Prone Positioning
Is It Safe and Effective?

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Prone positioning has been used as a treatment option for patients with acute lung injury or acute respiratory distress syndrome (ARDS) since the early 1970s. Prone position and extended prone position ventilation have been shown to increase end-expiratory lung volume, alveolar recruitment, and oxygenation in patients with severe hypoxemic and acute respiratory failure. Prone positioning is not a benign procedure and there are potential risks (complications) that can occur to both the patient and health care worker. Notable complications that can arise include the following: unplanned extubation, lines pulled, and tubes kinked; and back and other injuries to personnel. Prone positioning is a viable, inexpensive therapy for the treatment of severe ARDS. This maneuver consistently improves systemic oxygenation in 70% to 80% of patients with ARDS. With the utilization of a standardized protocol and a trained and dedicated critical care staff, prone positioning can be performed safely. Key words: acute lung injury, acute respiratory distress syndrome, ARDS, extended prone position ventilation, prone positioning

Numerous methods of improving ventilation and preventing further lung injury are used in patients with acute respiratory distress syndrome (ARDS). Present treatment of ARDS is largely supportive in nature, including the use of small tidal volumes, low plateau pressures, and respiratory rates.1 Correction of life-threatening hypoxia and improvement in respiratory mechanics and lung volumes are the main goals of treatment. Prone positioning is one relatively simple and inexpensive method to improve oxygenation and recruit alveoli, and should be considered early in the management of ARDS when atelectasis and lung edema predominate and alveolar recruitment is still possible.2–4 To understand the influence of prone positioning on ARDS, it is helpful to understand the nature of the disease.

Acute Respiratory Distress Syndrome

Acute Respiratory Distress Syndrome is defined as a condition affecting critically ill patients resulting from either direct or indirect injury to the lungs.4 The injury may have been caused by surgery, trauma, sepsis, or other serious illnesses. The resulting lung injury...
results in severe hypoxemia that is often refractory to conventional treatment. Despite the implementation of supportive treatment measures, mortality rates for ARDS continue to be high, ranging from 35% to 45% depending on the center.5

In ARDS, the alveoli of the lungs become damaged, resulting in increased capillary permeability and hyaline membrane formation.6 The increased permeability of the alveolar-capillary barrier favors edema formation. The balance between edema formation and edema clearance is critical for the patient to recover from lung injury. The accumulation of protein-rich fluid inside the alveoli contains macrophages and neutrophils, both of which release proinflammatory and anti-inflammatory cytokines. This fluid in the alveoli causes impaired oxygenation and creates the hallmark of bilateral infiltrates on chest x-ray and decreased lung compliance, originally described by Ashbaugh et al in 1967.7 This sequence of events can activate the coagulation cascade and promotes cellular responses leading to microvascular injury and multiorgan failure.8

It is beyond the scope of this article to review the entire lung structure and function but understanding the structure of the lungs with regard to aeration and blood flow assists in fully understanding the effect of positioning on ventilation. The bronchioles contain smooth muscle, which allow the dilation or constriction of the lungs based on the bodies need for oxygen. These terminate in alveoli, which are thin walled sacs responsible for oxygen and carbon dioxide exchange in the blood. The alveoli can be thought of as tiny bubbles whose surface is bathed with capillary blood. The effectiveness of the diffusion of gas in the alveoli requires minimizing the distance that gasses must move by diffusion between alveolar air and the capillary blood. The surface area for gas exchange is large, about 60 to 80 m², about the size of a tennis court.9

Since the bronchi and bronchioles have less surface area and are not the functional units of gas exchange, they contain less blood flowing through them than the alveoli. When a patient has ARDS, the anterior alveoli in a supine patient are more distended than the posterior alveoli. When the lungs become edematous, the lung begins to collapse under its own weight, squeezing out gas from the dependent regions causing compression atelectasis. In 1988, Gattinoni10 studied computed tomographic scans of normal subjects and those with ARDS, finding that gravity played an important role in ventilation and lung weight in ARDS. In patients with ARDS, the lung had an excess weight on average of 184% of the expected normal weight due to the increase in intravascular lung water.

In addition, the weight of the heart on the dependent region of the lung has a significant influence of the aeration of the lung.11 In patients with ARDS, the cardiac mass is increased, resulting in further alveolar collapse in the dependent regions of the lung.12 These 2 things, along with displacement of the abdomen, contribute significantly to alveolar collapse.

The patients with ARDS are often sedated and paralyzed.13 Therefore, the weight of the abdominal contents, no longer opposed by the diaphragm causes a displacement of the abdominal contents toward the posterior regions of the diaphragm contributing to basal atelectasis.14 Ventilation in the supine position, in the patient with ARDS at zero positive end expiratory pressure (PEEP) is distributed preferentially to the upper lung. During mechanical ventilation, the lung continuously collapses and inflates in its dependent parts at low levels of PEEP. At higher PEEP, the amount of collapsed tissue at end expiration is decreased.15 However, with the increased weight of the lungs and the compression of the heart and diaphragm, the supine patient has large regions of dependent, atelectatic lung.16

Perfusion in the ARDS patient is influenced by gravity, hypoxic vasoconstriction, and extrinsic vessel compression.17 Recent research suggests that perfusion in ARDS is more in the dependent, atelectatic regions.17 Review of all these factors indicates then, that in ARDS, the
lungs are edematous, heavy, and compressed in the dependent regions in a supine patient. Even though the perfusion is greatest gravitationally, in the dependent regions, the ventilation is significantly less, thereby causing ventilation perfusion mismatch.

As previously mentioned, ARDS can result from either direct or indirect lung injury. Pelosi et al1 stated that patients suffering from primary ARDS (direct injury) with consolidations seem to be less likely to be responsive to the recruitment effects of prone ventilation than those who suffer from secondary ARDS (indirect injury). The alveolar collapse seen in patients with secondary ARDS is widespread as opposed to being concentrated in one area as in seen in primary ARDS.1 The differences in the patterns of atelectasis could potentially allow a greater number of alveoli to be recruited by positioning the patient with secondary ARDS in the prone position.1

PRONE POSITIONING IN ARDS

In the last 25 years, there have been several reports using prone positioning as a tool to improve respiratory function in patients with ARDS. Bryan18 first described the use of prone positioning in 1974 and suggested that anesthetized and paralyzed patients in the prone position should exhibit a better expansion of the dorsal lung regions with consistent improvement in oxygenation. In 1976, Pheil and Brown19 showed that the prone position improved oxygenation in 5 patients without adverse effects. In a study by Gattinoni et al,20 the use of prone positioning improved oxygenation in more than 70% of the instances in which it was used, and about 70% of the effect occurred during the first hour of pronation. Pelosi et al21 suggest the prone position itself may exert a protective effect on the mechanically ventilated injured lung. Patients with ARDS are often exposed to high levels of PEEP and oxygen which are well-known to contribute to progressive lung damage in mechanically ventilated patients, and can contribute to the development of atelectasis and edema, thereby contributing to the impairment of gas exchange.21 The prone position may decrease ventilator-induced lung injury by allowing a lower FiO2 and lower airway pressures to achieve adequate oxygenation.22,23

Although an improvement in oxygenation is an expected outcome with prone ventilation, Potti et al24 suggested that oxygen and carbon dioxide responses to prone position are independent and, in fact, a decrease in the PaCO2 rather than an increase in PaO2/FiO2, is significantly associated with lung recruitability. Gattinoni et al25 retrospectively analyzed the 225 patients from the prone arms of previous studies and found a strong association between the PaCO2 response and outcome but no association with PaO2/FiO2 response. The PaCO2 responders seem to have a higher potential to be recruited with prone positioning than with nonresponders, revealing a difference in underlying lung pathologies.

Routine use of the prone position is not always warranted, but prone position ventilation is a safe, effective recruiting modality to improve oxygenation and is a salvage option for patients with severe ARDS.22,26-28 When a patient is turned prone, research has shown that there is a movement of lung densities from dorsal to ventral regions, and a more homogenous distribution of alveolar inflation occurs.29 This could be explained by redistribution of the lung weight, the cardiac mass no longer resting on the lungs, and redistribution of abdominal contents. Proning causes recruitment of the most atelectatic regions of the lungs by relieving external compression forces, thus improving ventilation-perfusion matching without subjecting the lungs to high airway pressures.30 It is believed that in the prone position, ventilation should redistribute from ventral regions (which are collapsed in the prone position) to dorsal regions, which are recruited in the prone position. Since the dorsal regions are heavier and more fluid filled in the supine position, changing to a prone position would change the position of the fluid by gravity.

Prone positioning has been advocated as a rescue maneuver in severe ARDS in multiple studies.19,25,31-34 At a minimum, it
also can enhance the mobilization of secretions, thus optimizing the effectiveness of chest physiotherapy and improve ventilation to previously atelectatic regions. In addition, prone positioning has been shown to reduce the risk of ventilator-associated pneumonia.

Previous studies on prone positioning included several limitations. Small sample size, initiation of positioning, length of time proned, type of proning, and use of lung protective ventilation in conjunction with proning were identified as limitations. However, the use of intermittent prone positioning has been documented to significantly improve oxygenation in 60% to 70% of acute lung injury patients with ARDS. Sud et al, in a 2008 systematic review and meta-analysis of the effect of prone positioning on clinical outcomes of patients with acute hypoxemic respiratory failure, concluded that despite an improvement in oxygenation and reduced risk for ventilator associated pneumonia associated with mechanical ventilation in the prone position, overall survival rates were not improved. Al-saghir and Martin reported in a meta-analysis that prone positioning did not improve overall mortality, except in possibly the more severely ill patients. However, there was no difference in the length of ventilator days or incidence of ventilator associated pneumonia between the prone and supine groups.

In 2010, another systematic review and meta-analysis reinforced the aforementioned mortality findings, stating that prone positioning reduces mortality in those with severe hypoxemia, defined by a baseline PaO2/FiO2 less than 100 mm Hg, but not in those with less severe hypoxemia. The prone position, therefore, may be useful as a rescue strategy in patients with severe hypoxemia.

WHEN TO PRONE AND HOW LONG?

Taccone et al randomized 342 patients with moderate (PaO2/FiO2 ratio between 100 and 200 mm Hg) and severe (PaO2/FiO2 ratio less than 100 mm Hg) ARDS to either a supine or prone group. The prone group was positioned on their abdomens for at least 20 hours per day, until the resolution of acute respiratory failure or the end of the 28-day study period. Findings from this study suggest a nonsignificant 10% difference in mortality favoring the prone group, and a significantly greater proportion of patients in the prone group experienced at least 1 complication than in the supine group. Of note, the rate of complications was almost 3 times greater in the prone group than in the supine group, and this rate was found to be significantly correlated with the number of days each prone group patient and supine group patient remained in the study.

Romero et al prospectively studied 15 patients diagnosed with severe ARDS and placed them in the prone position for at least 48 hours or until they reached an oxygenation index of 10 or less in 2 successive measurements. The authors found a statistically significant improvement in PaO2/FiO2 and oxygenation index, reduction of PaCO2, and plateau pressure, and increment of the static compliance with prolonged prone ventilation; all of which continued to improve while patients remained in the prone position and remained unchanged when the patients were returned to the supine position. They summarize that the improvement in oxygenation, ventilation, and static compliance probably reflect recruitment of alveolar units and dead space reduction. Ultimately, Romero et al describe prolonged prone ventilation as safe and easy to implement when performed by trained staff within an established protocol and suggest that prolonged prone ventilation could be considered part of a protective ventilatory strategy.

Mancebo et al hypothesized that prone ventilation would decrease mortality if implemented early in the course of ARDS, if applied for most of the day, and if maintained for prolonged period of time. A total of 136 patients were evaluated, 60 randomized to the supine group and 76 to the prone group. A
nonsignificant decrease in intensive care unit mortality was observed and a similar trend was noted for hospital mortality. Twenty-eight complications were noted. Multiple logistic regression analysis revealed that 3 variables were independently associated with increased risk of death: simplified Acute Physiology score II at inclusion (is a validated Acute Physiology tool that uses 17 variables: 12 physiological variables and 3 underlying disease variables to estimate the risk of death without having a primary diagnosis), the number of days elapsed between ARDS diagnosis and inclusion and random allocation to supine position. Limitations of the study included that the study was stopped secondary to decreased patient enrollment and it was underpowered. Despite these limitations, the authors suggest that prolonged prone ventilation is both safe and feasible and may potentially reduce mortality in patients with severe ARDS when applied early in the disease course and for a prolonged duration.

A literature review by Rowe suggested if a patient begins to decompensate when being returned to the supine position, they may need to be placed back in the prone position for longer than 12 hours or longer than the length of time generally regarded as acceptable at a given institution. Finally, Abroug et al sought to address optimal proning duration and found a trend toward an interaction between longer proning duration and reduction in mortality in their meta-analysis, and ultimately suggested that long-prone durations should be applied.

OPTIONS FOR PRONING

There are several options for proning. The simplest is the use of a flat sheet and nursing staff to complete a rotation in a standard bed (Figures 1 and 2). This method requires 4 staff members, 2 positioned on each side of the bed to manage the lines and tubes. Step 1, start with a flat sheet placed under the patient, and pull the patient to one side of the bed (we generally turn the patient toward the ventilator). The flat sheet, step 2, is then placed around the patient’s arm, on the side you are turning the patient toward. A second flat sheet, step 3, is placed on the bed and tucked under the patient. This sheet will pull through as you turn the patient prone, step 4. Lastly, step 5, straighten the sheet, adjust lines and tubes, and place the patient’s arms in the swimmers position, one arm positioned up toward the head and the second arm at the patient’s side. To supine the patient, reverse the process. This technique is simple and easy to perform, but most importantly, it allows full access to the patient. Other options include the use of a proning device such as the Vollman Prone Positioner (Hill Rom Services Inc, Batesville, Indiana; Figure 3). This device requires 2 to 3 staff members, is easy to use, and is relatively inexpensive. Other devices include a specialty bed known as the Rotoprone Therapy System (KCI USA Inc, San Antonio, Texas; Figure 4). This bed requires that the patient be “packed” in and secured before turning. It provides the advantages that it is automated and can be done by one staff member. However, for procedures such as extracorporeal membrane oxygenation or continuous renal replacement therapy the external bloodlines must be lengthened to extend from the bed to the machines. Quick access to the patient is a concern using this device. Also, the daily expense of the Rotoprone is significant, and may limit its use in many centers.

Precautions/contraindications when prone positioning

Before using prone positioning for treatment, the suitability of the patient should be evaluated. We have successfully proned patients with multiple lines and those on extracorporeal membrane oxygenation and continuous renal replacement therapy after careful assessment and planning.

Existing contraindications (Table 1) may preclude a patient from being placed in the prone position. Potential contraindications include hemodynamic instability, mean arterial pressure less than 60 or systolic blood pressure less than 90 (regardless of fluid resuscitation or inotropes), recent cardiopulmonary
Figure 1. The 5-step method to prone a patient using a regular bed, flat sheet, and 4 staff members, University of Michigan Surgical Intensive Care technique. A, step 1, with a flat sheet, pull the patient to one side of the bed using 4 staff members. B, step 2, place the flat sheet around the arm that will pull through (side you are turning toward). C, step 3, a second flat sheet is placed on the bed and tucked under the patient. D, step 4, using the sheet turn the patient over and position them prone. The arm and sheet will pull across the bed. E, step 5, discard the sheet that was used to supine patients. Straighten lines and tubes.
Figure 2. The 5-step method to supine a patient using a flat sheet and 4 staff members, University of Michigan Surgical Intensive Care technique. A, step 1, using a flat sheet, pull the patient to one side of the bed. B, step 2, place the flat sheet around the arm that will pull through (side you are turning toward). C, step 3, a second flat sheet is placed on the bed and tucked under the patient. This sheet will pull through as you are turning the patient. D, step 4, using the sheet, turn the patient over and position them prone. The arm and sheet will pull across the bed. E, step 5, discard the sheet that was used to supine patients. Straighten lines and tubes.
Figure 3. Vollman Proning Device. This device has adjustable head, chest, and pelvic supports, which are strapped to the patients and then used to turn them. With permission from K. Vollman.

Figure 4. The Rotoprone Therapy System. This bed requires that the patient be “packed” in and secured before turning. It provides the advantages that it is automated and can be done by one. With permission from Kinetic Concepts, Inc.

Complications associated with proning
There are several complications associated with the use of prone positioning. There is an increased incidence of pressure ulcers, endotracheal tube obstruction, or unintended or accidental chest tube removal. Sud et al found no significant differences in the risk of unplanned extubation, unplanned removal of central venous catheters or arterial lines, pneumoth-
Table 1. Precautions and Contraindications to Prone Positioning

<table>
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<th>Potential Precautions/Contraindications</th>
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<tr>
<td>Weight $\geq 135$ kg</td>
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<tr>
<td>Increased intraocular pressure</td>
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<tr>
<td>New tracheostomy</td>
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<tr>
<td>Maxillofacial surgery</td>
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<td>Hemodynamic instability</td>
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<td>Mean B/P &lt; 60 mm Hg</td>
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<tr>
<td>Systolic B/P &lt; 90 mm Hg</td>
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<td>Elevated intracranial pressure</td>
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<tr>
<td>Recent cardiopulmonary arrest</td>
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<td>Bleeding</td>
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<td>Rib fractures</td>
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Prone Positioning

Evidence-based practice guidelines should be in place for bedside nurses on critical care units that use prone positioning, including indications and contraindications, preprone assessment and safety practices, strategies for placing the patient in the prone position, assessment guidelines for monitoring the patient response to the prone positioning, and limb positioning in the prone position. Establishing and carefully evaluating different guidelines for prone positioning patients with ARDS is essential before implementing a standard protocol.

Procedure

Arterial blood gases, baseline $\text{FiO}_2$, $\text{SpO}_2$, and vital signs should be initially assessed to compare to proned values and any improvements in oxygenation. Measurement of the $\text{PaO}_2/\text{FiO}_2$ ratio should be done to assess the severity of lung injury. A $P/F$ ratio of less than 200 or less is a finding characteristic of ARDS. A $P/F$ ratio of 300 or less is more characteristic of acute lung injury, not ARDS. According to the University of Michigan prone protocol, there are some basic requirements to complete before initiating prone positioning (Table 2). Preoxygenate the patient before turning with $\text{FiO}_2$ of 1.0. The central lines and tracheotomy or endotracheal tube and any other lines should be secured and tracked during the turn. Adequate staff should be available for the oraces, or cardiac arrests. Other complications include transient oxygen desaturation, arrhythmias, hypotension, vomiting, accidental loss of central venous catheters, accidental extubation, and accidental loss of thoracic or abdominal drains. Facial edema was noted in several studies that improved after the patient was returned to the supine position. Conjunctival hemorrhage, vascular catheter malfunction during continuous renal replacement therapy, dislodgement of a PA catheter resulting in cardiac arrest (patient was resuscitated), indwelling bladder catheter and nasogastric tube displacement, kinking of thoracic tube, and one unplanned extubation were associated with a study examining prolonged proning periods.

Table 2. Preprone Position Requirements for Safe Prone Positioning the University of Michigan Surgical Intensive Care Checklist

- Preoxygenate the patient with $\text{FiO}_2$ 1.0.
- Secure the endotracheal tube and lines.
- Correct number of staff members to assist in the turn and monitor the turn.
- Adequate number supplies to assist in the turn (pads for bed, sheet, protection for the patient, or specialty bed).
- Experienced staff with working knowledge of how to perform the turn and how to supine the patient in the event of an emergency.
turn, depending on what method is used for proning. Even with an automated bed, a minimum of 2 staff members is suggested for safety. Any additional supplies, sheets, or padding should be immediately available prior to the turn. The staff should have the knowledge of how to perform the prone and also how to return the patient to the supine position in the event of an emergency. Any enteral feeding should be stopped, unless they are post pyloric feeds, prior to the turn, and until the head of the bed can be increased to prevent aspiration.52

The patient should be suctioned prior to the turn and eyelids closed and protected to prevent corneal abrasions. The patient can be suctioned after proning by positioning the head to accommodate access to the tracheotomy tube or the endotracheal tube. Finally, the patient’s pain score and sedation level should be assessed, and medications administered as needed before turning the patient. Turning can be a frightening experience if the patient is not sedated adequately. The patient can be positioned flat on the abdomen in the Rotoprone, (Figure 4) and in the swimmer’s position if sheets are used. In this manner, pillows will be used to partially support the abdomen and the upper arm (Figure 1, step 5).

During proning, the patient must be repositioned every few hours to minimize soft tissue injury and to maximize secretion mobilization and sputum removal. This can be accomplished just as you would if the patient were supine. Turn and position every 2 hours with pillows on the right, left, or belly. A patient is classified as a “Responder” if the PaO2 has increased by 10 mm Hg or more, and their oxygen index has increased by 20 mm Hg or more.35 Most patients will show an increase in oxygenation within the first 15 minutes of being proned. In the absence of an immediate response, the patient should be left prone for an additional 3 to 4 hours, if there is no deterioration in the patient’s condition, to allow the patient to respond.53 There are patients who are “non-responders.” Patients that do not respond within the trial period, or after proning for 4 to 6 hours should be returned to the supine position. An initial lack of response does not mean the patient is a non-responder.

SUMMARY

Despite the lack of conclusive evidence of improved morbidity and mortality, proning affords the patient with ARDS an opportunity to improve oxygenation and decrease areas of atelectasis.18-20,25,31-34 The method of proning is up to the individual institution, and no one method or device is absolutely required for improvement.

Prone positioning can pose risk to both the patient and the health care worker.1,20,22,28,29,31,39,44,50 Notable complications that can arise include unplanned extubation, lines being pulled, tubes becoming kinked as well as potential injuries to staff.1,20,31,39,44,50 Conversely, others feel that prone positioning is a viable and inexpensive therapy for the treatment of severe ARDS. This maneuver has proven to consistently improve systemic oxygenation 60% to 70% of patients with ARDS.18,44 Careful planning and evaluation of the patient status, knowledge of the proning process, and documentation of clinical effect can make a proning program safe and effective. To validate the safety of our prone positioning protocol we, here at the University of Michigan completed a retrospective analysis of patients who received prone therapy for the time period of May 1, 2010, to April 30, 2011. All patients prone during this study period were included in the analysis. A comparison group of patients who were not prone were also analyzed. Specifically, the study focused on (1) identifying patients who self-extubated during proning, (2) identifying patients who had a line or tube pulled during proning, and (3) identifying health care workers injuries while proning a patient. Our findings showed that prone positioning occurred for 118 days during the study period. One patient extubated during the study period but no lines or tubes were pulled. Our overall incidences of notable complications are 1 of 118 (0.85%). As a comparison, the number
of overall incidences while NOT proning (extubations/line pulls) during the study period was 91 of 6997 (1.30%). No employee injuries were noted secondary to proning a patient. On the basis of the current literature and the conclusions from our study, we would suggest that the use of prone positioning is an effective strategy for the treatment of severe hypoxemia in patients’ with ARDS. Prone positioning of patient’s with ARDS using a standardized protocol does not result in an increased incidence of lines pulls and extubations and finally proning does not result in increased injuries to health care workers.

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