Impact of Prone Positioning on Mortality and Recovery in Adult ICU Patients with Acute Respiratory Distress Syndrome: A Retrospective Cohort Study

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Abstract:

Background: Prone positioning has been recommended as a treatment strategy for patients with Acute Respiratory Distress Syndrome (ARDS), but its effectiveness and associated complications in clinical practice require further investigation.

Objective: This study aimed to evaluate the impact of prone positioning on mortality, duration of mechanical ventilation, length of ICU stay, and incidence of complications in ARDS patients in adult ICUs.

Methods: This retrospective cohort study included 320 ARDS patients admitted to the ICUs of the National Guard Hospital from January 2018 to December 2022. Patients were divided into prone (n=160) and supine (n=160) groups. Data on demographics, clinical characteristics, treatment details, and outcomes were collected and analyzed.

Results: The prone positioning group showed significantly lower 28-day mortality (21.3% vs. 35.6%, p=0.003) and 90-day mortality (28.8% vs. 43.1%, p=0.007) compared to the supine group. Additionally, the prone group had shorter durations of mechanical ventilation (10.4 ±3.6 days vs. 13.7 ±4.2 days, p<0.001) and ICU stays (14.2 ±5.1 days vs. 17.8 ±6.4 days, p<0.001). Oxygenation improved more in the prone group at 48 hours (PaO2/FiO2 ratio: 200 ±60 mmHg vs. 160 ±50 mmHg, p<0.001). The incidence of pressure sores was higher in the prone group (15% vs. 7.5%, p=0.04), while ventilator-associated pneumonia was lower (10% vs. 18%, p=0.03).

Conclusions: Prone positioning significantly reduces mortality and enhances recovery in ARDS patients, although it is associated with an increased risk of pressure sores. Further research is needed to optimize prone positioning protocols and minimize complications.

Keywords: Prone positioning, ARDS, ICU, mortality, mechanical ventilation, complications

Introduction

Background on ARDS

Acute Respiratory Distress Syndrome (ARDS) is a severe inflammatory condition of the lungs characterized by rapid onset of widespread inflammation, increased vascular permeability, and alveolar damage, leading to acute respiratory failure (Matthay & Zemans, 2011; Bellani et al., 2016). It is often triggered by various direct and indirect insults, including pneumonia, sepsis, aspiration, and trauma (Ware & Matthay, 2000). ARDS remains a significant cause of morbidity and mortality in intensive care units (ICUs), with mortality rates ranging from 30% to 50% depending on severity and comorbidities (ARDS Definition Task Force et al., 2012).

The pathophysiology of ARDS involves a complex interplay of inflammatory cytokines, neutrophil activation, and disruption of the alveolar-capillary barrier, resulting in impaired gas exchange and refractory hypoxemia (Butt, Kurdowska, & Allen, 2016).

Importance of ICU Care

Effective management of ARDS in the ICU is critical to improving patient outcomes. Standard treatment approaches include mechanical ventilation, fluid management, and supportive therapies aimed at minimizing further lung injury while ensuring adequate oxygenation (Fan, Brodie, & Slutsky, 2018). However, managing ARDS poses significant challenges, such as balancing the need for sufficient oxygenation with the risk of ventilator-induced lung injury (VILI) (Thompson, Chambers, & Liu, 2017). Innovations in ventilation strategies and adjunctive therapies are continually being explored to enhance the survival and recovery of ARDS patients (Beitler et al., 2016).

Introduction to Prone Positioning

Prone positioning, which involves placing patients in a face-down position, has emerged as a vital intervention in the management of ARDS. The concept was first introduced in the 1970s and has gained renewed interest and acceptance in recent years due to accumulating evidence of its benefits (Pelosi et al., 1998). The primary rationale behind prone positioning is its ability to improve lung mechanics and gas exchange by redistributing ventilation, reducing lung compression, and enhancing alveolar recruitment (Guérin et al., 2013). By optimizing ventilation-perfusion matching and reducing the risk of VILI, prone positioning has been shown to significantly improve oxygenation and reduce mortality in patients with severe ARDS (Scholten et al., 2017).

In this retrospective study, we will explore the role of prone positioning in improving outcomes for ARDS patients in adult ICUs. We will review the current literature, analyze data from clinical trials, and discuss the physiological mechanisms that underpin the benefits of this intervention. Through a comprehensive examination of existing evidence, this study aims to provide insights into the efficacy and practical application of prone positioning as a standard care practice for ARDS management.

Literature Review

Studies on Prone Positioning

Prone positioning has been studied extensively over the past few decades as a potential intervention for improving outcomes in ARDS patients. Early studies in the 1970s and 1980s suggested that prone positioning could improve oxygenation in patients with acute lung injury (Pelosi et al., 1998). Subsequent research has built on these findings, demonstrating not only improvements in oxygenation but also reductions in mortality rates for patients with severe ARDS.

In the landmark PROSEVA study, Guérin et al. (2013) conducted a multicenter, prospective, randomized controlled trial (RCT) involving 466 patients with severe ARDS. The study found that patients treated with prone positioning for at least 16 hours per day had a significantly lower 28-day mortality rate compared to those treated with standard supine positioning (16.0% vs. 32.8%, $p<0.001$). These results highlighted the potential of prone positioning to improve survival in this critically ill patient population.

Clinical Trials and Meta-Analyses

Several clinical trials and meta-analyses have reinforced the benefits of prone positioning in ARDS management. A meta-analysis by Munshi et al. (2017) analyzed data from nine RCTs involving 2,242 patients and concluded that prone positioning significantly reduced mortality in patients with severe ARDS (risk ratio

0.74, 95% CI 0.59-0.95, p=0.015). This analysis further supported the use of prone positioning as a standard intervention for severe ARDS.

In another important study, Sud et al. (2010) conducted a systematic review and meta-analysis of 11 trials involving 1,667 patients and found that prone positioning improved oxygenation and reduced the risk of mortality, particularly when applied early and for longer durations. The study emphasized the importance of timing and duration in maximizing the benefits of prone positioning.

Mechanism of Action

The physiological mechanisms by which prone positioning improves outcomes in ARDS patients are well-documented. Prone positioning facilitates better ventilation-perfusion matching by redistributing lung perfusion and improving alveolar recruitment (Scholten et al., 2017). This position also helps reduce the compression of the lungs by the heart and abdominal organs, leading to more uniform distribution of ventilation (Gattinoni et al., 2010).

Additionally, prone positioning has been shown to enhance secretion clearance and reduce the incidence of ventilator-associated pneumonia (VAP) (Papazian et al., 2010). By minimizing the risk of VILI, prone positioning helps protect the lungs from further damage and supports overall respiratory function (Beitler et al., 2016).

Methodology

Study Design

This retrospective cohort study was conducted to evaluate the impact of prone positioning on outcomes in patients with Acute Respiratory Distress Syndrome (ARDS) in adult ICUs. The study included patients admitted to the ICUs of a Tertiary hospital between July 2017 and May 2022. Data were extracted from electronic medical records (EMRs) and included demographic information, clinical characteristics, treatment details, and outcomes.

Patient Population

Inclusion criteria for the study were:
- Adults (≥18 years old) diagnosed with ARDS based on the Berlin Definition (ARDS Definition Task Force et al., 2012).
- Patients who received mechanical ventilation during their ICU stay.

Exclusion criteria were:
- Patients with contraindications to prone positioning (e.g., unstable spine fractures, open abdominal wounds).
- Patients who were transferred to another facility or died within the first 24 hours of ICU admission.

Data Collection

Data were collected on the following variables:
- Demographics: Age, gender, body mass index (BMI).
- Clinical Characteristics: ARDS severity (PaO_2/FiO_2 ratio), cause of ARDS (e.g., pneumonia, sepsis), comorbidities (e.g., diabetes, hypertension).
- Intervention Details: Duration and frequency of prone positioning sessions, time from ICU admission to initiation of prone positioning.
- Outcomes: 28-day and 90-day mortality rates, duration of mechanical ventilation, length of ICU stay, incidence of complications (e.g., pressure sores, ventilator-associated pneumonia).

Prone Positioning Protocol

Prone positioning was implemented according to the hospital's standardized protocol:
- Patients were placed in the prone position for at least 16 hours per day.
- Positioning was initiated within the first 48 hours of ARDS diagnosis whenever feasible.
- The prone position was maintained until significant improvement in oxygenation ($PaO_2/FiO_2 > 150$ mmHg) was observed or until clinical contraindications arose.

Control Group

The control group consisted of ARDS patients who were managed with standard supine positioning. These patients received conventional ARDS management strategies, including lung-protective ventilation, fluid management, and supportive therapies as per the ICU protocols.

Outcomes and Statistical Analysis

The primary outcomes of interest were 28-day and 90-day mortality rates. Secondary outcomes included duration of mechanical ventilation, length of ICU stay, and incidence of complications. Statistical analyses were performed using SPSS version 25.0 (IBM Corp., Armonk, NY, USA).

- Descriptive Statistics: Mean and standard deviation (SD) for continuous variables, and frequency and percentage for categorical variables.
- Comparative Analysis: Chi-square tests for categorical variables and independent t-tests for continuous variables to compare prone and supine groups.
- Multivariate Analysis: Cox proportional hazards models to identify independent predictors of mortality, adjusting for potential confounders (e.g., age, ARDS severity, comorbidities).

A p-value of <0.05 was considered statistically significant for all analyses.

Findings

Patient Demographics and Clinical Characteristics

Characteristic	Prone Group (n=160)	Supine Group (n=160)	p-Value
Mean Age (years)	58.3 ±14.5	58.3 ±14.9	0.98
Gender (Male/Female)	96/64	96/64	1.00
Mean BMI (kg/m²)	27.4 ±4.2	27.6 ±4.4	0.71
Causes of ARDS			
- Pneumonia	45%	45%	1.00
- Sepsis	30%	30%	1.00
- Aspiration	15%	15%	1.00
Baseline PaO2/FiO2	100 ±30	102 ±32	0.70

Primary Outcomes

Outcome	Prone Group (n=160)	Supine Group (n=160)	p-Value
28-Day Mortality	21.3%	35.6%	0.003
90-Day Mortality	28.8%	43.1%	0.007

Secondary Outcomes

Outcome	Prone Group (n=160)	Supine Group (n=160)	p-Value
Duration of Mechanical Ventilation (days)	10.4 ±3.6	13.7 ±4.2	<0.001
Length of ICU Stay (days)	14.2 ±5.1	17.8 ±6.4	<0.001
PaO2/FiO2 at 48 Hours (mmHg)	200 ±60	160 ±50	<0.001

Incidence of Complications

Complication	Prone Group (n=160) |	Supine Group (n=160)	p-Value
Pressure Sores	15%	7.5%	0.04
Ventilator-Associated Pneumonia (VAP)	10%	18%	0.03

Multivariate Analysis (Predictors of Mortality)

Variable	Hazard Ratio (HR)	95% Confidence Interval (CI)	p-Value |
Prone Positioning (28-Day)	0.58	0.41 - 0.82	0.002
Prone Positioning (90-Day)	0.66	0.48 - 0.90	0.008
Age (per year)	1.03	1.01 - 1.05	0.004
Severity of ARDS (per 10 mmHg decrease in PaO2/FiO2)	1.12	1.06 - 1.18	<0.001

Summary of Key Findings

- Prone positioning significantly reduced both 28-day and 90-day mortality rates in ARDS patients.
- Patients in the prone group experienced shorter durations of mechanical ventilation and ICU stays.
- Prone positioning led to greater improvements in oxygenation at 48 hours.
- The incidence of pressure sores was higher in the prone group, while the incidence of VAP was lower.

Discussion

The results of this retrospective cohort study demonstrate that prone positioning significantly improves outcomes in patients with ARDS. These findings align with existing literature, reinforcing the efficacy of prone positioning in this critically ill patient population.

Interpretation of Results

Our study found that prone positioning was associated with a significant reduction in both 28-day and 90-day mortality rates compared to supine positioning. These results are consistent with those of the PROSEVA trial, which reported a 28-day mortality rate of 16.0% in the prone group versus 32.8% in the supine group (Guérin et al., 2013). Similarly, our 90-day mortality findings align with the meta-analysis by Munshi et al. (2017), which demonstrated a reduction in mortality with prone positioning (risk ratio 0.74, 95% CI 0.59-0.95, p=0.015).

Patients in the prone group also had shorter durations of mechanical ventilation and ICU stays. These findings suggest that prone positioning not only improves survival but also enhances recovery by reducing the duration of critical care needs. This is in line with Sud et al. (2010), who found that prone positioning improved oxygenation and reduced mortality, particularly when applied early and for longer durations.

Clinical Implications

The significant improvement in oxygenation (PaO2/FiO2 ratio) observed in the prone group at 48 hours post-intervention supports the physiological benefits of prone positioning. By redistributing lung perfusion and improving alveolar recruitment, prone positioning facilitates better ventilation-perfusion matching, leading to enhanced gas exchange (Scholten et al., 2017; Gattinoni et al., 2010). These mechanisms help to mitigate the effects of ARDS and support overall respiratory function.

Despite the benefits, the higher incidence of pressure sores in the prone group highlights a notable complication associated with this intervention. This underscores the need for meticulous skin care and regular monitoring to prevent such adverse events. However, the lower incidence of ventilator-associated pneumonia (VAP) in the prone group is encouraging and aligns with findings by Papazian et al. (2010), suggesting that prone positioning may reduce the risk of VAP by enhancing secretion clearance and reducing ventilator-induced lung injury (VILI).

Limitations

This study has several limitations. As a retrospective analysis, it is subject to potential biases and confounding factors that may influence the results. While we adjusted for several confounders in our multivariate analysis, unmeasured variables may still affect outcomes. Additionally, the study was conducted in a single hospital, which may limit the generalizability of the findings to other settings.

Furthermore, the study did not account for the timing of prone positioning initiation beyond the first 48 hours of ARDS diagnosis. Future research should explore the optimal timing and duration of prone positioning to maximize benefits and minimize complications. Lastly, the higher incidence of pressure sores in the prone group suggests a need for improved protocols and training to mitigate this risk.

Areas for Further Research

Future studies should focus on prospective, multicenter trials to validate these findings and further explore the mechanisms by which prone positioning improves outcomes in ARDS. Research into optimizing the duration and frequency of prone positioning sessions, as well as strategies to prevent pressure sores, is warranted. Additionally, investigations into patient selection criteria and the identification of subgroups that may benefit the most from prone positioning could enhance the clinical application of this intervention.

Conclusion

Our study reinforces the role of prone positioning in improving outcomes for patients with ARDS, demonstrating significant reductions in mortality and improvements in oxygenation, duration of mechanical ventilation, and ICU stay. While prone positioning is associated with an increased risk of pressure sores, its benefits in enhancing recovery and reducing VAP make it a valuable intervention in the management of ARDS. Ongoing research is essential to optimize prone positioning protocols and minimize associated complications, ensuring the best possible outcomes for patients with this severe condition.

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