Nursing patients with ARDS in the prone position

Harcombe C (2004) Nursing patients with ARDS in the prone position. *Nursing Standard*. 18, 19, 33-39. Date of acceptance: November 11 2003.

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Summary

This article examines the main features of acute respiratory distress syndrome (ARDS), including the pathophysiology, clinical manifestations, complications and treatment. Patients with ARDS are critically ill and require close monitoring and mechanical ventilation in an intensive care unit. The benefits of prone positioning, one of the main treatment options for these patients, are discussed in detail. By understanding the physiological principles that underpin the prone position, the critical care nurse will be more effective in identifying patients who might benefit from this treatment.

INTENSIVE CARE UNITS (ICUs) have evolved through an increasing need to care for critically ill patients with varying dependencies and complex conditions. Intensive care involves the constant, close monitoring of seriously ill patients, which enables immediate treatment to be given if the patient's condition deteriorates. Acute respiratory distress syndrome (ARDS) is a condition that occurs in ICU patients and has a high mortality, despite the increase in technological advances in this area over recent years (Vollman 1997). ARDS is described as the most severe form of acute lung injury (Bernard *et al* 1994a), having a diverse aetiology and a complex pathophysiology. The high mortality associated with ARDS means that the cost to the NHS of treating these patients is substantial.

Numerous studies have shown a significant improvement in gas exchange in ARDS patients when they are placed in the prone position – lying on their stomach (Albert 1997, Ball 1999, Curley 1999, Jolliet *et al* 1998, Schmitz 1991, Thomas 1997). This article provides an analysis of the use of prone positioning in the management of patients with ARDS.

Pathophysiology

It is necessary to revise the normal respiratory function to understand the pathophysiology of ARDS. The primary function of the respiratory system is to supply oxygen to the metabolically active tissues and to remove carbon dioxide. Respiration has four components (ALA 2002):

- Mechanical movement of gases in and out of the lungs.
- Exchange of gases across a membrane.
- Carriage of gases to and from the tissues.
- Enables cells to produce energy through metabolic processes.

Therefore, any disease process or condition that interferes with any of these four components will result in respiratory problems. It is beyond the scope of this article to discuss each process in detail. However, Figure 1 illustrates the respiratory system, showing the intricate structures needed for breathing.

Ashbaugh *et al* (1967) were the first to describe the phenomenon that became known as ARDS. The condition was termed 'adult respiratory distress syndrome' because of the apparent similarities to infant respiratory distress syndrome. However, a 1992 consensus conference modified the terminology to 'acute respiratory distress syndrome' (Bernard *et al* 1994a, 1994b).

ARDS is a form of respiratory failure resulting from a variety of direct and indirect pulmonary injuries producing similar pathophysiological changes. ARDS can be caused by either direct or indirect injury to the lungs. Examples of causes of direct injury include pneumonia, aspiration of gastric contents, inhalation injury and fat emboli (Ware and Matthay 2000). In

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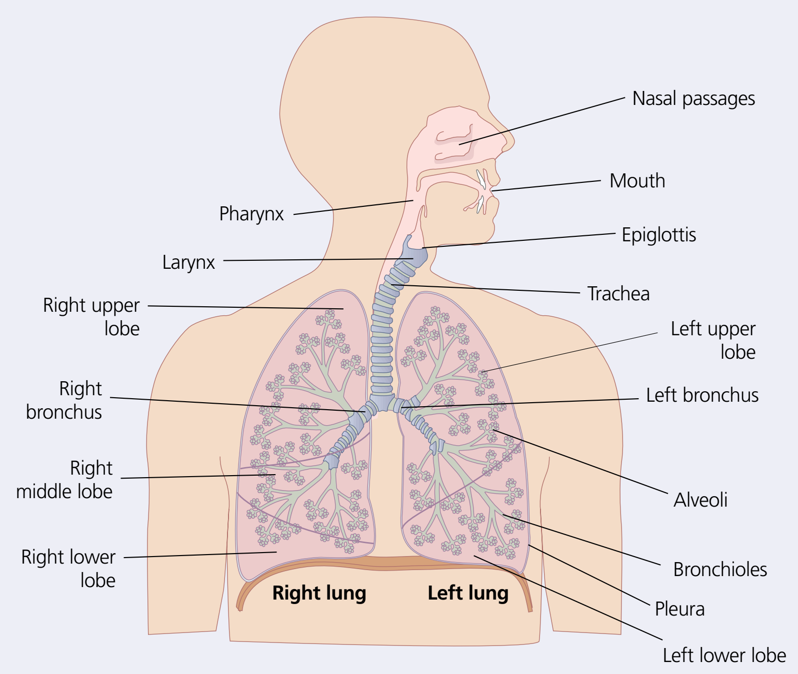
Key words

- Acute respiratory distress syndrome
- Prone positioning
- Respiratory system and disorders

These key words are based on the subject headings from the British Nursing Index. This article has been subject to double-blind review.

Figure 1. The respiratory system



contrast, indirect injury can result from an insult anywhere in the body, such as sepsis, multiple blood transfusions, shock, burns, drug overdose, cardiopulmonary bypass and acute pancreatitis (Ware and Matthay 2000).

Whether injury to the pulmonary epithelium and endothelium is direct or indirect, the result is increased permeability to water and protein (Luce 1998). The acute phase of ARDS is characterised by damage to type I alveolar epithelial cells combined with impaired production and function of surfactant (John 1998). It is useful to note that the function of the type I alveolar epithelial cells is to help protect the alveoli from filling with fluid. Thus, damage to these cells results in the formation of interstitial pulmonary oedema (Rita and Cydulka 1994). This oedema in turn damages type II alveolar epithelial cells, causing a deficiency in surfactant, which produces an increase in surface tension and alveolar collapse. Surfactant is a combination of lipoproteins which serve to reduce the surface tension of pulmonary fluids, thus allowing the exchange of gases in the alveoli. This contributes to the elasticity of pulmonary tissue.

The chronic phase of ARDS is illustrated by thickening of the endothelium, epithelium and interstitial space (John 1998). The process of pulmonary non-cardiogenic oedema is a progressive one with fluid and proteins accumulating in the interstitium, which does not affect gas exchange (Balk and Bone 1983, Brigham 1982). However, as the interstitial fluid overwhelms the local controlling factors, the increased hydrostatic pressure compresses the alveoli. This is the point where diminished gas exchange occurs, resulting in an abnormal deficiency of oxygen in the arterial blood (hypoxaemia). As fluid continues to flood the pulmonary interstitium and alveolar spaces, lung compliance and functional residual capacity – the volume of gas remaining in the lungs after a normal exhalation – decrease causing ventilation/perfusion (V/Q) imbalance (Richardson 1997), while the work of breathing, oxygen consumption and the dead space area all increase (Bernard *et al* 1987).

Dead space area refers to anatomical dead space and physiological dead space. Anatomical dead space is the gas present in the large conducting airways that does not come into contact with the capillaries. Conversely, physiological dead space is the alveolar gas that does not equilibrate fully with capillary blood. This represents excess alveolar ventilation relative to capillary blood flow. In normal conditions, dead space ventilation accounts for approximately 20-30 per cent of the total ventilation. Dead space ventilation increases when the alveolar-capillary interface is destroyed, for example, in emphysema or when blood flow is reduced, for example, during pulmonary embolism.

Signs and symptoms

The clinical findings in patients with ARDS are primarily due to the flux of protein and fluid into the alveoli and interstitium. The main signs are respiratory distress, profound hypoxaemia (despite an increased fraction of inspired oxygen (FiO_2)), and diffuse bilateral alveolar infiltrates on chest X-ray – often called 'white lung' (Figure 2) (Kolleff and Schuster 1995).

The patient with ARDS is breathless, with an abnormally rapid rate of breathing (tachypnoea), and increased effort of breathing is evident through the use of accessory muscles and intercostal retractions. The $PaCO_2$ (partial pressure of carbon dioxide in arterial blood) remains low at first due to hyperventilation; eventually, however, $PaCO_2$ retention will accompany the hypoxaemia. The cardiac output is low as a result of hypotension and tachycardia. Urine output may also decrease because of prolonged hypotension, ultimately affecting renal perfusion.

Sachdeva and Guntupalli (1997) found that alveolar collapse exposes patients to a sixfold increase in pulmonary infection. Patients with ARDS are also at risk of developing pneumonia due to long-term ventilation in the ICU environment. Barotrauma refers to an injury sustained to the lungs as a result of prolonged exposure to increased airway pressure. The risk of this occurring is greatly increased by the decreased compliance of the lungs in these patients. A pneumothorax can occur due to damage to the lungs caused by the high pressure ventilation necessary to treat ARDS.

There is a high risk of nosocomial infection associated with invasive lines, suppression of the immune response, the ICU environment and increased use of invasive equipment (Woodrow 2000).

Treatment

The therapeutic goals are to achieve adequate gas exchange by treating the initiating pathophysiological process and the systemic responses caused by altered pulmonary function. These goals are primarily accomplished by fluid management, oxygenation, drug therapy and nutrition. For the purpose of this article, fluid management and respiratory support are discussed. The value of nutrition and drug therapy in meeting the needs of the ARDS patient is also acknowledged.

Fluid management Intubation can cause a decrease in preload due to the change in thoracic pressure and the anaesthetic agents administered during intubation, which lower the blood pressure. Preload describes the pressure of blood contained in the ventricle at the end of diastole. A decrease in preload subsequently results in a reduced cardiac output – the total volume of blood pumped by the ventricle per minute. Ventilatory support with PEEP (positive-end expiratory pressure) is necessary to prevent alveolar atelectasis and improve oxygenation. High levels of PEEP reduce venous return, causing a drop in cardiac output, therefore fluid resuscitation is often required to maintain cardiac output and tissue perfusion. An increase in intravascular volume will increase preload and cardiac output.

Pulmonary artery wedge pressures (PAWP) are used to obtain more specific information about the functioning of the left side of the heart and provide a valuable guide to fluid management in patients with ARDS. A high PAWP should be avoided due to the risk of causing further non-cardiogenic pulmonary oedema. A Swan Ganz catheter needs to be inserted into the internal jugular vein to monitor the patient's PAWP. A balloon at the tip of the catheter is partially inflated and the catheter floats through the right atrium and the right ventricle into the pulmonary artery at which time the pulmonary artery pressure (PAP) can be determined. The catheter is then advanced into a branch of the pulmonary artery until it becomes wedged in a pulmonary capillary. The pressure measurements obtained reflect the pressures in the left atrium. The normal PAP is 25/10mmHg; the normal PAWP is 4-12mmHg (Bridges 2000).

It is crucial that a delicate balance is sought between providing adequate amounts of fluid to maintain tissue perfusion and avoiding further oedema (O'Connor *et al* 1998). If adequate tissue perfusion cannot be achieved without resorting to excessive fluid input, inotropic support should be commenced. The nurse is involved in the careful monitoring of acid-base balance, renal function, pharmacological support of cardiac output and vascular resistance.

Respiratory support Current approaches seek to provide ventilatory and haemodynamic support, to allow time for the lungs to recover from the acute insult (Mulnier and Evans 1995). The patient is intubated and mechanically ventilated in an effort to maintain adequate tissue oxygenation (O'Connor *et al* 1998, Thomas 1997). Current treatment has moved from short-term aims of normalising arterial blood gases to longer-term aims of limiting damage and recruiting alveoli (Artigas *et al* 1998). Prone positioning has been found to improve oxygenation (Chatte *et al* 1997, Curley *et al* 2000, Jolliet *et al* 1997, Mure *et al* 1997, Voggenreiter *et al* 1999). The prone position according to Gosheron *et al* (1998) is effective in the:

- Reduction of oxygen toxicity.
- Recruitment of alveolar space and the reduction of the risk of barotraumas.
- Optimisation of postural drainage.

Figure 2. Chest X-ray showing white lung


(Schalkwyk 2001)

Prone positioning

V/Q relationship The use of the prone position was first advocated over two decades ago (Bryan 1974) as a strategy for improving oxygenation in patients with acute bilateral lung injury disease, pneumonia and ARDS (Albarran 1992, Broccard *et al* 1997, Brussel *et al* 1993, Pappert *et al* 1994, Ryan and Pelosi 1996). Despite the numerous studies demonstrating a significant improvement in oxygenation, prone positioning is still underused (Gosheron *et al* 1998, Webster 1997). This reluctance may be due to the logistical difficulties in turning critically ill patients onto their stomachs (O'Connor *et al* 1998), as well as the unpredictability of the prone position. Misunderstanding of the physiology underlying the procedure may be an important reason why the procedure is still underused in the treatment of patients with ARDS.

The adequacy of gas exchange in the lungs is determined by the balance between pulmonary ventilation and capillary blood flow. This balance can be expressed as the ventilation/perfusion (V/Q) ratio. A perfect match is described as a V/Q ratio of 1.0. A V/Q ratio of >1.0 describes the condition where ventilation is excessive relative to capillary blood flow. This excess ventilation does not participate in gas exchange with the blood. Conversely, a V/Q ratio of <1.0 describes the condition where capillary blood flow is excessive relative to ventilation. The excess blood flow, known as intrapulmonary shunt, does not participate in pulmonary gas exchange. Therefore, it is clear that any lung injury alters the delicate V/Q match. Understanding this concept is fundamental to the appreciation of how prone positioning works.

This poor matching of ventilation and perfusion leads to alveolar dead space and areas of the lung being perfused but not ventilated, resulting in shunting. Shunted blood does not become reoxygenated and when it mixes with blood from well-ventilated alveoli it results in a lower then normal PaO_2 (partial pressure of oxygen in arterial blood) (Misasi and Keyes 1996). This corresponds to an extreme mismatching of ventilation and perfusion. Altering the patient's position to prone improves oxygenation by reducing the V/Q mismatch and decreases the shunt (Mure *et al* 1997, O'Connor *et al* 1998, Vollman 1997). Prone positioning shifts fluid from the dorsal aspects of the lungs, allowing undamaged alveoli in the dorsal areas to be recruited and subsequently filled with oxygenated air, thereby improving ventilation.

Tissue injury prevention Changing patients from a supine to a prone position may prevent the use of high inspiratory and expiratory pressures often required in mechanically ventilated patients with ARDS. By avoiding high ventilatory pressures, there is less possibility of causing permanent damage to alveoli and developing barotrauma (Stoller and Kacmarek 1990). Prone positioning may also improve gas exchange by redistributing blood to healthier lung regions in addition to enhancing the recruitment and reopening of previously dependent atelectatic areas (Langer *et al* 1988).

Repeated opening and closing of atelectatic alveoli during mechanical ventilation can also injure the lungs. PEEP and low tidal volumes have been found to counter these effects. PEEP is the addition of positive airway pressure to the end of the exhalation phase. PEEP reopens or recruits collapsed alveoli by redistributing fluid in the intra-alveolar space to the interstitial space. While it is crucial to provide sufficient oxygen to prevent cellular hypoxia, it is equally important to prevent the oxygen toxicity that results from high FiO_2 ventilator settings. The use of PEEP is central to decreasing FiO_2 levels in patients with ARDS, as by decreasing the shunt it allows FiO_2 levels to be reduced.

High levels of PEEP can, however, reduce venous return, affecting preload and reducing cardiac output. This effect may be lessened by the use of inotropic agents. The beneficial effects of prone positioning frequently allow a reduction in FiO_2 and PEEP levels, thereby reducing complications that are associated with these variables (Gosheron *et al* 1998).

The sample sizes used in studies on prone positioning are small and may not truly reflect the characteristics of all patients with ARDS. Wong (1998) found that studies consistently showed the benefits of prone positioning in terms of improvements in oxygenation, reduction in shunting, reduced oxygen requirements and reduced mortality, although available literature may be biased by reluctance to report unsuccessful cases (Ryan and Pelosi 1996).

Fridrich *et al* (1996) found that prone positioning may be more effective if initiated early in the treatment of patients with ARDS. This finding was supported by Blanch *et al* (1997). Gosheron *et al* (1998) found that prone positioning may more usefully prevent potential problems rather than resolve existing ones, and so should be instigated early. Too often, like other promising approaches, prone positioning is used once other approaches have failed. Mure *et al* (1997) and Pape *et al* (1998) found that early pronation was more effective than later intervention in preventing ARDS due to the structural and parenchymal changes that occur in the late or progressive stages of ARDS. Once the destruction of the alveolar structure, progressive fibrosis and emphysema-like changes have occurred, rotation between the supine and prone position is no longer effective (Breiburg *et al* 2000). The prone position should be the first treatment option before the introduction of other more complex interventions such as high-frequency jet ventilation, permissive hypercapnia and extracorporeal oxygenation (O'Connor *et al* 1998). Further research could support the use of prone positioning as a preventive measure in patients at high risk of developing ARDS.

Indications Following a detailed literature search, no studies were found that identified the optimal parameters to introduce the prone position. This could be the reason why many patients are only turned after all other ventilatory options have been exhausted. Without the existence of a set protocol for prone positioning, many patients are at risk of being 'missed'. It has been suggested that mechanically ventilated and well-sedated patients should be placed in the prone position if oxygenation is inadequate at greater than 50 per cent FiO_2, despite PEEP levels higher than $10cmH_20$, the pulmonary artery pressure (PAP) is <18mmHg (or there is no clinical sign of left ventricular failure), and bilateral infiltrates are present on the anterior-posterior chest X-ray (Dirkes and Dickinson 1998, Voggenreiter *et al* 1999). These criteria can be used to trigger a multidisciplinary team discussion regarding the patient's suitability for prone positioning, taking into consideration any exclusion criteria, specialist opinions, risk assessment and haemodynamic stability.

Frequency of turning There is no consensus of opinion regarding the length of time a patient should be placed in the prone position. This is possibly because no one can predict how a patient will react to being turned, in terms of haemodynamic stability and maintaining an adequate gas exchange. If oxygenation improves during the pronation period, the patient can be nursed in the prone position for up to 20 hours a day (Fridrich *et al* 1996). The frequency of turning will ultimately depend on the patient's response. If a patient is returned to the supine position too early, respiratory decompensation can occur, which means that oxygenation may return to pre-pronation levels (Curley *et al* 2000, Dirkes and Dickinson 1998, Mure *et al* 1997, Vollman 1997).

Contraindications Contraindications to prone positioning include spinal instability, increased intracranial pressure (Gentilello *et al* 1988), abdominal compartment syndrome, shock, multiple trauma, massive resuscitation, pregnancy, abdominal surgery and extreme obesity (Balas 2000). All of these conditions should be considered relative to the risk-benefit ratio of positioning a patient prone. The inherent risks of prone positioning are often offset by the need to provide adequate oxygenation.

Complications There are a number of potential complications associated with turning a patient prone. These include the possibility of self-extubation, loss of intravenous access (Fridrich *et al* 1996), difficulties in monitoring patients and in performing cardiopulmonary resuscitation (Vollman 1997). The positioning of ventilator tubing is also problematic due to the unusual position of the patient and there is also a risk of aggravating cardiovascular instability (Thomas 1997). Hess *et al* (1992) stated that sufficient numbers of well-trained staff are required to ensure the safety of the patient during the turning procedure. This may be a problem in ICUs with staff shortages, where the actual turn may result in job-related injuries (Summer *et al* 1989). Complications such as facial, orbital and ocular oedema are under-documented. However, most patients can be moved safely into the prone position, with forethought and adequate planning.

Nursing management

Preparation before turning The psychological issues around prone positioning are problematic for patients and their families. The patient's family will need to be informed before the procedure and the rationale for prone positioning and expected benefits should be explained. Prone positioning often results in massive facial oedema and the patient's eyes should be protected to avoid direct ocular pressure. The eyes should either be taped shut or have lubricant applied to prevent corneal drying and abrasions (Balas 2000).

It is important for the nurse to explain that significant facial oedema is likely, but that it usually resolves after the patient is returned to the supine position. The psychological issues stemming from a relative seeing the patient being nursed in the prone position should not be underestimated. It is an abnormal position, given that most patients are nursed supine.

The nurse should assess the patient's neurological status, as adequate sedation is imperative for all patients with ARDS; the level of sedation may need to be increased during the actual turn. Most patients may require sedation and paralysis because of the discomfort caused by the pressure-control mode of mechanical ventilation being used. The nurse should also assess and plan adequate pain management as many patients have surgical incisions. The nurse's ability to prevent physiological complications when a patient is immobile in the prone position is of prime importance. The condition of the patient's skin should be assessed and documented before the patient is turned.

Positioning the patient Once a decision has been made to pronate the patient, the actual turn has to be instituted. This is essentially a medical decision even though it is a nurse-led procedure in many ICUs and requires a team approach. The nurse should record baseline parameters before calling other members of staff to assist with the turn. This allows haemodynamic comparisons to be made following the turn. The patient's respiratory status should also be assessed. The endotracheal or tracheostomy tube should be secured and non-essential lines disconnected before the procedure. The ECG leads should be removed from the patient's chest and it may be necessary to administer a bolus dose of sedation before turning to ensure patient comfort during pronation.

Many authors state the number of people required to be present at the procedure (Ball *et al* 2001, Hess *et al* 1992, Marion 2001). However, in the author's experience the number of lines and the patient's size will determine the number of people required for the turn. An anaesthetist or senior nurse should be solely responsible for the safety of the endotracheal or tracheostomy tube and the safety of the patient's head.

Two nurses then slide the patient towards them with the aid of the bottom sheet, until the patient is positioned at the edge of the bed. A clean bottom sheet is placed alongside for the patient to roll onto. The patient's arm is placed underneath his or her hip on the side the patient will be rolled towards. One person should take charge of co-ordinating the turn and everyone should help to turn the patient slowly. The patient is then placed in the crawl position, with the head facing away from the lifted arm. If the opposite is done, there is a risk of damage to the brachial plexus of the other shoulder. The head should be placed carefully to the side, not face down. The limbs should be positioned with care to prevent extension or contracture of the shoulders and elbows. A pillow should be placed under the pelvis to ease pressure on the abdomen. The ECG dots should be positioned on the patient's back and arterial and other lines reconnected. The nurse should assess the patient's haemodynamic status continually during and after turning (Vollman 1997). In situations where there is a significant drop in blood pressure, fluid replacement may be required or it may be necessary to increase the level of inotropic support. The patient should be returned to the supine position if the oxygen saturation level drops significantly and does not improve after several minutes of increased FiO_2. Arterial blood gases should be performed once the patient has been undisturbed in the prone position for at least 30 minutes.

Ongoing management The position of the head should be altered every two to three hours to prevent pressure ulcers forming on the cheeks, ears and neck, and the arm positions should also be altered at this time (Gosheron *et al* 1998, Mure *et al* 1997). Special attention should be paid to the positioning of the breasts and the male genitalia as many patients will be on high inotropic support, making the pressure areas even more vulnerable. A small pillow can be placed under the iliac crest to avert pressure on the penis and scrotum, or under the upper chest to avoid compression of the breasts.

The importance of maintaining an 'unrestricted abdomen' is advocated in the literature (Chatte *et al* 1997, Douglas *et al* 1977). The aim of this is to allow the passive movement of the diaphragm and the downward displacement of the abdominal contents. Patients with ARDS already have high inspiratory pressures due to reduced lung compliance, and the addition of abdominal pressure could potentially cause a further rise in inspiratory pressure and barotrauma.

It is important to pre-oxygenate the patient before turning and also to note the position of the endotracheal tube, which should be tied securely. Closed circuit suction should be used as patients with ARDS are usually dependent on high levels of PEEP. The bedside nurse should note any trends and changes in the patient's airway pressures or tidal volumes, depending on the ventilator mode, to monitor progress. In the event of a cardiac arrest, the patient should be returned to the supine position immediately. It is important, as far as possible, to ensure there are enough staff available to assist in the event of this happening. Invasive lines need to be inspected frequently to ensure they are working effectively.

Kinetic therapy

If a patient cannot be placed in the prone position because of contraindications, other methods exist to increase gas exchange, achieving a similar therapeutic

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effect. Kinetic therapy has been found to be effective in patients with pulmonary dysfunction (Albarran and Price 1998). This therapy uses specific respiratory therapy products such as special beds. These work by facilitating gas exchange using rotation movements, to prevent 'pooling' of secretions. The criteria for patient placement on kinetic therapy may vary between ICUs, but this type of therapy is usually initiated before prone positioning is considered.

It has been suggested that the pulmonary function (PF) ratio can be used to identify early deterioration in respiratory function, as well as being used to initiate the introduction of kinetic therapy. The PF ratio is the PaO_2 value divided by the FiO_2 and is represented as a score in kilopascals – PaO_2 of 14kPa divided by an FiO_2 of 0.6 (60%) = 23kPa. This method provides a simple and effective way of calculating how efficiently the lung fields are transporting and using oxygen, thereby monitoring the effect of kinetic therapy.

Conclusion

The author has outlined the main features of ARDS, providing an overview of the issues surrounding this complex condition. The reluctance to move critically ill patients has been highlighted (Pappert and Falke 1996), despite the fact that the literature demonstrates that prone positioning is best instigated early in ARDS. Some of this reluctance may be due to a lack of knowledge, and training sessions on the disease process and the physiology of the prone position and its benefits would be of value for ICU staff. This may help to enhance nurses' confidence to initiate discussion on the prone patient.

Nurses who are equipped with the necessary knowledge and experience can be proactive in decisions to instigate treatments such as prone positioning. Having established the potential benefits of this intervention, it is time for nurses to take a more active part in the investigation and safe use of pronation. Although the benefits of prone positioning for ARDS patients are clear, research regarding specific issues is limited, for example, the most effective ventilator settings for use in conjunction with the prone position and the prevalence of pressure ulcers as a result of prone positioning.

Further research is required to assess the overall effect on outcome of any interventions used in the management of ARDS. This research could support the use of prone positioning as a preventive measure in patients at high risk of acute lung injury. Establishing guidelines and criteria for prone positioning in ICUs is also worth further investigation

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