Prone Positioning of Trauma Patients With Acute Respiratory Distress Syndrome and Open Abdominal Incisions

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A critical respiratory distress syndrome (ARDS) is a serious complication for patients with multiple trauma and may contribute to prolonged hospitalization and morbidity and mortality. ARDS is characterized by acute inflammatory lung injury that results in widespread pulmonary edema because of an increase in capillary permeability.

Diagnostic criteria for ARDS are respiratory failure as indicated by evidence of acute bilateral infiltrates on chest radiographs, severe hypoxemia (ratio of PaO₂ to fraction of inspired oxygen <200), and no evidence of left atrial hypertension (as indicated by clinical examination or pulmonary artery occlusion pressure <18 mm Hg).1

The mortality rate for patients with ARDS is as high as 40% to 60%.2-6 The actual survivability depends on multiple factors, including predisposing conditions, severity of illness, age, comorbid conditions, and, in patients with trauma, severity of the underlying lung injury.5-7

Sepsis is the most frequently identified risk factor for ARDS; other factors are aspiration of gastric material, severe pneumonia, severe trauma, use of cardiopulmonary bypass, multiple transfusions, fat embolism, and pancreatitis.5 For patients with multiple trauma, factors thought to contribute to the development of ARDS include pulmonary edema due to direct damage to lung parenchyma, multiple transfusions, activation of chemical mediators in response to a systemic inflammatory response syndrome or sepsis, multiple fractures, impaired mucociliary clearance, and immobilization.8

PATHOPHYSIOLOGY OF ARDS

In acute lung injury, inflammatory mediators and toxic substances such as free oxygen radicals and bradykinins are produced and released by cells associated with inflammation due to any cause (eg, trauma, sepsis, pneumonia). These toxic substances damage the pulmonary vascular endothelium and alveolar endothelium by increasing permeability, allowing the passage of plasma into the interstitial and alveolar spaces. The accumulation of fluid (edema) and a decrease in the production of surfactant results in impaired gas exchange. Gas exchange is further impeded as the dependent lung...
regions collapse beneath the increased weight of the edematous lung. As the condition progresses, deposition of fibrin and collagen lead to alveolar filling, pulmonary collapse, and, eventually, fibrosis.

In addition to treatment of the underlying cause of ARDS (eg, pulmonary laceration), mechanical ventilatory support is an integral component of care for patients with this syndrome. The objectives of using mechanical ventilation are to improve gas exchange, relieve respiratory distress, improve pressure-volume relationships, allow lung healing, and avoid complications (ie, barotrauma or oxygen poisoning). Other methods of improving oxygenation in patients with ARDS have been investigated, including the effects of prone positioning.

PHYSIOLOGY OF PRONE POSITIONING

In 1976, Piehl and Brown first reported that oxygenation improved when patients were in the prone position during treatment with mechanical ventilation. Since then, research has indicated that prone positioning is an effective therapeutic maneuver in improving oxygenation in patients with ARDS, although the exact mechanism of action has been widely debated. A major theoretical benefit of prone positioning is redistribution of ventilation and perfusion. Until recently, no data conclusively proved that use of the prone position decreased the mortality of patients with ARDS.

In 2001,Gattinoni et al found that use of the prone position improved oxygenation in greater than 70% of the instances in which it was used. However, despite an improvement in oxygenation, the mortality rate of patients with ARDS who were placed in a prone position did not differ significantly from that of patients treated in the conventional supine position.

In studies in which computed tomography was used, pulmonary infiltrates, atelectasis, and collapsed lung regions were preferentially located in the dorsal dependent regions when patients with ARDS were in the supine position. When the patients were rotated into the prone position, infiltrates seem to be redistributed toward the ventral region, thereby reducing intrapulmonary shunting and increasing pulmonary perfusion. The increase in ventilation-perfusion ratio most likely was due to the recruitment of previously atelectatic areas by gravitational forces.

Other possible explanations of the benefit of prone positioning in patients with ARDS include changes in functional residual capacity, shifts in the location of lung water and exudates, and changes in regional diaphragm motion. Other areas of research focus on the use of various techniques of ventilator support and the use of surfactant and inhaled nitric oxide in the treatment of ARDS.

Absolute contraindications for prone positioning have not been determined to date. Previous research suggested relative exclusion criteria. In some studies, exclusion criteria specific to trauma patients were identified as increased intracranial pressure (>25 mm Hg) despite adequate treatment, cervical spine fractures that could not be stabilized, intestinal ischemia, and severe inguinal and abdominal soft-tissue infection. Further exclusion criteria not specific to trauma patients included left ventricular failure, hemodynamic instability, unstable bone fractures (site not mentioned), and/or an active intra-abdominal process (undefined).

To date, few investigators have examined the effects of prone positioning in patients with multiple trauma and ARDS. Furthermore, information on the use of prone positioning in patients with open abdominal wounds (due to abdominal decompression or damage-control laparotomy) after blunt abdominal trauma is virtually nonexistent. Offner et al reported the use of prone positioning in 4 patients who had closed midline abdominal incisions after exploratory laparotomy. During that study, 2 patients were not treated with prone positioning because they had open abdominal incisions. Offner et al suggest, however, that prone positioning might be possible in patients with open abdominal incisions if an abdominal binder is used.

BARRIERS TO THE USE OF PRONE POSITIONING

Although prone positioning improves oxygenation in patients with ARDS, placing patients in the prone position is often cumbersome for nursing staff and not without safety concerns for the patients. Critically injured patients with ARDS often have endotracheal or tracheostomy tubes, multiple chest tubes, extremity traction, central venous and arterial catheters, open wounds or drains, and recent surgical incisions. Inadvertent dislodgement
of any of these devices when a patient is placed in the prone position could have adverse consequences.

Other potential complications associated with use of the prone position include peripheral nerve injuries, skin necrosis, corneal ulceration, abdominal wound dehiscence, and facial edema. Although the potential for skin breakdown is a concern for patients placed either supine or prone, Gattinoni et al found that during a 10-day period, the number of new or worsening pressure ulcers per patient was significantly higher in patients placed prone than in patients placed supine. The risks of these and other complications can be minimized, however, by using appropriate preparation and by anticipating potential deleterious events.

Offner et al suggest that institutions should develop protocols to standardize placing critically ill patients in the prone position. Such protocols should include indications for use of prone positioning, duration and frequency of prone positioning, and frequency of monitoring respiratory parameters. The protocols should also indicate the minimum number of personnel required to turn a patient, care of patients who are in the prone position, and troubleshooting guidelines for potential complications.

At Miami Valley Hospital, Dayton, Ohio, when a patient is placed in the prone position, a surgical resident and a respiratory therapist are present at the head of the bed to control the airway and ventilator tubes. Additionally, depending on the size of the patient and the remaining equipment, 3 to 5 nursing and ancillary staff members are present.

METHODS OF PLACING PATIENTS PRONE

Several methods of placing patients in a prone position have been described. In early studies, the CircOlectric bed (Stryker Medical, Kalamazoo, Mich) was used to oscillate patients into the prone position. In more recent studies, a manual 2-step procedure was used. Patients were first moved to the side position at the edge of the bed with a draw sheet and then turned directly onto the abdomen into the prone position. With this method, the use of support cushions or pillows placed under the chest and pelvis helps keep the abdomen free of restriction.

In 1996, Vollman and Bander introduced the Vollman Prone Positioner (Hill-Rom Services Inc, Batesville, Ind). The positioner, a lightweight portable support frame, serves as an anchor for the patient’s body during the turn and then acts as a cushion device to maintain the abdomen free of restriction while the patient is in the prone position.

Whichever method is chosen, meticulous care of patients and anticipation of complications must be ensured to prevent the dislodgement of critical tubes or catheters.

CASE STUDIES

The following are case studies of successful prone positioning of 2 patients who had open abdominal incisions after damage-control laparotomy (abdominal exploration to detect and control life-threatening injuries) after major blunt abdominal trauma. In addition, 1 of the 2 patients was maintained in cervical tong traction.

Case 1

R.B., a 31-year-old man, was admitted to the trauma service after a motor vehicle collision. His injuries included splenic rupture, multiple liver lacerations, left-sided pulmonary contusion, bilateral rib fractures, and an open-book pelvic fracture.

Upon his arrival, fluid and blood resuscitation was initiated because of profound hypovolemic shock, and R.B. was taken to the operating room for an exploratory laparotomy. He underwent splenectomy, and the liver was packed to control bleeding. A pelvic hematoma associated with the pelvic fracture was noted intraoperatively. Because the bowel wall was edematous as a result of the resuscitation, primary abdominal wall closure was not done in order to prevent abdominal compartment syndrome. The abdomen was closed temporarily with prosthetic material, and R.B. was taken to the angiography suite to further control bleeding. He underwent embolization of the left internal iliac and right infrahepatic vessels. After the surgery, he was admitted to the intensive care unit.

One day after admission, he began to have signs of ARDS, and use of prone positioning was tried. The prone position was not well tolerated because of hemodynamic instability. Within a few days, progressive respiratory failure developed, leading to a second attempt at prone positioning. The combination of total body weight and the extreme size of the abdominal protrusion (Figure 1) prevented the use of standard methods.

In a nontraditional approach, R.B. was positioned on a large inner tube to accommodate the
massive protrusion of enclosed bowel past the abdominal wall (Figure 2). The inner tube provided additional cushioning to the surrounding tissues, supporting the chest and pelvis while leaving the abdomen unrestricted. The remainder of the body was supported with towel rolls and a donut face cushion. Use of this method allowed prone positioning despite an open defect in the abdominal wall. R.B.’s position was changed from supine to prone or from prone to supine approximately every 4 hours during the next several weeks. The success of this treatment was indicated by the decreasing amount of ventilator support necessary to maintain adequate oxygenation.

R.B. had a prolonged and complicated hospital stay, including several episodes of pneumonia, sepsis, and acute renal failure. By 38 days after admission, R.B.’s respiratory status had markedly improved, and use of prone positioning was discontinued. He underwent abdominal closure with polygalactin 910 (Vicryl) mesh and split-thickness skin grafts, and he was transferred out of the intensive care unit to the medical-surgical unit. He was eventually discharged from the hospital after rehabilitation and is doing quite well.

Case 2
C.R., a 27-year-old man, was a pedestrian struck by a semitrailer truck at a high rate of speed. His injuries included an atlanto-occipital dissociation (dislocation of the first cervical vertebra from the skull), intracranial hemorrhage, grade IV liver laceration, mesenteric hematoma, right-sided perinephric hematoma, multiple left rib fractures, bilateral pulmonary contusions, right acetabular fracture, and an open-book pelvic fracture.

Upon C.R.’s arrival in the emergency department, fluid and blood resuscitation was initiated because of hemodynamic instability. He was emergently taken to the operating room for exploratory laparotomy and control of hepatic bleeding. During the surgery, coagulopathy developed, and he was given multiple blood transfusions. C.R. had severe hypoxia, for which he received maximal mechanical ventilator support. Bilateral chest tubes were placed because of hemotheraces and pneumothoraces but did not markedly improve his pulmonary status. A damage-control laparotomy was done. The liver was packed after surgical control of bleeding, and the abdomen was temporarily closed to prevent abdominal compartment syndrome.

C.R. was taken from the operating room directly to the intensive care unit for stabilization, resuscitation, and completion of radiological studies. Postoperative radiography revealed an atlanto-occipital dissociation, and computed tomography of the head indicated an intracranial hemorrhage. Intracranial pressure monitoring was started, and cervical tong traction was established. Measurements of intracranial pressure were within the normal reference range.

Despite maximum ventilation and oxygenation, C.R. remained hypoxic. It was determined that prone positioning might be beneficial. Radiographs were obtained before and after positioning to assess cervical alignment while C.R. was in traction. He was then transferred onto a Stryker frame so that cervical traction could be maintained while he was rotated into the prone position (Figure 3). His position was changed from prone to supine or from supine to prone every 4 hours; he tolerated this regimen well. Periodically, lateral cervical spine radiographs were obtained to ensure correct cervical alignment.
By 13 days after admission, C.R.’s respiratory status was improved, and prone positioning was discontinued. He later underwent operative fixation of the pelvic fractures and spine instability. Ultimately, the abdomen was closed by using polygalactin 910 mesh and split-thickness skin grafts. C.R. was weaned off the ventilator and was transferred to a rehabilitation facility, where physical therapy was continued. Upon discharge, he had functional, spastic motor movement of all 4 extremities and required assistance in walking. He later regained marked motor strength and currently is functioning independently.

DISCUSSION

In our experience, neither the prone positioner nor the manual 2-step procedure has been feasible in positioning all trauma patients with open abdominal incisions. Because of an increase in the protrusion of some of the abdominal contents, with these methods, keeping the unusually large abdomen unrestricted while placing the patient into a prone position is virtually impossible. In most instances, the use of rolled blankets under the chest and pelvis provides sufficient support while leaving the abdomen unrestricted. However, in the 2 cases reported here, the size of the abdominal protrusion was far greater than what the traditional blanket supports could accommodate. In addition, as in C.R.’s case, it would have been impossible to use either of these methods and still maintain cervical traction.

In both of our patients, marked hypoxia developed that met the criteria for ARDS despite maximal ventilator support by conventional standards. For this reason, prone positioning was deemed necessary despite the lack of supporting data on its use in patients with open abdominal incisions. In both instances, we created new techniques that enabled us to use prone positioning in these patients safely and effectively. In each case, the process was labor intensive and physically challenging for all personnel involved. Ultimately, with the collaboration of nursing staff, physicians, and physical and respiratory therapists, the tasks were successfully accomplished by using rather unconventional methods. Of note, periods in the supine position were necessary to allow nursing care and evaluation as well as medical intervention (ie, central venous access).

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References

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