen tension decreased significantly ($p < 0.05$) in the prone position. No other pulmonary or hemodynamic variables showed significant differences. Responders (9) and non-

responders (6) were identified. Non-responders demonstrated a decreased PaO₂ without hypoxemia, so prone positioning was not discontinued. Peak inspiratory pressure, plateau pressure, PaCO₂, and mean pulmonary artery pressure showed significant differences between groups, but not between positions. Non-responders in this study seemed to follow non-responders in other studies mentioned, yet two distinct differences were found in the non-responder group; additional lung pathologies and more segmental lung processes.

Mure, Martling, and Lindahl (1997) performed a clinical follow-up study on 13 patients after their institution had utilized prone positioning in a tertiary care academic hospital for 2 1/2 years. Oxygenation indices were compared in the prone and supine positions. Twelve of the thirteen patients showed improvements in oxygenation indices when positioned prone. Limitations to this study were the lack of controls due to the observational nature of the study, lack of randomization, and potential bias of the investigators due to anticipated positive results of this intervention.

Chatte et al. (1997) expanded the prone studies by having a larger sample size (32), longer periods of measurement (one hour before prone, one hour after proning, four hours after remaining in a prone position, and one hour after returning to a supine position), and used 294 periods of prone positioning. Findings replicated previous studies that found oxygenation was improved significantly during proning and persisted after returning to supine ($p < 0.001$). Seventy-eight percent of the patients were responders and 22% were non-responders. After the initial data collection session, patients were not limited to the four hours in the prone position. Side effects observed during the 294

sessions included: 1) mild cutaneous and mucosal damages affecting anterior chest wall, lips, tongue, or forehead without severity; 2) dependent edema; 3) apical atelectasia; 4) catheter removal; 5) venous line compression, and 6) extubation. A limitation addressed in this study was that improvement in survival could not be claimed without further comparison.

Finally, Stocker et al. (1997) expanded prone studies to include the use of low volume pressure limited ventilation with ARDS patients. The mortality rate of 25 patients suffering from ARDS were studied in a quasi-experimental design. Positive inspiratory pressures were limited to no greater than 35mbar, and prone positioning was instituted if the patients' diagnosis/condition allowed. Staff were familiar with prone positioning for patients and were convinced of its effectiveness, so 17 of the 25 patients were positioned in this manner. Time spent prone was individualized and ranged from .75 hours to 66 hours. Patients remained prone as long as their $\text{PaO}_2/\text{FIO}_2$ remained stable. The mortality rate of these patients was 12%, much lower than the predicted 40-70% mortality rate reported for patients with ARDS. None of the deceased died from progressive lung disease. Investigators attributed this success to low pressure ventilation coupled with prone positioning. Proning helped to alleviate the disadvantage of pressure limited ventilation: hypoxia. A limitation to this study was the lack of randomization. Investigators found data on ventilator induced lung injury too convincing to apply high pressures.

Animal Studies. Animal models have been used to investigate the physiologic rationale for the improved clinical findings in oxygenation of prone patients. Mutoh et al. (1992) studied six pigs to study the dependent and nondependent pleural pressures when

positioned in the supine and prone positions after volume infusion. Volume overload was found to increase the oxygen tension and pleural pressure in the dependent lung region. The degree of change was reduced by turning the animals to a prone position ($p < 0.05$). Results indicated that in supine animals, volume infusion alters regional pleural pressure in a way that likely causes airway closure in dependent lung regions. These changes were diminished by turning the animals to the prone position. When the animals were in the supine position, large areas of lung were held below their closing volume as the pleural pressure was not sufficiently negative to maintain airway patency. When prone, much less of the lung was affected, resulting in an improved match between ventilation and perfusion, thus increasing arterial oxygenation. A limitation to this model was that pigs do not have identical anatomy to humans.

Lamm, Graham, and Albert (1994) further investigated the reason for the prone effect through the use of a canine model with induced lung injury. Regional ventilation and perfusion was measured using 81mKr and 99mTc-MAA injections and single photon emission computed tomography. Four dogs were used as controls and four were given lung injuries through oleic acid. All animals were positioned in supine and prone positions during the CT. Four important findings of this study that support the benefits of prone positioning included: 1) improved oxygenation ($p < 0.01$) when prone, 2) ventilation/perfusion ratios were shifted to more normal values ($p < 0.05$), 3) decreased relative ventilation to perfusion heterogeneity, and 4) improvements found microscopically primarily in dorsal lung regions. The prone position generated a transpulmonary pressure sufficient to exceed airway opening pressure in dorsal lung regions where atelectasis,

shunt, and ventilation/perfusion heterogeneity are most severe, without adversely affecting ventral lung regions.

Similarly Broccard et al (1997) used an animal model to investigate the influence that body position had upon the extent and distribution of lung damage in an oleic acid canine model of acute respiratory distress syndrome when high tidal volumes and high positive end expiratory pressures were used with mechanical ventilation. Twelve dogs were anesthetized and paralyzed, 90 minutes later injected with oleic acid, and then randomized to be ventilated for four hours in with the supine or prone position using the same ventilatory patterns. After the experiment the lungs were excised for gravimetric determination and histologic examination. Hemodynamic measures between the two groups were not statistically different ($p>0.05$), however significant histologic differences were found ($p<0.01$). In the prone dogs histologic changes were more uniform and less extensive. In supine dogs the lung injury score was greater in the dependent than in the nondependent region ($p<0.01$). Limitations of this study included: 1) the indicators used to assess lung injury were not direct measurements of pulmonary vascular permeability or vascular functions; 2) the histologic score did not differentiate between direct mechanical injury or its consequences; 3) the study design did not allow conclusions of certainty that the observed differences between the groups reflected the effect of body position on superimposed ventilator induced lung injury, rather than on the evolution of oleic acid injury; and 4) hyperacute lung injury imperfectly models ARDS.

Summary. The review of the literature supports the intervention of prone positioning ventilated patients because of the improvement in oxygenation. Although

reasons why this effect occurs remain inconclusive, the following explanations have been offered by investigators.

When Langer et al. (1988) obtained CT scans on patients in their study in both prone and supine positions, they demonstrated a clearing of densities in previously dependent lung regions of the lungs, and a redistribution of densities following gravity after turning patients from supine to prone. Also, no negative effects of prone positioning were found in both patients that were classified as responders or non-responders. Although no baseline data could be determined that would indicate which patients would be non-responders, within ten minutes of positioning it became evident which patients would respond to this intervention and which would not.

Conclusions derived by Pappert et al. (1994) from their research were that improved oxygenation resulted from a redistribution of blood flow away from unventilated areas to regions with normal ventilation-perfusion ratios. A likely explanation is that this occurs from alveolar recruitment in previously atelectatic, but healthy lung regions.

Vollman and Bander (1996) offered possible explanations on why some patients were responders and why some were non-responders. The differences in lung pathologies of non-responders were thought to alter the structure and function of the pulmonary parenchyma of pulmonary vasculature to such an extent that position change had little effect on improving ventilation/perfusion matching. This supported the explanation that blood flow to better ventilated lung regions while prone was the major mechanism in improving gas exchange in the responder group.

Lamm et al. (1994) interpreted their data and those of previous investigators to suggest that after lung injury two major mechanisms occur. First, regional ventilation to large areas in the dorsal lung regions decrease or cease while perfusion to this same area is relatively maintained. Secondly, when patients are prone dorsal lung ventilation improves, ventral lung ventilation diminishes, and perfusion is unchanged. Clinically, this means that simply by positioning a patient prone, lung physiology is improved that may allow the use of lower levels of positive end expiratory pressure and reduced FIO₂.

Implications for Study

This study will broaden the research base for pediatric patients. Although the sample was a non-randomized convenience sample, attempts were made to have a larger sample size than any of the pediatric studies found. Furthermore, this research replicated other studies by studying the short term effect upon a child's oxygenation. Any patient requiring mechanical ventilation is subjected to lung damage, changes in hemodynamics, and unnatural pleural pressures. For this reason, all ventilated children were included in this sample instead of only children with a diagnosis of ARDS.

Research Question and Hypothesis

In light of the review of literature, the research question posed in this study was "will prone positioning a pediatric ventilated patient replicate adult and neonatal findings of increased oxygen ratio in the prone position". The hypothesis was that children needing mechanical ventilation would show a significant difference in oxygen ratios between the supine and prone position.

Definition of Terms

The following definitions of variables were used for this study.

1. **Vital signs:** The numerical measurement of a child's heart rate, respiratory rate, and blood pressure.

2. **Oxygen saturation:** The arterial oxygenation of hemoglobin as measured in percent oxygen by a pulse oximeter (Ramanathan, Duran, & Larrazabal, 1987).

3. **Oxygen ratio:** Patient saturation/FIO₂

4. **Ventilator settings:** Measurement of the parameters being delivered to a patient by mechanical ventilation. Parameters include: peak inspiratory pressure, peak end expiratory pressure, delivered breaths, oxygen concentration, mean airway pressure, tidal volume, minute ventilation, and mode of breath delivery.

5. **Medical diagnosis:** The label given to a disease process that guides medical and nursing interventions.

6. **Body position:** The direction a patient's body is lying: prone (abdomen down), supine (back on bed), or Fowler/lateral (either side lying on the bed).

7. **Trophicognosis:** Nursing care judgment arrived at by the scientific method (Leonard, 1990).

8. **Intervention:** Nurses' participation in the patient's environment after recognition of the patient's organismic response. Considered supportive (maintaining the status quo) or therapeutic (promoting healing and restoration) (Leonard, 1990).

9. **Evaluation:** Analysis and revision of trophicognosis and interventions based upon patient's organismic response to nursing care and the environment.

CHAPTER 3

METHODOLOGY

Study Design

A retrospective research design was employed in this study to examine oxygenation of ventilated children. Medical record audits were performed on ventilated children admitted to a large metropolitan hospital in Southwest Michigan between January 1998 and July 1998.

Study Site and Subjects

This study was conducted in an eight bed Pediatric Intensive Care Unit (PICU) at a regional center that services 17 area hospitals. Children admitted to the PICU could range in age from one week to 18 years. Medical records were audited for all children on the ventilator greater than 24 hours and physiologically able to be positioned prone. Children potentially unable to be placed in a prone position included: (1) trauma patients, (2) those requiring intracranial pressure (ICP) monitoring, (3) abdominal and spinal surgical patients, (4) patients with spinal injury, and (5) burn patients with grafts and injuries that cannot be manipulated in this position.

Seventy-four children were ventilated from January 1998 through July 1998 in the PICU. Twenty three (47%) out of 49 children who met the inclusion criteria were prone. Subjects ranged in age from one month to 16 years with a mean age of 2.31 years (s.d.=3.71 years). Fifty-two percent of the sample were female (n=12) and 47.8% were male (n=11).

The 23 children were admitted under one of nine admitting diagnoses. Fifteen children (65.2%) were admitted under a respiratory diagnosis. The remaining eight children had a diagnosis of either aspiration, brain tumor, post operative, sepsis, cor

pulmonale, Hunter's syndrome, spinal cord injury, or drowning. Thirty-nine percent of the children had an underlying lung pathology prior to this admission, while 60.9% had previously healthy lungs as shown in Table 2.

Table 2
Subject Demographics

	Patient #	Gender	Age in Months	Diagnosis	Lung Status
1	3	M	1	Respiratory	Normal
2	4	F	1.5	Respiratory	Normal
3	12	M	1.5	Sepsis	Normal
4	13	M	2	Cor. Pulm.	Normal
5	17	F	2	Respiratory	Damaged
6	20	M	2.5	Respiratory	Normal
7	15	F	3	Respiratory	Normal
8	1	F	5	Respiratory	Normal
9	16	F	5	Respiratory	Normal
10	6	M	8	Respiratory	Normal
11	21	M	11	Respiratory	Damaged
12	19	M	14	Respiratory	Damaged
13	5	F	15	Respiratory	Normal
14	8	F	16	Respiratory	Normal
15	22	F	17	Spinal Cord	Normal
16	23	F	18	Drowning	Normal
17	2	F	36	Respiratory	Damaged
18	9	F	36	Brain Tumor	Normal
19	14	M	36	Respiratory	Damaged
20	11	M	48	Post-op	Normal
21	18	M	48	Hunters	Damaged
22	7	F	120	Respiratory	Damaged
23	10	M	192	Respiratory	Damaged

Instruments

Oxygen saturation was obtained through pulse oximetry using Spacelabs pulse oximetry modules. Accuracy has been determined by the manufacturer (See Appendix A) and is presented in Table 3.

Table 3
Spacelabs Pulse Oximetry Specifications

Range	Accuracy
80-100%	+/- 2%
50-80%	+/- 3%
0-50%	Not Specified

Data were collected using an audit sheet for compilation of information. The data collected for this study included: 1) child's age; 2) gender; 3) diagnosis; 4) heart rate, respiratory rate, blood pressure and oxygen saturation before and after the intervention; 5) FIO₂ delivered per ventilator just prior to proning and two hours after the position change; 6) the number of hours between initial ventilation and proning; and 7) whether the child had an underlying lung condition. Oxygen ratios were calculated by dividing the patient's oxygen saturation level by the amount of FIO₂ delivered as measured by the ventilator. Oxygen ratios were calculated prior to proning and after the position change.

Procedure

PICU staff were encouraged to position all ventilated children that met criteria prone as soon as possible after admission. (see Appendix B for Protocol for Positioning). All ventilated children that were admitted to the PICU from January 1998 to July 1998 had their medical records audited. Data were collected by the investigator if the patient had been prone during their PICU stay.

Threats to Internal Validity

The major obstacle anticipated in this study was obtaining support and compliance from the PICU staff. Prone positioning of ventilated children was introduced as a new intervention for this critical care unit at the beginning of the study. As a result, implementation of proning was inconsistent. The protocol recommended proning upon initial stabilization, however the length of time before proning ranged from five hours to 166 hours (m=42.9; s.d.=40.1). The inconsistencies in the length of time before

implementing the intervention and potential effects were examined and reported with the other results of this study.

Another anticipated threat to the validity of this study was whether the children's FIO₂ would be weaned appropriately during the first two hours after first being prone. Oxygen is often not weaned until the clinician is convinced that the patient will tolerate a decrease in FIO₂. Weaning might not have taken place during the two hour timeframe for data collection when the patient might have tolerated it. Inconsistencies in weaning procedures could affect the calculated oxygen ratios. This issue was evaluated and discussed in Chapter 5.

Lastly, documentation was anticipated to be a problem. An instrument was developed to collect data for this study during medical record audits. However, data collection in this retrospective study was dependent upon appropriately documenting position changes from supine to prone and vital signs just prior to proning, as well as vital signs two hours after the position change was initiated. The PICU staff had recently undergone documentation inservices to prepare for a Joint Commission on Accreditation of Healthcare Organizations review, which included reminders for hourly data entries.

Upon completion of the data collection process, it was found that documentation was not a threat as predicted. All required data were accessible from the medical record and no missing data were present.

Many of the procedural issues were addressed by having only one data collection period. Staff did not have to be consistent in the proning regime in order for the data collection process to continue.

Human Subjects Considerations

Permission to conduct this study was obtained through the Human Use Committee at the data collection site and the Human Research Review Committee at Grand Valley State University. Consent for study was obtained through the hospital admission

form that parents or legal guardians sign upon a child's admission to the hospital.

Permission for data collection by staff and students for research purposes is included in the admission form. Records were identified by patient number to obtain them from medical records and recoded for data collection to protect patient identity.

CHAPTER 4

RESULTS

The purpose of this research was to examine the effect that positioning ventilated children prone had upon their oxygen ratio. Data analysis were completed using the Statistical Package for the Social Sciences (SPSS/WIN+) software.

Hypothesis and Research Question

Research has suggested that prone positioning of ventilated patients with ARDS improves oxygenation. This study was developed to build upon prior research. The pediatric population was chosen for study and expanded to include all ventilated children, not just those with ARDS.

The research question established for this study was: will prone positioning a ventilated child replicate adult and neonatal findings of increased oxygen ratios in the prone position. The research hypothesis for this study was that children requiring mechanical ventilation would show a significant difference in oxygen ratios between the supine and prone position.

Data analysis were performed using t-tests for paired and independent samples. A significance level of $p < 0.05$ was established for all statistical tests.

Hypothesis Testing

Before analysis could be performed, oxygen ratios were calculated from data obtained immediately prior to proning and two hours after the intervention. Oxygen ratios were computed by dividing the child's oxygen saturation level, as measured by the Spacelabs pulse oximeter, by the measured FIO_2 delivered by the ventilator. This number was considered the oxygen ratio used for comparison and analysis between the children.

A higher ratio meant that a child had a better saturation level in lower FIO₂. The mean oxygen ratio prior to proning (m=2.05; s.d.=0.62) was found to be lower than two hours after the children were proned (m=2.24; s.d.=0.60).

Table 4
Oxygen Ratios

	Pre-Proning	Post-Proning
Range	0.83-3.5	0.93-3.57
Mean	2.05	2.25
S.D.	0.62	0.60

The pre-proning and post-proning oxygen ratios were analyzed and found to be significantly different. Oxygen ratios were significantly higher two hours after the children were proned ($t = -2.41$; $df=22$; $p=0.02$) when compared to ratios when the children were positioned in the supine or lateral position.

Additional Analysis

Other variables were examined to investigate the impact they might have had upon the oxygen ratios of the children. These additional variables were gender, age, admitting diagnosis, lung status, and length of time between initial ventilation and proning. No significant differences were identified in oxygen ratios based upon gender or lung status prior to admission.

To evaluate if differences were present by diagnosis, two groups were formed. One group was comprised of the children with a respiratory admitting diagnosis and the second group included all other diagnoses. It was not possible to analyze data by

individual diagnosis due to the small sample size. No significant difference was found between the mean oxygen ratios of the two groups before and after proning. When the influence that age had upon oxygen ratios was examined, there was no significant difference in ratios before proning and after. Further analysis by age group was done however, because it was suggested by the investigator that children less than one year old were easier to prone, therefore were prone sooner. Based upon anecdotal findings, it was also speculated that younger children responded to the intervention better.

Two children, aged ten and sixteen years, were excluded from this analysis because they were nearly three standard deviations from the mean age. The remaining 21 children were divided into two groups; those less than one year of age and those aged one year through four years. Children, aged less than one year, showed improvements in mean oxygen ratios after proning (mean = 2.23, s.d. = 0.69, before proning, and mean = 2.41, s.d. = 0.69 after), but it was not a significant increase. However, children aged one to four years showed a significant increase between oxygen ratios before and after proning ($t = -2.98$, $df = 9$, $p = 0.015$). The mean oxygen ratio improved from 1.83 (s.d. = 0.54) before proning to 2.08 (s.d. = 0.53) after proning.

Table 5
Summary of Analysis by Age

	< 1 Year		1-4 Years	
	Pre-Prone	Post-Prone	Pre-Prone	Post-Prone
Mean Oxygen Ratio	2.23	2.41	1.83	2.08
S.D.	.694	.697	.547	.535
Hours Prior to Prone	26.4		41.7	
S.D.	20.2		30.2	

The two age groups were also examined to determine if the younger children were prone sooner. Although there was a 15 hour difference in the means of the two groups between initial ventilation and proning, this was not statistically significant.

Data were also individually reviewed for any other possible influences upon the children's oxygen ratios. Upon review, it was found that oxygen was not aggressively weaned during the study. Thirty-five percent of the sample (8) were not weaned with saturation levels greater than 93 in the two hours between proning and data collection. An additional 22% (5) had the FI_{O_2} weaned less than 10%. This represents 56% of the sample that may have had more dramatic post-proning oxygen ratios for analysis.

In summary, after examination of other variables that may have explained the improvement in the oxygen ratios of the 23 children when prone, these were not found to be significant. Therefore, the research hypothesis was supported. Proning, as an intervention, favorably impacts the oxygenation of a ventilated child.

CHAPTER 5

DISCUSSION AND IMPLICATIONS

The findings of this study supported the hypothesis that prone positioning of ventilated children will improve oxygen ratios. Analysis of the group of children prone indicated that those older than one year old benefited more than those less than one year of age. The diagnosis upon admission, hours from initial ventilation to proning, gender, and lung status did not influence the significance of proning.

Relationship of Findings to the Conceptual Framework

The interaction between the children in this study, the caregivers involved, and the significance that proning had upon the children supported Levine's Conservation model. Levine's focus on the patient in an impaired state of health, in need of intervention, supported the role of the children and caregivers in this study. As predicted by Levine's model, the caregivers in this study acknowledged the children's organismic response to an altered state of health. By proning the children, the caregivers attempted to assist the children conserve energy. The findings suggested that by proning and improving oxygen ratios, the body could spend energy on other essential priorities and achieve structural integrity.

Relationship of Findings to Previous Research

The results of this study support findings of eleven of fourteen human studies reviewed indicating that positioning ventilated patients in the prone position improves oxygenation. However, the scope of this study did not include determining the mechanism

that caused improved oxygenation. This study was undertaken to determine if positive results of proning would be replicated in the pediatric population at the institution where the study was performed.

When individual data were reviewed, as mentioned in Chapter 4, children less than one year did not respond as well as the older children. The children in this study seemed to replicate the findings of Hader and Sorenson (1988). The mean oxygen ratio of the less than one year group in this study improved as did those in Hader and Sorenson's work, as their research also found, not statistically so.

A possible reason for the lack of statistical significance in the less than one year group could be that four children could have been weaned but were not and two were non-responders. There were also two children that had oxygen saturation levels that decreased, but remained above 93%, an acceptable level at this institution. No children in the older age group were considered non-responders, but three children also showed a decrease in saturation but remained above 93%.

Additional explanations offered for the lack of significance in the younger children are that they have larger anterior/posterior diameters and less lung weight, which could mean that the zones of ventilation/perfusion do not change as much in younger children. Also, because anatomically younger children have weaker abdominal muscles and less rigid rib cages, they may have less net change in intra-thoracic pressures when positioned from supine to prone positions.

When comparing children that responded to proning (responders) compared to those that did not (non-responders), the non-responder group in this study (9%) was much

lower than reported in the literature. Non-responder percentages reported in the literature were 38% (Langer et al., 1988), 40% (Vollman and Bander, 1996), and 22% (Chatte et al., 1997). This was most likely because the other studies focused on patients with ARDS. This study investigated any child requiring mechanical ventilation, so may have included children that were not as critically ill as those in other research.

The most recent pediatric study found in the literature contradicts the findings of this study. Numa et al. (1997) with the largest sample in the literature, found an increase in oxygenation following prone positioning only in patients with obstructive lung disease. No statistical differences in patients with lung pathology or healthy lungs were found in the present study. Numa et al. recommended not to prone ventilated patients. In contrast, this study supports proning ventilated children. The 23 children in this study as a whole showed a statistically significant improvement in their oxygenation after being prone.

Limitations and Recommendations

There were several limitations to this study. The most obvious was the sample. The subjects comprised a small convenience sample. Although it was one of the larger samples of those reviewed in the literature, it was still too small to draw conclusions that could extend beyond this group. It did however replicate similar findings in other studies, that add power to the positive and worthwhile effects of proning a ventilated child. Lack of consistency with who was prone and when proning took place was also a limitation and frustration with the study. The protocol developed for proning was not followed, so children were rarely prone upon initial stabilization. Although this was determined not to be a significant factor, the lack of consistency in proning hindered it

from becoming a routine intervention. Children that may have benefited from proning were not included in the study.

A third limitation was the study design. Originally, data were to be collected as children were prone. It became clear within the first month of the study that needed data would not be obtained unless a person willing to collect the data concurrently was available 24 hours a day for the seven months of the study. This was not feasible within the realm of this study. If data collection had occurred as the children were ventilated, more may have been included in the study, and compliance with the protocol may have occurred. However, all needed data were found in the medical record with the revised study design.

Implications for Nursing

Based upon findings of this and previous research, proning should be considered on all children that are mechanically ventilated, within the framework of Levine's Conservation Model. The intervention is non-invasive and within the scope of nursing judgment and practice. Once the child is ventilated, the goal of the caregiver should be to assist the child to restore a state of health by conserving energy and structural, personal, and social integrity. In order to do this, the caregiver must assess the child's present state of adaptation and develop interventions accordingly. Incorporating research that shows that proning may improve oxygenation, the caregiver should assess the ventilated child to determine if criteria for proning is applicable. If proning is an option, the goal should be to assist the child conserve energy and improve oxygenation. Once the child is prone, the caregiver must continue to assess the child's adaptation and conservation of structural

integrity. In order to best maintain the child's well being while ventilated, it is necessary for the caregiver to provide comfort through proper positioning, suitable oxygen levels, sedation and pain control. The caregiver must continue to monitor and evaluate the child's response to the position changes. Through nursing intervention, the child can conserve energy and integrity in ways that may impact long term outcomes.

It is also important financially to assist the child recovery as rapidly as possible. Incorporating prone into standards of care may reduce the time a child spends on the ventilator and require intensive care.

Registered nurses can play an active role in the education of families and staff regarding the significance of prone as an intervention. They are in a key position to share research on prone with the multidisciplinary team to enhance understanding and acceptance of this intervention. As was initially found in the initiation of prone in the institution where this study took place, the idea of prone a ventilated patient may meet resistance. Equally as important is the need to explain to family members the rationale for prone an infant in an intensive care setting compared to a home setting. Confusion may occur between recommendations for not placing infants in a supine position to minimize the risk for sudden infant death and what they see in the intensive care.

Future Research

There are several areas of study that could be expanded from this study. No studies were found that investigate the long term effects of prone. Lung damage could be assessed by pulmonary function tests at determined intervals after ventilation and hospitalization and compared between prone and non-prone children.

This study was the only study known that proned all ventilated children.

Replication of this design would help determine whether the findings can be extended beyond this institution.

Another area for future study would be to investigate if proned children are on the ventilator less time and have a shorter length of stay. This could decrease family disruption and lower hospital costs profoundly.

It is clear from the literature that there are no consistent guidelines for proning patients. Several areas for further study stem from this lack of recommendation. These include the length of time a patient should be left in the prone position, when the intervention should be initiated, whether positioning aids are superior to proning unassisted, and whether the abdomen should be positioned unrestricted to reduce pressure on the lungs.

Ventilator management to accompany proning would also be a useful variable to investigate. Only one study, Stocker et al. (1997), investigated ventilator management with proning and found that lower ventilator pressures could be used.

In conclusion, in the institution of this study, the use of proning should be considered with all ventilated children to improve oxygenation using lower concentrations of oxygen. Detrimental effects of oxygen therapy have been documented, so any interventions that could minimize this damage should be implemented.

APPENDICES

APPENDIX A

SPACELAB PULSE OXIMETER MANUFACTURER SPECIFICATIONS

Specifications

SaO₂ Monitoring	Range: 0 - 100% Accuracy: 80 - 100%, $\pm 2\%$; 50 - 80%, $\pm 3\%$; 0 - 50%, not specified Display Resolution: 1% Averaging Time: Menu selectable (FILTER key): 0, 2, 4, and 8 seconds Settling Time: Display typically settles to within 1% of final reading in less than 15 seconds after the sensor is properly applied and FILTER = OFF.
Dimensions	Height: 4.45 in. (11.30 cm) Width: 2.23 in. (5.66 cm) Depth: 7 in. (17.78 cm) Weight: 2.2 lbs. (1.0 kg)
Power	+5V, 500 mA, (2.5 watts) +12V, 150 mA, (1.8 watts) -12V, 25 mA, (0.3 watts) Total power consumption less than 4 watts. All power is derived from the PC Bedside Monitor
Environmental Considerations	Operating: +10 to +50° C ambient temperature Storage: -20 to +85° C ambient temperature

Equipment Setup

The Pulse Oximetry module can be inserted and removed from the PC Bedside Monitor without interruption of bedside power. The module can be inserted into any of the four slot positions on the monitor.

Note

Do not remove the module when the front indicator light is ON. Before removing the module, be certain that the module indicator light is OFF. If not, press the NORMAL SCREEN key.

APPENDIX B
PROTOCOL FOR PRONING

PROTOCOL FOR PRONING

GUIDELINES FOR USE OF THE PRONE POSITION IN VENTILATED PATIENTS

Medical rationale: Several animal and human studies have shown the positive effect prone positioning has in the of acute respiratory distress syndrome (see reference list for suggested readings on sequelae prone positioning). The cause of this effect is not clear, however research has shown that prone position improves ventilation/perfusion matching (Lamm, W., Graham, N., & Albert, R., 1194). It has also been speculated that this maneuver may help reduce some of the factors believed to damage the lungs of patients with acute respiratory distress syndrome, such as excessive inspiratory pressure and a high inspired oxygen fraction (Ryan, D. & Pelosi, P., 1996). Broccard, A., Shapiro, R., Schmitz, L., Ravenscraft, S., & Marini, J. (1997), have also shown through animal study that prone positioning in comparison to supine position provide a number of positive results. These include less lung damage as indicated by histologic abnormalities, less time for evolution of lung compliance, greater distribution of lung water into dependent regions of the lungs, higher PaO₂, lower venous admixture and increased cardiac output and mean airway pressure. This technique when in used in combination with low volume pressure-limited ventilation and permissive hypercapnia lowers mortality in severe ARDS (Stocker, R., Neff, T., Stein S., & Ecknauer, E., 1997).

Nursing rationale: Levine's Conservation model describes four conservation principles that serve as a foundation for all nursing interventions. These are conservation of energy, conservation of structural integrity, conservation of personal integrity, and conservation of social integrity. Conservation refers to the ability to keep together or maintain a proper balance.

The goal for nursing interventions is to maintain the unity and integrity of the patient through the process of trophicognosis. Trophicognosis refers to the scientific approach in determining nursing care (Fawcett, J., 1995). In order to meet this goal, the nurse has a responsibility to recognize the patient's organismic response to an altered state of health. This organismic response is a change in behavior or levels of functioning as the patient tries to adapt to the environment. This response has been identified in four levels. These are response to fear, inflammatory response, response to stress, and sensory response. The nurse has the responsibility to provide interventions that promote the patient's adaptation to a state of illness and to evaluate the interventions as supportive or therapeutic (Leonard, M., 1990). Prone positioning is a nursing intervention that when used in the framework of Conservation is a nurse's responsibility to consider. It has been shown to conserve patients' energy and improve outcomes through decreased oxygen needs and decreased lung damage.

Suggested indications for use of prone position: Ventilated patients expected to remain on the ventilator greater than 24 hours.

Possible contraindications: (1) immobilized trauma patients; (2) those requiring ICP monitoring (consult with neurosurgeon); (3) post-abdominal and spinal surgery patients; (4) patient's with spinal injury; (5) burn patients where grafts and injuries can not be manipulated in this position. All ventilated patients should be considered as candidates and discussed with physicians.

Procedure:

1. Upon insertion of peripheral and central lines and completion of initial diagnostic testing, discuss with physician the implementation of the prone positioning guideline.
2. Assess vital signs, ventilator settings, and lung compliance prior to positioning to establish baseline.
3. Slowly turn patient to a 45 degree angle in the lateral position. If patient returns to baseline vital signs within 5 minutes, continue procedure to prone patient. If he/she does not return near baseline within 5 minutes of the position change assess the patient's imbalances in oxygen supply and demand. Imbalances between oxygen supply and demand must be addressed/corrected if possible prior to the procedure to offset any increases in demand created by the physical turn. The final decision to prone the hemodynamically unstable patient rests with the physician who must weigh the risks against the potential benefits of the prone position.
4. Explain the procedure to patient and family. Assure proper level of sedation is given.
5. Determine number of staff members required to turn the patient contingent upon size and diagnosis. Position 1-2 members on each side of the bed with an additional person at the head of the bed. The person at the head of the bed is responsible for monitoring the stability and position of the endotracheal tube, as well as the monitoring/intravenous lines that are located by the patients head. The person at the head of the bed is also responsible for positioning the ventilator tubing.
6. All IV tubing, invasive lines, and monitor leads are adjusted to prevent kinking, disconnection, or contact with the body during the turning procedure and while the patient remains in the prone position.
7. To implement turn: person(s) on the ventilator side of the bed grasp onto the patient's body at the head, chest, pelvic, and leg areas, while the person(s) on the opposite side reach under the patient at the same positions. The patient is then lifted and placed into a prone position. During the turning procedure, the individual at the head of the bed ensures that all tubes and lines are secure. The patient should be placed in the abdomen unrestricted position at this time by lifting and inserting pillows under the head, chest, and pelvic regions. (For larger patients, Vollman frame can be used. Contact Trauma Care Unit to obtain frame.)
8. Always turn the patient in the direction towards the ventilator. Turn the patient's head so it is facing away from the ventilator or face down. Without disconnecting the ventilator tubing from the ETT, place the portion of the tubing extending out from the

ETT on the side of the patient's face that is turned away from the ventilator. Loop the remaining ventilator tubing above the patient's head.

9. Gently rotate out parallel to the body the arms and hands that were in a tucked position and then flex them into a position of comfort lying parallel to the head. Minor adjustments of the patient's body may be necessary to obtain correct alignment once in the prone position.

10. Assess patient's tolerance to the turning procedure using physical cues such as respiratory rate and effort, heart rate, oxygen saturation, or blood pressure. If these parameters fail to return near baseline within 5 minutes of the turn, the patient may be displaying initial signs of intolerance. To determine the full effect of the position change upon oxygenation, 30 minutes after positioning arterial gases may be considered, but not necessary if lung compliance can be determined through ventilator readout.

11. Patient should be kept in prone position for 4-6 hours depending upon tolerance. If oxygen saturation begins to decrease and/or vital signs leave baseline, intolerance to position should be considered. Time frames should be individualized per patient according to response. Assess need to change head position every 2 hours to prevent neck stress.

12. Reverse above procedure to return to supine position.

13. Leave in supine position no longer than 2 hours if possible. (Prone position effects have been shown to decrease after supine for 2 hours).

14. Repeat procedure and sequencing of positioning while patient remains on the ventilator, or until deemed unnecessary by the physician/healthcare team.

15. Document in the nurses notes under significant findings, patient's response to the therapy, ability to tolerate the turn, length of time in the positions, positioning schedule used, and any complications noted during or after the procedure.

Adapted from Kathleen M. Vollman MSN, RN, CS, CCRN (1996) Guidelines for use of the Prone Position. Henry Ford Hospital, Detroit Michigan.

APPENDIX C

LETTER OF APPROVAL FROM GRAND VALLEY STATE UNIVERSITY



I CAMPUS DRIVE • ALLENDALE, MICHIGAN 49401-9403 • 616/895-6611

July 16, 1998

Mary Schira
6450 Westshire
Portage, MI 49024

Dear Mary:

Your proposed project entitled "*The Effect Prone Positioning has Upon Pediatric Ventilated Patient's Oxygen Ratio*" has been reviewed. It has been approved as a study which is exempt from the regulations by section 46.101 of the Federal Register 46(16):8336, January 26, 1981.

Sincerely,

Robert Hendersen, Chair
Human Research Review Committee

APPENDIX D
DATA COLLECTION TOOL AND DATA

APPENDIX E - DATA COLLECTION TOOL

Patient #	Age/Mos.	Gender	Diagnosis	Heart Rate/Pre	Resp Rate/Pre	Blood Pr/Pre	Sat/Pre	F102/Pre	Ratio/Pre	Hrs Before Proning	Heart Rate/Post	Resp Rate/Post	Blood Pr/Post	Sat/Post	F102/Post	Ratio/Post	Lung Status
1	5	F	Bronchitis	170	30(20)	075/42	95	46%	2.07	22	170	40(20)	082/44	97	39%	2.49	Normal
2	36	F	Pneumonia	148	35(35)	093/37	100	50%	2	15	148	34(34)	088/39	99	40%	2.48	Damaged
3	1	M	Bronchitis	176	43(30)	098/45	99	30%	3.3	16	176	30(30)	088/50	100	33%	3.03	Normal
4	1.5	F	Bronch/Pneumonia	168	44(44)	072/37	98	40%	2.45	6	167	33(44)	108/62	96	36%	2.87	Normal
5	15	F	Aspiration	136	25(25)	103/46	95	50%	1.9	49	136	25(25)	100/51	100	50%	2	Normal
6	8	M	Influenza/Pneum.	131	47(40)	096/46	92	55%	1.87	28	131	48(40)	95/46	91	55%	1.88	Normal
7	120	F	Pneumonia	128	18(18)	100/38	94	50%	1.88	168	128	18(18)	098/53	93	49%	1.9	Damaged
8	16	F	Pneumonia	160	30(30)	100/56	83	100%	0.83	40	160	30(30)	103/56	93	100%	2.93	Normal
9	36	F	Brain Tumor	172	38(20)	097/36	98	59%	1.66	5	172	52	117/68	99	47%	2.12	Normal
10	192	M	Pneumonia	83	30(0)	104/67	96	40%	2.4	114	83	28	114/49	97	40%	2.43	Damaged
11	48	M	Post-Adenoidectomy	75	25(20)	98/49	100	38%	2.62	28	75	20(20)	93/68	100	38%	2.63	Normal
12	1.5	M	Sepsis	104	30(30)	098/49	98	34%	2.88	33	104	30(30)	091/45	97	34%	2.85	Normal
13	2	M	Pneumonia	136	40(40)	081/38	98	58%	1.69	68	136	40(40)	095/57	97	53%	1.83	Normal
14	36	M	Cor Pulmonale	90	22(10)	091/32	95	60%	1.58	84	90	21(10)	110/40	96	41%	2.34	Damaged
15	3	F	Pneumonia/Seizures	156	50(50)	100/46	97	50%	1.94	13	156	48	098/40	91	60%	1.52	Normal
16	5	F	Pneumonia	177	34(34)	085/28	95	57%	1.67	16	177	34(34)	081/29	95	67%	1.67	Normal
17	2	F	Asp. Pneumonia	145	20(20)	074/23	98	28%	3.5	21	145	20(20)	78/28	100	28%	3.57	Damaged
18	48	M	Hunter's	144	24(24)	128/56	98	43%	2.28	15	144	24	129/56	98	40%	2.45	Damaged
19	14	M	Bronchitis	168	30(30)	101/42	92	65%	1.42	40	168	30(30)	128/59	95	50%	1.9	Damaged
20	2.5	M	RSV	164	56(30)	092/48	96	60%	1.6	8	164	36	109/48	100	32%	3.13	Normal
21	11	M	Pneumonia	142	28(28)	118/49	90	49%	1.84	60	142	28	149/64	93	44%	2.11	Damaged
22	17	F	Spinal Cord Injury	132	24(15)	121/57	95	62%	1.53	100	132	26	126/52	93	62%	1.5	Normal
23	18	F	Drowning	140	77(34)	125/69	98	39%	2.51	41	140	39	133/76	99	39%	2.54	Normal

REFERENCES

LIST OF REFERENCES

Artigue, G., Foli, K. & Johnson, T. (1994). Myra Estrin Levine: Four conservation principles. In MArriner-Tomey, A., (Ed.), *Nursing theorists and their work* (3rd ed., pp. 199-210). St. Louis: Mosby-Year Book.

Bjornson, K., Deitz, J., Blackburn, S., Billingsley, F., Garcia, J., & Hays, R. (1992). The effect of body position on ventilated preterm infants. Pediatric Physical Therapy, 109-115.

Bryan, C. (1974). Comments of a devil's advocate. American Review of Respiratory Disease, 110, 143-144.

Broccard, A., Shapiro, R., Schmitz, L., Ravenscraft S., & Marini, J. (1997). Influence of prone position on the extent and distribution of lung injury in a high tidal volume oleic acid model of acute respiratory distress syndrome. Critical Care Medicine, 25, (1), 16-27.

Chatte, G., Sab, J., Dubois, J., Sirdot, M., Gassorgues, P., & Robert, D. (1997). Prone position in mechanically ventilated patients with severe acute respiratory failure. American Journal of Respiratory Critical Care Medicine, 155, 473-478.

Davey, S., Huether, S., & Budd, M . (1994). Structure and function of the pulmonary system. In K. McCance & S. Huether (Eds.), Pathophysiology: The Biological Basis for Disease in Adults and Children (pp. 1137). St. Louis: Mosby-Year Book Inc.

Douglas, W., Rehder, K., Beynen, F., Sessler, A., & Marsh M. (1977). Improved oxygenation in patients with acute respiratory failure: The prone position. American Review of Respiratory Disease, 115, 559-566.

Fawcett, J. (1995). Levine's Conservation Model. Analysis and evaluation of conceptual models of nursing (165-215). (3rd ed.). Philadelphia, PA: F.A. Davis Co.

Fox, M., & Molesky, M. (1989). The effects of prone and supine positioning on arterial oxygen pressure. Neonatal Network, 25-29.

Froese, A. & Bryan, C. (1974). Effects of anesthesia and paralysis on diaphragmatic mechanics in man. Anesthesiology, 41, 242-254.

Gattinoni, L., Pelosi, P., Vitale, G., Pesenti, A., D'Andrea, L., & Mascheroni, D. (1991). Body position changes redistribute lung computed tomographic density in patients with acute respiratory failure. Anesthesiology, 74, 15-23.

Hader, C., & Sorenson, E. (1988). The effects of body position on transcutaneous oxygen tension. Pediatric Nursing, 14, (6), 469-473.

Heulitt, M., Anders, M., & Benham, D. (1994). Acute respiratory distress syndrome in pediatric patients: Redirecting therapy to reduce iatrogenic lung injury. Respiratory Care, 40, (1), 74-85.

Katz, R., Pollack, M., & Spady, D. (1984). cardiopulmonary abnormalities in severe acute respiratory failure. The Journal of Pediatrics, 104, 357-364.

Lai-Fook, S. Wilson, T., Hyatt, R., & Rodarte, J. (1976). Elastic constants of inflated lobes of dog lungs. Journal of Applied Physiology, 40, 508-513.

Lamm, W., Graham, M., & Albert, R. (1994). Mechanism by which the prone position improves oxygenation in acute lung injury. American Journal of Respiratory Critical Care Medicine, 150, (1), 184-193.

Langer, M., Mascheroni, D., Marcolin, R., & Gattinoni, L. (1988). The prone position in ARDS patients: A clinical study. Chest, 94, 103-107.

Leonard, M. (1990). Myra Estrin Levine. In J. George (Ed.), Nursing theories: The base for professional nursing practice (pp.181-192). Englewood Cliffs, New Jersey: Prentice-Hall.

Levine, M. (1966). Adaptation and assessment: A rationale for nursing intervention. American Journal of Nursing, 66, 2450-2453.

Levine, M. (1991). The conservation principles: A model for health. In K.M. Schaefer & J.B. Pond (Eds.), Levine's conservation model: A framework for nursing practice (pp. 39-43). Philadelphia: FA Davis.

Liu, S., Margulies, S., & Wilson, T. (1990). Deformation of the dog lung in the chest wall. Journal of Applied Physiology, 68, 1979-1987.

Milic-Emil J. (1986). Static distribution of lung volumes. In: P Mackem & J. Mead (Eds.). Handbook of physiology. The respiratory system, Vol. 3, (pp.561-574). Bethesda, MD: American Physiology Society.

Murdoch, I. & Storman, M. (1994). Improved arterial oxygenation in children with the adult respiratory distress syndrome: The prone position. ACTA Pediatrics, 83, 1043-1046.

Mure, M., Martling, C., & Lindahl, S. (1997). Dramatic effect on oxygenation in patients with severe acute lung insufficiency treated in the prone position. Critical Care Medicine, 25, 1539-1544.

Mutoh, M., Guest, R., Lamm, W., & Albert, R. (1992). Prone position alters the effect of volume overload on regional pleural pressures and improves hypoxemia in pigs in vivo. American Review of Respiratory Disease, 146, 300-306.

Numa, A., Hammer, J., & Newth, C. (1997). Effect of prone and supine positions on functional residual capacity, oxygenation, and respiratory mechanics in ventilated infants and children. American Journal of Respiratory Critical Care Medicine, 156, 1185-1189.

Pfenninger J., Gerber, A., Tschappeler, H., & Zimmerman, A. (1982). Adult respiratory distress syndrome in children. Journal of Pediatrics, 101, 352-357.

Pappert, D., Rossaint, R., Slama, K., Gruning, T., & Flake, K. (1994). Influence of positioning on ventilation-perfusion relationships in severe adult respiratory syndrome. Chest, 106, 1511-1516.

Piehl, M. & Brown, R. (1976). Use of extreme position changes in acute respiratory failure. Critical Care Medicine, 4, 13-14.

Ramanathan, R., Durand, M., & Larrazabal, C. (1987). Pulse oximetry in very low birth weight infants with acute and chronic lung disease. Pediatrics, 103, 612-617.

Ryan, D. & Pelosi, P. (1996). The prone position in acute respiratory distress syndrome. British Medical Journal, 312, 860-861.

Schuster, D. (1995). What is acute lung injury? What is ARDS? Chest, 107, 1721-1726.

Stocker, R., Neff, T., Stein, S., & Ecknauer, E. (1997). Prone positioning and low volume pressure limited ventilation improve survival in patient with severe ARDS. Chest, 111, 1008-1017.

Timmons, O., Dean, M., & Vernon, D. (1991). Mortality rates and prognostic variables in children with adult respiratory distress syndrome. The Journal of Pediatrics, 419, 896-899.

Vollman, K. & Bander, J. (1996). Improved oxygenation utilizing a prone position in patients with acute respiratory distress syndrome. 1105-1111.

Vollman, K. (1997). Prone positioning for the ARDS patient. Dimensions of Critical Care Nursing, 16, (4), 184-193.