INITIAL EVALUATION OF THE EFFECTIVENESS OF PRONE POSITION VENTILATION FOR TREATING ACUTE RESPIRATORY DISTRESS SYNDROME IN PATIENTS WITH SEVERE BURNS

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ABSTRACT[1]

***Introduction**: In patients with severe ARDS, prone-position ventilation is thought to be effective in improving air exchange and safe.*

***Objectives**: To evaluate the effectiveness of improving blood oxygenation and lung mechanics after prone position ventilation, the safety of the treatment, and its outcomes.*

***Subjects and methods**: A prospective comparative study was conducted on 14 adult burn patients with ARDS, treated in the Intensive care unit at the National Burn Hospital, from 8/2021 to 10/2022. Indicators include blood oxygenation; lung mechanics before, during, and after prone position ventilation. Clinical criteria: Accidents, complications during the ventilation process, and the outcomes of prone position ventilation.*

***Results**: The average burn area was 53.92 ± 21.05%, mean deep burn area was 27.07 ± 14.75%. There were six out of 14 patients with an inhalation injury. During the prone position ventilation process, blood oxygenation improved over time, and the PaO_2/FiO_2 ratio increased gradually compared with before ventilation ($p < 0.05$). Static lung compliance increased sharply after prone-position ventilation, from 22.5 ml/cmH_2O to 25.36 ml/cmH_2O ($p < 0.05$). Peak airway pressure, plateau pressure, and mean airway pressure decreased significantly after prone position ventilation ($p < 0.05$). Prone position ventilation was quite safe: no patients underwent hypotension, cardiac arrest, endotracheal tube obstruction, or slip of the endotracheal tube; one patient had a slip of a central venous catheter (7.14%), and six patients had facial edema (42.84%). The rate of improved oxygenation in patients was high (85.72%), and the mortality rate was 64.3%.*

***Conclusion**: Prone position ventilation was effective in improving blood oxygenation, and lung mechanics and safe for patients with severe ARDS.*

***Keywords:** Prone position ventilation, burns, ARDS*

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Ngày nhận bài: 02/1/2023; Ngày phản biện: 10/1/2023; Ngày duyệt bài: 15/1/2023
https://doi.org/10.54804/yhthvb.6.2022.181

1. INTRODUCTION

Acute Respiratory Distress Syndrome (ARDS) is a common complication in patients with severe burns with a high mortality rate, ranging from 40% to 60%. Artificial ventilation with low Vt and alveolar recruitment maneuvers are currently the basic ventilation methods in the treatment of ARDS. The lung injury is heterogeneous in ARDS; the alveoli are dilated in the sternal lung area and solidified on the dorsal side when the patient is supine. The prone position has the effect of reducing excessive alveolar stretch in the sternal lung area and recruiting the alveoli in the two dorsal lung regions. Thus synchronizing the ventilation/perfusion ratio (VA/Q) in lung regions. Thereby helping to improve blood pressure oxygenation and lung mechanics in ARDS patients. The prone position of the patient with ARDS has been applied by Piehl MA since 1976 [1]. Studies on prone-position ventilation have shown marked improvements in blood oxygenation, pulmonary mechanics, and relative safety [2].

In Vietnam, Do Minh Duong (2017) conducted a study on the effectiveness of prone position ventilation to treat ARDS in non-burn patients with good results [3]. In burn patients, there have been no studies evaluating the effectiveness of prone position ventilation for ARDS treatment. Therefore, we conducted this study to evaluate the effect of prone position ventilation on the change of some pulmonary mechanical parameters, blood oxygenation status, and safety of prone position ventilation in patients with severe burns and ARDS.

2. SUBJECTS AND METHODS

* A prospective study was conducted on 14 burn patients with ARDS, treated at the ICU, Le Huu Trac National Burn Hospital, from April 2021 to October 2022, with the following criteria:

- Age between 16 and 60 years

- Diagnosed with ARDS (according to Berlin congress 2012)

- Artificial ventilation according to ARDS Network 12-14 hours with no improvement in blood gas, PaO_2/FiO_2 ratio ≤ 100 mmHg or PaO_2/FiO_2 ≤ 150 mmHg but tends to decrease with PEEP ≥ 5 cmH_2O, FiO_2 ≥ 60%.

* The procedure for prone position ventilation is based on a study by Guerin (2013) [2].

- Maintain 16 hours of prone position ventilation per day when blood oxygenation improves and there are no dangerous complications.

+ After the patient is moved to the supine position, continue to monitor blood oxygen, and lung mechanics, do hygiene, take chest X-rays, and perform procedures if necessary.

+ If the PaO2/FiO2 ratio is less than 150 after 6 hours in the supine position, continue to place the patient in a second or third prone position.

- Stop prone-position ventilation

+ When the patient does not respond to the prone position: Blood oxygenation does not improve after 6 hours in the prone position. These patients were moved to the supine position and were given the same mechanical ventilation as in the prone position.

+ When there are dangerous complications such as blockage or slip of the endotracheal tube, circulatory arrest, or hypotension (systolic blood pressure < 60mmHg after increasing the dose of vasopressors without response), these patients were moved to the supine position and treated for complications such as CRP, reintubation of the endotracheal tube, and pleural opening for air drainage.

+ Patients are no longer indicated: $PaO_2/FiO_2 \geq 150$ with PEEP ≤ 10 cmH_2O, $FiO_2 \leq 60\%$ after 6 hours of changing from prone to supine. Supine position ventilation was maintained for these patients.

- The patient is ventilated continuously, with breathing mode and ventilator parameters the same as during supine ventilation. Adjusting PEEP and FiO_2 according to the guidelines of the ARDS Network.

* **Evaluation criteria**: Evaluation of changes in blood oxygenation status and some pulmonary mechanical norms during prone position ventilation: 1 hour, 6 hours, 12 hours, 16 hours, and 6 hours after the patient was moved back to the supine position (corresponding to times T_1, T6, T_{12}, T_{16}, and T_{12}).

- PaO_2/FiO_2 ratio.

- Some lung mechanical parameters: static pulmonary compliance, plateau pressure, mean airway pressure (mPaw), peak airway pressure (P_{peak}).

- Complications during prone position ventilation, causes and mortality rate.

- The outcomes of prone position ventilation.

+ Improved blood oxygenation: when the PaO_2/FiO_2 ratio increases above 20 mmHg after the patient is moved to a prone position for 6 hours.

+ There is no improvement in blood oxygenation when the PaO_2/FiO_2 ratio rises to less than 20 mmHg or when the PaO_2/FiO_2 ratio decreases compared with before prone position ventilation.

Image 1: The patient was placed in a prone position for ventilation

3. RESULTS

Tabe 1: Patients' characteristics (n = 14)

Characteristics		$\bar{X}$ ± SD (n = 14)	Min - Max
Age (Age)		38.86 ± 8.14	21 - 60
Total burn area (%)		53.92 ± 21.05	0 - 82
Deep burn area (%)		27.07 ± 14.75	0 - 50
Duration of supine ventilation before prone ventilation (hrs)		17 ± 3.26	12 - 24
Inhalation injury (n, %)		6/14 (42.86%)	
Male/Female		12/2 (85.72%)	
Causes of burn (n, %)	Dry heat	11 (78.58%)	
	Electricity	2 (14.28%)	
	Chemicals	1 (7.14%)	
Levels of ARDS (n, %)	Moderate	12 (85.72%)	
	Severe	2 (14.28%)	

Comments: All patients were severely burned, with an average total burn area of 53.92% and a deep burn area of 27.07%. In addition, 42.86% of patients had combined respiratory burns. Before prone position ventilation, supine artificial ventilation lasted 17 ± 3.26 hours. At the time of artificial ventilation in the prone position, most of the patients had moderate ARDS (85.72%)

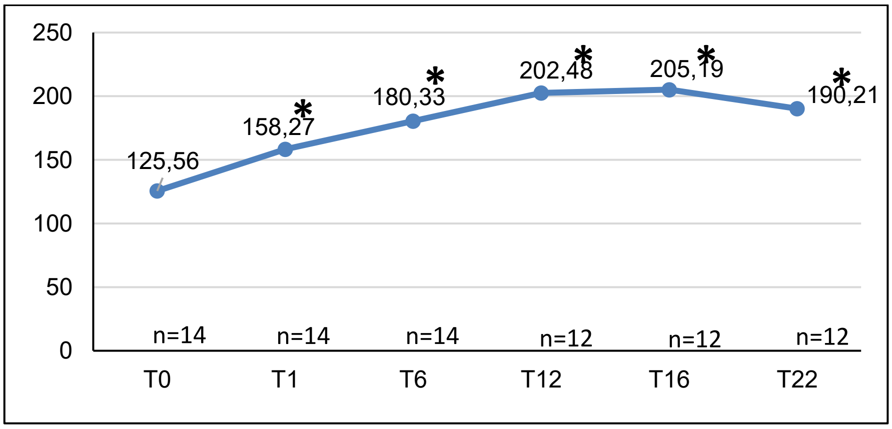
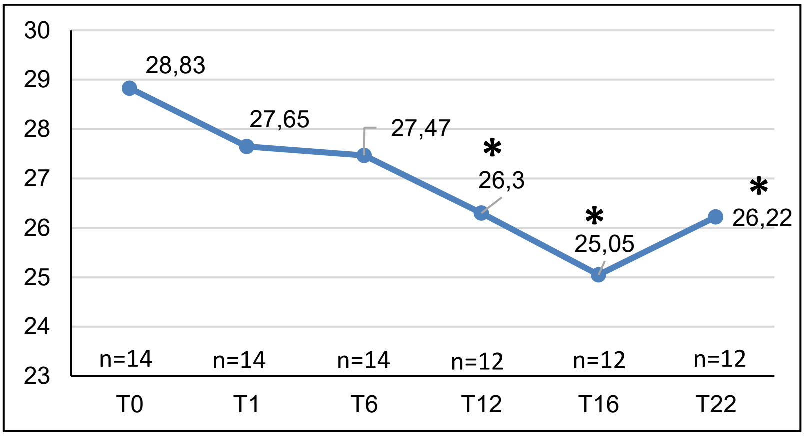


Chart 1: Changes in the PaO_2/FiO_2 ratio during prone position ventilation.

*Note: *p < 0.05 when comparing the PaO_2/FiO_2 ratio between time points in the prone position compared to T_0.*

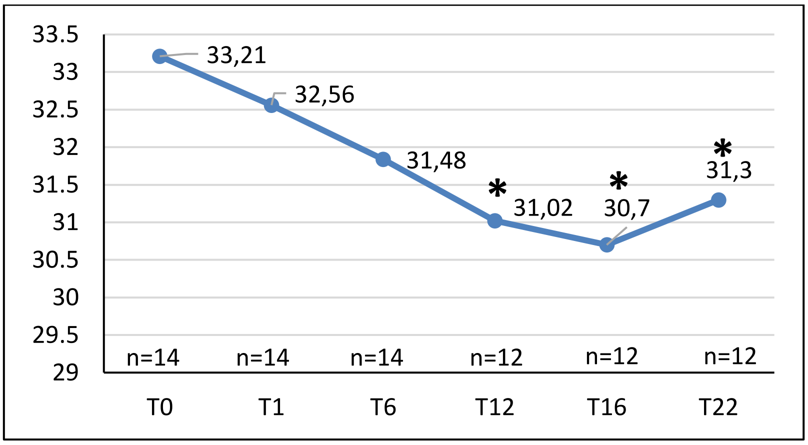
The PaO_2/FiO_2 ratio gradually increased and reached its peak at T_{16}. The ratio of PaO_2/FiO_2 at times during prone ventilation was higher than the ratio of PaO_2/FiO_2 at T_0 ($p < 0.05$). When the patient was moved back to the supine position for 6 hours (T_{22}), the P_aO_2 ratio decreased but was still higher than at T_0.

Chart 2: Changes in the plateau pressure (Pplateau)



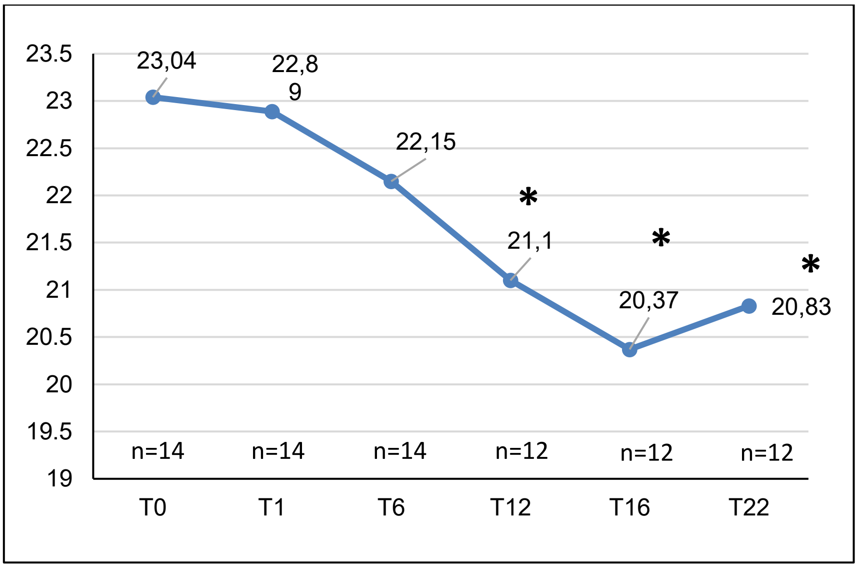
Comments: Pplateau was lower after the patient was placed in the prone position for 12 and 16 hours compared to before ($p < 0.05$). When the patient was moved back to the supine position for 6 hours, the pressure was still lower compared to before the prone position ($p < 0.05$).

Chart 3. Changes in peak airway pressure (Ppeak)



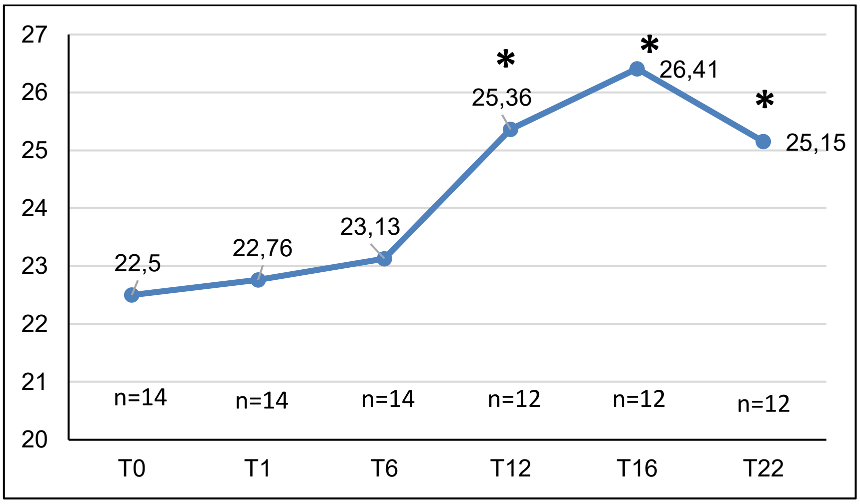
Comments: Ppeak was lower after the patient was placed in the prone position for 12 and 16 hours compared to before ($p < 0.05$). When the patient was moved back to the supine position for 6 hours, the pressure was still lower compared to before the prone position ($p < 0.05$).

Chart 4. Changes in the mean airway pressure (mPaw)



Comments: mPaw was lower after the patient was placed in the prone position for 12 and 16 hours compared to before ($p < 0.05$). When the patient was moved back to the supine position for 6 hours, the pressure was still lower compared to before the prone position ($p < 0.05$).

Chart 5: Static lung compliance (Cstatic)



Comments: Cstatic was higher after the patient was placed in the prone position for 12 and 16 hours compared to before ($p < 0.05$). When the patient was moved back to the supine position for 6 hours, Cstatic was still higher compared to before the prone position ($p < 0.05$).

Table 2. Accidents and complications related to prone-position ventilation

Accidents, complications	Number (n = 14)	Proportion (%)
Hypotension	0	0
Pneumothorax, Pneumomediastinum	0	0
Gastric reflux	2	14.28
Faicial edema	6	42.84
Slip of central venous catheter	1	7.14
Slip of endotracheal tube	0	0
Pressure injuries	2	14.28
The burn wound changes its depth	1	7.14

Ventilation in the prone position was quite safe, and no patient had hemodynamic effects. There were two patients with gastric reflux after milk infusion, accounting for 14.28%, one patient had a slip of the catheter (7.14%); one patient had a deep injury (7.14%); and two patients had pressure ulcers on the face (14.28%).

Table 3. The results of the prone position ventilation and treatment.

Results		Number (n = 14)	Proportion (%)
Improved blood oxygenation	Yes	12	85.72
	No	02	14.28
The total number of prone position ventilation used (numbers/patient)	Once	13	92.86
	Twice	01	7.14
The results of the treatment	Survival	5	35.7
	Death	9	64.3

Comments: The percentage of patients with improved blood oxygenation after artificial ventilation in the prone position was high, 12 out of 14 patients (85.72%). The majority of patients (92.86%) only underwent one session of prone-position ventilation. The mortality rate in the study was still high at 64.3%.

Table 4. Causes and times of death (n = 9)

Characteristics		n	%
Causes of death	MOF	6	66.67
	Septic shock	1	11.11
	Respiratory failure	2	22.22
Times of death	Within week 1	6	66.67
	Within week 2	2	22.22
	Within week 3	1	11.11

Comments: Most of the patient died in the first week after ARDS, at a rate of 66.67%. The main cause of death was multiple organ failure (66,67%).

4. DISCUSSION

4.1. Changes in blood oxygenation following the prone position ventilation

Artificial ventilation in the prone position is considered one of the measures to improve blood oxygenation due to the effect of opening the collapsed alveoli and recruiting the alveoli in the dorsal region to participate in the gas exchange process, improving the ventilation/perfusion ratio. Piehl MA et al (1976) performed prone ventilation on 5 patients with severe ARDS for the first time; the study results showed that there was an improvement in blood oxygenation after prone ventilation, with PaO_2 increasing by 47 ± 16mmHg compared to pre-ventilation [1].

In a subsequent study by Romeo CM et al (2009) on 15 patients with severe ARDS who were ventilated in the prone position, the PaO_2/FiO_2 ratio increased significantly after ventilation from 92 ± 12 mmHg to 227 ± 43 mmHg at 2 hours before moving the patient to the supine position, with $p < 0.0001$ [4].

Prone position ventilation poses significant challenges to caring for and monitoring burn patients. Therefore, to date, very few studies in the world have been published applying this method of ventilation. In 2022, Hale DF and colleagues did the first study to apply prone position ventilation to treat ARDS in 18 burn patients. Research results show that artificial ventilation in the prone position effectively improves blood oxygenation; the PaO_2/FiO_2 ratio increases significantly after 48 hours of ventilation from 87 ± 37 to 210 ± 98 mmHg [5]. According to our study results, the PaO_2/FiO_2 ratio increased significantly after 1 hour (from to with $p < 0.05$) and continued to increase to the highest level after 16 hours of ventilation (from 125,56 mmHg to 158,27 mmHg with $p < 0.05$). This result is consistent with the studies of Piehl MA (1976), Romero Cm (2009), and Hale DF (2012) [1], [4], [5].

4.2. Changes in pulmonary mechanic parameters after prone position ventilation

Most studies have shown that prone-position ventilation improves lung mechanics. Pulmonary mechanical parameters such as plateau pressure (Pplateau), peak airway pressure (Ppeak), and mean airway pressure (mPaw) decreased and static pulmonary compliance (Cstatic) increased significantly after prone position ventilation [2 - 4].

Research by Guerin C, et al (2013) conducted a multicenter study in 466 ARDS patients with $PaO_2/FiO_2 \leq 150$. The study results showed that the Plateau in the prone group of patients decreased by more than 3 cmH_2O compared with the supine group of patients at day 3 ($p < 0.05$) [2].

Domestically, a study by Do Minh Duong (2017) once again demonstrated the effectiveness of improving lung mechanics after prone position ventilation: the plateau pressure decreased and the static lung compliance significantly increased at 12 hours of prone ventilation ($p = 0.01$) [3].

The results of our study (charts 2, 3, 4, and 5) also showed that pulmonary mechanical indices such as plateau pressure, peak airway pressure, and mean airway pressure were all decreased, and static lung compliance increased after prone position ventilation ($p < 0.05$). Although the number of our patients is small, initial results show that prone position ventilation is effective in improving lung mechanics.

4.3. Complications associated with prone position ventilation

Accidents and complications in prone position ventilation can occur when changing positions or during patient care and treatment. Complications may be related to hemodynamics (heart rate, blood pressure), gastrointestinal (vomiting, reflux), or position changes (obstruction or slip of endotracheal tube, catheter; facial edema, pressure ulcers). Most studies on prone ventilation have shown that this mode of ventilation is relatively safe, with no difference between the prone group of patients and those in the supine position. The study results of Pelosis P (1998) found that the heart rate did not change at the time points before, during, and after switching to the supine position: 111 ± 24; 115 ± 23 và 116 ± 14 beats/min, respectively [6].

Gattinoni L (2001) the rate of facial edema was 29%, and the rate of catheter slip was 0.7% [7]. In our study, there was no patient with hypotension, but facial edema accounted for 42.84%, higher than the study of the above authors. This can be explained by the fact that our six patients all had facial burns, so when lying in the prone position, it is easier to cause edema than in patients without facial skin lesions. In addition, in the study, there were 2 patients (14.28%) with grade I ulcers on the face. This result is similar to the study of Hale DF (2012), in which up to 4 out of 18 patients (accounting for 22%) had pressure ulcers on the face [5].

4.4. The outcomes of prone position ventilation and treatment

Most of the studies on prone position ventilation show a high percentage of patients with improved blood oxygenation. In Nakos's study (2000), the rate of improvement in blood oxygen was 75% and improved immediately after the patient was in the prone position for 30 minutes [8]. Guerin (2013) found that prone position ventilation increases blood oxygenation in more than 70% of patients, and of these, 70% had improved blood oxygenation within the first hour [2].

The results from Table 3 show that blood oxygenation improved in most of the patients after prone position ventilation in 12 out of 14 patients (accounting for 85.72%). The mechanism of improved blood oxygenation is when the patient is prone to die to the release of the dorsal lung by gravity and increased alveolar recruitment. Meanwhile, perfusion in the dorsal lung area has decreased but remains higher than in the sternum lung area. As a result, the ventilation/perfusion ratio (VA/Q) increases and improves oxygenation [9]

Regarding mortality rate, a meta-analysis by Munshi L et al (2017) of 8 randomized controlled trials found no statistically significant difference in mortality rate between the prone and supine artificial ventilation groups. However, there was a significant reduction in mortality rate in studies that performed prone position ventilation for 12 hours (p = 0.04) compared to the group that performed prone position ventilation for less than 12 hours (p = 0.72). The analysis showed an association between the duration of prone ventilation and mortality rate [10].

Guerin C, et al (2013) discovered that using artificial ventilation in the prone position for 17 hours per day reduced the 28th-day mortality rate decreased from 32.8% to 16% with a p-value of 0.001 [2]. The study by Hale DF et al (2012) in burn patients had the highest mortality rate of 67%. The author believed that the higher mortality rate in this study than in other studies is partly due to the severity of burn disease [5].

In our study, the prone position ventilation was performed early (within 12-24 hours after artificial ventilation according to ARDSnet), the prone position time lasted 16 hours per day, and combined with a lung protective strategy, the mortality rate was 64.3%. The main cause of death was multiple organ failure (66.57%). This result is equivalent to the studies on burn patients [5].

5. CONCLUSION

Prone-position ventilation is effective in improving blood oxygenation and pulmonary mechanics and is relatively safe in patients with severe ARDS. In the future, larger sample size studies will be required to determine the timing of prone position ventilation, standardize ventilation and care procedures in burn patients, improve mortality rate, and minimize accidents and complications.

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