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Prone Positioning in Acute Respiratory Distress Syndrome Patients

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PRONE POSITIONING IN ACUTE RESPIRATORY DISTRESS SYNDROME PATIENTS

by

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ABSTRACT

Introduction: Acute respiratory distress syndrome (ARDS), seen in critically ill patients, is a disease process that affects the lungs and directly impacts a patient's oxygenation. Despite treatment, patients often die of ARDS secondary to systemic complications. Prone positioning has been introduced as a treatment to improve the outcomes of ARDS patients. This thesis summarized and critiqued recent literature on the outcomes of prone positioning in ARDS patients.

Methodology: An initial literature search was conducted using CINAHL Plus with Text, Medline, Cochrane Database of Systematic Reviews, and US National Library of Medicine National Institutes of Health. Multiple search terms were used. Inclusion criteria consisted of peer reviewed research articles, academic journal articles, and evidence-based research or practices published within the last ten years. All studies included adult subjects and were published in the English language. Studies that did not address patient outcomes such as mortality, length of stay, or hemodynamic oxygenation were excluded from the review.

Results: The review of literature contains one meta-analysis and two studies. Data indicated that prone positioning was statistically significant in reducing mortality when performed in sessions of 12 hours or longer ($p=0.05$). Hemodynamic oxygenation improved significantly after at least 48 hours of implementing prone positioning. There was no trend in the length of stay or duration in mechanical ventilation whether supine or prone positioning was used. Complications such as endotracheal tube dislodgement, incidence of ventilator-associated pneumonia, and pressure ulcers were reported in both supine and prone position with an increased risk of pressure ulcers and endotracheal tube obstruction in the prone position groups.

Conclusions: Findings support a benefit in patient outcomes in patients placed in prone position with ARDS. Mortality was reduced when prone sessions lasted longer than 12 hours possibly due to the improvement in patient oxygenation 48 hours after initiation of prone positioning intervention. Further research is needed to solidify these findings and establish guidelines and optimal procedural methods to maximize patient outcomes and lower the incidence of patient complications.

DEDICATION

To my mom and dad, thank you for your endless support and for teaching me to aim for the stars. You've always inspired me to work hard and dream big. Your passion to learn and strong work ethics have allowed me to become the person that I am today. Thank you for your never-ending patience and for instilling ambition in me.

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INTRODUCTION

Acute respiratory distress syndrome (ARDS), seen in critically ill patients, is a syndrome that affects the lungs and directly impacts a patient's oxygenation. Even with treatment, patients may still die of this syndrome that has systemic effects. Prone positioning has been introduced as a method used to improve the outcomes of ARDS patients. The purpose of this paper is to present and interpret the most recent literature on the outcomes of prone positioning in ARDS patients.

BACKGROUND

Acute Respiratory Distress Syndrome

Acute respiratory distress syndrome (ARDS) is a life-threatening condition that occurs in critically-ill patients and requires prompt treatment. This condition occurs when the lungs suffer severe widespread injury, interfering with their ability to perform gas exchange (Hudson, 2010). The incidence of ARDS in the United States is about 190,000 cases per year (Modrykamien & Gupta, 2015). ARDS was reported in the 1960s medical literature and it appeared to occur with traumatic injuries with approximately a 70 percent mortality rate (Blume, 2009). More recently, the mortality rate has declined; however, there is still a 26-58 percent mortality worldwide (Sauls, 2017).

ARDS is caused by either an indirect or direct factor. A direct factor is one where the injurious agent reaches the lungs through the airways or by trauma to the chest (Hudson, 2010). Examples of a direct cause include bacterial, fungal or viral pneumonia, pulmonary contusion, or prolonged inhalation of high concentrations of oxygen, smoke or toxic substances (Blume, 2009). An indirect cause is where the injury occurs outside of the lungs or the injurious agent travels through the blood stream and then reaches the lungs (Hudson, 2010). Indirect causes include sepsis, shock, or traumatic brain injury (Blume, 2009). It was recently noted by the Mayo Clinic (2017) that the most common cause of ARDS is sepsis, an infection that effects the blood stream and eventually directly impacts the body's organs if left untreated.

Diagnostic criteria was developed at the 1994 American-European Consensus and is coined the "Berlin definition" of ARDS. The Berlin definition for ARDS includes acute onset, occurring within seven days, and bilateral opacities that are detected on a computerized topography (CT) scan or chest X-ray. The presence of edema in the lungs must not be fully explained by cardiac conditions or merely fluid overload. The definition further categorizes ARDS severity into mild, moderate, or severe based on the patient's PaO_2/FiO_2.

Table 1. Classifying ARDS Severity

ARDS Severity	**PaO_2/FiO_2**	**Mortality**
Mild	200-300	27%
Moderate	100-200	32%
Severe	<100	45%

Note. Reprinted from "Meet the New ARDS: Expert panel announces new definition, severity classes", by PulmCCM. 30 December 2012. Retrieved from https://pulmccm.org/ards-review/consensus-panel-announces-new-definition-severity-classes-for-ards-jama/

The part of the lungs that are damaged in ARDS are the alveoli. The alveoli are crucial to lung function because they are the site of gas exchange. Gas exchange is the process in which oxygen enters the bloodstream and carbon dioxide is then eliminated from the blood stream to the lung. The alveolar-capillary membrane, located in the alveoli, creates the blood-air barrier in which the gas exchange transverses. When the alveolar-capillary membrane is damaged, fluid inundates the lung, thus gas exchange is impaired (Hudson, 2010).

Furthermore, while ARDS is manifested acutely and progresses rapidly (Drahnak & Custard), it can be divided into three main stages: the exudative, proliferative and fibrotic stage.

1- The exudative phase occurs in the first 72 hours and acute inflammation occurs due to the release of a cascade of cytokines and other inflammatory mediating cells (Brashers & Huethers, 2017). The inflammation leads to increased capillary membrane permeability allowing for leakage of proteins, fluids, and blood cells (Brashers & Huethers, 2017). The leakage then causes the alveoli to flood thus preventing effective gas exchange from occurring, otherwise known as pulmonary edema. During this phase, surfactant is inactivated; surfactant is the substance that reduces surface tension in the alveoli and allows the alveoli to remain open during exhalation (Goerke, 1998).

2- During the second phase, the proliferative phase, the inflammatory process in the lungs occurs systemically throughout all tissues leading to an increased capillary membrane permeability (Blume & Byrum, 2009). The clotting (coagulation) and clot breakdown (fibrinolytic) systems are activated in the lungs. Clots are formed in the small capillaries of the lungs and overtime the alveoli lose their elastic properties and become fibrotic (Blume & Byrum, 2009). The lung tissues essentially begin to scar, as granulation tissue can be seen, thus worsening hypoxemia.

3- The final phase is the fibrotic phase where the remodeling and fibrosis of lung tissue occurs (Brashers & Huethers, 2017). The fibrotic tissue is permanent, and the patient will suffer from long-term effects due to the permanent loss of tissue. These effects include impaired gas exchange and obstructive and restrictive effects on the lung (Blume & Byrum, 2009). The alveoli are diminished due to the decreased surface area for gas exchange.

Treatment for ARDS focuses on improving blood oxygen levels and providing supportive care (National Heart, Lung and Blood Institute, 2012). To improve blood oxygen levels, oxygen must be given to the patient. This can be done using a mask that delivers high concentrations of oxygen to maximize the delivery of oxygen (Arbour, 2014). If this method does not improve oxygen levels, a more invasive method is the use of a ventilator. The ventilator takes on the work of breathing for the patient. It fills one's lungs directly with oxygen-rich air via an endotracheal, nasotracheal, or tracheostomy tube and uses positive pressure in order to keep the alveoli from collapsing.

Supportive care involves relieving and minimizing symptoms, preventing complications and improving the quality of the patient's life. The maintenance of fluid and nutritional balance is important because these patients are on a ventilator and unable to intake fluids or nutrition via the oral route. The patient will require parenteral or enteral feedings that meet the high energy requirements necessary. In addition, ensuring fluid balance is a delicate task because of the excess fluid in the lungs that are present. At the same time, the patient may also be hypotensive because while the lungs are flooding, the patient often does not have enough blood volume to maintain an adequate blood pressure (Hudson, 2010).

Another intervention performed when treating this condition is placing a patient in prone position. Prone is defined as laying face-down. Rather than being positioned primarily supine or side-lying, prone positioning is a strategy that has been specifically used on ARDS patients. While finding a cure for ARDS altogether is not truly realistic, the focus of reducing the burden of ARDS is to continuously improve the treatment of care for patients (Hudson, 2010).

Prone Positioning

Prone positioning is a supplementary strategy available when managing ARDS that was first introduced in 1974. The earlier attempts of prone positioning were implemented in ARDS patients later in the disease process as a rescue-maneuver. Currently, clinical evidence supports early implementation of the prone positioning because once the patients reaches the fibrotic phase of ARDS, the lungs are unable to be recruited, increase oxygen intake, or effectively participate in gas exchange when placed in prone positioning (Koulouras et al., 2016). Guerin et al. (2013) concluded that early application of prolonged prone-positioning sessions significantly decreased 28-day and 90-day mortality.

When placed in prone position, the patient benefits by having improved regional ventilation and perfusion, the secretion and redistribution of extravascular lung water, and less weight on the soft tissues (Drahnak & Custer, 2015). Turning a patient prone alters the V/Q (ventilation perfusion) ratio by shifting perfusion from the posterior bases of the lung to the anterior portion, thus improving ventilation (Sauls, 2017). The lungs are then less compressed by the heart because the heart exerts more pressure on the sternum when the patient is prone. Less pressure is exerted on the pleura and lung allowing for greater lung expansion (Drahnak & Custer, 2015).

Gattinoni et al. (2013) states that when ARDS patients are in prone position, alveolar inflation is increased compared to supine positioning. This allows for a more homogenous distribution of stress and strain on the alveoli.

Oxygenation has shown to improve as well because the dorsal region lung recruitment exceeds ventral derecruitment (Gattinoni et al., 2013). As seen in a computed tomography scan in Gattinoni (2013), the opacities of the lung are redistributed from the dorsal to ventral zones when positioned prone.

Many procedural factors must be performed to ensure that prone positioning is implemented safely for ARDS patients. A patient may be placed into prone position using an automated bed or this can be accomplished manually. A key component of placing a patient in prone position manually is ensuring staff adequacy and the use of proper body mechanics to ensure patient safety as well as decreasing the risk of injury to staff members.

Regardless of which method is used to prone the patient, healthcare professionals involved in the procedure must be trained, educated and demonstrate competency. Like many medical interventions, there are possible complications that may occur with prone positioning in ARDS patients. It is compulsory to ensure a patent airway when placed in this position. There is a risk for tubes to become dislodged or kinked and these types of complications must be anticipated and resolved immediately.

Prone positioning also puts the patient's integumentary system at risk for breakdown and injury. A patient's pressure points and boney prominences must be padded as with supine positioning. Unlike supine positioning though, prone positioning puts a patient's eyes at risk for drying and abrasions. Ensuring there is minimal pressure exerted on the patient's eyes, covering the eyes, or applying eye lubricant are actions to be implemented by the nurse when caring for a prone positioned patient.

While there are serious complications that may arise with prone positioning, the risks of prone positioning often counterbalance the need for adequate oxygenation and need to be weighed on an individual basis (Drahnak & Custer, 2015).

PROBLEM

Prone positioning has the potential to improve mortality rates and outcomes in patients diagnosed with ARDS, yet this practice has not been widely adopted. A barrier to prone positioning is partially due to the lack of published evidence supporting the practice.

The current focus on research of prone positioning is to not only explain the improvement of mortality rates and patient outcomes with the strategy, but to also address the procedure itself. Factors such as the length of time that the patient remains in prone position, the management and decrease of the risks involved, or whether the patient is placed in prone position manually or mechanically are all significant factors hospitals must consider when adopting this intervention. Complications such as pressure ulcers and the dislodging of tubes connected to the patient are barriers to critical care teams performing prone positioning.

This honors thesis investigated the following question. In patients with acute respiratory distress syndrome (ARDS), does prone positioning improve oxygenation and other outcomes compared to traditional supine positioning?

PURPOSE

The purpose of this study was to interpret recent research regarding patient outcomes when prone positioning was implemented in ARDS patients. This research will explore different methods and factors involved in the procedure, such as length and timing of prone positioning for ARDS patients.

SIG NIFICANCE

This literature review is important because it will interpret and analyze current literature pertaining to prone positioning in patients with ARDS. ARDS mortality remains relatively high and prone positioning could have a positive direct impact on patient mortality. Prone positioning could potentially lower a patient's length of stay in the hospital and optimize the patient's time in the hospital, thus lowering healthcare costs. By improving the knowledge of healthcare professionals about the physiological benefits, patient outcomes, and procedure of prone positioning, the procedure may be implemented in more hospitals (Drahnak & Custer, 2015).

ARDS patients typically have long hospitalizations and significant utilization of healthcare resources. Cost-effective treatment for ARDS is beneficial to the patient, hospital, and overall healthcare. The average daily cost of care in the ICU ranges from 2,278 to 3,518 dollars (Bice et al., 2013) and studies have shown that each subsequent day a patient spends in the ICU, the cost increases. Since almost all ARDS patients require mechanical ventilation, it is important to note that mechanically ventilated patients accrue higher total costs than non-mechanically ventilated patients (Bice et al., 2013). Methods that reduce the duration of mechanical ventilation and the length of stay in the ICU are being researched in order to lower the cost of treating ARDS (Bice et al., 2013).

METHODS

An initial literature search was conducted, and the findings were reported in the form of a literature review. The databases that were used included CINAHL Plus with Text, Medline, Cochrane Database of Systematic Reviews, and US National Library of Medicine National Institutes of Health. The search terms that were used are: “prone position*”, “acute respiratory distress syndrome or ARDS”, “supine position*”, “respiratory distress syndrome”, position*, and “patient position*”.

Material was limited to peer reviewed research articles, academic journal articles, and evidence-based research or practices. All material that was used was published within the last ten years (2007 to 2017). Inclusion criteria also included studies published in the English language and performed on human subjects.

This literature review solely focused on the outcomes of adult patients. Therefore, exclusion criteria included pediatric* or paediatric*, child*, adolescen*, kid*, or youth. Research that did not relate to acute respiratory distress patients will be excluded.

A total of three articles were used in the review of literature, one meta-analysis, one therapeutic study and one prospective interventional study. All articles utilized were peer-reviewed and were selected once inclusion criteria was deemed met. Articles were excluded if outcomes were not evaluated or additional therapies, such as extracorporeal membrane oxygenation (ECMO), were utilized in the study. See Figure 1 for further information.

RESULTS

Patient Mortality

Mortality refers to the death of the patient included in the study. This outcome was assessed at different periods of time in each study. Mortality was recorded at day-28, day-90, during the patient's stay in the ICU, or by the time the patient was discharged from the hospital. Mortality was assessed and reported in all studies included in this literature review.

Hale et al (2012) studied patients that had varying degrees of burns who all were diagnosed with ARDS and were placed in prone position. This study had the highest mortality rate, 67% (12/18), of all studies included in this review of literature, regardless of the time period mortality was evaluated. The expected mortality of patients with 30-39.9% total body surface area (TBSA) burns is 5.4% (Hale et al, 2012). The mean percent TBSA was 37±26%, suggesting that a majority of the population carried an additional mortality related to their high degree of critical illness and multisystem failure (Hale et al, 2012). The added mortality of higher TBSA burns are a contributing factor to the relatively high mortality rate in this study.

Romero et al. (2009) contained 15 patients who had severe ARDS that was unresponsive to positive-end expiratory pressure adjustment. All patients were subjected to prone position therapy because there was only one study group included. Mortality was recorded until time of discharge from the hospital. Six out of the 15 patients died, and its statistical significance was not recorded.

The meta-analysis, Munshi et al. (2017) reports that out of the eight randomized controlled trials included, there was no statistically significant difference in mortality between supine and prone positioning. Although, a reduction in mortality was shown to favor prone positioning in studies that implemented prone position sessions 12 hours or longer when compared to studies with sessions lasting less than 12 hours (Munshi et al., 2017). In studies where patients were placed in prone position for less than 12 hours, decreased mortality did not favor prone positioning after statistical analysis.

Mortality is the primary outcome of the studies included in the literature review. This stems from the initial goal of implementing prone position, which was to reduce mortality rates in a disease process that has an average mortality of 26-58% (Sauls, 2017).

Length of Stay (LOS)

The LOS refers to the amount of time, in days, the patient spent in a certain setting. The LOS was measured in either their amount of days spent at the hospital or in the ICU. Lengths of stays were reported in terms of supine and prone groups and then further broken down into survivors versus nonsurvivors in certain studies. The LOS was not reported in the meta-analysis.

Table 2. Summary Data Related to ICU Length of Stay

Study	Supine Group Survivors, days	Prone Group Survivors, days	Supine Group Nonsurvivors, days	Prone Group Nonsurvivors, days
Guerin et al. (2013)	26±27	24±22	16±11	21±20
	p=0.05			
Fernandez et al. (2008)	7.6±7.6	12.0±10.6	23.0±19.9	11.9±6.9
	p=0.3		p=0.2	
Mancebo et al. (2006)	22±14.1	27.9±18.5	17±27.9	10.9±12.5
	P-value not reported			
	Supine Group, days	**Prone Group, days**	**P-value**	
Taccone et al. (2009)	16	17.5	0.17	
Romero et al. (2009)	Not reported	23 ± 10	Not reported	

Table 2 displays the reported LOS in four studies included in the meta-analysis and one study (Romero et al., 2009) that was not included. When comparing the LOS across different studies among different groups, there is no consistent trend in LOS.

In Hale et al (2012), the LOS in patients who survived hospital discharge ranged from 39 to 377 days. The prolonged LOS and wide range cannot be determined to solely attribute to the patient's ARDS diagnosis or to the prone position intervention because the patient population consisted of burn victims. Unfortunately, no average LOS was calculated in this study and no supine study group was used to compare findings.

Hemodynamic Oxygenation

Hemodynamic monitoring includes measurements such as oxygenation levels and the ratio of arterial oxygen pressure to the fractional inspired oxygen (PaO_2/FiO_2). These measurements can be obtained via the ventilatory support machine.

These data were only obtained in a select number of studies included in this literature review. PaO_2/FiO_2 was recorded at inclusion to demonstrate the initial severity of ARDS but was not evaluated after prone position sessions in all studies. The meta-analysis considered the PaO_2/FiO_2 a secondary outcome and reported that PaO_2/FiO_2 on day 4 was significantly higher in prone position groups compared to supine position groups (Munshi et al., 2017). Fernandez et al. (2009) and Mancebo et al. (2006) are studies included in the meta-analysis and are reported in this section of this literature review to compare and gain insight on the outcomes of PaO_2/FiO_2 results.

Romero et al. (2009), documented PaO_2/FiO_2 two hours before prone positioning was initiated and reported a median value of 92±12. The PaO_2/FiO_2 two hours before returning to supine position increased to 227±43. The increase from PaO_2/FiO_2 12 hours before change to prone position to two hours after the change of prone position was statistically significant ($p<.0001$). While patients demonstrated improved oxygenation through an increase in PaO_2/FiO_2, there was no supine group for comparison.

Hale et al. (2012) also did not have a supine study group for comparison, but the mean PaO_2/FiO_2 immediately before prone positioning was 87±37. Forty-eight hours after prone positioning, the PaO_2/FiO_2 increased to 210±98. Sixty-seven percent of the participants responded with a 50 percent improvement in PaO_2/FiO_2 within 48 hours after prone positioning was initiated (Hale et al., 2012).

The Fernandez et al. study (2008) was included in the meta-analysis and consisted of a supine and prone position group. The prone group demonstrated an increase in the PaO_2/FiO_2 within six hours and reached statistical significance on day 3 (234±85 vs. 159±78, $p = 0.009$). During the study, from pre-randomization to day 7, the supine group did not reach a mean value PaO_2/FiO_2 above 200 (Fernandez et al, 2008).

The Mancebo et al. study (2006) was included in the meta-analysis and yielded similar results to Fernandez et al. (2008). The PaO_2/FiO_2 was measured in intervals of 30-60 minutes after randomization. The first measurement reported began with the patient in supine position and lasted until day-4 with the patient in supine or prone position depending on which group the patient was in. The prone group mean had a higher PaO_2/FiO_2 ($p<0.001$) that reached 200 compared to the supine group that never reached 200.

The PaO_2/FiO_2 data provided evidence that prone positioning improves patient oxygenation compared to traditional supine positioning. Prone position patient's oxygenation surpassed that of the supine positioned patients at least 48 hours after prone positioning was implemented.

Complications

Prone positioning is a procedure that involves a high risk for certain complications. A priority concern includes ensuring a patent airway when positioning and maintaining patients in prone position. Prone positioned patients are also susceptible to integumentary complications, such as pressure ulcers, facial edema, and corneal abrasions. Overall, it is important to investigate these incidences because they have the potential to affect the outcome of patient.

Among the eight studies included in the meta-analysis, barotrauma, ventilator-associated pneumonia, unplanned central catheter removal and unplanned extubation occurred (Munshi et al, 2017). Munshi et al. (2017) reported that there were no differences between prone positioning compared to supine positioning. Although, patients in prone position were reported to be at an increased risk of endotracheal tube obstruction and pressure sores (Munshi et al., 2017).

In Romero et al. (2009) there were no displacements of tubes or lines during the repositioning of the patients. Out of the 15 patients, two patients developed grade II pressure ulcers in which one ulcer developed on the nasal septum and one on the cheek. All 15 patients developed facial edema that subsided when returned to supine position (Romero et al., 2009). The small amount of pressure ulcers was given credit to the fact that preventative skin breakdown measures were used diligently and that the participating staff members were previously familiarized with the procedure as well.

Hale et al. (2012) had eight complications occur in six different patients but had no airway dislodgements during the study. Pressure ulcers and facial edema occurred in both patients who did and did not have facial burns. There was a high incidence of ventilator-associated pneumonia (67%) and six patients experienced venous thromboembolic events (six percent).

Duration of Mechanical Ventilation

Patients who are ventilated for prolonged periods of time are at risk for complications such as barotrauma and ventilator-associated pneumonia. The duration of mechanical ventilation was reported only in a limited number of studies. The studies reported below were included in the meta-analysis and are included in the following section to compare results.

Fernandez et al. (2008) compared supine group survivors and nonsurvivors to prone group survivors and nonsurvivors. The prone group survivors mean duration of mechanical ventilation in days were longer than the supine group (12.0±10.6 vs. 7.6±7.6, respectively). Taccone et al. (2009) measured the duration of mechanical ventilation at day-28. The prone group survivors had a mean of 25 days while the supine group survivors had 19 days. The only similarity between the two studies is that the prone group was ventilated longer than the supine group on average.

While the results for the length of mechanical ventilation varied between studies and the data were limited, it is an important factor to investigate because of its implications, including the effect on the cost of care and the risk of a patient contracting a hospital acquired infection.

Duration of Prone Positioning

Different durations of prone positioning were implemented among the studies. The meta-analysis best demonstrates the relationship of the duration of prone positioning with patient mortality.

Munshi et al. (2017) results found a correlation between the duration of prone positioning to mortality. A higher reduction in mortality was observed in the five trials that placed patients in prone position for 12 hours or more ($p=0.04$), compared to the three studies where patients were in prone position for less than 12 hours ($p=0.72$) (Munshi et al., 2017).

The two studies, Hale et al (2012) and Romero et al. (2009), that were not included in the meta-analysis did not have a comparison supine group. Hale et al (2012) maintained prone position sessions that were a total of at least 16 hours per day. Romero et al (2009) maintained continuous prone position sessions that lasted longer than 24 hours with an overall mean of 55±7 days.

The studies that took place after 2005 placed patients in prone position sessions lasting over 12 hours per day. Mancebo et al. (2006) was the first study to implement longer prone position sessions and deemed that longer and earlier prone position sessions were feasible and safe and contributed to a reduction in mortality rates. A majority of the studies included in this review of literature conducted prone position sessions lasting over 12 hours and the results favor longer durations of prone positioning (≥12 hours) in regard to achieving the greatest benefit in terms of mortality rates.

DISCUSSION

The two studies and one meta-analysis included in this study all included samples of patients with varying severities of ARDS who were placed in prone position as a component of ARDS treatment. All the studies included addressed the outcomes of ARDS patients placed in prone positioning, were peer reviewed, and took place in a hospital setting.

Throughout the literature, the inclusion criteria were similar, which generated populations with similar baseline characteristics. The Berlin criteria also allows for a universal standard to be met when diagnosing ARDS. Therefore, with the assumption that each participant was diagnosed properly and accurately, all ARDS patients involved in all studies had like characteristics.

Prone positioning was favorable in terms of reducing patient mortality. When comparing prone and supine groups, Munshi et al (2017) reported a nonsignificant difference between the two on the effect of patient mortality. Although when comparing studies with prone groups with long (≥12 hours) versus shorter (<12 hours) prone position duration, the studies that maintained longer prone sessions had a reduced mortality ($p=0.05$). Munshi et al. (2017) compared its findings to other meta-analyses that reported a reduction in prone positioning in terms of mortality that reached statistical significance and stated that the difference in results may be due to the time point of the mortality assessment. The lack of statistical significance in mortality rates may be due to the difference in severities of ARDS the patients may have, the presence of comorbidities, or the difference in methodology among the studies.

Overall, the outcomes shown in this literature review may only benefit a limited number of patients within the ARDS population. Prone positioning is contraindicated in those with conditions such as spinal injuries, facial injuries, or unmonitored increased intracranial pressure

(Drahnak & Custer, 2015). There has also been a recent shift to investigating the outcomes of prone positioning in patients with severe ARDS. Both Hale et al. (2012) and Romero et al. (2009) contain populations consisting of patients with severe ARDS ($PaO_2/FiO_2 < 150$) and Munshi et al. (2017) concluded that mortality is reduced in patients with a $PaO_2/FiO_2 < 200$. With this data, it can be inferred that prone positioning may have the most benefit on only a small portion of the ARDS population. This small portion includes those who do not have conditions that will indefinitely interfere with the safety of prone positioning and possibly patients with severe ARDS. Further research will be needed to define a target ARDS population that prone positioning can be implemented safely upon and will yield the most benefit. Guerin et al. (2013) best demonstrates this focus by placing patients in prone position within an hour a diagnosis and focusing on those diagnosed with severe ARDS.

Another area of discussion includes the timing of prone positioning from time of diagnosis to the implementation of prone positioning. Guerin et al. (2013) reported a decreased mortality at day 28 and 90 and concluded that the prone position intervention should be best used as a first-line intervention rather than a rescue maneuver (Guerin, et al., 2013). Prone positioning was implemented within the first hour after randomization. In comparison, Mancebo et al. (2006), prone position mortality never reached statistical significance ($p = 0.12$) possibly due to the fact that the time of diagnosis to randomization was an average of one day (1.04 ± 1.30 d) after diagnosis. Mancebo et al. (2006) concluded that the interval between the onset of ARDS and prone positioning application may be an important determinant to the effectiveness of prone positioning.

The LOS data were inconsistent and showed no trend among studies. This may be due to the differing patient severities, hospital protocol, or complications that arose during the time of hospitalization. If a correlation between prone positioning and prolonged length of stay was shown, then patients would be considered at a higher risk for hospital-acquired infections due to their prolonged exposure to the hospital environment and would have an increased projected cost of care.

Munshi et al. (2017) reported that complications showed no differences between prone and supine positioning, possibly suggesting that the risk of complications is similar in both types of positioning. The meta-analysis further clarified and reported that prone positioning had increased risks of endotracheal tube obstruction and pressure sores.

Overall, complications occurred in each of the studies included in this review of literature. The complications ranged from facial edema, pressure ulcers, and tube dislodgement. All studies reported complications, which holds implications for future studies to have the initiative of working towards a standard of care that avoids the most common complications in prone positioned patients. By anticipating adverse effects and implementing preventative measures such as creating a skin care bundle that reduces the risk for pressure ulcer formation on the anterior portion of the body or by implementing a tube checklist that will prevent dislodgement or obstruction will in turn reduce the occurrence of complications associated with prone positioning.

The PaO_2/FiO_2 ratio was not a primary focus in the studies included in the literature review, but the findings appear to favor prone positioning. The patients in prone groups had a greater increase in PaO_2/FiO_2 ratio from before to after prone position initiation and ended with higher PaO_2/FiO_2 values when compared to supine groups. This demonstrates the effectiveness of prone positioning in its ability to improve oxygenation in ARDS patients. Munshi et al. (2017) suggests that prone positioning oxygenation benefit is not significantly higher until prone positioning has been implemented for four days, intermittently. This finding also supports that longer prone position sessions have the potential to yield better patient benefit when compared to traditional supine positioning.

Mortality, on the other hand, was reported more consistently among the studies. Overall, it was deemed that patients who were placed in prone position had a reduction in mortality rates in each study compared to those positioned in the supine position but was not statistically significant. The results of the meta-analysis concluded that prolonged periods of prone positioning produced improved mortality rates. Therefore, it would potentially benefit future studies to initiate longer prone positioning sessions that are at least twelve hours or more per day. Munshi et al. (2017) mentions that a possible reason for decreased mortality with longer prone positioning sessions because of the decreased occurrence of ventilator-induced lung injuries. Research suggests that prone positioning decreases and homogenizes lung stress and strain, and in turn decreases ventilator-induced lung injuries (Guerin et al., 2013). The Guerin et al. (2013) study contained prone sessions of at least 16 hours because of previous research showing that prone positioning reduces overinflated lung areas and promotes alveolar recruitment. Implementing longer prone position sessions possibly allows for the physical effects of prone positioning to take effect on ARDS lungs and allows for optimal benefit. Compared to supine positioning, prone positioning avoids the hyperinflation of lungs and lessens the risk of the patient to experience a ventilator-induced lung injury. Prone positioning has the ability to recruit injured lungs and thus provides improved oxygenation and in turn can reduce mortality compared to traditional supine positioning.

Prone positioning was shown to improve outcomes for ARDS patients such as decreasing mortality rates and increasing oxygenation. Outcomes such as length of stay and duration of mechanical ventilation did not show a relationship in regard to prone positioning. Patient complications occurred in both supine and prone position groups suggesting that prone and traditional supine positioned patients are both at risk for similar complications.

LIMITATIONS

Prone positioning is an intervention that is not yet widely used in practice and can be considered a complex procedure. During this review of literature, several limitations were identified in the current research.

In Munshi et al. (2017) alone, four out of eight studies were discontinued prematurely due to “slow enrollment”. The discontinuations limited the amount of data that could have been gathered for that study and did not allow for data to reach statistical significance. Furthermore, the number of participants also varies greatly among the studies used. Three out of the eight studies in Munshi et al. (2017), as well as studies by Hale et al. (2012) and Romero et al. (2009), had fewer than fifty subjects. The low sample size may not truly represent the entire population, especially if outliers are present in the data.

Another limitation of this literature review is the lack of more recent studies. The PROSEVA trial (Guerin et al., 2013) was the most recent study included that investigated early prone positioning in patients with severe ARDS. Although the meta-analysis itself was published in 2017, five out of the eight studies were published over ten years ago. Therefore, the parameters of the literature review had to be adjusted, spanning to research published over 10 years ago.

The contemporary approach to prone positioning includes implementing prone positioning early in regard to the time of diagnosis and for sessions to be continuous and over 12 hours in duration (Munshi et al., 2017). Not all studies included in this review of literature included methods that implemented earlier and prolonged prone positioning. The lack of this approach was due to many of the studies building off of one another. Many of the studies included reference studies before them and demonstrate research evolving and adapting to new findings from previous research.

Differing and variable results in patient outcomes may also be attributed to the difference in settings among the studies including the difference in hospital settings and geographic location. Patient populations also tend to vary around the world. Murthy and Wunsch (2012) stated that in studies comparing US ICU patients to the UK, Japan, and New Zealand, all countries that contain less ICU beds than the US, the US ICU patients were consistently older, but less severely ill. Knowledge of variation in approaches to care are important for appropriate interpretation and broad application of study results because many new treatments and techniques are studied across countries and then implemented in the care of critically ill patients worldwide (Murthy & Wunsch, 2012). International comparisons of ICU resources have demonstrated that the definitions of critical illness and ICU beds vary due to the differences in ability to provide organ support and variable staffing (Prin & Wunsch, 2012).

Nursing is considered an applied discipline that is implemented differently based upon the social, political, and cultural climate in which it is practiced (Jones & Coeling, 2000). Different themes are apparent when investigating the difference in nursing around the world. Two important themes include the fact that there are different levels of education preparation for nurses and that there are explicit standards for credentialing to maintain safe practice (Jones & Coeling, 2000). Overall, the different standards of practice, varying levels of education, and different hospital protocols may serve as a limitation in this review of literature.

The Munshi et al. (2017) meta-analysis inclusion criteria required studies to have both a supine and prone study group. Hale et al. (2012) and Romero et al. (2009) were not included in the meta-analysis because of their lack of a supine comparison group, but still met the inclusion criteria of this literature review. The lack of comparison groups limits the generalization of findings and the validation that prone positioning allows for better outcomes compared to the traditional supine positioning performed for ARDS patients.

Despite these limitations, this literature review addresses the ARDS patient outcomes when prone positioning is used during treatment and its implications for future research.

FUTURE IMPLICATIONS

Research

After reviewing the literature, mortality was identified as the primary outcome. Throughout the research included, mortality had been shown to be reduced among prone positioned patients. Studies should consistently include mortality, length of stay, and ventilator hours as outcome measures for comparison.

Another area of research that needs to be studied is the procedure itself. This aspect includes the ideal amount of time from diagnosis to prone positioning, amount of time spent in prone position, the type of bed used in this process, and the preventative measures taken to avoid complications. In order to further improve patient outcomes, research should begin focusing on which methods lead to the best outcome when implementing prone positioning.

The PaO_2/FiO_2 ratio in relationship to mortality should be studied further as well. Although this literature review shows that placing patients in prone position for 12 hours or more reduces mortality compared to prone positioning sessions that are less than 12 hours, determining a more specific range of time in prone position may be more ideal when implementing it in practice considering some studies contained sessions lasting up to 18 hours per day on average. An optimal minimum and maximum duration of prone positioning should be determined through future research.

Avoiding and lowering the risk of complications should be a priority focus when executing prone positioning. Because the different types of complications are understood, future research should aim towards obtaining a protocol or standard plan of care dedicated to preventing complications. It is important to create interventions to protect the airway and anterior portion of the integumentary system. Researching different methods such as the use of eye drops versus film eye covers or types of padding and skin barrier protection to prevent skin breakdown for the patient in prone position will allow for the best methods to be implemented in practice. Nursing care is crucial to the reduction of complications because they continuously assess the patient and implement these preventative measures as needed and prophylactically.

Future studies researching prone positioning in ARDS patients should consider including a comparison group to better evaluate the effectiveness of the interventions being tested. This will allow for a direct comparison and will aid in generalizing the results. As prone positioning for ARDS patients becomes better understood and established, research can evolve from containing both a supine and prone study group to comparing different interventions applied to prone groups only. By having comparing interventions among solely prone groups, research will be able to report which interventions yield the most optimal outcomes.

Finally, prone positioning is not used for all ARDS patients. Research should aim to identify which group(s) of ARDS patients respond best to this type of therapy. Different groups such as mild, moderate, or severe ARDS patients may be one strategy for stratification to gain a better understanding of the relationship of severity of ARDS to outcomes. Like Hale et al. (2012), researchers interested in prone positioning may begin to conduct research on specific populations whether the populations have burns, are obese, or are post-operative patients. The findings from this literature review can guide the next step for future research.

Education

Drahnak and Custer (2015) believe that the foundation for the success of prone positioning lies within in-depth training and in-service training for hospital team members.

A majority of the studies claimed that the staff involved were highly trained and familiarized with the procedure. Guerin et al. (2013), the most recent study used in this review states that the centers participating in the study were all skilled in the process of turning patients from supine to prone position. The study credits the staffs' training to the low rate of complications that occurred in the study. Guerin et al. (2013) results may not be generalized to centers who use staff that lack training on this procedure. As hospitals begin to slowly adopt prone positioning and create their own trials, there must be training provided and a review of literature prior to implementing this procedure in their own facility.

Therefore, standardized training programs should be developed in which healthcare team members should attend prior to implementing prone position therapy for ARDS patients. The training program would need to address all parts of prone position therapy including indications for prone positioning, understanding whom is eligible for the intervention, and the maneuver itself, how to assess and care for a patient who is in prone position, education on complications to anticipate and how to prevent them. Simulations and a hands-on approach would allow for nurses to become more comfortable and allow for additional practice. After attending the training program, the team members should be evaluated on their competency regarding the prone positioning of patients. Nurses especially should be able to not only perform the maneuver safely but understand how to assess the patient's response to prone positioning including hemodynamic monitoring and frequent respiratory assessments.

While education involves investing in time and funds, the outcome of well-trained staff has the potential to save money on the cost of care and in turn can reduce complications, furthermore reducing lengths of stays and the need for additional interventions. Education is a crucial part of prone position therapy and it should be mandatory for staff members involved to be formally trained in order to maximize safety and outcomes for patients.

Nursing Practice

The results of this review of literature have implications for nursing practice. While the studies do not directly refer to nurses or investigate their practice specifically, it is important to acknowledge the role nurses have in implementing prone positioning in ARDS patients.

Nurses are a crucial asset in prone positioning therapy because they are on the front line of patient care and follow the patient through their course of care. The nurses' role starts by assessing if the patient's eligibility for this intervention and extends to the ongoing assessment and evaluation of the patient in response to therapy and treatment (Chadwick 2010). Therefore, nurses must have a thorough understanding and be knowledgeable of whom is eligible for prone positioning.

Nurses are also responsible for physically preparing, placing, and assessing the patient in prone position. Each study included addresses the incidence of complications that ranged from airway tube dislodgement to the occurrence of pressure ulcers. Nursing care regarding prone positioning includes actively implementing precautions and preventative measures that reduce the risk for complications to occur.

A priority nursing care role, includes ensuring a patent airway is maintained during prone positioning therapy whether repositioning the patient or while in prone position. Nurses must be aware of the risk for tube dislodgement or obstruction and implement an optimal way to secure the tube during the change in position and while maintaining the position as well.

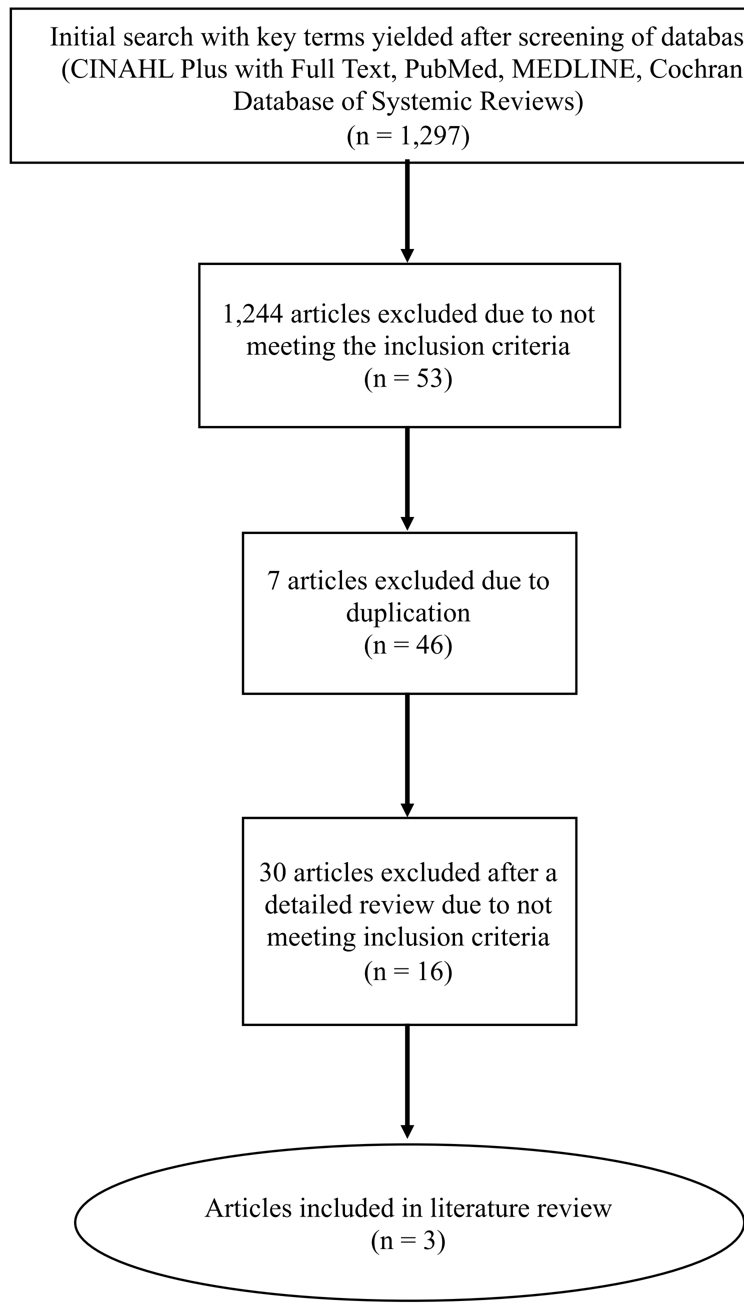
Another major complication with prone positioning pertains to the patient's integumentary system. A nurse's role, whether or not the patient is in prone position, is to maintain the integumentary system and take necessary precautions to prevent skin breakdown. The plan of care should include interventions with the goal of protecting the integumentary system. The nurse must be aware of which regions the patient is most susceptible to developing skin breakdown. It is vital for the nurse to be involved in the padding of the high-risk areas and to perform frequent skin assessments. Looking at the research performed and understanding that a common complication of prone positioning relates to skin breakdown, allows for the nurse to recognize that skin care is a priority in the patient's plan of care. Steps such as changing and emptying tubes before turning the patient should also be considered to avoid the leaking and oozing of secretions (Drahnak & Custer, 2015). Unlike supine positioning, prone positioning puts increased pressure on the patient's forehead and cheeks. The nurse must implement a plan to avoid pressure applied to this area, as well as the patient's eyes. Nurses must also consider the placement of electrodes on the patient's chest and may need to place these pads to the patient's posterior region, rather than anterior, to avoid additional skin breakdown under and around the pads. Each patient is different and requires informed nursing judgement as well as a solid understanding of the mechanisms of prone positioning to allow for the nurse to implement optimal skincare for the patient.

In practice, multiple people must be involved in the turning of patients. By understanding the patient's needs and priorities, a team of healthcare professionals will be able to best maneuver the patient when positioning the patient. Nurses are leaders in repositioning the patient because they understand the patient's current needs and prioritization of care. Everyone involved in placing the patient in prone position should be formally trained on the procedure, and nurses can be leaders in directing team members when preparing and repositioning the patient. It is important for nurses to understand how to delegate tasks such as having one healthcare team member ensure a patent airway and deciding how many team members are needed when turning the patient.

Nurses play a direct hands-on role in the care of patients. Prone positioning has an immense implication on nursing practice because of their presence and expertise that is crucial to maintain safety and ensure optimal outcomes for these patients.

APPENDIX A: LIST OF FIGURES

Figure 1: Flow Diagram of Study Selection Process



Key terms: prone position, acute respiratory distress syndrome, ARDS
Inclusion criteria: English language, adult humans, peer-reviewed, Publication Date: 2007 to 2017

APPENDIX B: LIST OF TABLES

Table 1: Classifying ARDS Severity

ARDS Severity	**PaO_2/FiO_2**	**Mortality**
Mild	200-300	27%
Moderate	100-200	32%
Severe	<100	45%

Note. Reprinted from "Meet the New ARDS: Expert panel announces new definition, severity classes", by PulmCCM. 30 December 2012. Retrieved from https://pulmccm.org/ards-review/consensus-panel-announces-new-definition-severity-classes-for-ards-jama/

Table 2: Summary Data Related to ICU Length of Stay

Study	Supine Group Survivors, days	Prone Group Survivors, days	Supine Group Nonsurvivors, days	Prone Group Nonsurvivors, days
Guerin et al. (2013)	26±27	24±22	16±11	21±20
	p=0.05			
Fernandez et al. (2008)	7.6±7.6	12.0±10.6	23.0±19.9	11.9±6.9
	p=0.3		p=0.2	
Mancebo et al. (2006)	22±14.1	27.9±18.5	17±27.9	10.9±12.5
	P-value not reported			
	Supine Group, days	**Prone Group, days**	**P-value**	
Taccone et al. (2009)	16	17.5	0.17	
Romero et al. (2009)	Not reported	23 ± 10	Not reported	

Table 3: Research of Prone Positioning in Acute Respiratory Distress Syndrome Patients

Author, Pub, Year, Country	Inclusion Criteria	Study Design	Interventions	Outcomes Measured	Findings	Conclusions
Hale et al., 2012, USA	Patients with varying severity of burns, were diagnosed with ARDS and had a PaO2/FiO2 <150mmHg; Study Group (n=18)	Therapeutic study; Study Group (one group all placed in prone position)	Patients were placed in prone position until oxygenation and ventilation allowed ventilator settings to be weaned. All patients were placed in prone position for at least 16 hours a day for 3 days.	Mortality at 28-days to ICU discharge and to hospital discharge; Length of stay; PaO_2/FiO_2 immediately before and after PP, 6h, 12h, 24h, 36h, and 48h after; Duration of prone position; Complications related to prone positioning	Mortality 28-day 12/18 (67%) Mortality to hospital discharge 6/18 (33%) Hospital Length of Stay, days Survivors ranging from 39-377 PaO_2/FiO_2 Immediately before: 87 (±37) Immediately after: 133 (±71) 6h: 165 (±106) 12h: 170 (±102) 24h: 214 (±128) 36h: 236 (±136) 48h: 210 (±98) Duration of Prone Position At least 16h/day Complications related to prone positioning Airway emergency/ dislodgement: 0	Prone positioning improved oxygenation and was deemed safe for burn patients with severe ARDS. Prone positioning improved oxygenation for at least 48h without significant morbidity. Mortality remained relatively high out of the 18 participants.

					Pressure ulcer: 4 (22%) DVT: 1 (6%) PE: 0 (0%) VAP: 12 (67%)	
Munshi et al., 2017.	Randomized controlled trials that compared mechanically ventilated adult patients with ARDS placed in prone position and supine position. All studies reported on mortality; Study Group (n= 2,129), Supine Group (n=1,093), Prone Group (n=1,036)	Systematic review and meta-analysis; Study Group (one group placed in prone position); Control Group (one group placed in supine position)	The studies included placed ARDS in either prone or supine positioning when undergoing mechanical ventilation.	Mortality; PaO_2/FiO2; Complications;	<u>Mortality</u> No significance between supine and prone positioning (RR 0.84, 95% CI, 0.68-1.04; I^2, 59%). Mortality reduction in studies with longer durations of prone. 90-day mortality and 6-month mortality did not demonstrate a difference between prone and supine positioning. <u>PaO_2/FiO_2</u> PaO_2/FiO_2 on day 4 was significantly higher in prone position group than in supine position group <u>Complications</u> 4 studies reported barotrauma and ventilator-associated pneumonia 3 studies reported unplanned central catheter removal 8 studies reported unplanned extubation.	Findings support that prone position mortality is reduced in patients with moderate to severe ARDS (PaO_2/FiO_2 <200) and for a longer duration (≥12 hours). Prone positioning poses an increased risk for endotracheal tube obstruction and pressure sores.

					No difference between prone and supine positioning found. Increased risk of endotracheal tube obstruction and pressure sores in prone positioned patients.	
Romero et al., 2009, Chile	Patients diagnosed with severe ARDS determined by the American-European Consensus Conference criteria (PaO_2/FiO_2 of 100 mm Hg or less, persistent oxygenation index (OI) of 15 or more); invasive mechanical ventilation of 72 hours or less;	Prospective interventional study; Study Group (one group all placed in prone position)	Patient underwent prone positioning ventilation for 48 hours or until the oxygenation index was 10 or less (extended PPV).	Mortality; Length of stay; PaO_2/FiO_2; Length of prone position; Duration of mechanical ventilation; Pressure ulcer formation	Mortality Deaths 6/15 (40%) Survival 9/15 (60%) ICU length of stay 23 ± 10 days PaO_2/FiO_2 Supine (12 hours before prone) 133±24 Prone final (2 hours before return to supine position) 227±43 Duration of Mechanical Ventilation 35 ± 11 hours Duration of Prone Position At least 20h/day Pressure ulcers	Prone positioning ventilation is safe and effective in patients with severe ARDS and for an extended period of time. Prone positioning is shown safe and effective when performed by trained staff and with an established protocol.

	Study Group (n=15)				Two patients developed grade II pressure ulcers (one on the nasal septum, and one on the cheek)	

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