Effect of combined lateral and supine positioning on oxygen saturation in ICU patients during the mechanical ventilator weaning process: A randomized controlled trial

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Abstract

Background: Prolonged mechanical ventilation in ICU patients increases mortality risk and length of stay. Ineffective weaning can exacerbate the patient's condition and further elevate mortality risk due to hypoxemia-induced cellular damage, contributing to ICU overcrowding.
Purpose: This study investigates the effect of lateral positioning on oxygen saturation in ICU patients undergoing mechanical ventilator weaning.
Methods: A randomized controlled trial (RCT) with block randomization was conducted, enrolling 60 participants assigned to either the intervention group ($n = 30$) or the control group ($n = 30$). The intervention group received 5% FiO_2 and was repositioned every two hours (right lateral, supine, left lateral), whereas the control group remained supine with 5% FiO_2. Oxygen saturation (SaO_2) was measured using pulse oximetry before and after the intervention. As the data were not normally distributed, the Mann-Whitney U test was used to compare SaO_2 changes between groups, with statistical significance set at $p < 0.05$.
Results: Baseline characteristics, including age, gender, and ventilator duration, were comparable between groups ($p > 0.05$). The median increase in SaO_2 was 6% (IQR: 1–8%) in the intervention group and 1% (IQR: 0–3%) in the control group, with a significant between-group difference of 5% ($p < 0.001$). A large effect size ($\eta^2 = 0.68$) indicated a substantial impact of lateral positioning on SaO_2.
Conclusions: Lateral positioning significantly improves oxygen saturation in ICU patients undergoing ventilator weaning, potentially reducing complications associated with prolonged mechanical ventilation.

Keywords: critical patients; lateral position; mechanical ventilation; oxygen saturation

Introduction

Most intensive care unit (ICU) patients require mechanical ventilation (MV) due to their inability to breathe independently (Adamski, 2015). However, prolonged MV use increases the risk of mortality, extended hospital stays, therapy-related complications, and a decline in post-treatment functional activity (Marik, 2015). Weaning from MV is essential for restoring spontaneous breathing and can be performed gradually or abruptly. Successful weaning is sustaining spontaneous breathing without MV support for at least 48 hours while maintaining normal oxygen saturation levels (Morton et al., 2016; Othman, 2017).

Oxygen saturation (SaO_2), the percentage of oxygen-bound hemoglobin, typically ranges from 95% to 100% (Hafen & Sharma, 2022). Various factors influence SaO_2 levels during weaning, including age, gender, Glasgow

Coma Scale (GCS) score, oxygen therapy, fraction of inspired oxygen (FiO_2), positive end-expiratory pressure (PEEP), airway clearance, circulatory status, and activity level (Annesi et al., 2017; Kozier et al., 2012). Weaning failure is often associated with hypoxemia, which can lead to cellular injury, organ dysfunction, and an increased burden on ICU resources (Marik, 2015). One of the primary contributors to weaning failure is an imbalance between the respiratory muscle workload and weakness (Adamski, 2015).

Positioning plays a crucial role in enhancing respiratory muscle function and improving oxygenation. Studies suggest that lateral positioning can reduce the work of breathing and optimize diaphragmatic movement (Pujiati, 2019; Mezidi & Guérin, 2018; Patel et al., 2022). Additionally, it enhances pulmonary circulation, facilitating better oxygen binding to hemoglobin (Clarissa, 2019; Banasik, 2010). However, previous studies on lateral positioning and oxygenation have yielded inconsistent findings, potentially due to sample characteristics, underlying health conditions, and intervention duration variations. Some studies reported no significant changes in oxygen saturation (Agustina et al., 2021; Ferrando et al., 2020) others observed improved arterial oxygenation (PaO_2) in patients with acute respiratory distress syndrome (ARDS) (Hartanto, 2021).

To address these inconsistencies, this study investigates the effect of lateral positioning on oxygen saturation in ICU patients undergoing ventilator weaning. Unlike previous research, this study continuously monitors patients for 24 hours while implementing positional changes every two hours (right lateral, supine, and left lateral). Recent studies have highlighted the role of lateral positioning in improving oxygenation in critically ill patients (Hassan & Baraka, 2021; Sunaina et al., 2022). Supporting the rationale for this investigation. Furthermore, a preliminary study conducted in the ICU of Margono Soekarjo Hospital found that 74.34% of 1,085 patients required MV; however, the impact of lateral positioning on oxygen saturation remains unclear. Therefore, this study aims to provide stronger clinical evidence regarding the role of lateral positioning in optimizing oxygenation during the weaning process.

Materials and Methods

Design

This study utilized a randomized controlled trial (RCT) with a pre-test and post-test control group design. This approach directly compared the intervention and control groups by measuring key variables before and after the intervention. Including pre- and post-test assessments enhanced the study's ability to evaluate the intervention's effectiveness while reducing potential confounding factors.

Sample and Setting

Data was collected from April to May 2021 in the Intensive Care Unit (ICU) of Prof. Dr. Margono Soekarjo Hospital, Purwokerto, Central Java, Indonesia. The inclusion criteria for participants were as follows: ICU treatment for more than 48 hours, undergoing the weaning process, aged 20–60 years, stable hemodynamic status, Glasgow Coma Scale (GCS) score above 8, and a positive end-expiratory pressure (PEEP) value between 6 and 10 cm H_2O. Patients were excluded if they were terminally ill or had spinal disorders, pulmonary diseases, or anemia. Participants were withdrawn from the study if they experienced hemodynamic instability, cardiac electrical disturbances, or chose to discontinue participation.

Sample Size Calculation

The sample size was determined using the formula for an unpaired comparative analytical study with two groups, which is commonly used in experimental research to ensure sufficient statistical power for detecting significant differences (Dahlan, 2017). The formula used was:

$$n_1 = n_2 = 2x\left(\frac{[z_\alpha + z_\beta] \times S}{x_1 - x_2}\right)^2$$

$$n_1 = n_2 = 2x\left(\frac{[1.96 + 1.28] \times 3.14}{3}\right)^2$$

$$n_1 = n_2 = 2x\left(\frac{10.2}{3}\right)^2$$

$$n_1 = n_2 = 23$$

Description

n1 = n2 : Minimum sample size
Zα : Type I error (1.96)
Zβ : Type II error (1.28)
S : Pooled standard deviation from related studies (3.14) (Apriliawati, 2017)
x1-x2 : Minimum clinically significant change in SaO_2 (3) (Kristiani et al., 2020)

Based on this calculation, the minimum required sample size per group was 23 participants. To account for an estimated 10% dropout rate, the sample size was adjusted to 26 participants per group. However, due to the availability of eligible patients during recruitment, an additional four participants were included in each group, resulting in a final total of 30 participants per group.

Increasing the sample size beyond the initially calculated minimum is a common practice in experimental research. This enhances the robustness and generalizability of findings, reduces the risk of Type II errors, and increases the precision of effect estimates. A larger sample size strengthens statistical power, ensuring more reliable and valid conclusions (Heriansyah et al., 2022; Kristiani et al., 2020; Syahran et al., 2019).

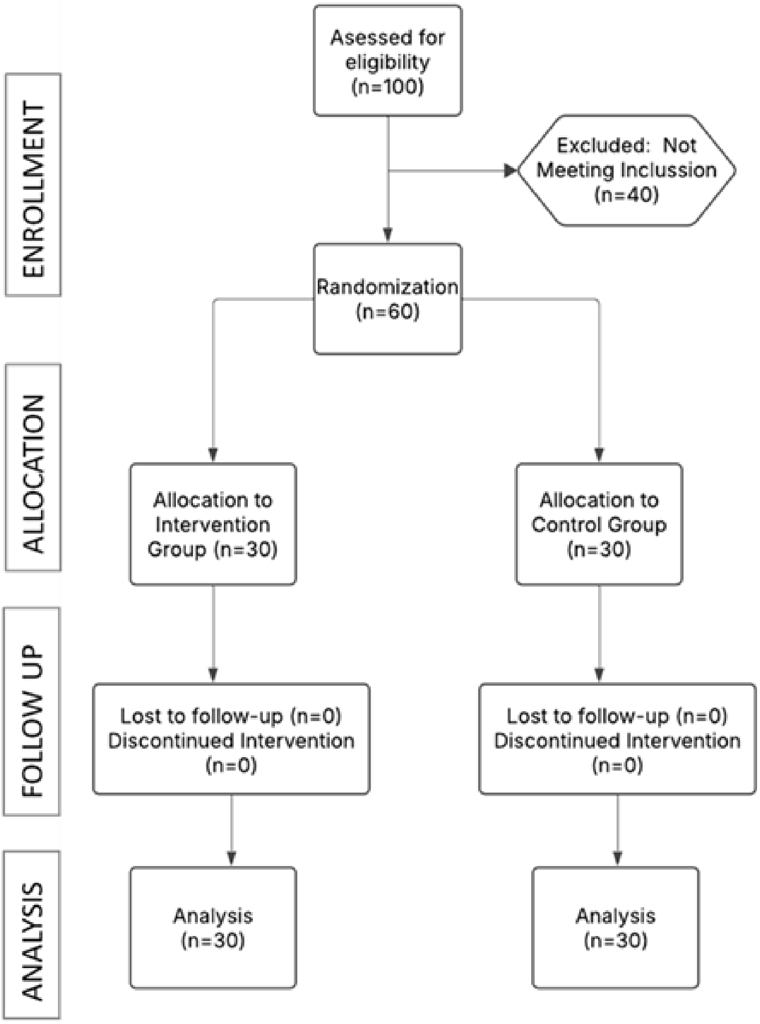

Figure 1. Respondent Selection Chart (CONSORT DIAGRAM)

Participant Selection and Randomization

Out of 100 ICU patients screened, only 60 met the inclusion and exclusion criteria. These patients were randomly assigned to either the intervention or control group, with 30 participants in each group. The selection process is illustrated in Figure 1.

Eligible ICU patients were selected based on the inclusion and exclusion criteria. Informed consent was obtained from their families, and if consent was given, patients were assigned a label number based on their admission sequence (1 to 60).

Participants were allocated using a block randomization system to ensure equal distribution and maintain balance across groups. A computer-generated randomization list was used for unbiased allocation. To minimize selection bias, an independent research assistant who was not involved in intervention administration or outcome assessment conducted the randomization.

Due to the nature of the intervention (patient positioning), blinding participants and intervention providers was not feasible. However, single blinding was implemented, ensuring that data analysts remained blinded to group assignments to minimize bias in outcome analysis. This methodological approach enhances the internal validity and reliability of the study's findings (Purnawan et al., 2022).

Intervention

The study was conducted with the support of six trained research assistants, all ICU nurses holding basic ICU training certifications. These assistants were assigned across three shifts—morning, afternoon, and night—with two assistants per shift. Their primary responsibilities included repositioning patients every two hours and recording pre- and post-intervention oxygen saturation levels.

Lateral positioning was adjusted between 30° and 45°, depending on each patient's response and tolerance. The positioning sequence consisted of right lateral, supine, and left lateral positions, each maintained for two hours and systematically rotated over 24 hours.

To ensure consistency in oxygen saturation

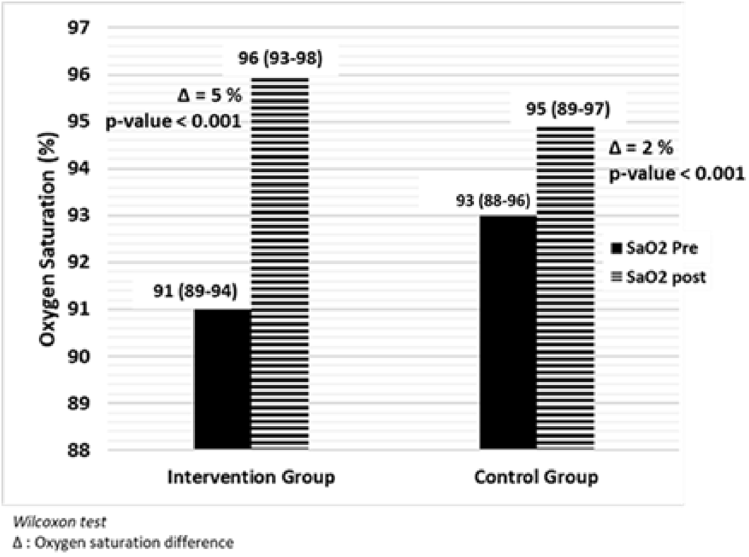

Figure 2. Difference between pre and post SaO2

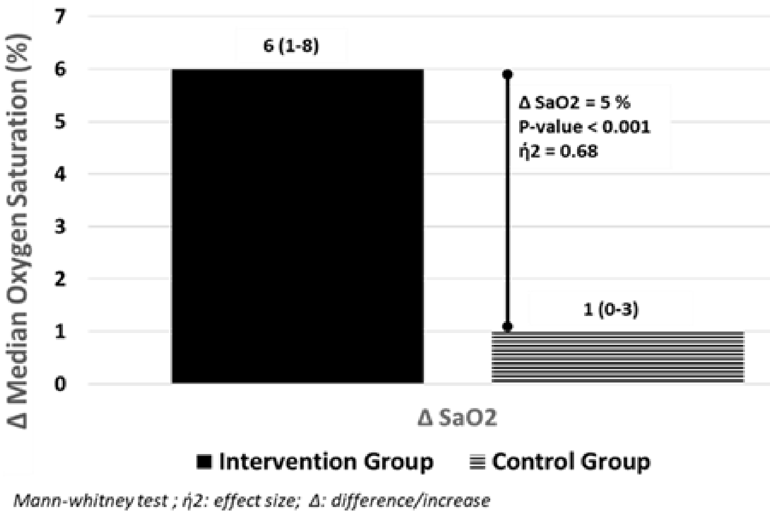

Figure 3. The difference in SaO2 Increase between the Two Groups

measurements across shifts, the Intraclass Correlation Coefficient (ICC) was calculated, yielding a reliability score of 0.80. This result indicates a high level of agreement among research assistants conducting measurements during morning, afternoon, and night shifts. A single designated researcher measured each patient's oxygen saturation to standardize data collection further and minimize inter-observer variability.

Oxygen saturation was measured using pulse oximetry devices connected to bedside monitors. All ICU equipment, including pulse oximeters, underwent routine calibration every six months as part of a validity and quality control protocol. These measures ensured data collection accuracy, precision, and consistency throughout the study.

The intervention and control groups received the same fraction of inspired oxygen (FiO_2) at 5% throughout the study. Each participant in the intervention group underwent systematic repositioning every two hours over 24 hours, totaling eight positional changes (alternating between left lateral, supine, and correct lateral positions)—this structured intervention aimed to optimize respiratory muscle function and improve oxygenation through consistent mechanical stimulation. The total intervention period spanned six weeks, allowing for the sequential enrollment of eligible patients.

In contrast, the control group received standard ICU care alongside 5% FiO_2 oxygen administration. Standard therapy included routine pharmacological and non-pharmacological treatments, with positional changes occurring only as part of routine nursing care, such as during hygiene procedures (e.g., bathing). This approach ensured uniformity in standard care while maintaining a clear distinction between the control and intervention groups.

Both groups underwent hemodynamic monitoring every two hours, including assessments of heart rate (HR), respiratory rate (RR), blood pressure (BP), mean arterial pressure (MAP), and oxygen saturation (SaO_2). Suctioning was performed when necessary, based on clinical indicators such as audible secretions, declining oxygen saturation, or increased respiratory effort.

Throughout the study, no participants dropped out due to adverse events such as hemodynamic instability, vomiting, hypoxia, or a decline in Glasgow Coma Scale (GCS) score. This ensured the uninterrupted completion of the study protocol as planned.

Variables

This study examined two primary variables: the independent variable—lateral positioning—and the dependent variable—oxygen saturation (SaO_2). The primary objective was to evaluate the effect of positional changes on ICU patients' oxygen saturation levels.

Oxygen saturation was measured using a calibrated pulse oximeter (CMS50N Contec, Omron) to ensure accuracy and reliability. Measurements were taken every two hours throughout the 24-hour intervention period, with the highest recorded value in each session used for analysis. The pulse oximeter was recalibrated before each use according to the manufacturer's guidelines to maintain measurement precision.

Participants in the intervention group underwent systematic repositioning every two hours, alternating between left lateral, supine, and correct lateral positions. In contrast, the control group remained in the supine position. This intervention aimed to enhance respiratory function and optimize oxygenation. The dependent variable, oxygen saturation, was analyzed to assess the impact of these positional changes, providing insights into the relationship between patient positioning and oxygenation levels.

Data Collection

Oxygen saturation was measured at two key time points: before (pre-intervention) and after 24 hours (post-intervention). This measurement strategy was chosen to evaluate the cumulative effect of lateral positioning on oxygen saturation over 24 hours, rather than capturing short-term fluctuations that might occur with each position change.

Frequent measurements every two hours were deemed unnecessary, as previous studies suggest that oxygen saturation changes induced by positional adjustments do not significantly fluctuate within short intervals, particularly when assessing cumulative effects over an extended period. After the post-intervention measurement, patients in the control group were repositioned every two hours as part of standard ICU care.

A senior ICU nurse, who also served as an assistant researcher at Prof. Dr. Margono Soekarjo Hospital in Purwokerto, conducted data collection, ensuring consistency and reliability in data acquisition.

Data Analysis

Non-parametric data, such as age and duration of mechanical ventilator use, were reported as median and interquartile range (IQR). In contrast, categorical data, such as sex, were presented as frequency distributions. A chi-square test was used to assess the homogeneity of age and sex between groups, whereas the Levene test was applied to compare variance in mechanical ventilator duration. Since all 60 randomized participants completed the study without dropouts, statistical analyses were conducted using a per-protocol approach. Differences in oxygen saturation before and after the intervention within each group were analyzed using the Wilcoxon test. At the same time, between-group comparisons were performed using the Mann-Whitney test due to non-normally distributed data (Dahlan, 2019).

The effect size of oxygen saturation improvement was calculated using eta squared (η^2) to determine the magnitude of the intervention effect. The eta squared value was computed using the formula available at https://www.psychometrica.de/effect_size.html. All statistical analyses were conducted using SPSS version 26.

Ethical Clearance

This study was approved by the Health Research Ethics Committee of a government-based hospital in Central Java, Indonesia, in 2022 (No: 420/15533). It was conducted using the principles outlined in the Helsinki Declaration. Participants were selected based on well-defined inclusion and exclusion criteria, and informed consent was obtained to ensure that participants and their families fully understood the study's objectives, procedures, and potential risks.

Patient safety was a priority, and ICU protocols for patient positioning were strictly adhered to. Continuous monitoring and necessary adjustments were made to minimize potential risks associated with repositioning. Research assistants, who were thoroughly trained in the study protocol, worked under supervision, and scheduled breaks were provided to ensure their well-being during the 24-hour observation period. These measures ensured compliance with ethical standards and safeguarded study participants and research personnel.

Results

The demographic and clinical characteristics analysis, including age, duration of mechanical ventilator use, and sex distribution, revealed no significant differences between the intervention and control groups. The statistical results demonstrated p-values of 0.77 for age, 0.06 for ventilator duration, and 0.17 for sex distribution, confirming the homogeneity of both groups in these variables.

The pre- and post-intervention SaO_2 levels in both groups were analyzed using the Mann-Whitney test, with the results presented in Figure 2. The analysis indicated a significant increase in the median SaO_2 levels in both the intervention and control groups ($p < 0.001$). The intervention group exhibited a 5% increase in SaO_2, while the control group demonstrated a 2% increase. Although both groups showed statistically significant improvements, a clinically meaningful change in SaO_2 was observed only in the intervention group. A change in SaO_2 is considered clinically significant in critically ill patients if it exceeds 3% (Kristiani et al., 2020).

The between-group comparison of SaO_2 improvements was also conducted using the Mann-Whitney test, as shown in Figure 3. The results revealed a statistically significant difference in the increase in SaO_2 between the two groups ($p < 0.001$). The median SaO_2 increase in the intervention group was 5% higher than in the control group. Furthermore, the effect size, indicated by $\eta^2 = 0.68$, suggests that lateral positioning substantially improved SaO_2 levels among ICU patients undergoing ventilator weaning. This 5% increase is clinically significant, as previous studies have established that a minimal change of 3–5% in SaO_2 is clinically meaningful (Kristiani et al., 2020).

Discussion

This study's findings indicate that the intervention and control groups had comparable characteristics in terms of age, gender, and duration of mechanical ventilator use. These factors are known to influence oxygen saturation and the success of ventilator weaning in ICU patients. Age, for example, affects pulmonary capacity, alveolar surface area, and diffusion capacity, all of which tend to decline with aging, impacting oxygenation and the likelihood of successful weaning (Yuswandi et al., 2020; Hakim et al., 2022). The influence of age on oxygen saturation is particularly pronounced in individuals with systemic disorders (Colodny, 2001). Additionally, gender differences play a role, as critically ill female patients tend to exhibit a leftward shift in the oxygen dissociation curve (ODC), allowing for better oxygen saturation at lower partial pressures of oxygen (Annesi et al., 2017; Yasseen et al., 2023). The duration of mechanical ventilation is another critical factor, as prolonged ventilator use increases the risk of complications that may hinder successful weaning (Elbaradey et al., 2015). However, homogeneity testing confirmed that these variables were evenly distributed across both groups, ensuring they did not introduce bias into the study results.

Effect of Lateral Positioning on Oxygen Saturation

The Wilcoxon test results indicated a significant increase in SaO_2 in both groups, likely due to the administration of 5% FiO_2, which was provided to prevent hypoxia during the weaning process. The additional oxygen supply enhanced hemoglobin oxygen binding and facilitated systemic oxygen distribution (Morton et al., 2016).

However, the Mann-Whitney test revealed a significantly more significant increase in SaO_2 in the intervention group compared to the control group. This difference can be attributed to the combined effects of FiO_2 supplementation and the lateral positioning intervention. The lateral position has been shown to enhance respiratory muscle strength, improve lung capacity, and facilitate adequate oxygenation in patients on mechanical ventilation (Yuswandi et al., 2020).

Lung capacity plays a crucial role in oxygenation, as increased lung volume allows for greater hemoglobin binding capacity, ultimately improving oxygen saturation (Kozier et al., 2012; Yuswandi et al., 2020). This study's findings align with previous research demonstrating that lateral positioning significantly increases PaO_2 compared to the supine and semi-Fowler positions (Mahvar, 2012; Tongyoo et al., 2006). Furthermore, lateral positioning has been associated with improved respiratory function and reduced respiratory muscle workload, potentially shortening the duration of mechanical ventilation in critically ill patients (Pujiati, 2019; Lai et al., 2016; Lin & Lin, 2012). Experimental studies have also reported that lateral positioning significantly enhances animal models' partial oxygen pressure (PaO_2) (Tongyoo et al., 2006).

Physiological Mechanisms Underlying Lateral Positioning

Lateral positioning improves oxygenation by preventing airway collapse, a common issue in supine patients due to gravitational effects (Stanchina et al., 2003). Additionally, studies have shown that functional residual capacity (FRC) is significantly greater in the lateral than the supine position, providing a better opportunity for gas exchange (Pinna et al., 2015). The lateral position also enhances pulmonary perfusion, optimizing oxygen transport in the alveoli and improving overall oxygenation (Hewitt et al., 2016).

Beyond respiratory benefits, lateral positioning positively influences cardiovascular function by optimizing cardiac output and reducing cardiac workload (Hewitt et al., 2016). This effect is crucial, as optimal cardiac performance supports efficient oxygen delivery to tissues (Aries et al., 2012). Previous studies have confirmed lateral positioning significantly increases PaO_2 in mechanically ventilated patients (Karmiza et al., 2014). This improvement is likely due to an increased cardiac index, which enhances oxygen distribution to body cells (Thomas et al., 2007).

Study Limitations

This study has several limitations that should be acknowledged. First, the randomized controlled trial (RCT) protocol was not registered, which may impact transparency and reproducibility. Future research should prioritize trial registration to enhance study credibility. Second, hemoglobin (Hb) levels, influencing SaO_2, were not analyzed as a potential confounding factor. However, anemia was included as an exclusion criterion to mitigate this limitation, ensuring that all participants had adequate Hb levels for effective oxygen transport. Third, while designed to optimize lung recruitment and oxygenation, the two-hourly repositioning protocol increased nursing workload and may have impacted patient comfort, particularly during night shifts. Frequent repositioning could disrupt sleep, which is essential for ICU recovery. Future studies should explore alternative repositioning schedules that balance oxygenation benefits with patient comfort and sleep preservation, ensuring a more patient-centered approach to ICU care.

Conclusions

This study demonstrates that a structured two-hourly lateral repositioning protocol significantly improves oxygen saturation (SaO_2) in ICU patients undergoing weaning from mechanical ventilation. The intervention group experienced a clinically meaningful increase in SaO_2 compared to the control group, highlighting the beneficial effects of lateral positioning on oxygenation. These findings support the integration of systematic repositioning into ICU care protocols to optimize oxygenation and facilitate the weaning process.

Declaration of Interest

The authors declared no conflicts of interest.

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References

Adamski. (2015). The differences between two selected intensive care units located in central and northern europe – preliminary observation. *Anaesthesiology Intensive Therapy, 47*(2).

Agustina, N., Nurhaeni, N., & Hayati, H. (2021). Right lateral position can improving oxygen saturation and respiratory rate on under-five children with pneumonia. *La Pediatria Medica E Chirurgica.* https://doi.org/10.4081/pmc.2021.262

Annesi, S. M., Brooks-brunn, J. A., Byers, J. F., Casey, P. E., Cash, J., & Corbin, J. (2017). Brunner and suddarth's textbook of medical-surgical nursing 14th edition. Lippincott Williams & Wilkins (Vol. 79). https://doi.org/10.1111/mono.12088

Apriliawati, A. (2017). The effect of prone position to oxygen aturations'level and respiratory rate among infants who being installed mechanical ventilation in nicu koja hospital'. *IMC 2016 Proceedings, 1*(1).

Aries, M. J. H., Aslan, A., Elting, J. W. J., Stewart, R. E., Zijlstra, J. G., Keyser, J. D., & Vroomen, P. C. A. J. (2012). Intra-arterial blood pressure reading in intensive care unit patients in the lateral position'. *Journal of Clinical Nursing, 21*(18).

Banasik, J. L. (2010). Effect of lateral positions on tissue oxygenation in the critically ill. *Heart & Lung, The Journal of Acute and Critical Care, 30,* 4.

Clarissa. (2019). Early mobilisation in mechanically ventilated patiens: a systematic integrative review of definition and activities'. *Journal Of Intensive Care, 7*(3).

Colodny, N. (2001). Effects of age, gender, disease, and multisystem involvement on oxygen saturation levels in dysphagic persons. *Dysphagia, 16*(1), 48–57. https://doi.org/10.1007/s004550000042

Dahlan, M. S. (2017). Determining sample size in medical and health research. Epdiemiologi Indonesia.

Dahlan, M. S. (2019). Statistics for medical and health sciences (6th ed.). Epdiemiologi Indonesia.

Elbaradey, G. F., Elshmaa, N. S., & Ganna, S. A. (2015). Can integrative weaning index be a routine predictor for weaning success? *Indian Journal of Critical Care Medicine*. https://doi.org/10.4103/0972-5229.171352

Ferrando, C., Artigas, R. M., Arruti, E., Tamayo, G., Hernández-Sanz, M. L., Martín-Grande, A., Kacmarek, R. M., Villar, J., Suárez-Sipmann, F., Vendrell, M., Sánchez□Etayo, G., Alcón, A., Belda, I., Agustí, M., Carramiñana, A., Gracia, I., Panzeri, M., León, I., Balust, J., … Vidal, A. M. A. (2020). Awake prone positioning does not reduce the risk of intubation in COVID-19 treated with high-flow nasal oxygen therapy: A multicenter, adjusted cohort study. *Critical Care.* https://doi.org/10.1186/s13054-020-03314-6

Hafen, B. B., & Sharma, S. (2022). Oxygen saturation. StatPearls Publishing, Treasure Island (FL). http://europepmc.org/books/NBK525974

Hakim, R. I., Hadisaputro, S., Suhartono, S., & Runjati, R. (2022). Efect of hypnopressure on anxiety in pregnant women with preeclampsia. *Jurnal Kebidanan.* https://doi.org/10.26714/jk.11.2.2022.121-132

Hartanto, D. (2021). Acute respiratory distress syndrome: Pathophysiology and management.

Cermin Dunia Kedokteran. https://doi.org/10.55175/cdk.v48i5.1374

Hassan, E. A., & Baraka, A. (2021). The effect of reverse trendelenburg position versus semi-recumbent position on respiratory parameters of obese critically ill patients: A randomised controlled trial. *Journal of Clinical Nursing*. https://doi.org/10.1111/jocn.15645

Heriansyah, H., Yakub, A. S., Harmiady, R., Junaidi, J., & Yulianto, M. (2022). Suctioning and its impact on oxygen saturation in ventilated patients with endotracheal tubes. *Media Keperawatan Politeknik Kesehatan Makassar*. https://doi.org/10.32382/jmk.v13i2.3077

Hewitt, N., Bucknall, T., & Faraone, N. M. (2016). Lateral positioning for critically ill adult patients. *The Cochrane Database of Systematic Reviews, 2016*(5), CD007205. https://doi.org/10.1002/14651858.CD007205.pub2

Karmiza, M., Emil, & Huriani. (2014). The effect of left lateral position with 30-degree head elevation on partial oxygen pressure in mechanically ventilated patients. *Jurnal Ners, 9*(1).

Kozier, B., Erb, G., Berman, A., & Snyder, S. (2012). Kozier and Erb's fundamentals of nursing: concepts, process and practice. *Nurse Education in Practice, 12*(2), e12. https://doi.org/10.1016/j.nepr.2011.09.002

Kristiani, A. H., Riani, S., & Supriyono, M. (2020). Analysis of changes in oxygen saturation and respiratory rate in ventilated patients undergoing suctioning in the ICU of Mardi Rahayu hospital, Kudus. *Jurnal Perawat Indonesia.* https://doi.org/10.32584/jpi.v4i3.811

Lai, C., Chou, W., Chan, K., Cheng, K., Yuan, K., Chao, C., & Chen, C. (2016). Early mobilization reduces duration of mechanical ventilation and intensive care unit stay in patients with acute respiratory failure. *Archives Of Physical Medicine And Rehabilitation, 11*(7).

Lin, C. K., & Lin, C. C. (2012). Work of breathing and respiratory drive in obesity. *Respirology, 17*(3), 402–411. https://doi.org/10.1111/j.1440-1843.2011.02124.x

Mahvar, T. (2012). The effect of positioning after coronary artery bypass graff'. *Life Science Journal, 9*(3).

Marik, P. E. (2015). Evidence-Based Critical Care Third Edition. Admission Discharge Criteria' (3rd ed., Vol. 4, Issue 4). Springer International Publishing.

Mezidi, M., & Guérin, C. (2018). Effects of patient positioning on respiratory mechanics in mechanically ventilated ICU patients. *Annals of Translational Medicine, 6*(19), 384. https://doi.org/10.21037/atm.2018.05.50

Morton, P. G., Fontain, D., Hudak, C., M., Gallo, B., & M. (2016). Critical Care (P. A. Holistik & Eds.; Vol. 1). EGC.

Othman, H. A. (2017). Ventilator-associated pneumonia, incidence and risk factors in the emergency intensive care unit of Zagazig University Hospital. *Egyptian Journal of Chest Diseases and Tuberculosis, 6*(7).

Patel, N., Chong, K., & Baydur, A. (2022). Methods and applications in respiratory physiology: Respiratory mechanics, drive, and muscle function in neuromuscular and chest wall disorders. *Frontiers in Physiology, 13*(June), 1–17. https://doi.org/10.3389/fphys.2022.838414

Pinna, G. D., Robbi, E., La Rovere, M. T., Taurino, A. E., Bruschi, C., Guazzotti, G., & Maestri, R. (2015). Differential impact of body position on the severity of disordered breathing in heart failure patients with obstructive vs. central sleep apnoea. *European Journal of Heart Failure, 17*(12), 1302–1309. https://doi.org/10.1002/ejhf.410

Pujiati, L. (2019). The effect of right lateral positioning on hemodynamic parameters in patients with congestive heart failure during the circadian cycle in Medan. Tesis, Faculty of Nursing, Universitas Sumatera Utara.

Purnawan, I., Setiyarini, S., Probosuseno, P., & Widyastuti, Y. (2022). The effect of the dreamer spiritual therapies on saliva cortisol hormone and pain score patients in the intensive care unit : a true-experimental study. *Macedonian Journal of Medical Sciences, 9,* 281–287.

Stanchina, M. L., Malhotra, A., Fogel, R. B., Trinder, J., Edwards, J. K., Schory, K., & White, D. P. (2003). The influence of lung volume on pharyngeal mechanics, collapsibility, and genioglossus muscle activation during sleep. *Sleep, 26*(7), 851–856. https://doi.org/10.1093/sleep/26.7.851

Sunaina, N. P., Shweta, A. P., & Andrews, M. (2022). Impact of lateral positioning on oxygenation in noninvasively ventilated COVID-19 patients. *International Journal of Health Sciences.* https://doi.org/10.53730/ijhs.v6ns2.8078

Syahran, Y., Romadoni, S., & Imardiani, I. (2019). The effect of endotracheal tube suctioning on oxygen saturation levels in patients with respiratory failure in the icu and emergency department of Prabumulih Regional General Hospital in 2017. *Jurnal Berita Ilmu Keperawatan.* https://doi.org/10.23917/bik.v12i2.4551

Thomas, P. J., Paratz, J. D., Lipman, J., & Stanton, W. R. (2007). Lateral positioning of ventilated intensive care patients: A study of oxygenation, respiratory mechanics, hemodynamics, and adverse events. *Heart and Lung: Journal of Acute and Critical Care, 36*(4), 277–286. https://doi.org/10.1016/j.hrtlng.2006.10.008

Tongyoo, S., Vilaichone, W., Ratanarat, R., & Permpikul, C. (2006). The effect of lateral position on oxygenation in ARDS patients: A pilot study. *Journal of the Medical Association of Thailand, 89(SUPPL. 5)*, 55–61.

Yasseen, B. A., Elkhodiry, A. A., El-sayed, H., Zidan, M., Kamel, A. G., Hamdy, R., El-Shqnqery, H. E., Samir, O., Sayed, A. A., Badawy, M. A., Saber, A., Hamza, M., El-Messiery, R. M., Ansary, M. El, Abdel-Rahman, E. A., & Ali, S. S. (2023). Evidence associating neutrophilia, lung damage, hyperlactatemia, blood acidosis, impaired oxygen transport, and mortality in critically ill covid-19 patients. *bioRxiv.* https://doi.org/10.1101/2023.09.17.558185

Yuswandi, Y., Warongan, A. W., & Rayasari, F. (2020). Hemodynamic status of patients under mechanical ventilation in the left lateral position with a 30-degree head elevation. *Journal of Islamic Nursing, 5*(2).