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The Effectiveness of Prone Positioning in Patients with Acute Respiratory Distress Syndrome: A Literature Review

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A B S T R A C T

Acute respiratory distress syndrome (ARDS) is connected with the high mortality rate. The syndrome appears in the form of a decrease in pulmonary compliance which causes mechanical changes and gas exchange in the lungs resulting in hypoxemia which is indicated by a decrease of oxygen saturation. Prone positioning (PP) can be an intervention in moderate to severe respiratory disorders in ARDS, which aims to increase oxygen saturation. Objective: This study aims to determine the extent to which prone positioning given to ARDS patients can increase oxygen saturation. This study applies the literature review method. The search for the literature used the scientific database, such as Proquest, ScienceDirect, and Pubmed/MEDLINE with the publication years of 2019-2021. Total of 1332 articles were selected, there are 11 articles that fulfill the criteria. The review results of the 11 articles show that prone positioning has been able to increase oxygen saturation in patients with ARDS, with varying durations of pronation. The average duration of pronation is 30 to 90 minutes. The use of prone positioning can increase oxygenation and the ability of the respiratory system in patients with ARDS. The application of prone positioning in patients with moderate to severe respiratory disorders is considered quite safe.

Kata kunci:

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A B S T R A K

Acute respiratory distress syndrome (ARDS) dikaitkan dengan angka kematian yang tinggi. Sindrom yang muncul berupa penurunan komplians paru, yang menyebabkan perubahan mekanik dalam paru-paru dan pertukaran gas yang mengakibatkan hipoksemia yang ditunjukkan dengan penurunan saturasi oksigen. Posisi pronasi (PP) dapat menjadi satu intervensi pada gangguan pernafasan sedang hingga berat pada ARDS, yang bertujuan meningkatkan saturasi oksigen. Studi ini bertujuan untuk mengetahui sejauh mana pemberian posisi pronasi pada pasien ARDS dapat meningkatkan saturasi oksigen. Studi ini menggunakan metoda tinjauan literatur. Pencarian literatur menggunakan database ilmiah antara lain Proquest, ScienceDirect, dan Pubmed/medline dengan tahun publikasi 2019-2021. Dari total 1332 artikel yang diseleksi, ada 11 artikel yang memenuhi kriteria. Hasil tinjauan dari 11 artikel menunjukkan bahwa posisi pronasi mampu meningkatkan saturasi oksigen pada pasien dengan ARDS, dengan durasi pemberian posisi pronasi yang berbeda-beda. Rata -rata durasi pemberian posisi pronasi adalah 30-90 menit. Penggunaan posisi pronasi mampu meningkatkan oksigenasi dan kemampuan sistem pernafasan pada pasien dengan ARDS. Penerapan posisi pronasi pada pasien dengan gangguan pernapasan sedang hingga berat dinilai cukup aman.

INTRODUCTION

Acute respiratory distress syndrome (ARDS) is a condition marked with the inflammation response from alveolar-capillary membrane because there is direct or indirect trauma. ARDS is connected with the high mortality rate (Bellani et al., 2016). This syndrome shows a decrease of pulmonary compliance, causing mechanical changes and gas exchange in the lungs resulting in hypoxemia (Rotta et al., 2015).

Prone positioning (PP) has become a part of the moderate to severe respiratory disorder management in patients of ARDS for several years (Guérin et al., 2020). Several studies have confirmed that oxygenation improves more when patients are given prone positioning instead of supine position (SP) (Guérin et al., 2013; Jayakumar et al., 2021). Prone positioning will cause the homogeneity of pulmonary alveolar so that there is no ventral lung region hyperinflation or dorsal lung collapse. Giving prone positioning can increase oxygen binding in the lung dorsal region so that oxygen saturation increases (Azizah et al., 2020).

Oxygen saturation is the measure of the percentage of oxygen that haemoglobin can carry (Guyton & hall, 2016). Oxygen saturation measured with the oximetry ratio of pulse/Fio_2 (SF) is highly correlated with the ratio of Pao_2 / Fio_2 (PF) in patients with ARDS (Chen et al., 2015).

Since the emergence of SARS-CoV-2, several studies have focused on pulmonary compliance, namely the acute breathing syndrome, which is the main problem in patient treatment at the intensive unit. This condition is connected with the high mortality rate (Grasselli et al., 2020). Some research states that ARDS has a significant side effect on the liver function. Several studies specifically discuss the effect of ARDS on the liver function, where ARDS patients who were mechanically ventilated had an increased risk of liver function disorder up to three folds (van den Akker et al., 2013).

Kidney disfunction or acute kidney failure is a common complication in patients with ARDS with the study reporting up to 35%. The combination of acute kidney failure and ARDS shows worse outcomes including a higher mortality rate and increase length of hospital stay (Park & Faubel, 2021). The acute kidney injury is the most common extra pulmonary organ disfunction associated with ARDS and affects nearly 50% of patients. The development of acute kidney failure is the independent risk factor for death in patients with ARDS (Clemens et al., 2016).

The clinical manifestation of ARDS is shortness of breath like dyspnea and tachypnea which can quickly progress to respiratory failure. Supportive therapy management needs to be done to get a better outcome for patients with ARDS.

ne of the supportive therapies to increase body oxygenation is to provide prone positioning in patients with ARDS. This position can improve the heart function by increasing blood return to the right heart chamber and lowering pulmonary vascular pressure. This can help the heart pump blood better and produce the increase of the distribution of oxygen to the body (Marini & Gattinoni, 2020). Therefore, it is necessary to conduct a literature review to explore various research evidences regarding the application of prone positioning in ARDS patients in improving the body′s oxygen saturation.

METHOD

The writing method used is a literature study by investigating various published articles related to the topic on the effectiveness of prone positioning on increasing oxygen saturation in ARDS patients. The exploration of the articles was conducted through scientific databases including Proquest, ScienceDirect, and Pubmed/medlineusing the search keywords, namely acute respiratory distress syndrome OR severe hypoxemia AND positioning therapy OR prone positioning. The literature in this study was screened based on the inclusive criteria, namely within the last 3 years (2019-2021), suitable with the topic of prone positioning and ARDS, and using English.

RESULTS AND DISCUSSION

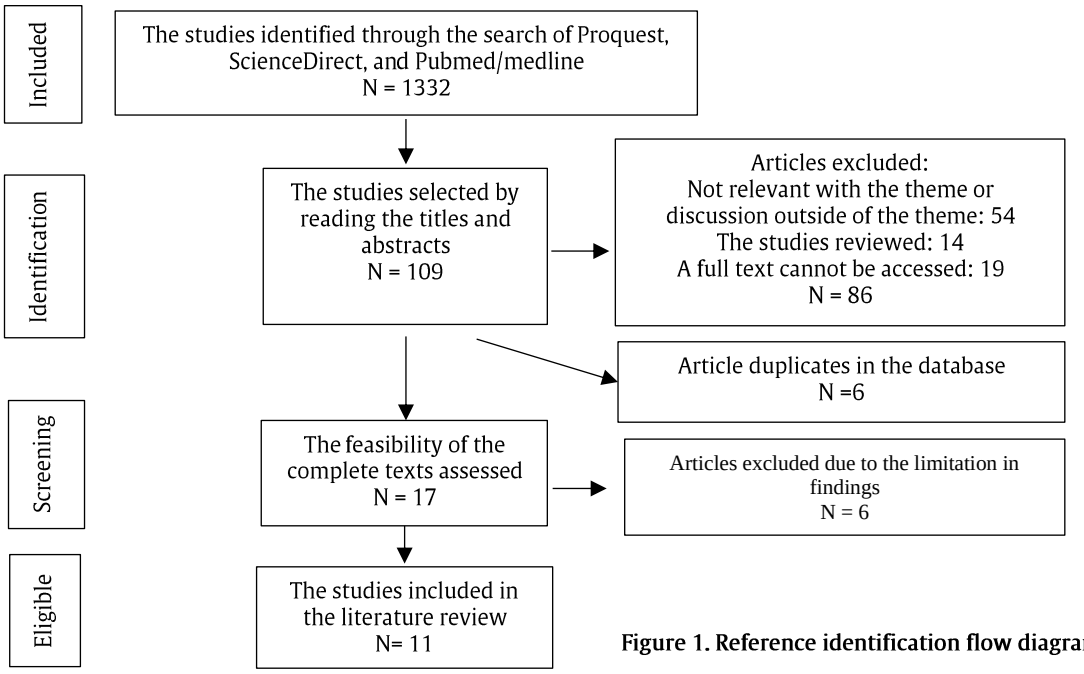

Figure 1. Reference identification flow diagram

Table 1: Study characteristics

No	Author	Method and the number of samples	Duration of prone positioning	Result
1	Solverson et al., (2021). *Tolerability and safety of awake prone positioning COVID-19 patients with severe hypoxemic respiratory failure*	Cohort study, 17 ICU patients	75 minutes	Prone positioning can be given in average of 2 hours for the period of 75 minutes per session. There are 17 patients, 16 with nasal cannula ventilation and 1 with HFNC. All patients show oxygenation increase from 91% to 98%.
2	Tonelli et al., (2021). *Early awake proning in critical and severe COVID-19 patients undergoing noninvasive respiratory support: A retrospective multicenter cohort study*	Cohort study, 114 patients	3 hours	Effective early prone positioning is given to patients who are conscious and breathe spontaneously. Prone positioning can increase PaO2/FiO2. The patients given prone positioning could be released from the ICU earlier than those receiving standard treatment.
3	Jouffroy et al., (2020). *Impact of prone position in non-intubated spontaneously breathing patients admitted to the ICU for severe acute respiratory failure due to COVID-19*	Retrospective observational study, 379 patients	Twice a day for 3 and 6 hours	From the retrospective observational study conducted, the researchers are divided into several groups, where patients are given prone positioning twice a day for 3 and 6 hours, FiO2, PaO2/FiO2, and PaCO2 previously and at the last position of the first laying down with the chest down ward, and they are also given pH at that position. Prone positioning can increase oxygenation, increase the average of the SpO2 achievement level from 94% to 98%. In addition, an increase of PaO_2/FIO_2 from 89 to 165 mmHg is also found.
4	Taboada et al., (2020). *Effectiveness of Prone Positioning in Nonintubated Intensive Care Unit Patients with Moderate to Severe Acute Respiratory Distress Syndrome by Coronavirus Disease 2019*	Prospective observational study, 7 patients	The average time for prone positioning is 10 hours and there are 16 sessions.	Prone positioning can increase oxygen saturation and increase the achievement of SpO_2 from an average of 94% to 98%. In addition, an increase of PaO_2/FIO_2 from 114 to 207 mmHg during prone positioning and 160 after prone positioning is also found.
5	Caputo et al., (2020). *Early Self-Proning in Awake, Non-intubated Patients in the Emergency Department: A Single ED's Experience During the COVID-19 Pandemic*	Cohort observational study, 50 patients	30 -120 minutes	Prone positioning increases oxygen saturation from 84% to 94% after the treatment.
6	Jayakumar et al., (2021). *Standard Care Versus Awake Prone Position in Adult Nonintubated Patients with Acute Hypoxemic Respiratory Failure Secondary to COVID-19 Infection–A Multicenter Feasibility Randomized Controlled Trial*	Randomized Controlled Trial, 60 patients	1-6 hours maximum in one day	Prone positioning takes around 6 hours a day for 2 hours per session. From the results of the intervention in the group given prone positioning, 73% (22 out of 30 patients) are able to maintain their prone positioning more than 4 hours a day. PaO2 increases from the average of 73.6 mmHg to 94.9 mmHg. In the control/supine group, only 53% (16 out of 30 patients) were able to do prone positioning within 2 hours. These results of this study indicate that using prone positioning is safe and can help increase oxygen saturation.
7	Shelhamer et al., (2021). *Prone Positioning in Moderate to Severe Acute Respiratory Distress Syndrome Due to COVID-19: A Cohort Study and Analysis of Physiology*	Cohort study, 335 patients	16 hours, for 7 days with the monitoring of the prone maneuverer checklist	There is almost 40% decrease in the mortality rate with prone positioning. There is a significant increase of oxygen saturation after giving prone positioning on day 1-3. Moreover, the oxygen saturation index, oxygenation index, and PaO2: FiO2 increase significantly on day 4-7.

8	Weiss et al., (2021), *Prone positioning for patients intubated for severe acute respiratory distress syndrome (ARDS) secondary to COVID-19: a retrospective observational cohort study*	Retrospective cohort study, 42 patients	At least for 16 hours with the monitoring of the oxygenation and hemodynamic status	There is a difference in the increase of oxygen saturation with variation of the time the prone positioning given. Prior internal practice of SpO2 in 1 hour is 96.0% (93.0-99.0), the result after 2 hours after the prone positioning practice is 97.5% (95-99), and the result after 4 hours after PP is given is 97.0% (95.0-99.0).
9	Zhan et al., (2021). *Effects of 45° prone position ventilation in the treatment of acute respiratory distress syndrome: A protocol for a randomized controlled trial study*	Randomized controlled clinical trial, 268 patients	Control group: 0° of prone positioning for 16 hours in a day and turning the position every 2 hours. Intervention group: prone positioning 0° for 2 hours, then turning over 45° to the left for 2 hours and turning over 45° to the right for 2 hours, and eventually returning to the supine position with the chest down ward 0°. This cycle will last for 16 hours.	Giving 45° of prone positioning can reduce the incident of pressure injury and increase oxygenation (Ph of arterial blood, PO_2/FiO_2, SpO_2) in patients with ARDS.
10	Wendt et al., (2021). *Prone Positioning of Patients with Coronavirus Disease 2019 Who Are Nonintubated in Hypoxic Respiratory Distress: Single-Site Retrospective Health Records Review*	Retrospective chart review, 31 patients	30 -85 minutes	There is an increase of SpO_2 from 90% to 96% after PP; there is a decrease of pulse frequency from 93 to 88 times/minute after PP and breathing frequency from 31 to 22 times/minute.
11	Clarke et al., (2021). *Prone positioning improves oxygenation and lung recruitment in patients with SARS-CoV-2 acute respiratory distress syndrome; a single centre cohort study of 20 consecutive patients*	Prospective cohort study, 20 patients	10-16 hours	There is an average increase in the ratio of PaO_2/FiO_2 in giving prone positioning compared with the supine position. (IQR, 67-228). The majority (90%) of the patients experience the increase of PaO2/ Ratio FiO_2 > 20% of the normal value.

Table 2. Duration of prone positioning

No	Author	Duration of prone positioning	Average
1	Solverson et al., (2021). *Tolerability and safety of awake prone positioning COVID-19 patients with severe hypoxemic respiratory failure*	75 minutes	In average patients can tolerate to be given prone positioning for 30 minutes – 1.5 hours in the articles reviewed.
2	Tonelli et al., (2021). *Early awake proning in critical and severe COVID-19 patients undergoing noninvasive respiratory support: A retrospective multicenter cohort study*	3 hours	
3	Jouffroy et al., (2020). *Impact of prone position in non-intubated spontaneously breathing patients admitted to the ICU for severe acute respiratory failure due to COVID-19*	3 hours conducted as many as twice in a day	
4	Taboada et al., (2020). *Effectiveness of Prone Positioning in Nonintubated Intensive Care Unit Patients with Moderate to Severe Acute Respiratory Distress Syndrome by Coronavirus Disease 2019*	The average time for prone positioning is 10 hours and there are 16 sessions.	
5	Caputo et al., (2020). *Early Self-Proning in Awake, Non-intubated Patients in the Emergency Department: A Single ED's Experience During the COVID-19 Pandemic*	30 -120 minutes	
6	Jayakumar et al., (2021). *Standard Care Versus Awake Prone Position in Adult Nonintubated Patients with Acute Hypoxemic Respiratory Failure Secondary to COVID-19 Infection–A Multicenter Feasibility Randomized Controlled Trial*	1-6 hours maximum in one day	

7	Shelhamer et al., (2021). *Prone Positioning in Moderate to Severe Acute Respiratory Distress Syndrome Due to COVID-19: A Cohort Study and Analysis of Physiology*	16 hours, for 7 days with the monitoring of the prone maneuverer checklist	
8	Weiss et al., (2021), *Prone positioning for patients intubated for severe acute respiratory distress syndrome (ARDS) secondary to COVID-19: a retrospective observational cohort study*	At least for 16 hours in the monitoring of the oxygenation and hemodynamic status with the monitoring of the prone maneuverer checklist	
9	Zhan et al., (2021). *Effects of 45° prone position ventilation in the treatment of acute respiratory distress syndrome: A protocol for a randomized controlled trial study*	Control group: prone positioning 0° for 16 hours in a day and turning the position every 2 hours. Intervention group: prone positioning 0° for 2 hours, then turning over 45° to the left for 2 hours and turning over 45° to the right for 2 hours, and eventually returning to the supine position the chest downward 0°. This cycle will last for 16 hours.	
10	Wendt et al., (2021). *Prone Positioning of Patients with Coronavirus Disease 2019 Who Are Nonintubated in Hypoxic Respiratory Distress: Single-Site Retrospective Health Records Review*	30 -85 minutes	
11	Clarke et al., (2021). *Prone positioning improves oxygenation and lung recruitment in patients with SARS-CoV-2 acute respiratory distress syndrome; a single centre cohort study of 20 consecutive patients*	10-16 hours with the monitoring of the prone maneuverer checklist	

There were 1332 articles found at the beginning of the search. After the identification was conducted, 109 articles remained. Furthermore, a selection was made which resulted in the disqualification of 86 articles because they were not relevant with the theme in the title and abstract. There were six (6) duplicate articles in the database and 6 other articles had limited relevance to the findings. In the end, there were 11 articles obtained that fulfill the requirements for the literature review. The reference identification flow diagram is shown in Figure 1

According to the research of Taboada et al., (2020), prone positioning can increase oxygenation and increase the mean of SpO2 from 94% to 98%. In addition, their research found that PaO2/FIO2 increased from 89 to 165 mmHg. This study also discovered that the position of laying down with the chest downward can increase oxygenation and the life survival in COVID-19 patients with moderate to severe ARDS level. This condition is explained by Jouffroy et al. (2021) that support the research. A similar thing also happened in the research of Solverson et al. (2021) in which prone positioning increases SpO_2 from 91% to 98%. The study of Wendt et al. (2021) shows an increase of SpO_2 from 90% to 96% after PP, a decrease of pulse from 93 to 88 times/minute after PP, and a decrease of breathing frequency from 31 to 22 times/minute. In the research of Weiss et al., (2021), it is stated that SpO_2 in 1 hour is 96.0% (93.0-99.0), the result after 2 hours after prone positioning practice is 97.5% (95-99), and the result in 4 hours after PP is 97.0% (95.0-99.0). The study of Shelhamer et al. (2021) shows nearly 40% decrease in the mortality rate with prone positioning. After 7 days of giving prone positioning, there is an increase of oxygen saturation by as much as 24%.

The research of Jayakumar et al. (2021) shows that prone positioning lasted 6 hours per day for 2 hours per session. From the intervention result in the group given prone positioning, 73% (22 out of 30 patients) were able to maintain the prone positioning for more than 4 hours a day. PaO2 increased from the average of 73.6 mmHg to 94.9 mmHg. In the control/supine group, only 53% (16 out of 30 patients) were able to do prone positioning for 2 hours. The results of this study indicate that using prone positioning is safe and can help increase oxygen saturation. A similar thing is revealed by Clarke et al., (2021), stating that there is an average increase in the ratio PaO2/FiO2 out of 132 in the prone positioning compared with the supine position (IQR, 67-228). The majority of the patients (90%) had an increase in PaO2/FiO2 >20% of the normal value. Zhan et al. (2021) stated that the effect of prone positioning 45° in ARDS can reduce the pressure injury to happen and increase oxygenation (Ph of artery blood, PaO2 /FiO2, SpO2) in patients with ARDS. An effective early prone positioning is given to the patients who are conscious and breathe spontaneously. Prone positioning can increase PaO2/FiO2. Patients in prone positioning were discharged from ICU earlier than those receiving standard treatment (Tonelli et al., 2021).

Based on the research of Jouffroy et al. (2021) and Jayakumar et al. (2021), it is stated that prone positioning is given with the maximum duration for 6 hours. In contrast to the results of the study of Tonelli et al. (2021), prone positioning is carried out for minimum of 3 hours, while the study of Solverson et al. (2021) shows that in average the patients could tolerate prone positioning for 75 minutes. Wendt et al. (2021) stated prone positioning is given for 30-85 minutes. Clarke et al. (2021), Zhan et al. (2021), Shelhamer et al. (2021), and Weiss et al. (2021) in their research found that the prone positioning is given to patients with ARDS for 10-16 hours with the position change every 2 hours. Research by Caputo et al. (2020) shows that prone positioning is given to the patients with a duration varying between 30-120 minutes depending on the capability of the patients in tolerating prone positioning.

DISCUSSION

Improving oxygen saturation of ARDS patients is very important. Therefore, it is necessary to do various interventions to increase the pulmonary function that will have the impact on increasing oxygen saturation. Based on the 11 articles reviewed, 7 articles are the observational retrospective studies, 2 articles are the observational perspective studies, and 2 are the RCT studies; from all of those, it is evident that prone positioning given to ARDS patients has a positive effect in increasing oxygen saturation.

From this study, it is discovered that prone positioning is given in varying times and episodes or intervals. The optimal duration of a PP session remains unclear. The international recommendation is to position patients in PP for at least 12 hours (Fan et al., 2017). Jochmans et al. (2020) explained that the physiological effect of PP is beneficial for at least 16 hours to maximum 24 hours and done for two hours in every session, and at least PP is given within 24 hours if the ratio of PaO_2/FiO_2 remains under 150. Similarly, Gattinoni et al. (2001) and Guerin et al. (2004) explained that even though the optimal duration of PP is not known for sure, most research has given PP repeatedly lasting 6-8 hours or prolonged PP with a duration of 16-20 hours (Taccone et al., 2009; Mancebo et al., 2006).

Guérin et al. (2013) explained that the decrease of the mortality rate in severe ARDS patients can be achieved through the application of prone positioning with an average duration time of 17 hours per day with the average of four sessions per patient. It was discontinued for further improvement in PaO_2:FiO_2 $\geq$150 mmHg, FiO $\leq$ 0.6, PEEP $\leq$ 10 cm H_2O and maintained for at least four hours after the last session of PP. Malhotra, A. & Kacmarek, R. M. (2020) explained the application of PP in early ARDS maintained for 18-20 hours in a row, with the position change in accordance with the need for intervention in treatment. Munshi et al. (2017) explained that the effective PP increases oxygenation and decreases the mortality of heavy ARDS patients if applied at least 12 hours per day. Most studies apply the prone positioning protocol for both $\geq$3 hours twice a day, 10-12 hours, or more than 16 hours. However, there is no research published to confirm the frequency and the optimal duration for prone positioning. Moreover, tolerance may limit the duration of prone positioning (Rosén et al., 2021; Ferrando et al., 2020; Sartini et al., 2020; Perez-Nieto et al., 2022).

The progression of respiratory failure in ARDS develops immediately after the dyspnea and hypoxemia onset. When heavy pneumonia (ARDS) occurs, pulmonary alveoli become inflamed and clogged. In this condition, the lungs become full with liquid, become stiff, and are difficult to develop and do contraction so that this will make patients hard to breathe, and it is necessary to have help to release patients from the feeling of discomfort (Marzuki et al., 2021). The rehabilitative supportive treatment in COVID-19 patients with heavy symptoms including breathing exercise, physical modality such as Neuromuscular Electrical Stimulation (NMES) and positioning, one of which is prone positioning, can increase oxygen saturation. Prone positioning can improve respiratory physiology and cardiovascular stability by reducing abdominal pressure.

According to Caputo et al., (2020), the arrangement of prone positioning is an act that can increase oxygenation safely. Correct procedure in performing maneuver can reduce the risk of injury (back injury) to staff and patients. The patients are positioned with parallel arms, unsupported belly, cushions placed under the shoulders and hips (using soft cushions) with the face facing right or left. The position is changed every 2-4 hours (Guérin et al., 2020). Prone positioning can increase oxygenation (Fazzini et al., 2022), increase oxygen saturation (Friedman et al., 2021), and develop diaphragm muscle and lung development (Telias et al., 2020).

Prone positioning can increase gas exchange by reducing transpulmonary pressure (the differences between breathing path opening pressure and pleura pressure). Prone positioning transfers pressure in the thoracic cavity and internal abdominal organ outside the lungs, expanding the limited diaphragm movement. Because the independent position of the lung dorsal part is streamed by gravity, prone positioning also increases ventilation in poorly ventilated alveolar areas, producing better breathing (Jagan et al., 2020).

From the results of the literature search, it is also obtained that giving PP with varying durations of providing the position has the effect of changing the oxygen saturation level of ARDS patients. Providing the most intervention in this position for 120 minutes can increase oxygen saturation of patients more significantly.

During the implementation of the prone positioning intervention, it is necessary to do the monitoring of patients' condition continuously. Several things that are monitored are breathing frequency, oxygen saturation, the pulse rate, blood pressure, invasive artery pressure, and MAP, as well as EKG. In addition, the side effects occurring post giving prone positioning are breathing exhaustion and tachypnea has to be monitored (Taboada et al., 2020).

CONCLUSIONS AND SUGGESTIONS

This systematic review shows that prone positioning can improve oxygenation and increase the respiratory function in ARDS patients. Thus, this saturation improvement can reduce the mortality rate in the moderate to severe ARDS subgroup. However, it is necessary to reconsider doing new clinical tests using the similar sample and methodology, applying the protocol conformity from the prone positioning therapy technique in ARDS patients.

ETHICAL CONSIDERATIONS

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Conflict of Interest Statement

No potential conflicts of interest have been reported regarding the submitted articles

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