UTJECAJ POZICIONIRANJA I RESPIRATORNE FIZIOTERAPIJE NA KLINIČKE ISHODE U MEHANIČKI VENTILIRANIH BOLESNIKA - SUSTAVNI PREGLED

The impact of positioning and respiratory physiotherapy on clinical outcomes in mechanically ventilated patients – a systematic review

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SUSTAVNI PREGLED / SYSTEMATIC REVIEW
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Abstract

Introduction: Patients on mechanical ventilation in intensive care units often experience complications such as ventilator-associated pneumonia (VAP), prolonged hospitalization, and pressure ulcers. Patient positioning and respiratory physiotherapy are increasingly recognized as key non-pharmacological interventions that can influence treatment outcomes.

Aim: The aim of this paper was to investigate the impact of positioning and physiotherapy interventions on clinical outcomes in mechanically ventilated patients.

Materials and Methods: A systematic search was conducted in the databases PubMed, Scopus, Web of Science, PEDro, Physiopedia, and CRORIS for the period from January 1, 2015., to May 31, 2025. Combined MeSH terms and free-text key words were used, following the PICO framework. A total of 18 original studies meeting the predetermined quality criteria were included. Review articles, and those unrelated to the topic were excluded.

Results: The analysis showed that combined interventions such as prone positioning and respiratory physiotherapy ignificantly reduced the duration of mechanical ventilation, incidence of VAP, and overall length of hospital stay. The most positive outcomes were observed in interventions that included active physiotherapy combined with targeted positioning.

Conclusion: Positioning and respiratory physiotherapy are effective, safe, and clinically justified interventions that significantly improve treatment outcomes. Their systematic implementation in intensive care protocols is recommended.

Key words: mechanical ventilation, patient positioning, respiratory physiotherapy, ventilator-associated pneumonia, intensive care, prone position, physiotherapy interventions.

Sažetak

Uvod: Kod bolesnika na mehaničkoj ventilaciji u jedinicama intenzivne skrbi često dolazi do komplikacija poput ventilator-asocirane pneumonije (VAP), produljene hospitalizacije. Pozicioniranje bolesnika i respiratorna fizioterapija sve se više prepoznaju kao ključne nefarmakološke mjere koje mogu utjecati na ishod liječenja.

Cilj: Cilj ovog rada bio je istražiti utjecaj pozicioniranja i fizioterapijskih intervencija na kliničke ishode mehanički ventiliranih bolesnika.

Materijali i metode: Provedena je sustavna pretraga baza; PubMed, PEDro, Physiopedia i CRORIS za razdoblje od 1. siječnja 2015. do 31. svibnja 2025. godine. Korišteni su kombinirani MeSH termini i slobodni tekstualni izrazi, uz primjenu PICO okvira. Uključeno je 18 originalnih studija koje su ispunjavale zadane kriterije kvalitete, a isključeni su studije izvan teme.

Rezultati: Analiza pokazuje da su kombinirane intervencije, poput prone pozicije i respiratorne fizioterapije značajno utjecale na smanjenje trajanja mehaničke ventilacije, incidencije VAP-a, te ukupne duljine boravka u bolnici. Najviše pozitivnih rezultata zabilježeno je kod intervencija koje su uključivale aktivnu fizioterapiju uz ciljano pozicioniranje.

Zaključak: Pozicioniranje i respiratorna fizioterapija su učinkovite, sigurne i klinički opravdane mjere koje značajno poboljšavaju ishode liječenja. Preporučuje se njihova sustavna implementacija u protokole intenzivne skrbi.

Ključne riječi: mehanička ventilacija, pozicioniranje bolesnika, respiratorna fizioterapija, ventilator-asocirana pneumonija, intenzivna njega, prona pozicija, fizioterapijske intervencije.

Introduction

Mechanical ventilation is a fundamental form of support for patients with acute respiratory failure, particularly in intensive care units (ICUs). Although it is life-saving, prolonged mechanical ventilation is associated with a range of serious complications, including ventilator-associated pneumonia (VAP), atelectasis, respiratory muscle weakness, pressure ulcers, and extended hospital stays (1,2). In this context, increasing attention is being directed toward non-pharmacological interventions, especially respiratory physiotherapy and patient positioning as key strategies for optimizing treatment and preventing secondary complications. Respiratory physiotherapy encompasses a set of interventions aimed at improving ventilation, promoting secretion clearance, and preventing secondary respiratory complications. These techniques include patient positioning, facilitation of passive and active breathing, in-bed and out-of-bed mobilization, manual and mechanical drainage methods (percussion, vibration), PEEP devices, incentive spirometry, and neuromuscular stimulation (3,4,5). These interventions have been shown to reduce the duration of mechanical ventilation, improve oxygenation, and facilitate weaning (6,7). The combination of physiotherapy and active positioning is particularly beneficial for sedated patients and those with severe hypoxia (8,9,10). Patient positioning is a clinically significant intervention that utilizes gravity and perfusion redistribution to enhance ventilation/perfusion (V/Q) matching in the lungs. The most studied positions include: the prone position, which promotes alveolar recruitment in the dorsal lung regions; the semi-recumbent position (30–45°), which reduces the risk of aspiration; and lateral and rotational positioning, which facilitate secretion drainage and redistribution (10,11). Numerous studies confirm that prone positioning combined with physiotherapy significantly reduces mortality in ARDS patients, especially when applied for more than 12 hours per day (10,12). Conversely, the supine position has been associated with a higher incidence of pressure ulcers and aspiration (13,14,15).

Positioning of mechanically ventilated patients is one of the fundamental procedures in intensive care, with critical importance for respiratory and overall clinical stability. Proper positioning helps prevent atelectasis, enhances alveolar ventilation, facilitates secretion clearance, and reduces the risk of respiratory infections and complications such as aspiration or hypoxemia (16). Regular repositioning of the body, with the use of appropriate equipment and technology, allows for better redistribution of pulmonary ventilation and perfusion, thereby improving oxygenation and reducing the risk of hypostatic changes. The use of modern so-called smart hospital beds, which allow automatic inclination adjustments, micro-movements, and lateral positioning, greatly facilitates the daily work of healthcare providers and contributes to safer and more effective care (17). However, each positioning maneuver requires careful consideration of several important factors: stabilization of the endotracheal tube and other invasive lines, prevention of pressure injuries, ensuring proper body alignment, and continuous monitoring of vital parameters. An individualized approach, taking into account the patient's underlying condition, respiratory status, and therapeutic goals, is essential for the appropriate implementation of this intervention (18).

Materials and Methods

This systematic review utilized the PICO framework to structure the research question:

Population (P): Adult patients on mechanical ventilation in intensive care units, regardless of the underlying diagnosis.

Intervention (I): Respiratory physiotherapy and/or therapeutic positioning (prone, semi-recumbent, lateral), including manual hyperinflation, percussion, mobilization, and a multimodal approach.

Comparison (C): Standard medical care without targeted physiotherapy or positioning strategies (supine position).

Outcomes (O): Incidence of VAP, mortality, oxygenation (SpO2, PaO2/FiO2), length of stay (LOS), duration of mechanical ventilation (MV), and time to weaning.

A systematic search of electronic databases; PubMed, Scopus, Web of Science, PEDro, Physiopedia, and the national database CRORIS was conducted for the period from January 1, 2015, to May 31, 2025. The search was performed in May 2025 using a combination of MeSH terms and free-text keywords: "mechanical ventilation," "respiratory physiotherapy" OR "chest physiotherapy," "positioning" OR "prone position" OR "lateral positioning," "intensive care," "ventilator-associated pneumonia," "mobilization." The search strategy was informed by methodologies from previous studies (3,18) and adapted according to PRISMA 2020 guidelines (19). Inclusion criteria encompassed: original scientific papers (RCTs, meta-analyses, systematic reviews, observational and retrospective cohort studies, and pilot studies); studies involving adult patients (>18 years) on invasive mechanical ventilation; interventions clearly defined as respiratory physiotherapy and/or positioning; and studies reporting at least one relevant clinical outcome, published in English or Croatian. Exclusion criteria included: case reports, letters to the editor, studies involving pediatric populations, and studies without clearly defined intervention groups. Titles and abstracts were independently screened by two reviewers. Potentially relevant full texts were retrieved and assessed. Methodological quality was evaluated using the PEDro scale (20) for quantitative studies and further analyzed using the GRADE approach to assess the overall strength of evidence (21). The PEDro scale assesses methodological quality across 11 criteria, including randomization, blinding, and data completeness. The GRADE system categorizes evidence strength into four levels—high, moderate, low, and very low based on study design, consistency of results, directness of evidence, precision, and risk of bias. A total of 18 studies meeting all inclusion criteria were included in the final review. Levels of evidence and heterogeneity among studies were considered during result interpretation. The most common study designs were randomized controlled trials (n=9), meta-analyses and systematic reviews (n=5), quasi-experimental study (n=1), cohort study (n=2), and pilot study (n=1). Data were organized by intervention type and outcomes. Relative risks and mean values were used for quantitative data (where available), while qualitative data were synthesized narratively. Due to methodological heterogeneity and outcome variability, a meta-analysis was not conducted; instead, a narrative synthesis of findings was performed, in line with current recommendations (23).

Results

Study extraction by database is summarized in **Table 1.** The data screening process is illustrated by the PRISMA flow diagram **(Figure 1).** A qualitative synthesis of included studies, categorized by study design, outcomes, and methodological quality, is presented in **Table 2.**

Table 1. Study extraction by database

Database	Studies Identified	Excluded	Included
PubMed	56	49	7
Scopus	42	38	4
Web of Science	39	37	2
PEDro	26	23	3
Physiopedia	17	15	2
CRORIS	11	10	0
TOTAL:	193	172	18

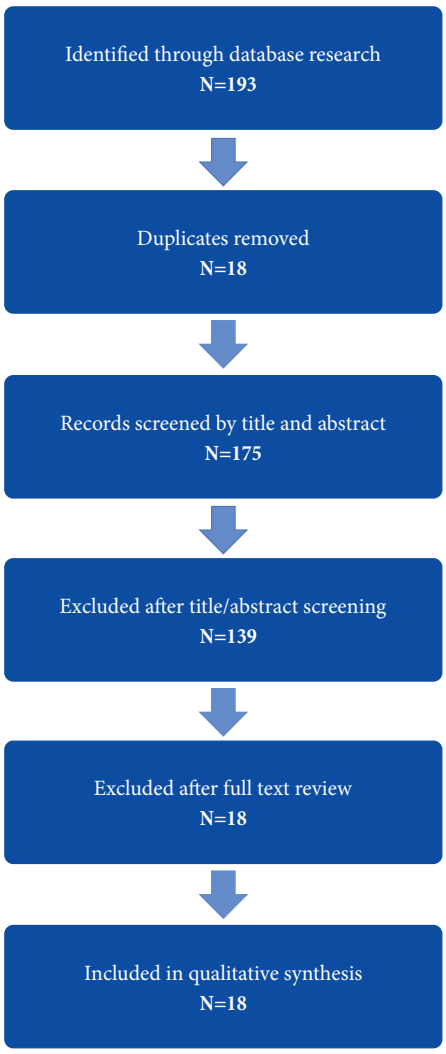

Figure 1. PRISMA Flow diagram of included studies

Table 2. Qualitative synthesis of included studies by study type, outcomes, and quality

Author(s)	Year	Study Type	Participants	Intervention(s); Clinical outcomes	GRADE	PEDro Score
Wang et al. (23)	2016	Cochrane Review	759	Semi-recumbent positioning; reduced VAP, no significant change in mortality, ICU/ hospital LOS, or ventilation duration	Moderate	N/A
Demir et al.	2025	RCT	94	Prone positioning vs non-prone; improved oxygenation (SpO2, PaO2/ FiO2), better ventilator parameters	Moderate	7
Lippi et al.	2022	Systematic review and meta-analysis	12 RCTs (1200) Meta-analysis (540)	Multimodal physiotherapy including respiratory physiotherapy; improved oxygenation, shorter duration on MV, enhanced functional recovery	Moderate	N/A
Azimi et al.	2025	RCT	60	Lung squeezing technique (LST), chest vibration/percussion (CVPT); improved weaning index in LST group; on change in oxygen saturation or vital signs	Moderate	7
Berti et al.	2019	RCT	49	Manual hyperinflation + chest compression; faster ICU discharger-improved Murray score, shortened MV duration	Moderate	7
Elrefaey & Zidan	2020	RCT	42 ICU patients with VAP	Manual hyperinflation + respiratory physiotherapy; lateral position improved arterial blood gases (SpO2, PaO2/FiO2)	Moderate	6
Pozuelo Carrascosa et al.	2018	Systematic review and meta-analysis of RCTs	5 RCTs, 650	Multimodal respiratory physiotherapy; reduced mortality, unclear effect on VAP incidence and ICU length of stay	Moderate	N/A
Pozuelo Carrascosa et al.	2022	Systematc review and Network meta-analysis	RCT (under MV 120) Meta-analyses/ systematic review (1560)	Semi-recumbent; prone; lateral-Trendelenburg position; reduced VAP incidence, MV duration, ICU and hospital stay; reduced mortality with prone positioning; no effect prone on VAP	High	N/A
Ruo-Yan Wu et al.	2023	Systematic review and meta-analysis	2567	Convencional PT, exercise –besed PT, NEMS, progressive mobility, multi-component protocols; reduce MV duration, improved weaning success, better functional recovery, no increase in complications	High	N/A
Khalil et al.	2021	Quasi-experimental trail (prospective)	73	Manual hyperinflation combined with expiratory rib cage compression and endotracheal suctioning; improvement in PaO2, SPo2 after interventions and body positions	Moderate	N/A

Author(s)	Year	Study Type	Participants	Intervention(s); Clinical outcomes	GRADE	PEDro Score
Bassi et al.	2017	RCT	395 (LTP 194) (SRP 201)	Trendelenburg vs. semi-recumbent positioning; LTP significantly reduced incidence of VAP; no difference in mortality or ICU/MV duration	Moderate	7
Ayzac et al.	2015	Retrospective analysis, RCT (secondary)	466 (237 prone, 2 supine)	Prone positioning; no VAP difference	Moderate	N/A
Mora-Arteaga et al.	2015	Systematic review and meta-analysis	2 119 patients from 7 RCTs	Prone positioning compared to supine; improved ventilation, reduce mortality	Moderate	N/A
Stilma et al.	2021	Multicenter observational cohort	734 ventilated COVID-19 patients (18 centers)	Prone positioning; slightly increased ICU/hospital discharge; no ventilator-free days	Low	N/A
Garcia-Vidal et al.	2021	Retrospective cohort study	81 COVID-19 patients 144 non COVID-19 patients	No specific interventions; COVID-19 patients had significantly higher incidence of VAP vs non-COVID	Low	N/A
Ivaldi et al.	2021	Pilot Study	2 staff members	Exoskeleton for prone – helped staff positioning; reduced back strain and fatigue	Low	N/A
Naghibi et al.	2023	RCT	120	Higher ventilator inspiratory pressure (30 cmH20) vs lower pressure setting (20 cmH2o); lower clinical pulmonary infection, no difference in mortality, lower CPIS, SOFA	Moderate	7
Maertens et al.	2018	Systematic review and meta-analysis	11 RCT, 2092 patients on MV	Positioning with inflatable cuffs; reduced VAP, mortality, MV duration and ICU stay	Moderate	N/A

Abbreviations: RCT – randomized controlled trial;VAP – ventilator-associated pneumonia; ICU – intensive care unit; LOS – length of stay; MV – mechanical ventilation; SpO_2 – peripheral capillary oxygen saturation; PaO_2/FiO_2 – arterial oxygen partial pressure to fraction of inspired oxygen ratio; LST – lung squeezing technique; CVPT – chest vibration and percussion technique; PT – physiotherapy; NEMS – neuromuscular electrical stimulation; CPIS – clinical pulmonary infection score; SOFA – sequential organ failure assessment; GRADE – Grading of Recommendations Assessment, Development and Evaluation; PEDro Score – Physiotherapy Evidence Database Score; N/A – not applicable; LTP – lateral Trendelenburg position; SRP – semi-recumbent position.

Discussion

The results of this systematic review clearly underscore the importance of integrating respiratory physiotherapy and targeted positioning into routine care for mechanically ventilated patients. These non-pharmacological measures are increasingly recognized as essential components not only for supporting primary therapy but also as active contributors to reducing the duration of mechanical ventilation, minimizing complications, and improving overall patient recovery. Positioning in the ICU is no longer viewed as a passive action, but rather as a dynamic therapeutic intervention. The prone position optimizes the ventilation/perfusion ratio, reduces compression of the posterior lung regions, promotes ventilation redistribution, and facilitates secretion drainage. Numerous studies confirm the positive effects of prone positioning in patients with ARDS and severe hypoxemia (24, 30). A randomized trial involving 94 patients showed that prone positioning significantly improved oxygenation parameters (SpO2, PaO2/FiO2) (22). These findings were corroborated by a network meta-analysis that included data from 120 randomized controlled trials (11). However, some studies reported no statistically significant effect of the prone position on the incidence of VAP, suggesting potential clinical heterogeneity (29). The semi-recumbent position (30–45°) is recognized as a measure that reduces the risk of aspiration. Although it has not shown significant effects on mortality or duration of ventilation, it has been effective in preventing VAP (12). A multicenter study reported that the lateral Trendelenburg position significantly reduced the incidence of VAP compared to the semi-recumbent position (28). Furthermore, a meta-analysis confirmed that positioning, in combination with inflated endotracheal cuffs, can reduce VAP, mortality, ventilation duration, and ICU length of stay (35). Several high-quality systematic reviews and meta-analyses consistently affirm the effectiveness of multimodal respiratory physiotherapy (3, 25, 26). These interventions improve oxygenation, accelerate weaning, reduce ventilation duration, and enhance functional independence. Importantly, these protocols do not increase the risk of complications, making them safe for routine implementation. Among specific techniques, manual hyperinflation, vibrations, expiratory chest compression, and the "lung squeezing" method are particularly noteworthy. In a randomized study, the LST technique improved the weaning index, although it had no significant impact on oxygenation (4). The combination of manual hyperinflation and chest compression shortened ventilation duration and expedited ICU discharge (23). Applying this technique in the lateral position also improved arterial blood gas values (24). Combined techniques that include suctioning have demonstrated improvements in oxygenation parameters (27). The use of exoskeletons for assisted prone positioning exemplifies how technology can enhance patient safety and reduce the physical burden on healthcare professionals (33). However, some studies indicate limited benefits of early prone positioning in patients with COVID-19 (31, 32). Additionally, higher inspiratory pressure may reduce CPIS without affecting mortality (34), highlighting the need for additional parameters in evaluating intervention outcomes. Positioning and respiratory physiotherapy are complementary strategies that are safe, effective, and evidence-based. Proper implementation can reduce the burden on the healthcare system and improve patient outcomes. However, broader adoption requires additional resources, staff training, and a multidisciplinary approach. Systematic incorporation of these interventions into intensive care protocols is justified, though further scientific validation is necessary through standardized trials. Although the presented results are strongly suggestive, methodological diversity among included studies significantly limits the ability to conduct meta-analyses and draw definitive conclusions. Most included studies had moderate methodological quality, with an average PEDro score between 6 and 7, indicating certain limitations such as lack of blinding or incomplete participant follow-up. Evidence quality assessment using the GRADE approach showed that most studies provided moderate strength of evidence, with some rated as high-quality (e.g., network meta-analyses) and others with low evidence levels. This variability further limits the generalizability of the conclusions. Nonetheless, the presence of several well-designed randomized trials and systematic reviews provides a relatively solid foundation for recommending the integration of physiotherapeutic and positioning strategies into intensive care protocols. Additional high-quality research with standardized protocols is needed to strengthen the evidence base and enable clearer clinical guidelines.

Conclusion

This review evaluates current evidence and clinical practices in the care of mechanically ventilated patients through a detailed and methodologically structured analysis. Its strength lies in the inclusion of the most recent studies from relevant scientific databases, using clearly defined selection criteria. The focus on combined non-pharmacological interventions, respiratory physiotherapy and positioning is particularly noteworthy, as they are examined in relation to each other rather than in isolation. The systematic review demonstrates the clear clinical value of respiratory physiotherapy and targeted positioning in managing mechanically ventilated patients. These combined non-pharmacological measures contribute to reducing the duration of ventilatory support, lowering the incidence of complications such as VAP, and improving oxygenation and overall treatment outcomes. An integrated approach that combines active mobilization techniques with therapeutic

positions such as prone and semi-recumbent—tailored to the patient's individual condition proves especially effective. Nevertheless, the results must be interpreted with caution due to potential limitations. Chief among these is the methodological heterogeneity of the studies, including differing designs, intervention definitions, and outcome measures, which prevented meta-analysis. The variable quality of evidence further complicates the ability to draw general conclusions, and the lack of data on long-term outcomes remains a concern. The exclusion of grey literature and limitation to studies published in Croatian and English may have resulted in a partial representation of the existing body of evidence. Moreover, the absence of standardized protocols in most studies limits the applicability of findings across different clinical settings. Therefore, there is a clear need for further high-quality research to develop evidence-based guidelines aimed at improving and harmonizing practices in intensive care units.

References

1. Van Nieuwenhoven, C. A., Vandenbroucke-Grauls, C., Van Tiel, F. H., Joore, H. C. A., Van Schijndel, R. J. M. S., Van Der Tweel, I., Ramsay, G., & Bonten, M. J. M. (2006). Feasibility and effects of the semirecumbent position to prevent ventilator-associated pneumonia: A randomized study*. Critical Care Medicine, 34(2), 396–402. https://doi.org/10.1097/01.ccm.0000198529.76602.5e
2. Dolinay, T., Hsu, L., Maller, A., Walsh, B. C., Szűcs, A., Jerng, J., & Jun, D. (2024). Ventilator Weaning in Prolonged Mechanical Ventilation—A Narrative Review. Journal of Clinical Medicine, 13(7), 1909. https://doi.org/10.3390/jcm13071909
3. Lippi, L., De Sire, A., D'Abrosca, F., Polla, B., Marotta, N., Castello, L. M., Ammendolia, A., Molinari, C., & Invernizzi, M. (2022). Efficacy of Physiotherapy Interventions on weaning in mechanically ventilated Critically Ill Patients: A Systematic Review and Meta-Analysis. Frontiers in Medicine, 9. https://doi.org/10.3389/fmed.2022.889218
4. Azimi, F., Nazari, A. M., Yadollahi, F., Etemadifar, S., Kheiri, S., & Masoudi, R. (2025). The comparison of two types of physiotherapy techniques on selected weaning indices of patients requiring mechanical ventilation: a single blind randomized controlled trial. Scientific Reports, 15(1). https://doi.org/10.1038/s41598-025-03701-5
5 Othman, S. Y., Elbiaa, M. A., Mansour, E. R., El-Menshawy, A. M., & Elsayed, S. M. (2023). Effect of neuromuscular electrical stimulation and early physical activity on ICU-acquired weakness in mechanically ventilated patients: A randomized controlled trial. Nursing in Critical Care, 29(3), 584–596. https://doi.org/10.1111/nicc.13010
6. Ibañez, J., Raurich, J. M., Abizanda, R., Claramonte, R., Ibañez, P., & Bergada, J. (1981). The effect of lateral positions on gas exchange in patients with unilateral lung disease during mechanical ventilation. Intensive Care Medicine, 7(5), 231–234. https://doi.org/10.1007/bf01702625
7. Drolet, A., DeJuilio, P., Harkless, S., Henricks, S., Kamin, E., Leddy, E. A., Lloyd, J. M., Waters, C., & Williams, S. (2012). Move to improve: the feasibility of using an early mobility protocol to increase ambulation in the intensive and intermediate care settings. Physical Therapy, 93(2), 197–207. https://doi.org/10.2522/ptj.20110400
8. Robak, O., Schellongowski, P., Bojic, A., Laczika, K., Locker, G. J., & Staudinger, T. (2011). Short-term effects of combining upright and prone positions in patients with ARDS: a prospective randomized study. Critical Care, 15(5). https://doi.org/10.1186/cc10471
9. Stiller, K. (2000). Physiotherapy in intensive care. CHEST Journal, 118(6), 1801–1813. https://doi.org/10.1378/chest.118.6.1801
10. Munshi, L., Del Sorbo, L., Adhikari, N. K. J., Hodgson, C. L., Wunsch, H., Meade, M. O., Uleryk, E., Mancebo, J., Pesenti, A., Ranieri, V. M., & Fan, E. (2017). Prone position for Acute Respiratory Distress Syndrome. A Systematic Review and Meta-Analysis. Annals of the American Thoracic Society, 14(Supplement_4), S280–S288. https://doi.org/10.1513/annalsats.201704-343ot
11. Pozuelo-Carrascosa, D. P., Cobo-Cuenca, A. I., Carmona-Torres, J. M., Laredo-Aguilera, J. A., Santacruz-Salas, E., & Fernandez-Rodriguez, R. (2022). Body position for preventing ventilator-associated pneumonia for critically ill patients: a systematic review and network meta-analysis. Journal of Intensive Care, 10(1). https://doi.org/10.1186/s40560-022-00600-z
12. Wang, L., Li, X., Yang, Z., Tang, X., Yuan, Q., Deng, L., & Sun, X. (2016). Semi-recumbent position versus supine position for the prevention of ventilator-associated pneumonia in adults requiring mechanical ventilation. Cochrane Library, 2016(1). https://doi.org/10.1002/14651858.cd009946.pub2
13. Higgins TS, Altman KW, Best SR, et al. Technical Brief: Head-of-Bed Elevation to Reduce Risk of Aspiration and Ventilator-Associated Events. Agency for Healthcare Research and Quality (AHRQ). Published 2023. Available at: https://www.ahrq.gov
14. Smith, A., & Dunn, K. M. (2022). Research Note: Deriving latent trajectories in health research. Journal of Physiotherapy, 69(1), 61–64. https://doi.org/10.1016/j.jphys.2022.11.001
15. Yıldızeli, Ş. O. (2024). Determinants of hospital stay, mortality, and readmission in aspiration pneumonia patients. European Journal of Geriatrics and Gerontology. https://doi.org/10.4274/ejgg.galenos.2024.2024-2-1
16. 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
17. Ghersi, I., Mariño, M., & Miralles, M. T. (2018). Smart medical beds in patient-care environments of the twenty-first century: a state-of-art survey. BMC Medical Informatics and Decision Making, 18(1). https://doi.org/10.1186/s12911-018-0643-5
18. Tobin, M. J., Laghi, F., & Jubran, A. (2020). Caution about early intubation and mechanical ventilation in COVID-19. Annals of Intensive Care, 10(1). https://doi.org/10.1186/s13613-020-00692-6
19. Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., . . . Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ, n71. https://doi.org/10.1136/bmj.n71
20. Reliability of the PEDro scale for rating quality of randomized controlled trials. (2003, August 1). PubMed. https://pubmed.ncbi.nlm.nih.gov/12882612/
21. Guyatt, G. H., Oxman, A. D., Vist, G. E., Kunz, R., Falck-Ytter, Y., Alonso-Coello, P., & Schünemann, H. J. (2008). GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. BMJ, 336(7650), 924–926. https://doi.org/10.1136/bmj.39489.470347.ad
22. Demir, B. D., Enç, N., & Börekçi, Ş. (2025). The effect of prone positioning on ventilator parameters, blood gas levels, and ventilator-associated pneumonia in intensive care unit patients: a randomized controlled trial. BMC Nursing, 24(1). https://doi.org/10.1186/s12912-025-02817-3

23. Berti, J. S. W., Tonon, E., Ronchi, C. F., Berti, H. W., De Stefano, L. M., Gut, A. L., Padovani, C. R., & Ferreira, A. L. A. (2012). Hiperinsuflação manual combinada com compressão torácica expiratória para redução do período de internação em UTI em pacientes críticos sob ventilação mecânica. Jornal Brasileiro De Pneumologia, 38(4), 477–486. https://doi.org/10.1590/s1806-37132012000400010

24. Elrefaey, B. H., & Zidan, M. S. (2020). Efficacy of manual hyperinflation on arterial blood gases in patients with ventilator-associated pneumonia. Bulletin of Faculty of Physical Therapy, 25(1). https://doi.org/10.1186/s43161-020-00006-8

25. Pozuelo-Carrascosa, D. P., Torres-Costoso, A., Alvarez-Bueno, C., Cavero-Redondo, I., Muñoz, P. L., & Martínez-Vizcaíno, V. (2018). Multimodality respiratory physiotherapy reduces mortality but may not prevent ventilator-associated pneumonia or reduce length of stay in the intensive care unit: a systematic review. Journal of Physiotherapy, 64(4), 222–228. https://doi.org/10.1016/j.jphys.2018.08.005

26. Wu, R., Yeh, H., Chang, K., & Tsai, M. (2023). Effects of different types and frequencies of early rehabilitation on ventilator weaning among patients in intensive care units: A systematic review and meta-analysis. PLoS ONE, 18(4), e0284923. https://doi.org/10.1371/journal.pone.0284923

27. Khalil, N. S., Ismaeel, M. S., Askar, A. H., & Sayed, M. S. (2021). Effects of manual hyperinflation with rib cage compression and endotracheal suctioning on arterial blood gas parameters in mechanically ventilated patients at a university hospital, Egypt. Egyptian Journal of Bronchology, 15(1). https://doi.org/10.1186/s43168-021-00096-5

28. Bassi, G. L., Panigada, M., Ranzani, O. T., Zanella, A., Berra, L., Cressoni, M., Parrini, V., Kandil, H., Salati, G., Selvaggi, P., Amatu, A., Sanz-Moncosi, M., Biagioni, E., Tagliaferri, F., Furia, M., Mercurio, G., Costa, A., Manca, T., Lindau, S., . . . Torres, A. (2017). Randomized, multicenter trial of lateral Trendelenburg versus semirecumbent body position for the prevention of ventilator-associated pneumonia. Intensive Care Medicine, 43(11), 1572–1584. https://doi.org/10.1007/s00134-017-4858-1

29. Ayzac, L., Girard, R., Baboi, L., Beuret, P., Rabilloud, M., Richard, J. C., & Guérin, C. (2015). Ventilator-associated pneumonia in ARDS patients: the impact of prone positioning. A secondary analysis of the PROSEVA trial. Intensive Care Medicine, 42(5), 871–878. https://doi.org/10.1007/s00134-015-4167-5

30. Mora-Arteaga, J., Bernal-Ramírez, O., & Rodríguez, S. (2015). Efecto de la ventilación mecánica en posición prona en pacientes con síndrome de dificultad respiratoria aguda. Una revisión sistemática y metanálisis. Medicina Intensiva, 39(6), 352–365. https://doi.org/10.1016/j.medin.2014.11.003

31. Stilma, W., Van Meenen, D. M. P., Valk, C. M. A., De Bruin, H., Paulus, F., Neto, A. S., & Schultz, M. J. (2021). Incidence and Practice of Early Prone Positioning in Invasively Ventilated COVID-19 Patients—Insights from the PRoVENT-COVID Observational Study. Journal of Clinical Medicine, 10(20), 4783. https://doi.org/10.3390/jcm10204783

32. Garcia-Vidal, C., Sanjuan, G., Moreno-García, E., Puerta-Alcalde, P., Garcia-Pouton, N., Chumbita, M., Fernandez-Pittol, M., Pitart, C., Inciarte, A., Bodro, M., Morata, L., Ambrosioni, J., Grafia, I., Meira, F., Macaya, I., Cardozo, C., Casals, C., Tellez, A., Castro, P., . . . Torres, A. (2020). Incidence of co-infections and superinfections in hospitalized patients with COVID-19: a retrospective cohort study. Clinical Microbiology and Infection, 27(1), 83–88. https://doi.org/10.1016/j.cmi.2020.07.041

33. Ivaldi, S., Maurice, P., Gomes, W., Theurel, J., Wioland, L., Atain-Kouadio, J., Claudon, L., Hani, H., Kimmoun, A., Sellal, J., Levy, B., Paysant, J., Malikov, S., Chenuel, B., & Settembre, N. (2021). Using exoskeletons to assist medical staff during prone positioning of mechanically ventilated COVID-19 patients: a pilot study. In Lecture notes in networks and systems (pp. 88–100). https://doi.org/10.1007/978-3-030-80744-3_12

34. Naghibi, T., & Karimi, H. (2022). The impact of inspiratory pressure level on prevention of ventilator-associated pneumonia: A double-blind, randomized clinical trial. The American Journal of the Medical Sciences, 365(2), 162–168. https://doi.org/10.1016/j.amjms.2022.07.020

35. Maertens, B., Blot, K., & Blot, S. (2017). Prevention of Ventilator-Associated and early postoperative pneumonia through tapered endotracheal tube cuffs: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. Critical Care Medicine, 46(2), 316–323. https://doi.org/10.1097/ccm.0000000000002889