❖RESEARCH CONNECTIONS❖

Prone positioning for the treatment of adult respiratory distress syndrome

***Castro D Arias RN; MN,** Faculty of Nursing, University of Alberta, Alberta, Canada
Bijaya Pokharel RN; MN candidate, Faculty of Nursing, University of Alberta, Alberta, Canada
Elizabeth Papathanassoglou RN; PhD, MSc, Faculty of Nursing, University of Alberta, Alberta, Canada
Colleen M Norris RN; PhD, Faculty of Nursing, University of Alberta, AB, Canada; School of Public Health, University of Alberta, Alberta, Canada

Key Words: Adults ❖ ARDS ❖ intensive care unit ❖ prone position ❖

***E-mail:** arias@ualberta.ca

SUMMARY

- The prone position has recently gained much attention by demonstrating significant clinical improvements in the oxygenation status in adults diagnosed with acute respiratory distress syndrome (ARDS).
- The purpose of this review was to evaluate the prone position as a treatment modality for ARDS, and to identify best practices in the care and treatment of patients with this condition. Main outcome measures included oxygenation, mortality and morbidity.
- A systematic iterature review was undertaken using Medline, Cumulative Index of Nursing and Allied Health Literature (CINAHL) and Scopus databases. Articles were included in the review if they were peer-reviewed reports of original research, published in the English language between 2000 and 2016, and focused on using the prone position as treatment for ARDS by nurses working in an adult ICU.
- Ten articles met the eligibility criteria to be included in the review, involving 1891 ARDS patients. There was significant heterogeneity with regard to the onset and duration of prone positioning. The prone position has been demonstrated to bring about significant improvements in the oxygenation status in adults diagnosed with severe ARDS. The survival benefit is less clear and appears to be conveyed by longer applications of proning.
- More research is warranted as to the role of proning as part of a comprehensive ARDS treatment bundle. Prone positioning may increase the risk for a number of complications and it presents challenges to nursing workflow. As such, it is important to explore strategies to minimize risks and optimize the patient's experience and outcomes with respect to ARDS.

INTRODUCTION

Though it has been utilized in the treatment of acute respiratory distress syndrome (ARDS) for a number of years, the prone position (PP) has recently gained much attention. The PP has been demonstrated to bring about significant clinical improvements in the oxygenation status and mortality in adults diagnosed with ARDS (Guérin et al., 2013; Sud et al., 2008; Sud et al., 2010). Though previous studies have demonstrated an improvement in oxygenation with the prone position, those same studies have failed to consistently demonstrate a survival benefit (Sud et al., 2008; Rowe, 2004). The Proning Severe ARDS Patients (PROSEVA) trial was the first of its kind to demonstrate a ninety-day mortality benefit in patients who had received the prone intervention as compared with their supine counterparts, and its findings have since been corroborated by retrospective analyses (Guérin et al., 2013; Sud et al., 2010). Though beneficial in many ways, proning patients may have unintended detrimental ramifications. Given the relative infancy of the prone position as a vindicated treatment modality, protocols and guidelines, though available, have not been formally evaluated and there is little information regarding adherence to these resources (Guérin et al., 2013; Rowe, 2004).

As proning is gaining prominence, an exploration of the putative benefits of the prone position, and alternative treatments currently used in practice with varying degrees of success, is necessary. Finally, while there is controversy surrounding the incidence of adverse outcomes associated with proning a patient, potential unintended sequelae that have been identified are endotracheal tube displacement, catheter or device removal, pressure ulcer formation, plexus root injuries, cornea injury, hemodynamic instability, abdominal hypertension, and enteral nutrition intolerance. The purpose of this review is to comprehensively review the literature on using the prone position as a treatment modality for ARDS and identify best practices in the care and treatment of patients with ARDS. Main outcome measures included, oxygenation, mortality and morbidity; whereas we also assessed specifics of proning protocols and underlying physiological mechanisms.

METHODS

This paper is a systematized literature review. We searched PubMed, CINAHL and Scopus using different combinations of search terms like "prone", "ARDS", "intensive care unit", and "adult". The limit was set to clinical trials.

Eligibility criteria

The articles were screened using pre-defined inclusion and exclusion criteria. Articles were included if they were published in the English language between 2000 and 2016, used a cross-sectional or prospective randomized controlled trial (RCT) design and focused on therapeutic benefits or adverse outcomes of prone position in adult patients with ARDS. The studies were excluded if they used combination of treatments and not prone position alone, and if they were secondary studies.

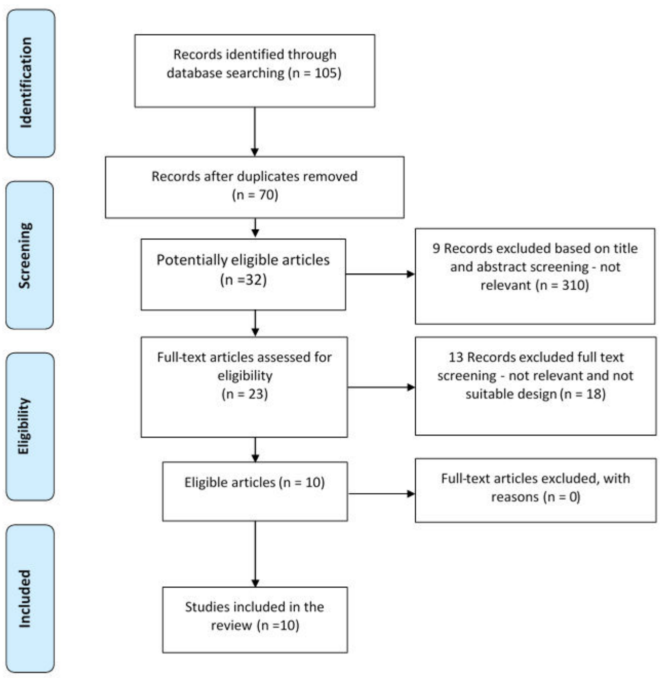
Data Extraction

Data extraction included characteristics of participants (age group and medical condition), specifics of intervention and control group (sample size, duration of intervention, and type of intervention or control), study design, outcome measures (partial pressure of oxygen in arterial blood, arterial blood gas, pulmonary arterial blood pressure, arterial blood pressure, pulmonary arterial occlusion pressure, cardiac index) and outcomes (oxygenation status, mortality, and morbidity). The articles screening and data extraction was performed independently by two researchers (CA, BP).

Quality Assessment

The tool provided by Cochrane collaboration to assess the risk of bias was utilized to assess the quality of the selected studies (Cochrane Bias Methods Group, 2016). The tool analyzes six domains of bias. The quality of the articles was assessed in two parts. The first part provided a free-text brief description of study characteristics while the second part allowed the assessment of bias that could have affected the study results.

Figure 1. Flowchart of the literature search and article selection process



FINDINGS

Based on the eligibility criteria, ten studies were identified. The article selection flowchart is provided in Figure 1. The studies involved a total of 1891 patients with ARDS admitted to an intensive care unit.

Study characteristics

The characteristics of the selected studies are presented in Table 1. Most of the studies were prospective randomized controlled studies. The sample size ranged from 20 to 466. Research designs used by the studies included RCTs (n=4) and prospective randomized studies (n= 6). One of the studies assessed the effectiveness of prone position under different ventilator conditions (Staudinger et al., 2001). Most of the studies compared prone against the supine position in the control group; while one study also included a prone-upright group (Robak et al., 2011).

Outcome measures

The most common outcome measure was the oxygenation status measured through the PaO2:FiO2 ratio. Some studies reported mortality and morbidity to assess the effects of prone position on survival of patients with ARDS. Overall, outcome measures included the effects of prone position on oxygenation, survival, duration of mechanical ventilation and associated morbidities.

Prone position intervention

The use of prone position in the identified studies was heterogeneous in terms of the minimum number of hours and the duration that the prone position was maintained for. Some studies maintained the prone position for fixed duration of time while other studies maintained the position until the patient recovered or died. However, all the studies maintained the position for a number of days, consecutively. The timing of outcome measurements also varied as in some studies outcome measurements were performed everyday while in others at pre-set intervals. In only two studies, the description of the intervention was unclear (Ayzac et al., 2016; Mancebo et al., 2006).

Quality assessment

Overall, the studies were stronger in terms of sample sizes and the number of sites where the patients were recruited from. However, some studies had poor recruitment rate resulting in weaker statistical power. Importantly, the reporting of baseline differences across the recruited patients such as types of medications used, the effect of certain ICU procedures were not clearly reported; which made the comparison of the outcomes between studies difficult. Among the studies, six did not make clear whether they employed allocation concealment. In the remaining studies, the level of blinding was not made clear (n = 4) (Table 2). Based on the quality assessment table, the weaker aspect was the incomplete reporting of the presence or absence of allocation concealment.

Oxygenation status

The PP group has been demonstrated to bring about significant improvements in the oxygenation status in adults diagnosed with severe ARDS (Ayzac et al., 2016; Gattinoni et al., 2001; Guerin et al., 2013; Mancebo et al., 2006; Robak et al., 2011; Staudinger et al., 2001; Varpula et al., 2003; Voggenreiter et al., 2005). However, the effect was not significantly different between the patients assigned to the PP and the supine position (Ayzac et al., 2016; Mancebo et al., 2006; Gattinoni et al., 2001; Staudinger et al., 2001; Voggenreiter et al., 2005) (Table 1).

Physiological mechanisms

Attaining euoxia involves components of both ventilation and respiration, and the PP has been shown to positively affect both components (Robak et al., 2011; Staudinger et al., 2001; Varpula et al., 2003; Voggenreiter et al., 2005).

Improvement of ventilation/perfusion mismatch

One of the putative benefits of PP appears to be its ability to reduce intrapulmonary shunt away from the dorsal regions of the lungs, promoting increased ventilation to already perfused regions of the lung (Satudinger et al., 2001; Varpula et al., 2003).

Fluid clearance

While PP brings about improved oxygenation as a primary intervention, it also prompts secondary synergetic effects with regard to the volume of ventilation and the utilization of PEEP (Guerin et al., 2013; Staudinger et al., 2001).

Authors (year), country	Study purpose	Sample size and patients' characteristics/ Interventions	Specifics of intervention	Study design and outcome variables	Tools/ instruments	Significant findings
Gattinoni et al. (2001), Italy and Switzerland.	To assess the effect of prone position on survival of patients with ARDS	n = 304 patients with ARDS or ALI. n1 = 152 (prone position); n2 = 152 (supine position).	Prone group content. Prone position was maintained for at least 6 hours every day for 10 consecutive days.	RCT. Severity of illness, non-pulmonary or organic system failure, number of days without system failure	Simplified Acute Physiology Score records of respiratory and biochemical variables	• Survival did not improve significantly in patients placed in prone position as compared to supine position. • The 10 day mortality rate difference between prone group (21.1%) and supine group (25%) did not differ significantly.
Staudinger et al (2001), Austria	To assess as well as compare the effects of prone position and continual rotation on oxygenation status and hemodynamics of the patient with ARDS	n = 26 Patients with ARDS under mechanical ventilation. n1 = 12 (prone position); n2 = 14 (axial rotation)	NO inhalation was performed before the position change for each intervention group. Patient in prone position group was changed to supine for 2-4 hours, once in 24 hours. 124 degrees was the maximum angle beyond which the patient was not rotated in the axial rotation group. The rotation was performed continuously.	Randomized prospective study. PaO_2, ABP, PAP, ABP, PAOP, central venous pressure, CI, intrapulmonary shunt fraction	Thermodilution pulmonary artery catheter, pressure gauge transducers, arterial blood gas	• The improvement in the oxygenation status and hemodynamics was seen in both intervention groups ($p < 0.05$). However, the effect was more pronounced in the prone position group. • Prone was also better tolerated.
Varpula et al. (2003), Finland	To assess the effect of the type of ventilator support (SIMV-PC/PS or APRV) on improvement in oxygenation secondary to prone position.	n = 45 patients with ALI. n1 = 21 (SIMV-PC/PS); n2 = 24 (APRV)	Ventilator support protocol. SIMV-PC/ PS: PEEP maintained at 10 cm H_2O, mandatory frequency = 12 per minute. APRV: spontaneous breathing was permitted. Higher pressure level always maintained below 35 cm H_2O and maintained to 12 pressure shifts every minute. Position was changes to prone when the ratio of $PiO_2/FiO_2 < 200$ mm of Hg. Duration: 6 hours prone/6 hours supine.	Prospective randomized intervention study (blinded). Gas exchange.	Arterial cannulae, pulmonary artery catheters, spirometry	• The improvement in the oxygenation status and hemodynamics was seen in both intervention groups ($p<0.05$). However, the effect was more pronounced in the prone position group. • Prone was also better tolerated. • The response of oxygenation (mean PaO2/FiO2) to prone position was significantly better ($P=0.001$) when spontaneous breathing was allowed in APRV (104.0±50.7 mmHg) as compared to SIMV-PC/PS (66.9 ±38.2 mmHg).
Voggenreiter et al. (2005), Germany	To examine the effect of prone position on the duration of mechanical ventilation.	n = 40, patients with ALI or ARDS. n1=21 (prone , position); n2=19 (supine position)	Prone position content. Prone position was maintained during the night shift for minimum 8 hours and maximum 23 hours. Intervention continued until PaO2/FiO2 >300 mmHg.	Prospective randomized study (level of blinding not reported). Duration of mechanical ventilation, PaO_2:FiO_2, QS:Qt, prevalence of pneumonia.	Chest X-ray, lung injury score.	• There was no significant difference ($p > .05$) between the mean duration of ventilator support in prone group (30 ± 17 days) and supine group (33 ± 23 days). • Prone position was also associated with significant reduction in the prevalence of pneumonia ($p = 0.048$) • PaO_2:FiO_2 at day 4 compared to day 0 improved significantly (p = 03). However, PaO_2:FiO_2 at day 10 compared to day 0 did not improve significantly ($p = 0.31$).
Mancebo et al. (2006), Spain and Mexico	To assess benefits of early initiation and administration duration of prone ventilation in patients with ARDS	n = 142, patients with ARDS and had tracheal intubation no more than 48 hrs ago. n1=76 (prone position); n2=60 (supine position)	Prone position content. Prone ventilation was maintained for 20 hours per day.	RCT (level of blinding unclear). ICU mortality, hospital mortality, duration of stay.	Simplified Acute Physiology Score	• The patients who received prone ventilation within 48 hours of eligibility had 15% absolute and 25% relative reduction in hospital mortality. The finding was not statistically significant when compared to supine position ($p < 0.05$).
Fernandez et al. (2008), Spain	To assess the effect of prone position on survival of ventilated patients with ARDS	n = 40, patients with ARDS under mechanical ventilation. n1 = 19 (supine position); n2 = 21 (prone position)	Prone position content. Prone position was continued for minimum 20 hours every day until morbidity or recovery.	RCT. 60-day survival, length of ICU stay, duration of mechanical ventilation.	Simplified Acute Physiology Score, Lung injury score	• The outcome variables did not show statistically significant improvement among patients assigned to prone position ($p < 0.05$). • The study does not dismiss the potential survival benefits of prone position due to small sample size.
Taccone et al. (2009), Italy and Spain	To assess the effect of prone position on the duration of survival of patients with ARDS	n = 342, patients with ARDS. n1 = 19 (supine position); n2 = 21 (prone position)	Prone position content. Prone position maintained for minimally 20 hours per day. Rotational bed used except in five settings.	RCT (blinded). Severity of illness, severity of organ dysfunction, ventilator free days, mortality and death.	Simplified Acute Physiology Score II, Sequential Organ Failure Assessment (SOFA) score	• Prone position did not show any significant survival benefits either in general population or in the patients with hypoxemia. • None of the outcome measures demonstrated significant improvement in the patients who were assigned to prone position group ($p > 0.05$).
Robak et al. (2011), Austria	To assess the combined effect of prone and upright position on maintaining oxygenation status in patients with ARDS	n = 20, Patients with ARDS. Randomly assigned to prone group or prone-upright group; n1 = 174 (Supine position); n2 = 168 (prone position)	Intervention Content. Group A: Prone positon for 2 hours followed by combined upright and prone position for 2 hours. Group B: Initial upright position immediately followed by prone position for 2 hours, then upright + prone position for 2 hours	Randomized prospective study (level of blinding unclear). PaO_2:FiO2,, PaCO2, Gas exchange, Compliance of respiratory system.	Arterial blood gas Bicore monitoring system	• Median PaO_2:FiO_2 ratio increased significantly ($p < 0.01$) when the position was changed from supine (Group A: 135; Group B: 133) to prone position (Group A: 160; Group B: 142). • The change in median PaO_2:FiO_2 ratio was more significant ($p < 0.001$) when the position was changed from supine (Group A: 135; Group B: 133) to prone + upright for 2 hours (Group A: 191; Group B: 188).
Guerin et al. (2013), France and Spain	To examine the effect of early application of prone positioning on improving the outcomes of ARDS	n = 466, Patients with ARDS. n1 = 237 (prone position); n2 = 229 (supine group)	Prone position content. Position changed to prone within one hour of assignment. Position maintained for minimally 16 hours every day. Intervention discontinued when improvement in oxygenation status measured even after 4 hours in supine position.	Prospective RCT (presence/absence of allocation concealment not noted). Mortality, time to successful extubation, length of ICU stay, ventilation free days, pneumothorax, non-invasive ventilation, tracheotomy.	McCabe score, Simplified Acute Physiology Score, chest radiography, arterial blood gas, sepsis related organ failure assessment	• Mortality at 28 day was significantly higher ($p < 0.001$) in supine position (75) as compared to prone position (38). • Successful extubation significantly higher ($p < 0.001$) higher in prone position (n = 186) as compared to supine position (n = 145). • At day 90, mean ventilation free days was significantly higher ($p < 0.001$) in prone group (57 ± 34) as compared to supine group (43 ± 38).
Ayzac et al. (2016), France	To examine the effects of prone position on the incidence of ventilator-associated pneumonia (VAP).	n = 466 patients with ARDS and under mechanical ventilation. n1 = 229 (supine position); n2 = 327 (prone position)	Prone position content. Patients assigned to prone position within one hour of randomization. Position maintained for 16 hours continually.	Prospective RCT (ancillary study). VAP.	Blood hematology (total count/differential count), arterial blood gas	• Incidence of VAP was 1.18 (0.86-1.60) per 100 ventilator days in supine position and was 1.54 (1.15-2.02) per 100 ventilator days in prone position. The difference was not statistically significant ($p = 0.10$). • The cumulative probability was lower in supine group (46.5%) as compared to prone group (33.5%) but the difference was not statistically significant ($p = 0.11$). • Prone positioning did not improve the incidence of VAP in patients with ARDS.

Table 1. Summary of studies on prone position in adult patients with ARDS

ARDS: Acute Respiratory Distress Syndrome, GICU: General Intensive Care Unit, PaO2: Partial Pressure of Oxygen in Arterial Blood, NO: Nitric Oxide, ABG: Arterial Blood Gas, PAP: Pulmonary Arterial Blood Pressure, ABP: Arterial Blood Pressure, PAOP: Pulmonary Arterial Occlusion Pressure, CI: Cardiac Index, RCT: randomized controlled trial, SIMV-PC/PS: Pressure-controlled Synchronized Intermittent Mandatory Ventilation with Pressure Support , APRV: Airway Pressure Release Ventilation, VAP: Ventilator Associated Pneumonia.

Studies	Sequence generation	Allocation concealment	Blinding			Incomplete outcome data	Selective outcome reporting	Other sources of bias
			Participants	Personnel	Outcome assessors			
Gattinoni et al. (2001)	+	?	?	?	?	+	+	?
Staudinger et al. (2001)	+	?	?	?	?	+	+	+
Varpula et al. (2003)	+	+	+	+	?	+	?	-
Voggenreiter et al. (2005)	+	?	?	?	?	+	+	+
Mancebo et al. (2006)	+	+	?	?	?	-	-	-
Fernandez et al. (2008)	+	-	-	-	-	+	+	-
Taccone et al. (2009)	+	-	-	-	-	+	+	+
Robak et al. (2011)	+	+	+	?	?	+	+	?
Guerin et al. (2013)	+	?	?	?	?	+	+	?
Ayzac et al. (2016)	+	?	?	?	?	+	+	+

Table 2. Assessment for risk of bias (Cochrane Collaboration)

+ Low risk of bias, ? risk of bias unclear, - high risk of bias

Ventilator-induced lung injury

The significant benefits noted in the PROSEVA trial (Guerin et al., 2013) were attributed to the preventive effects of prone positioning on ventilator induced lung injury (VILI).

Mortality and morbidity

PP has been associated with significant decreases in morbidity, such as Ventilator Associated Pneumonia (VAP) (Ayzac et al., 2016). However, the studies did not show any significant improvement in mortality (Fernandez et al., 2008; Gattinoni et al., 2001; Taccone et al., 2009). The duration of PP was similar in the studies by Fernandez et al (2008) and Taccone et al (2009), at 20 hours per day whereas the study by Gattinoni et al (2001) limited the intervention duration to at least 6 hours per day only. Regardless of the duration, the findings did not show any significant improvement in survival duration. On the other hand, the study that showed survival benefit of PP could not demonstrate that the survival benefit was significantly higher than shown by supine position group (Mancebo et al., 2006).

Onset and duration of prone positioning

The study by Mancebo et al (2006) did not reveal any significant difference in the oxygenation status between the patients who received PP within 48 hours of tracheal intubation and those who received the PP later than that. Taccone et al. (2009) did not find any survival benefit with the longer duration of PP; which was associated with significantly greater complications. More recently, the PROSEVA trial group utilized a mean duration of PP of 17 hours in their study protocol, and this yielded statistically significant survival benefit in favor of the PP in both the short (28 days) and long term (90 days) (Guérin et al., 2013).

DISCUSSION

When a patient is in the prone position, gravity exerts its effect on lung parenchyma, shifting all the thoracic structures downward. Anatomically, there is more lung tissue in the dorsal thorax than the ventral thorax; however, due to the effect of gravity, the posterior is less compressed and therefore tidal volumes delivered to the lung through mechanical ventilation are able to aerate a proportionally larger area in the posterior lung structures (Kallet, 2015; Varpula et al., 2003).

The reduced compression of the voluminous dorsal lung structures also facilitates improved perfusion to the larger area of lung vasculature that is able to receive cardiac output from the left ventricle (Kallet, 2015). Although studies have demonstrated an improvement in oxygenation with the prone position, those same studies failed to consistently demonstrate a survival benefit, and therefore PP was not used routinely, but rather as a rescue or salvage therapy (Rowe, 2004; Sud et al., 2008).

A key feature of ARDS is overwhelming pulmonary edema. Pro-inflammatory cytokines and aggregate neutrophil responses contribute to an overwhelming cycling of fluid spilling in the lung interstitium and alveolar spaces (Matthay & Zemans, 2011). The PP can facilitate resolution of this edema by improving lymphatic drainage as the heart is subjected to gravitational forces reducing compression of lymphatic vessels, prompting better drainage (Gattinoni et al., 2013). It has also been suggested that alveolar recruitment strategies prompt stimulation of aquaporins in the alveolar membrane walls, which improve the overall clearance of fluid (Constantin et al., 2007; Kallet, 2015).

VILI is perhaps one of the greatest indications for the prone position, as PP has been found to mitigate its effects (Gattinoni et al., 2013). VILI tends to occur in areas of the lung that are dependent: in a supine patient these are the posterior regions, and in the prone position the anterior regions (Gattinoni et al., 2013; Walkey et al., 2012). As oxygenation improves, patients require less aggressive means of oxygen support, which reduces oxidative stress on lung parenchyma from exogenous sources of oxygen. Overall, the PP optimizes V/Q matching while minimizing VILI and excessively high oxygen requirements, resulting in improved mortality (Gattinoni et al., 2013; Guérin, 2014; Walkey et al., 2012). As with other advantages of the prone position, the effect on VILI seems to be a constellation of synergistic effects rather than a single positive effect. Homogenizing pressure delivered during mechanical ventilation additionally reduces repeated opening and closing of alveolar units, reducing atelectrauma (Gattinoni et al., 2013).

The PROSEVA trial was the first of its kind to demonstrate both a 28-day and 90-day survival benefit in patients with severe ARDS who had received the prone intervention, as compared with their supine counterparts (Guerin et al., 2013). This study had significant power and spurred inquiry into why previous studies had not demonstrated this benefit, but has since had its findings corroborated by retrospective meta-analyses of older studies (Guérin et al., 2013; Sud et al., 2010). However, a recent meta-analysis did not reveal any significant mortality benefit of prone position over supine position (Bloomfield et al., 2014). On the other hand, there are contrasting views with regards to the effect of the duration and time of introduction of prone position on oxygenation status.

In a recent review, early, rather than late, utilization of the PP has been reported as having the largest impact on improved respiratory status (Kallet, 2015). In the early exudative phase of ARDS, the PP has the potential to facilitate early clearance of secretions and edema, reduce the stress of reactive oxygen species, and mitigate the harmful effects of mechanical ventilation (Kallet, 2015). However, adoption of the PP in the fibroproliferative phase of ARDS has also been shown to be beneficial in numerous studies and therefore should not be withheld (Kallet, 2015).

The effect of longer periods of PP have also been explored: Romero et al. (2009) conducted a small study (N=15) utilizing the PP for a mean duration of 55 hours, with improvement of numerous ventilation parameters and minimal adverse outcomes; in particular, no statistically significant increase in pressure ulcers were observed. It must be noted that strategies to mitigate pressure ulcer formation were utilized in this extended-duration trial, and this center was well-practiced in PP utilization, which likely affected their favorable adverse outcome rates. Given that studies are growing longer in duration with regard to PP utilization, it is likely that healthcare will explore and utilize longer PP durations.

Limitations

The search strategy used for the study was limited to three databases only. Significant articles could have been missed provided the limited time and resources available for article selection.

CONCLUSIONS

The findings reveal significant benefits of prone position in patients with ARDS; although, a recent meta-analysis (Bloomfield et al., 2013) did not support the survival benefit reported by PROSEVA and subsequent studies (Guerin et al., 2013; Mancebo et al., 2006). One of the benefits of PP is the reduction of VILI. It appears that the prone position more equally distributes the driving pressures produced by ventilators, reducing barotrauma to the functional units of the lung, which, in turn, contributes to the cessation of the harmful inflammatory cascade that occurs in early ARDS, reduces atelectrauma, and improves the ventilation/ perfusion ratio (Gattinoni et al., 2013; Guérin, 2014; Walkey et al., 2012).

On the other hand, the optimal duration of the PP has not yet been determined, though it is an area of fervent study. Early trials into proning utilized brief average PP periods of between seven to eight hours and, although there was evidence of improved oxygenation, mortality was not significantly improved (Gattinoni et al., 2001; Guerin et al., 2004). The PROSEVA trial group showed significant shorter and longer term survival benefit with a mean duration of PP of 17 hours (Guérin et al., 2013).

This landmark study provided the impetus for the wide adoption of the PP in the treatment of patients with severe ARDS. Until more research is done with regards to the ideal PP duration, the PROSEVA trial protocol should be utilized.

Much is known about the physiological benefits, risks, and sequelae associated with proning. As a new and relatively inexpensive treatment modality, the PP has demonstrated significant benefits for patients, but more work remains to be done as to the role of proning as part of a comprehensive ARDS treatment bundle along with other auxiliary treatments. Additionally, the PP is not an entirely benign intervention, as it increases the risk for a number of complications and presents challenges to nursing workflow. The role of nursing in the management of the critical care patient is ubiquitous; nurses potentially affect every facet of the patient's outcome. As such, it is imperative these health care professionals explore strategies to minimize risks and optimize the patient's experience and outcome with respect to ARDS.

REFERENCES

Ayzac L, Girard R, Baboi L, et al. (2016). Ventilator-associated pneumonia in ARDS patients: the impact of prone positioning. A secondary analysis of the PROSEVA trial', Intensive Care Medicine 42(5), 871-878.

Bloomfield R, Noble D, Sudlow A (2015). Prone position for acute respiratory failure in adults, The Cochrane Database Of Systematic Reviews, 11, CD008095.

Cochrane Bias Methods Group (2016). Assessing risk of bias in included studies. [Online] Available at: http://methods.cochrane.org/bias/assessing-risk-bias-included-studies.

Constantin J, Cayot-Constantin S, Roszyk L, et al. (2007). Response to recruitment maneuver influences net alveolar fluid clearance in acute respiratory distress syndrome, Anesthesiology, 106(5), 944-951.

Fernandez R, Trenchs X, Klamburg J, et al. (2008). Prone positioning in acute respiratory distress syndrome: A multicenter randomized clinical trial, Intensive Care Medicine 34(8), 1487-1491.

Gattinoni L, Taccone P, Carlesso E, Marini J (2013). Prone position in acute respiratory distress syndrome. Rationale, indications, and limits', American Journal of Respiratory and Critical Care Medicine, 188(11), 1286-1293.

Gattinoni L, Tognoni G, Pesenti A, et al. (2001). Effect of prone positioning on the survival of patients with acute respiratory failure. New England Journal of Medicine 345(8), 568-573.

Guérin C (2014). Prone position. Current Opinion in Critical Care 20(1), 92-97.

Guerin C, Gaillard S, Lemasson S, et al. (2004). Effects of systematic prone positioning in hypoxemic acute respiratory failure: a randomized controlled trial, JAMA 292(19), 2379-2387.

Guérin C, Reignier J, Richard J, et al. (2013). Prone positioning in severe acute respiratory distress syndrome, New England Journal Of Medicine, 368(23), 2159-2168.

Kallet RH (2015). A comprehensive review of prone position in ARDS. Respiratory Care 60(11), 1660-1687.

Luks AM (2013). Ventilatory strategies and supportive care in acute respiratory distress syndrome. Influenza and Other Respiratory Viruses 3(7), 8-17.

Mancebo J, Fernández R, Blanch L, et al. (2006). A multicenter trial of prolonged prone ventilation in severe acute respiratory distress syndrome, American Journal of Respiratory and Critical Care Medicine 173(11), 1233-1239.

Matthay M, & Zemans R (2011). The acute respiratory distress syndrome: pathogenesis and treatment', Annual Review of Pathology 6, 147-163.

Rimeika D, Nyrén S, Wiklund N, et al. (2004). Regulation of regional lung perfusion by nitric oxide', American Journal of Respiratory and Critical Care Medicine 170(4), 450-455.

Robak O, Schellongowski P, Bojic A, et al. (2011). Short-term effects of combining upright and prone positions in patients with ARDS: a prospective randomized study. Critical Care (London) 15(5), R230.

Romero C, Cornejo R, Gálvez L, et al. (2009). Extended prone position ventilation in severe acute respiratory distress syndrome: a pilot feasibility study. Journal of Critical Care 24(1), 81-88.

Rowe, C (2004). Development of clinical guidelines for prone positioning in critically ill adults. Nursing In Critical Care 9(2), 50-57.

Staudinger T, Kofler J, Müllner M, et al. (2001). Comparison of prone positioning and continuous rotation of patients with adult respiratory distress syndrome: results of a pilot study. Critical Care Medicine 29(1), 51-56.

Sud S, Friedrich J, Taccone P, et al. (2010). Prone ventilation reduces mortality in patients with acute respiratory failure and severe hypoxemia: systematic review and meta-analysis, Intensive Care Medicine 36(4), 585-599, Accessed 05 July 2017.

Sud S, Sud M, Friedrich J, Adhikari N (2008). Effect of mechanical ventilation in the prone position on clinical outcomes in patients with acute hypoxemic respiratory failure: a systematic review and meta-analysis. Canadian Medical Association Journal 178(9), 1153-1161.

Taccone P, Pesenti A, Latini R, et al. (2009). Prone positioning in patients with moderate and severe acute respiratory distress syndrome: a randomized controlled trial, JAMA 302(18), 1977-1984.

Varpula T, Jousela I, Niemi R, Takkunen O, Pettilä V (2003). Combined effects of prone positioning and airway pressure release ventilation on gas exchange in patients with acute lung injury. Acta Anaesthesiologica Scandinavica 47(5), 516-524.

Voggenreiter G, Aufmkolk M, Stiletto R, et al. (2005). Prone positioning improves oxygenation in post-traumatic lung injury: a prospective randomized trial. Journal of Trauma 59(2), 333-343.

Walkey A, Summer R, Ho V, Alkana P (2012). Acute respiratory distress syndrome: epidemiology and management approaches. Clinical Epidemiology 4,159-169.