
Narrative Review

Adverse Events of Prone Positioning in Mechanically Ventilated Adults with Acute Respiratory Distress Syndrome

<https://doi.org/10.4187/respcare.09194>

Cite as: RESPCARE 2021; 10.4187/respcare.09194

Received: 9 April 2021

Accepted: 19 July 2021

This Fast Track article has been peer-reviewed and accepted, but has not been through the composition and copyediting processes. The final version may differ slightly in style or formatting and will contain links to any supplemental data.

Alerts: Sign up at rc.rcjournal.com/alerts to receive customized email alerts when the fully formatted version of this article is published.

Title page

Title: Adverse Events of Prone Positioning in Mechanically Ventilated Adults with Acute Respiratory Distress Syndrome

Running head: Adverse Events of Prone Positioning (AE-PRONE)

Authors

Felipe González-Seguel MSc PT*^{1,2} (a,b,c,d,e,f), Juan José Pinto-Concha MSc PT^{2,3}(a,b,c,d,f),
Nadine Aranís MSc PT^{1,2}(b,d,f), Jaime Leppe MSc PT²(c,f)

¹ Servicio de Medicina Física y Rehabilitación and Departamento de Paciente Crítico, Clínica Alemana Universidad del Desarrollo, Santiago, Chile.

² Master program in Physical Therapy and Rehabilitation, Carrera de Kinesiología, Facultad de Medicina, Clínica Alemana Universidad del Desarrollo, Santiago, Chile.

³ Centro de Paciente Crítico Adulto, Clínica INDISA, Santiago, Chile.

Contributions of each author: ^aLiterature search, ^bData collection, ^cStudy design, ^dAnalysis of data, ^eManuscript preparation, ^fManuscript review

Declaration: This study was performed under the Master program in Physical Therapy and Rehabilitation, Carrera de Kinesiología, Facultad de Medicina, Clínica Alemana Universidad del Desarrollo, Santiago, Chile

Sources of financial support: None

Conflict of interest: The authors of this paper have no conflicts of interest to declare.

***Correspondence:** Felipe González-Seguel PT MSc, Servicio de Medicina Física y Rehabilitación and Departamento de Paciente Crítico, Facultad de Medicina, Clínica Alemana Universidad del Desarrollo, Av. Plaza 680, Santiago, Chile. E-mail: feligonzalezs@udd.cl ORCID: <https://orcid.org/0000-0001-9099-2389>

Abstract (300/300)

INTRODUCTION: Prone positioning is a therapy utilized globally to improve gas exchange, minimize ventilator-induced lung injury, and reduce mortality in acute respiratory distress syndrome (ARDS), particularly during the ongoing coronavirus disease 2019 (COVID-19) pandemic. While the respiratory benefits of prone positioning in ARDS have been accepted, the concurrent complications could be undervalued. Therefore, this study aimed to identify the adverse events related to prone positioning in ARDS, and secondarily, to collect strategies and recommendations to mitigate these adverse events.

METHODS: In this scoping review, we searched recommendation documents and original studies published between June 2013 and November 2020 from six relevant electronic databases and the websites of intensive care societies.

RESULTS: We selected 41 documents from 121 eligible documents, comprising 13 recommendation documents and 28 original studies (involving 1,578 patients and 994 prone maneuvers). We identified more than 40 individual adverse events, and the highest pooled occurrence rates were that of severe desaturation (37.9%), barotrauma (30.5%), pressure sores (29.7%), ventilation-associated pneumonia (28.2%), facial edema (16.7%), arrhythmia (15.4%), hypotension (10.2%), and peripheral nerve injuries (8.1%). The reported mitigation strategies during prone positioning include alternate face rotation (18 [43.9%]), repositioning every 2 hours (17 [41.5%]), and the use of pillows under the chest and pelvis (14 [34.1%]). The reported mitigation strategies for performing the prone maneuver comprise one person being at the headboard (23 [56.1%]), the use of a pre-manuever safety checklist (18 [43.9%]), vital sign monitoring (15 [36.6%]), and ensuring appropriate ventilator settings (12 [29.3%]).

CONCLUSIONS: We identified >40 adverse events reported in prone positioning ARDS studies, involving additional AEs not yet reported by previous systematic reviews. The

pooled adverse event proportions collected in this review could guide research and clinical practice decisions, and the strategies to mitigate adverse events could promote future consensus-based recommendations.

Keywords: prone position; mechanical ventilation; acute respiratory distress syndrome, respiratory failure, adverse events, complications

Introduction

Acute respiratory distress syndrome (ARDS) has a mortality rate between 20% and 48%¹⁻³ and survivors commonly experience long-term physical, cognitive, and mental impairments^{4,5}. Prone positioning is among the well-known strategies to counteract ARDS⁶⁻⁸, and is an inexpensive intervention that requires no complex technology, making it feasible worldwide⁹. In particular, early (between 12 and 24 hours after ARDS diagnosis) and extended prone positioning (>16 hours per day) demonstrated decreased mortality from 41% to 24% in the 2013 Prone Severe ARDS Patients (PROSEVA) trial¹⁰ when compared with supine positioning. Subsequently, prone positioning has been incorporated as a strong recommendation in international practice guidelines of ARDS,¹¹⁻¹⁴ including the World Health Organization guidelines for the management of the coronavirus disease 2019 (COVID-19)¹⁵.

Although prone positioning is an established therapy worldwide for improving gas exchange, minimizing ventilator-induced lung injury, and reducing mortality in ARDS^{10,16}, the literature demonstrates several adverse events (AEs), such as unplanned extubation, removal of invasive devices, transient desaturation, airway obstruction, facial edema, and pressure sores^{10,17-21}. Currently, prone positioning has been widely applied even in awake patients supported with non-invasive ventilation or oxygen therapy²²; however, patients who are mechanically ventilated and sedated are more likely to reveal complications related to position changes. Four systematic reviews with meta-analyses involving up to 11 randomized controlled trials published between 2001 and 2013 (including the PROSEVA trial) revealed that a significant increase in new pressure sores, airway obstruction, and unplanned extubation occurred with prone positioning than with supine positioning²³⁻²⁶.

Since the publication of the PROSEVA trial, and particularly from the onset of the ongoing pandemic, global recommendations for prone positioning have been given greater emphasis¹¹⁻¹⁴, which could lead to an increase in the incidence and intensity of AEs. This is predominantly relevant for inexperienced clinicians in prone positioning processes, who may be compelled to undertake this therapy during the pandemic²⁷. To safely prone ventilated patients with ARDS in intensive care units (ICUs), minimizing human resource impacts, appropriate training, simulation, and health system planning must be undertaken²⁸. Numerous guidelines recommend safe tips to minimize risk²⁹⁻³¹; however, to implement prone positioning, clinicians must also recognize and consider the potential AEs. While the respiratory benefits of prone positioning in patients with ARDS is widely accepted, the concurrent complications could be undervalued. Although some reviews on prone positioning have compiled AEs^{21,30,32}, there have been no reviews that specifically include studies after the PROSEVA trial. Moreover, there are no reviews that fully collected AEs associated with prone positioning in mechanically ventilated adults with ARDS. Therefore, a scoping review is a recommended first step to systematically map the available literature from this landmark point^{33,34}.

Accordingly, the primary objective of this study was to identify AEs related to prone positioning in mechanically ventilated adults with ARDS, and secondarily, to collect strategies and recommendations to mitigate the AEs during prone positioning implementation.

Review of the Literature

Study Design

This scoping review of the AEs of prone positioning (AE-PRONE) was performed according to the Joanna Briggs Institute framework (JBI)^{34,35} and followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) extension for Scoping Reviews Checklist³⁶. The protocol was registered on the International Platform of Registered Systematic Review and Meta-analysis Protocols database (registration number: INPLASY2020120020), which is available at <https://doi.org/10.37766/inplasy2020.12.0020>. Ethical approval was not required in this study.

Research Question

The research questions of this scoping review were formulated based on the authors' concern about the type and quantity of AEs associated with prone positioning, especially after the publication of the PROSEVA trial¹⁰, and even more during the ongoing COVID-19 pandemic. We structured the research questions using the population, concept, and context (PCC) method³⁴, searching for AEs related to prone positioning in mechanically ventilated adult patients with ARDS, and strategies or recommendations to mitigate AEs of prone positioning implementation.

Operational Definitions

"Adverse events" were defined according to the conceptual framework of the International Classification for Patient Safety³⁷ as an incident that can be a reportable circumstance, near miss, no harm incident, or harmful incident, involving an unintentional and/or unexpected

event or occurrence that may result in injury or death. AEs can be classified as those associated with the prone positioning maneuver and those associated with the management of patients while in the prone position, and can be detected during or immediately following the prone maneuver, including oxygen desaturation, loss of intravascular lines, unscheduled extubation, and hemodynamic instability, or as a long-term finding, including peripheral nerve injuries and pressure sores³⁰. For the purposes of extraction, AEs were also considered as “complications” or “side effects”, and were classified individually and by domain group according to type or the bodily system affected. “Mitigation strategy” was defined as any measure, effort, or recommendation to minimize or avoid AEs during the prone positioning maneuver or during the period when the patient was in the prone position³⁰.

Search Strategy

Biomedical database searches and manual searching were performed between October 26, 2020 and November 1, 2020 (JPC and FGS), following stages recommended by the JBI (for more details of the search strategy see the **Supplemental File**). The main search was carried out in the following biomedical databases: PubMed (NCBI), Cumulative Index of Nursing and Allied Health Literature (CINAHL) plus full text (EBSCO), Scientific Electronic Library Online (SciELO) Citation Index (Clarivate), Cochrane Library (free access from the Chilean Ministry of Health), Literatura Latinoamericana de Información en Ciencias de la Salud (LILACS), and WorldWideScience. The details of the search strategy used for each database are presented in **Supplementary Material Table S1**. The manual search was undertaken to acquire recommendation documents in the websites of scientific societies affiliated with the World Federation of Intensive and Critical Care (WFICC).

Eligibility Criteria

Based on the PCC method, the following inclusion criteria were established: 1) Population: mechanically ventilated patients who required prone positioning due to ARDS; 2) Concept: AEs reporting; and 3) Context: documents involving patients in the ICU published from June 1, 2013 to November 1, 2020. The start of the study period was established from the publication date of the PROSEVA trial (included)¹⁰.

We included original studies (randomized controlled trials, non-randomized trials, prospective and retrospective observational studies, case reports, and any letter, editorial, or correspondence with original data) and recommendation documents that provided advice to avoid or minimize AEs (including care protocols, guidelines, or any non-original study providing clinical recommendations). The exclusion criteria were: documents on awake prone positioning (i.e., receiving non-invasive ventilation or high-flow nasal cannula), pediatric or neonatal population, animal or experimental models, unavailable full text, and documents written in languages other than English or Spanish. Documents that did not mention the presence or absence of AEs among patients that underwent prone positioning were excluded from data extraction. Additionally, reviews were excluded from data extraction but were used to look for non-duplicate citations of pertinent documents.

Document Selection

Two reviewers blinded from each other's judgment (JPC and NA) independently screened all documents related to prone positioning in mechanically ventilated adults with ARDS using the title, abstract, and full-text according to the eligibility criteria previously

described. Any disagreements were resolved by a third reviewer (FGS). For more details of the document selection see the **Supplemental File**.

Data Extraction and Analysis

The authors (JPC, NA, and FGS) collectively developed a standardized data charting form that included relevant variables according to the research questions. The data charting form was iteratively updated as needed, and each author independently abstracted the information from the recommendation documents (JPC and NA) and original studies (JPC and FGS), including all supplementary materials (for more details of the data extraction see the **Supplemental File**).

We generated summary tables reporting counts and percentages for document characteristics, AE proportions, and a compilation of available mitigation strategies and recommendations to minimize or avoid AEs. To calculate the pooled proportion of AEs according to the patients in the prone position, we used the proportion of patients who experienced AE and divided this value by the total number of patients who received prone positioning (according to the data from the original studies). To calculate the pooled proportion of AEs according to the number of prone positioning maneuvers, we used the proportion of the number of AE occurrences during the prone maneuver and divided this value by the total number of positioning change maneuvers performed (according to the data from the original studies). When possible, we presented descriptive data as overall or pooled medians (interquartile range [IQR], or minimum – maximum).

Results

Literature Search and Document Characteristics

This scoping review was conducted between August 2020 and March 2021. The literature search identified 732 citations from scientific databases and 19 from the manual searches. After removing duplicates and screening by title and abstract, 134 full texts were reviewed, yielding 121 eligible documents reporting prone positioning in mechanically ventilated patients with ARDS. Of these documents, 22 (18.2%) were only used to look for relevant citations and 58 (47.9%) were not selected due to the lack of AE reporting. Finally, 41 documents were selected for this review, including 28 original studies and 13 recommendation documents (**Fig. 1**). Of these, 39 (95.1%) were written in English and 2 (4.9%) in Spanish. An overview of the document characteristics is presented in **Table 1**. Remarkably, 19 (46.3%) were published in 2020, and 15 (36.6%) were focused on COVID-19-related ARDS. A summary of the main characteristics of each individual document included in this study is presented in **Supplementary Material Table S2**.

Adverse Events Related to Prone Positioning

Nine domain groups of AEs were identified in the original studies (number of studies [percentage]): pressure sores or skin injuries (13 [46.4%]), invasive devices (11 [39.3%]), respiratory system (9 [32.1%]), cardiovascular system (7 [25.0%]), musculoskeletal system (6 [21.4%]), visual system (5 [17.9%]), gastrointestinal system (4 [14.3%]), nervous system (2 [7.1%]), and others (4 [14.3%]). We identified AEs related to the prone position in 25 studies comprising a total of 1,578 patients who received prone positioning (**Table 2**) with a pooled median (IQR) age of 57 (48–60) years. With the data from 17 studies, the pooled median (IQR) total duration of the prone position was 2 (0.9 to 5) days. We also identified AEs related to the prone positioning maneuver in six studies comprising 994 prone positioning maneuvers (**Table 3**). The highest pooled proportions of AE occurrence were

severe desaturation (37.9%), barotrauma (30.5%), pressure sores (29.7%), ventilation-associated pneumonia (28.2%), facial edema (16.7%), and arrhythmia or bradycardia (15.4%). Only three studies compared AE occurrence between the supine and prone groups (**Supplementary Material Table S3**). Among the original studies, 15 (53.6%) reported a total of 14 AE detection methods (**Supplementary Material Table S4**). In addition, we identified only four adverse events in the case reports: meralgia paresthetica^{38,39}, intraocular pressure increase⁴⁰, optic neuropathy⁴¹ and lower cranial nerve paralysis⁴².

Mitigation Strategies for Adverse Events Related to Prone Positioning

Combining data from the original studies and recommendation documents, **Table 4** presents a literature-based matching between AEs related to prone positioning and the identified mitigation strategies. The most frequently reported mitigation strategies for managing patients in the prone position were as follows: alternate face rotation (18 [43.9%]), repositioning every 2 hours (17 [41.5%]), the use of pillows under the chest and pelvis (14 [34.1%]), one upper limb abducted next to the head (11 [26.8%]), the use of a facial or head padding (11 [26.8%]), the use of protective measures for eyes (11 [26.8%]), placing the patient in a swimming position (10 [24.4%]), placing the patient in the reverse Trendelenburg position (10 [24.4%]), and free abdomen to minimize abdominal pressure (10 [24.4%]) (**Table 5**). Unexpectedly, no original study or recommendation document reported early mobilization (i.e., neuromuscular electrical stimulation or passive mobilization) as a mitigation strategy for prone positioning of mechanically ventilated patients. The manual prone positioning maneuver was the most common maneuver, reported in 14 (34.1%) documents. The most frequently reported mitigation strategies for performing the prone maneuver were: one person being at the head of the patient (23

[56.1%]), the use of a pre-maneuver safety checklist (18 [43.9%]), vital sign monitoring (15 [36.6%]), ensuring appropriate ventilator settings (12 [29.3%]), rotation opposite to the catheter side (10 [24.4%]), pre-oxygenation with 100% O₂ (10 [24.4%]), and interruption of enteral nutrition (10 [24.4%]) (**Table 6**). The overall median (min-max) number of staff members involved in the prone positioning maneuver was 5 (3–8) in the original studies and 5 (3–7) in the recommendations, mainly including physicians, nurses, and respiratory therapists. Additionally, the training of staff members involved in the management of patients placed in the prone position was reported in only 11 (39.3%) original studies, and was suggested by eight (61.5%) recommendation documents.

Discussion

We identified more than 40 individual AEs within nine domains from the original studies, despite almost half of the eligible studies not reporting any AEs. To our knowledge, this is the first scoping review to specifically and comprehensively collect AEs related to prone positioning in mechanically ventilated patients with ARDS. We identified studies reporting AEs according to the number of patients placed in the prone position (n=25) and the number of prone maneuvers (n=6). Moreover, from the original studies and recommendation data, we identified >30 strategies to mitigate AEs during the prone position, and almost 20 strategies to perform the prone positioning maneuver.

Our findings can be contrasted with previous systematic reviews that, as a secondary aim, have also reported the occurrence of AEs in patients placed in the prone position^{23–26}. Considering the AEs reported by systematic reviews, the reported data up to the publication of the PROSEVA trial, and our scoping review, the pooled proportions were similar in

terms of pressure sores, ventilator-associated pneumonia, cardiac arrest, pneumothorax, arrhythmia, airway obstruction, unplanned extubation, removal of venous or arterial lines, and endotracheal tube displacement (**Supplementary Material Table S5**). Remarkably, we identified similar overall values, showing a lower proportion of AEs in our scoping review, except for ventilator-associated pneumonia and arrhythmia, which were slightly higher.

Owing to the wide coverage of scoping reviews, we identified additional AEs from non-randomized controlled trials and compared the data with preceding randomized controlled trials^{23–26}. From single studies, we identified back pain⁴³, barotrauma⁴⁴, vomit⁴⁵, hemoptysis¹⁰, and bleeding⁴⁵ as AEs. Additionally, we found relevant AEs reported in at least two original studies that were not informed by previous reviews^{23,24}. For instance, pressure sores were reported by severity grade in two studies^{17,46}, highlighting Grade I and II (with redness and blisters) as the most prevalent (between 8.3% and 9.8% patients, respectively), and showing fewer grades in patients who received suitable nutritional intake⁴⁶. Severe desaturation was reported in 3.4% of all prone positioning maneuvers^{47,48} and in 37.9% of patients while in the prone position^{10,49,50}. In the PROSEVA trial, 65.4% of patients presented with severe desaturation (pulse oximetry saturation <85%) during prone positioning, compared to 71.6% in the supine group¹⁰. We believe that the proportion of AEs that occurred during the maneuver should be calculated separately from those that occurred while the patients were in the prone position. Remarkably, acquired peripheral nerve injury associated with the use of prone positioning has been rarely reported and is likely undervalued. However, in two recent reports, it was surprising that between 13.1%⁵¹ and 14.5%⁵² of patients with COVID-19 had peripheral nerve injury after prone positioning, including injuries to the brachial plexus, ulnar, radial, sciatic, and median

nerves. In our review, only four studies reported a pooled proportion of any peripheral nerve injury (8.1%)^{43,49,52,53}, which could indicate an underestimation in other studies.

We found relevant mitigation strategies for AEs related to body position in patients placed in the prone position. The swimming position was reported in seven (53.8%) recommendations but was performed in only three (10.7%) original studies, whereas the complete prone positioning (180°) was mentioned in only one recommendation but was performed in seven (25.0%) studies. Although the PROSEVA trial used complete prone positioning with arms placed alongside the body, we also observed a trend in the recommendation of the swimming position; however, there is heterogeneity in its description, with the majority of documents describing it as placing the face towards the abducted and flexed arm^{29,30,54}, whereas others describe it as placing the face towards the straight arm⁵⁵. Currently, there is no completely safe and suitable positioning of the body that will ensure the minimization of nerve injury in every patient, but some authors promote an understanding of the principles of a safe position and encourage the maintenance of a high clinical suspicion of potential brachial plexus injury during the prone position, especially for unconscious and paralyzed patients⁵⁴. To reduce the risk and impact of brachial plexus injury, some guidelines recommend the swimming position, avoiding excessive rotation, neck extension, shoulder extension or subluxation, arm abduction beyond 70° with elbow extension, and external rotation of the shoulder beyond 60°⁵⁴. Regarding the application of thoracopelvic supports (pillows under the chest and pelvis), seven (25.0%) studies and seven (53.8%) recommendations reported minimizing the intra-abdominal pressure. Controversially, Chiumello et al. demonstrated that these supports decrease chest wall compliance, increase pleural pressure, and slightly deteriorates

hemodynamics without any advantage in gas exchange, along with a higher likelihood of pressure sores⁵⁶. Regardless of the main position of the entire body, the reverse Trendelenburg⁵⁷ position has been reported as a recommended strategy to mitigate face pressure sores, ventilator-associated pneumonia, facial edema, eye injuries, lower cranial nerve paralysis, vomiting, transient increase in intracranial pressure, and severe desaturation (**Table 4**), and is even better if combined with alternating face rotation and repositioning every 2 hours. Despite the well-known safety and benefits of passive mobilization and neuromuscular electrical stimulation in sedated patients⁵⁸⁻⁶¹, no study has reported early mobilization as a mitigation strategy, which is likely vital to minimize nerve injuries and ICU-acquired weakness after prone positioning.

AEs related to prone maneuvers can be mitigated by following at least 20 strategies identified in our scoping review, including using a pre-maneuver safety checklist, vital sign monitoring, ensuring appropriate ventilator settings, and having a leader (physician or respiratory therapist) at the head of the patient, which have also been previously reported³⁰. The number of staff members is also important, as it influences the occurrence of AEs during the maneuver³⁰. The median number identified was five staff members, but this number depends on each team's experience level and the patient type. For those with extracorporeal membrane oxygenation or morbid obesity requiring prone positioning, the number of members reported ranged from 4 to 8^{47,62} and 5 to 6⁴⁵, respectively.

Although preceding meta-analyses support the significant reduction in overall mortality of patients with ARDS treated with prone positioning²³⁻²⁶, the risk of AEs should be carefully considered during the decision-making process, especially in ICUs with less experience^{23,27}. While most AEs can be severe but immediately corrected, others may be less prevalent but

may require long-term care. In this scoping review, several mitigation strategies related to maintaining safe body positions were collected, emphasizing the prevention of AEs originating from incorrect body and limb positions that could be maintained over time. Future clinical trials should incorporate the screening of long-term AEs, which we believe are still underestimated, as well as peripheral nerve and eye injuries, which could be determinants of the quality of life of survivors. In addition, future studies should report the presence and absence of AEs in both the prone and supine groups to minimize design-related bias.

This review is not exempted from limitations. The findings of this scoping review cannot be generalized beyond patients with ARDS treated in the ICU with prone positioning. Due to the emerging need to obtain recent information on prone positioning, we did not include documents published before 2013. However, we captured useful data on AEs that became available after the landmark PROSEVA trial. We did not identify new randomized or controlled clinical trials reporting AEs related to prone positioning between 2013 and 2020, limiting the comparison of AE occurrence between the prone and supine groups. Due to the observational nature of the original studies included, the causality of AE occurrence likewise cannot be confirmed. Moreover, additional confounding and mediator factors could explain an AE⁶³, and the prone position itself could be a mediator of the greater severity experienced by a patient presenting with an event. Finally, no cause-effect analysis had been performed between the mitigation strategies and the occurrence of AEs, nor did we explore the relationships between the length of prone positioning sessions and AEs. However, the findings of our review could serve as precursors for future studies.

Conclusion

Several AEs related to prone positioning in mechanically ventilated patients with ARDS were identified, involving additional AEs not yet reported by previous systematic reviews. The pooled AE proportions reported in this scoping review might guide research and clinical practice decisions, especially for ICU teams with little to no experience in the management of patients who need prone positioning. The strategies for mitigating AEs that have been collected in this scoping review could promote future consensus-based recommendations.

REFERENCES

1. Franca SA, Toufen C, Hovnanian ALD, Albuquerque ALP, Borges ER, Pizzo VRP, Carvalho CRR. The epidemiology of acute respiratory failure in hospitalized patients: A Brazilian prospective cohort study. *J Crit Care* 2011;26(3):330.e1-330.e8.
2. Stefan MS, Shieh M-S, Pekow PS, Rothberg MB, Steingrub JS, Lagu T, Lindenauer PK. Epidemiology and outcomes of acute respiratory failure in the United States, 2001 to 2009: a national survey. *J Hosp Med* 2013;8(2):76–82.
3. Brun-Buisson C, Minelli C, Bertolini G, Brazzi L, Pimentel J, Lewandowski K, et al. Epidemiology and outcome of acute lung injury in European intensive care units Results from the ALIVE study. *Intensive Care Med* 2004;30(1):51–61.
4. Herridge MS, Tansey CM, Matté A, Tomlinson G, Diaz-Granados N, Cooper A, et al. Functional disability 5 years after acute respiratory distress syndrome. *N Engl J Med* 2011;364(14):1293–1304.
5. Nelliott A, Dinglas VD, O’Toole J, Patel Y, Mendez-Tellez PA, Nabeel M, et al. Acute Respiratory Failure Survivors’ Physical, Cognitive, and Mental Health Outcomes: Quantitative Measures versus Semistructured Interviews. *Ann Am Thorac Soc* 2019;16(6):731–737.
6. Acute Respiratory Distress Syndrome Network, Brower RG, Matthay MA, Morris A, Schoenfeld D, Thompson BT, Wheeler A. Ventilation with Lower Tidal Volumes as Compared with Traditional Tidal Volumes for Acute Lung Injury and the Acute Respiratory Distress Syndrome. *N Engl J Med* 2000;342(18):1301–1308.
7. Combes A, Peek GJ, Hajage D, Hardy P, Abrams D, Schmidt M, et al. ECMO for severe ARDS: systematic review and individual patient data meta-analysis. *Intensive Care Med* 2020;46(11):2048–2057.

8. Papazian L, Forel J-M, Gacouin A, Penot-Ragon C, Perrin G, Loundou A, et al. Neuromuscular Blockers in Early Acute Respiratory Distress Syndrome. *N Engl J Med* 2010;363(12):1107–1116.
9. Li X, Scales DC, Kavanagh BP. Unproven and Expensive before Proven and Cheap: Extracorporeal Membrane Oxygenation versus Prone Position in Acute Respiratory Distress Syndrome. *Am J Respir Crit Care Med* 2018;197(8):991–993.
10. Guérin C, Reignier J, Richard JC, Beuret P, Gacouin A, Boulain T, et al. Prone positioning in severe acute respiratory distress syndrome. *N Engl J Med* 2013;368(23):2159–2168.
11. Fan E, Del Sorbo L, Goligher EC, Hodgson CL, Munshi L, Walkey AJ, et al. An Official American Thoracic Society/European Society of Intensive Care Medicine/Society of Critical Care Medicine Clinical Practice Guideline: Mechanical Ventilation in Adult Patients with Acute Respiratory Distress Syndrome. *Am J Respir Crit Care Med* 2017;195(9):1253–1263.
12. Chiumello D, Brochard L, Marini JJ, Slutsky AS, Mancebo J, Ranieri VM, et al. Respiratory support in patients with acute respiratory distress syndrome: an expert opinion. *Crit Care* 2017;21(1):240.
13. Phua J, Weng L, Ling L, Egi M, Lim C-M, Divatia JV, et al. Intensive care management of coronavirus disease 2019 (COVID-19): challenges and recommendations. *Lancet Respir Med* 2020;8(5):506–517.
14. Alhazzani W, Møller MH, Arabi YM, Loeb M, Gong MN, Fan E, et al. Surviving Sepsis Campaign: guidelines on the management of critically ill adults with Coronavirus Disease 2019 (COVID-19). *Intensive Care Med* 2020;46(5):854–887.
15. World Health Organization. Clinical management of severe acute respiratory

infection when novel coronavirus (nCoV) infection is suspected: interim guidance.

Available at: <https://apps.who.int/iris/handle/10665/330893>. 2020. p. Accessed Oct 26, 2020.

16. Marini JJ, Josephs SA, Mechlin M, Hurford WE. Should Early Prone Positioning Be a Standard of Care in ARDS With Refractory Hypoxemia? *Respir Care* 2016;61(6):818–829.
17. Lucchini A, Bambi S, Mattiussi E, Elli S, Villa L, Bondi H, et al. Prone Position in Acute Respiratory Distress Syndrome Patients. *Dimens Crit Care Nurs* 2020;39(1):39–46.
18. Guérin C, Gaillard S, Lemasson S, Ayzac L, Girard R, Beuret P, et al. Effects of Systematic Prone Positioning in Hypoxemic Acute Respiratory Failure. *JAMA* 2004;292(19):2379-2387.
19. Mancebo J, Fernández R, Blanch L, Rialp G, Gordo F, Ferrer M, et al. A Multicenter Trial of Prolonged Prone Ventilation in Severe Acute Respiratory Distress Syndrome. *Am J Respir Crit Care Med* 2006;173(11):1233–1239.
20. McCormick J, Blackwood B. Nursing the ARDS patient in the prone position: the experience of qualified ICU nurses. *Intensive Crit Care Nurs* 2001;17(6):331–40.
21. Kallet RH. A Comprehensive Review of Prone Position in ARDS. *Respir Care* 2015;60(11):1660–1687.
22. Touchon F, Trigui Y, Prud'homme E, Lefebvre L, Giraud A, Dols A-M, et al. Awake prone positioning for hypoxaemic respiratory failure: past, COVID-19 and perspectives. *Eur Respir Rev* 2021;30(160):210022.
23. Lee JM, Bae W, Lee YJ, Cho Y-J. The Efficacy and Safety of Prone Positional Ventilation in Acute Respiratory Distress Syndrome. *Crit Care Med*

- 2014;42(5):1252–1262.
24. Park SY, Kim HJ, Yoo KH, Park YB, Kim SW, Lee SJ, et al. The efficacy and safety of prone positioning in adults patients with acute respiratory distress syndrome: a meta-analysis of randomized controlled trials. *J Thorac Dis* 2015;7(3):356–367.
 25. Mora-Arteaga JA, Bernal-Ramírez OJ, Rodríguez SJ. Efecto de la ventilación mecánica en posición prona en pacientes con síndrome de dificultad respiratoria aguda. Una revisión sistemática y metanálisis. *Med Intensiva* 2015;39(6):352–365.
 26. Bloomfield R, Noble DW, Sudlow A. Prone position for acute respiratory failure in adults. *Cochrane Database Syst Rev* 2015;(11):CD008095.
 27. Guérin C, Albert RK, Beitler J, Gattinoni L, Jaber S, Marini JJ, et al. Prone position in ARDS patients: why, when, how and for whom. *Intensive Care Med* 2020;46(12):2385–2396.
 28. Klaiman T, Silvestri JA, Srinivasan T, Szymanski S, Tran T, Oredeko F, et al. Improving Prone Positioning for Severe Acute Respiratory Distress Syndrome during the COVID-19 Pandemic. An Implementation-Mapping Approach. *Ann Am Thorac Soc* 2021;18(2):300–307.
 29. Oliveira VM, Piekala DM, Deponti GN, Batista DCR, Minossi SD, Chisté M, et al. Safe prone checklist: construction and implementation of a tool for performing the prone maneuver. *Rev Bras Ter Intensiva* 2017;29(2):131–141.
 30. Parhar KKS, Zuege DJ, Shariff K, Knight G, Bagshaw SM. Prone positioning for ARDS patients-tips for preparation and use during the COVID-19 pandemic. *Can J Anaesth* 2021;68(4):541–545.
 31. Oliveira VM de, Weschenfelder ME, Deponti G, Condessa R, Loss SH, Bairros PM,

- et al. Good practices for prone positioning at the bedside: Construction of a care protocol. *Rev Assoc Med Bras* 2016;62(3):287–293.
32. Munshi L, Del Sorbo L, Adhikari NKJ, Hodgson CL, Wunsch H, Meade MO, et al. Prone Position for Acute Respiratory Distress Syndrome. A Systematic Review and Meta-Analysis. *Ann Am Thorac Soc* 2017;14(Supplement_4):S280–S288.
33. Munn Z, Peters MDJ, Stern C, Tufanaru C, McArthur A, Aromataris E. Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Med Res Methodol* 2018;18(1):143.
34. Peters MDJ, Godfrey CM, Khalil H, McInerney P, Parker D, Soares CB. Guidance for conducting systematic scoping reviews. *Int J Evid Based Healthc* 2015;13(3):141–146.
35. Arksey H, O'Malley L. Scoping studies: towards a methodological framework, *International Journal of Social Research Methodology*. *Int J Soc Res Methodol Theory Pract* 2005;8(1):19–32.
36. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Ann Intern Med* 2018;169(7):467-473.
37. Thomson R, Lewalle P, Sherman H, Hibbert P, Runciman W, Castro G. Towards an International Classification for Patient Safety: a Delphi survey. *Int J Qual Heal Care* 2009;21(1):9–17.
38. Bellinghausen AL, LaBuzetta JN, Chu F, Novelli F, Rodelo AR, Owens RL. Lessons from an ICU recovery clinic: two cases of meralgia paresthetica after prone positioning to treat COVID-19-associated ARDS and modification of unit practices. *Crit Care* 2020;24(1):580.

39. Juhl CS, Ballegaard M, Bestle MH, Tfelt-Hansen P. Meralgia Paresthetica after Prone Positioning Ventilation in the Intensive Care Unit. *Case Reports Crit Care* 2016;2016:1–3.
40. Saran S, Gurjar M, Kanaujia V, Ghosh PS, Gupta A, Mishra P, et al. Effect of prone positioning on intraocular pressure in patients with acute respiratory distress syndrome. *Crit Care Med* 2019;47(9):E761–E766.
41. Panchabhai TS, Bandyopadhyay D, Kapoor A, Akindipe O, Lane C, Krishnan S. Acute ischemic optic neuropathy with extended prone position ventilation in a lung transplant recipient. *Int J Crit Illn Inj Sci* 2016;6(1):45–47.
42. Trejo-Gabriel-Galan JM, Perea-Rodriguez ME, Aicua-Rapun I, Martinez-Barrio E. Lower cranial nerves paralysis following prone-position mechanical ventilation. *Crit Care Med* 2017;45(8):e865–e866.
43. Sahoo J, Gurjar M, Mohanty K, Majhi K, Sradhanjali G. Prone ventilation in H1N1 virus-associated severe acute respiratory distress syndrome: A case series. *Int J Crit Illn Inj Sci* 2019;9(4):182–186.
44. Xu Y, Sun Q, Yu Y, Liang W, Liu X, Yang C, et al. Prone position ventilation support for acute exacerbation of interstitial lung disease? *Clin Respir J* 2018;12(4):1372–1380.
45. De Jong A, Molinari N, Sebbane M, Prades A, Futier E, Jung B, et al. Feasibility and Effectiveness of Prone Position in Morbidly Obese Patients With ARDS. *Chest* 2013;143(6):1554–1561.
46. Jové Ponseti E, Villarrasa Millán A, Ortiz Chinchilla D. Análisis de las complicaciones del decúbito prono en el síndrome de distrés respiratorio agudo: estándar de calidad, incidencia y factores relacionados. *Enferm Intensiva*

- 2017;28(3):125–134.
47. Kipping V, Weber-Carstens S, Lojewski C, Feldmann P, Rydlewski A, Boemke W, et al. Prone position during ECMO is safe and improves oxygenation. *Int J Artif Organs* 2013;36(11):821–832.
 48. Kimmoun A, Levy B, Chenuel B, Barde S, Didelot A, Chenuel B, et al. Usefulness and safety of a dedicated team to prone patients with severe ARDS due to COVID-19. *Crit Care* 2020;24(1):1–4.
 49. Short B, Parekh M, Ryan P, Chiu M, Fine C, Scala P, et al. Rapid implementation of a mobile prone team during the COVID-19 pandemic. *J Crit Care* 2020;60:230–234.
 50. Guérin C, Beuret P, Constantin JM, Bellani G, Garcia-Olivares P, Roca O, et al. A prospective international observational prevalence study on prone positioning of ARDS patients: the APRONET (ARDS Prone Position Network) study. *Intensive Care Med* 2018;44(1):22–37.
 51. Miller C, O’Sullivan J, Jeffrey J, Power D. Brachial Plexus Neuropathies During the COVID-19 Pandemic: A Retrospective Case Series of 15 Patients in Critical Care. *Phys Ther* 2021;101(1):pzaa191.
 52. Malik GR, Wolfe AR, Soriano R, Rydberg L, Wolfe LF, Deshmukh S, et al. Injury-prone: peripheral nerve injuries associated with prone positioning for COVID-19-related acute respiratory distress syndrome. *Br J Anaesth* 2020;125(6):e478–e480.
 53. Le MQ, Rosales R, Shapiro LT, Huang LY. The Down Side of Prone Positioning. *Am J Phys Med Rehabil* 2020;99(10):870–872.
 54. Simpson AI, Vaghela KR, Brown H, Adams K, Sinisi M, Fox M, Quick T. Reducing the Risk and Impact of Brachial Plexus Injury Sustained From Prone Positioning—A Clinical Commentary. *J Intensive Care Med* 2020;35(12):1576–1582.

55. Ibarra G, Rivera A, Fernandez-Ibarburu B, Lorca-García C, Garcia-Ruano A. Prone position pressure sores in the COVID-19 pandemic: The Madrid experience. *J Plast Reconstr Aesthetic Surg* 2020;S1748-6815(20):30732–30734.
56. Chiumello D, Cressoni M, Racagni M, Landi L, Li Bassi G, Polli F, et al. Effects of thoraco-pelvic supports during prone position in patients with acute lung injury/acute respiratory distress syndrome: a physiological study. *Crit Care* 2006;10(3):R87.
57. Bein T, Bischoff M, Brückner U, Gebhardt K, Henzler D, Hermes C, et al. S2e guideline: positioning and early mobilisation in prophylaxis or therapy of pulmonary disorders. *Anaesthetist* 2015;64(S1):1–26.
58. Camargo Pires-Neto R, Fogaça Kawaguchi YM, Sayuri Hirota A, Fu C, Tanaka C, Caruso P, et al. Very Early Passive Cycling Exercise in Mechanically Ventilated Critically Ill Patients: Physiological and Safety Aspects - A Case Series. *PLoS One* 2013;8(9):e74182.
59. Hickmann CE, Castanares-Zapatero D, Deldicque L, Van den Bergh P, Caty G, Robert A, et al. Impact of Very Early Physical Therapy During Septic Shock on Skeletal Muscle. *Crit Care Med* 2018;46(9):1436–1443.
60. Medrinal C, Combret Y, Prieur G, Robledo Quesada A, Bonnevie T, Gravier FE, et al. Comparison of exercise intensity during four early rehabilitation techniques in sedated and ventilated patients in ICU: a randomised cross-over trial. *Crit Care* 2018;22(1):110.
61. Gutiérrez-Arias RE, Zapata-Quiroz CC, Prenafeta-Pedemonte BO, Nasar-Lillo NA, Gallardo-Zamorano DI. Effect of Neuromuscular Electrical Stimulation on the Duration of Mechanical Ventilation. *Respir Care* 2021;66(4):679–685.
62. Kimmoun A, Roche S, Bridey C, Vanhuyse F, Fay R, Girerd N, et al. Prolonged

prone positioning under VV-ECMO is safe and improves oxygenation and respiratory compliance. *Ann Intensive Care* 2015;5(1):35.

63. Lederer DJ, Bell SC, Branson RD, Chalmers JD, Marshall R, Maslove DM, et al. Control of Confounding and Reporting of Results in Causal Inference Studies. Guidance for Authors from Editors of Respiratory, Sleep, and Critical Care Journals. *Ann Am Thorac Soc* 2019;16(1):22–28.

Figure Legends

Fig 1. Document selection flow diagram

*Websites of scientific societies affiliated with the World Federation of Intensive and Critical Care (WFICC).

CINAHL = Cumulative Index of Nursing and Allied Health Literature

SciELO = Scientific Electronic Library Online

LILACS = Literatura Latinoamericana de Información en Ciencias de la Salud

IMV = invasive mechanical ventilation

ICU = intensive care unit

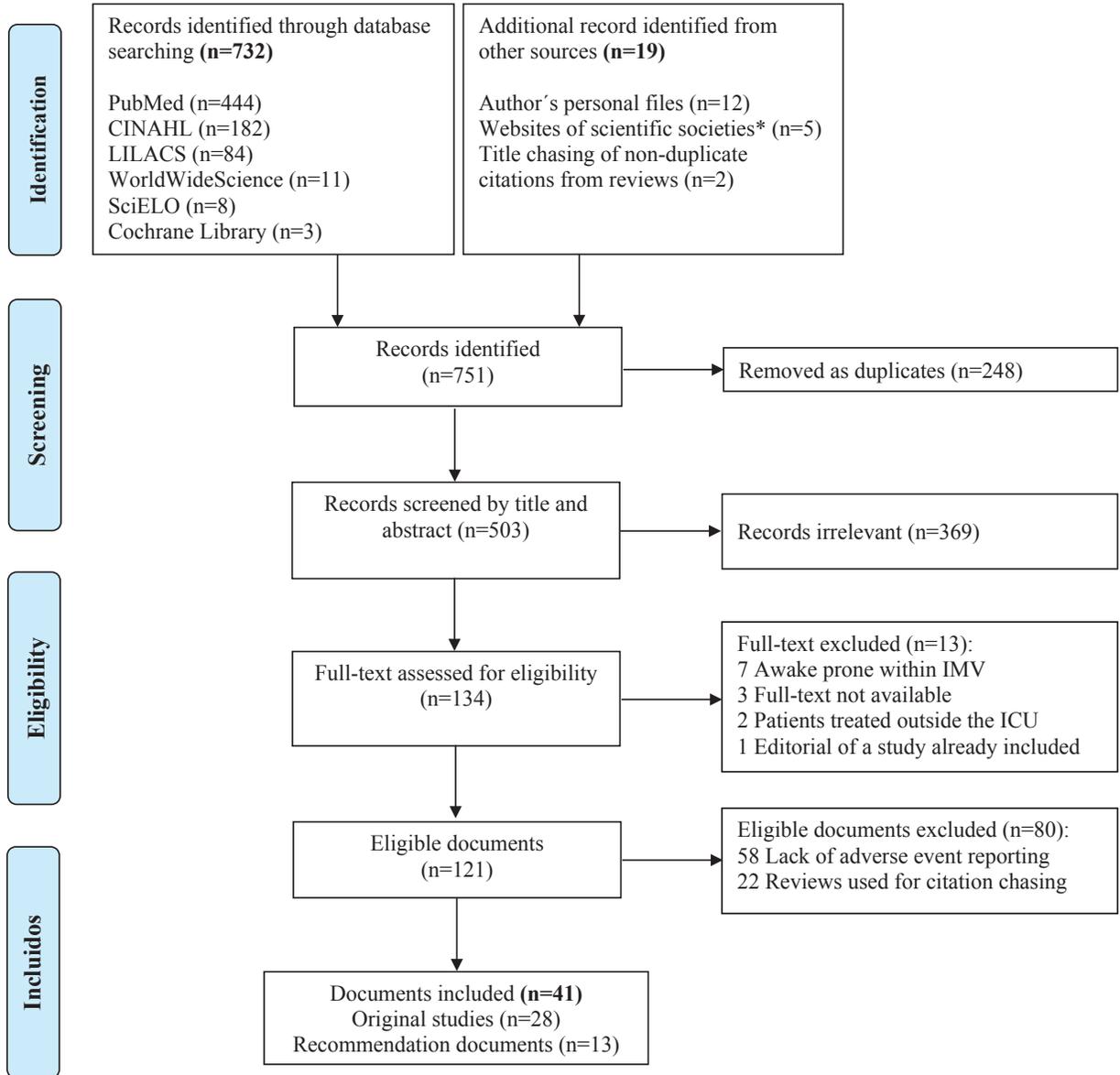


Table 1. Overview of Included Documents Reporting Adverse Events Related to Prone Positioning in Acute Respiratory Distress Syndrome Patients

Characteristics	Original studies n = 28, n (%)	Recommendations n = 13, n (%)	Overall n = 41, n (%)
Year of publication			
2017 to 2020*	19 (67.9)	11 (84.6)	30 (73.2)
2013 to 2016	9 (32.1)	2 (15.4)	11 (26.8)
Region			
Europe†	16 (57.1)	7 (53.8)	23 (56.1)
United States	9 (32.1)	2 (15.4)	11 (26.8)
Asia‡	3 (10.7)	2 (15.4)	5 (12.2)
Brazil	0 (0.0)	2 (15.4)	2 (4.9)
Design			
Retrospective observational study§	15 (53.6)	n/a	15 (36.6)
Case report	8 (28.6)	n/a	8 (19.5)
Prospective observational study	4 (14.3)	n/a	4 (9.8)
Randomized controlled trial	1 (3.6)	n/a	1 (2.4)
Clinical practice guideline	n/a	5 (38.5)	5 (12.2)
National guideline	n/a	3 (23.1)	3 (7.3)
Clinical commentary	n/a	2 (15.4)	2 (4.9)
Care protocol	n/a	2 (15.4)	2 (4.9)
Checklist	n/a	1 (7.7)	1 (2.4)
Target population			
Non-COVID-19–related ARDS	17 (60.7)	9 (69.2)	26 (63.4)
COVID-19–related ARDS	11 (39.3)	4 (30.8)	15 (36.6)
Extracorporeal membrane oxygenation¶	2 (7.1)	0 (0.0)	2 (4.9)
Morbid obese with ARDS¶	1 (3.6)	0 (0.0)	1 (2.4)
Exacerbation of interstitial lung disease¶	1 (3.6)	0 (0.0)	1 (2.4)
Journal or Source Scope			
Critical care and intensive care medicine	16 (57.1)	7 (53.8)	23 (56.1)

Medicine miscellaneous	2 (7.1)	3 (23.1)	5 (12.2)
Pulmonary and respiratory medicine	3 (10.7)	0 (0.0)	3 (7.3)
Surgery	2 (7.1)	0 (0.0)	2 (4.9)
Anesthesiology	1 (3.6)	1 (7.7)	2 (4.9)
Physical therapy and rehabilitation	1 (3.6)	1 (7.7)	2 (4.9)
Nursing	1 (3.6)	1 (7.7)	2 (4.9)
Nutrition and Dietetics	1 (3.6)	0 (0.0)	1 (2.4)
Dermatology	1 (3.6)	0 (0.0)	1 (2.4)

*Includes one study published online in 2020, yet currently publication date is 2021¹.

†Documents from European countries included France (n=7), United Kingdom (n=7), Spain (n=4), Germany (n=2), Italy (n=2) and Denmark (n=1).

‡Documents from Asian countries included India (n=2), Japan (n=1), China (n=1) and Saudi Arabia (n=1).

§Includes one secondary analysis² and one ancillary study³ both originated from PROSEVA trial data.

||Include a research letter with two case reports⁴.

¶Also included in the category: Non-SARS-CoV-2-related ARDS.

COVID-19 = coronavirus disease 2019

ARDS = acute respiratory distress syndrome

n/a = not applicable

Table 2. Adverse Events Related to Prone Positioning in Acute Respiratory Distress**Syndrome Patients**

Adverse event	No. of studies contributing data*	No. (%) of patients with adverse event†	95% CI
Pressure sores (by body site)‡			
Pressure sores in general	7	195/656 (29.7%)	26.2–33.2
Face (ie, chin, cheekbone)	7	113/595 (19.0%)	15.8–22.1
Chest	4	40/443 (9.0%)	6.4–11.7
Lower limb (ie, foot, heel, knee, trochanter)	4	29/449 (6.5%)	4.2–8.7
Ears	2	9/120 (7.5%)	2.8–12.2
Back of head	1	6/191 (3.1%)	0.7–5.6
Back	1	2/189 (1.1%)	0.0–2.5
Sacrum	1	40/196 (20.4%)	14.8–26.1
Pressure sores (by severity grade)			
Grade I	2	17/205 (8.3%)	4.5–12.1
Grade II	2	20/205 (9.8%)	5.7–13.8
Grade III	2	0/205 (0.0%)	0.0–0.0
Grade IV	2	3/205 (1.5%)	0.0–3.1
Invasive devices			
Removal of venous or arterial lines	7	4/452 (0.9%)	0.0–1.7
Unscheduled extubation	5	32/413 (7.7%)	5.2–10.3
Displacement of endotracheal tube	4	9/466 (1.9%)	0.7–3.2
Airway obstruction	2	11/272 (4.0%)	1.7–6.4
Respiratory system			
Severe desaturation (SpO ₂ < 85%)	3	162/428 (37.9%)	33.3–42.4
Ventilation-associated pneumonia	2	96/340 (28.2%)	23.5–33.0
Pneumothorax	2	3/104 (2.9%)	0.0–6.1
Barotrauma	1	11/36 (30.6%)	15.5–45.6
Cardiovascular system			

Cardiac arrest	5	19/559 (3.4%)	1.9–4.9
Hypotension	3	40/393 (10.2%)	7.2–13.2
Arrhythmia or bradycardia	2	42/273 (15.4%)	11.1–19.7
Musculoskeletal system			
Peripheral nerve injuries in general	4	15/185 (8.1%)	4.2–12.0
Brachial plexus injury	3	4/174 (2.3%)	0.1–4.5
Ulnar nerve injury	1	6/83 (7.2%)	1.7–12.8
Radial nerve injury	1	3/83 (3.6%)	0.0–7.6
Sciatic nerve injury	1	3/83 (3.6%)	0.0–7.6
Median nerve injury	1	2/83 (2.4%)	0.0–5.7
Back pain	1	1/11 (9.1%)	0.0–26.1
Visual system			
Eye hemorrhage or edema	3	8/226 (3.5%)	1.1–5.9
Gastrointestinal system			
Vomit	1	1/66 (1.5%)	0.0–4.5
Hemoptysis	1	6/237 (2.5%)	0.5–4.5
Nervous system			
Transient increase in intracranial pressure	2	2/102 (2.0%)	0.0–4.7
Others§			
Facial, periorbital or tongue edema	3	17/102 (16.7%)	9.4–23.9
Bleeding	1	1/66 (1.5%)	0.0–4.5

*Counting studies that collected data on adverse events, regardless of whether an event occurred.

†Proportion of patients who experienced the adverse event due to prone positioning divided by the total number of patients who received prone positioning from original studies contributing data.

‡Two other body sites (head and penis) were reported in one study². In this study only includes patients presenting skin injuries; therefore, data of this adverse event was not used for this table.

§Meralgia paresthetica, intraocular pressure increase, optic neuropathy and lower cranial nerves paralysis are not presented in this table as were only informed in case reports.

SpO₂ = peripheral oxygen saturation

CI = confidence interval

Table 3. Adverse Events Related to the Positioning Change Maneuver in Acute Respiratory Distress Syndrome Patients

Adverse event	No. of studies contributing data*	No. (%) of maneuvers with adverse events†	95% CI
Invasive devices			
Disconnection of ventilator lines	3	5/920 (0.5%)	0.1–1.0
Removal of venous or arterial lines	3	1/250 (0.4%)	0.0–1.2
Removing of nasogastric tube	2	2/441 (0.5%)	0.0–1.1
Unscheduled extubation	2	0/441 (0.0%)	0.0–0.0
Airway obstruction	1	2/74 (2.7%)	0.0–6.4
Respiratory system			
Severe desaturation (SpO ₂ < 85%)	2	15/441 (3.4%)	1.7–5.1
Cardiovascular system			
Hypotension	1	7/74 (9.5%)	2.8–16.1
Arrhythmia or bradycardia	1	3/74 (4.1%)	0.0–8.5
Cardiac arrest	1	1/74 (1.4%)	0.0–4.0
Gastrointestinal system			
Vomit	1	5/526 (1.0%)	0.1–1.8
Other			
Bleeding‡	1	10/74 (13.5%)	5.7–21.3

*Counting studies that collected data on adverse events, regardless of whether an event occurred.

†Proportion of the number of occurrences of adverse events during the positioning change maneuver to prone or supine divided by the total positioning change maneuvers performed from studies contributing data.

‡Bleeding: reported in only one study of patients with extracorporeal membrane oxygenation.

SpO₂ = peripheral oxygen saturation

CI = confidence interval

Table 4. Literature-based Matching Between Adverse Events Related to Prone Positioning and Identified Mitigation Strategies

	Pressure sores	Peripheral nerve injuries*	VAP	Facial edema	Eye injuries†	Lower cranial nerves paralysis	Vomit or hemoptysis	Transient increase in ICP	Invasive devices displacements‡	Airway obstruction	Barotrauma	Severe desaturation	Hemodynamic instability§
Strategies during prone position													
Swimming position		✓											
Incomplete prone positioning (135° - 180°)		✓		✓									
Reverse Trendelenburg¶	✓		✓	✓	✓	✓	✓	✓				✓	
One upper limb abducted next to the head		✓											
Upper limbs placed alongside the body		✓											
Slide scapulae up the back with slight shoulder shrug		✓											
Head placement over the upper edge of the bed	✓				✓				✓				
One lower limb with hip and knee semi-flexed		✓											
Upper limbs placed up straight besides the head		✓											
Keep all joints in a neutral anatomical position		✓											
Avoid neck hyperextension		✓											
Avoid extension of the shoulder		✓											
Avoid arm abduction > 70°		✓											
Avoid depression of the shoulder girdle		✓											
Avoid non-physiologic limbs movements		✓											
Pillows under chest and pelvis	✓						✓						
Pillow under shinbone minimizing equine position		✓											
Alternate face rotation	✓	✓		✓	✓	✓							

	Pressure sores	Peripheral nerve injuries*	VAP	Facial edema	Eye injuries†	Lower cranial nerves paralysis	Vomit or hemoptysis	Transient increase in ICP	Invasive devices displacements‡	Airway obstruction	Barotrauma	Severe desaturation	Hemodynamic instability§
Palms facing inwards or anteriorly		✓											
Palms under their buttocks		✓											
Avoid non-physiologic limbs movements		✓											

*Peripheral nerve injuries include brachial plexus injury, ulnar nerve injury, radial nerve injury, sciatic nerve injury, median nerve injury, back pain and meralgia paresthetica.

†Eye injuries include eye hemorrhage or edema, intraocular pressure increase and optic neuropathy.

‡Invasive devices removal or displacements include removal of venous or arterial lines, unscheduled extubation, displacement of endotracheal tube, disconnection of ventilator lines and removing of nasogastric tube.

§Hemodynamic instability includes cardiac arrest, hypotension and arrhythmia.

||Swimming position definition (also called “swim position” or “swimmer position”) vary depends on the reference, mainly is described as one arm raised (elbow flexed 90° and shoulder abducted within 45–80°) and head rotated toward the raised arm; the other arm is positioned alongside the body with the palms facing inwards or upwards.

¶For reverse Trendelenburg position the following degrees of inclination were reported: 10°, 25° to 30° and 30°.

**One person at the head of patient/bed dedicated to ensure the endotracheal tube, ventilator and nasogastric tube, directing, coordinating and supervising the procedure.

VAP = ventilation-associated pneumonia

ICP = intracranial pressure

Table 5. Mitigation Strategies to Manage Patients While in the Prone Position

Strategies	Original studies n = 28, n (%)	Recommendations n = 13, n (%)	Overall n = 41, n (%)
Prone whole-body position			
Swimming position*	3 (10.7)	7 (53.8)	10 (24.4)
Reverse Trendelenburg†	6 (21.4)	4 (30.8)	10 (24.4)
Complete prone positioning (180°)	7 (25.0)	1 (7.7)	8 (19.5)
Incomplete prone positioning (135° - 180°)	1 (3.6)	1 (7.7)	2 (4.9)
Limbs and head position			
One upper limb abducted next to the head	3 (10.7)	8 (61.5)	11 (26.8)
Upper limbs placed alongside the body	8 (28.6)	0 (0.0)	8 (19.5)
Avoid neck hyperextension	2 (7.1)	3 (23.1)	5 (12.2)
Slide scapulae up the back with slight shoulder shrug	1 (3.6)	3 (23.1)	4 (9.8)
Avoid extension of the shoulder	1 (3.6)	3 (23.1)	4 (9.8)
Head placement over the upper edge of the bed	3 (10.7)	1 (7.7)	4 (9.8)
Arm abduction of 80°	1 (3.6)	2 (15.4)	3 (7.3)
Avoid arm abduction > 70°	0 (0.0)	2 (15.4)	2 (4.9)
Avoid depression of the shoulder girdle	0 (0.0)	2 (15.4)	2 (4.9)
One lower limb with hip and knee semi-flexed	1 (3.6)	1 (7.7)	2 (4.9)
Upper limbs placed up straight besides the head	1 (3.6)	0 (0.0)	1 (2.4)
Keep all joints in a neutral anatomical position	0 (0.0)	1 (7.7)	1 (2.4)
Avoid non-physiologic limbs movements	1 (3.6)	0 (0.0)	1 (2.4)
Pillows use			
Pillows under chest and pelvis	7 (25.0)	7 (53.8)	14 (34.1)
Pillow under shinbone minimizing equine position	4 (14.3)	3 (23.1)	7 (17.1)
A triangular pillow under the anterior iliac crests	1 (3.6)‡	0 (0.0)	1 (2.4)
Care measures			
Alternate face rotation	11 (39.3)	7 (53.8)	18 (43.9)
Repositioning every 2 hours	11 (39.3)	6 (46.2)	17 (41.5)
Facial or head padding§	6 (21.4)	5 (38.5)	11 (26.8)

Protective measures for eyes	4 (14.3)	7 (53.8)	11 (26.8)
Free abdomen	5 (17.9)	5 (38.5)	10 (24.4)
Bony prominences padding	4 (14.3)	4 (30.8)	8 (19.5)
Hand rolls	0 (0.0)	3 (23.1)	3 (7.3)
Repositioning every 1 hour	1 (3.6)	1 (7.7)	2 (4.9)
Hourly joint movement and skin marks observation	1 (3.6)	1 (7.7)	2 (4.9)
Bed-related characteristics			
Alternating-pressure mattress	3 (10.7)	1 (7.7)	4 (9.8)
Prone positioner	0 (0.0)	3 (23.1)	3 (7.3)
Suitable mattress	1 (3.6)	1 (7.7)	2 (4.9)

*Swimming position definition (also called “swim position” or “swimmer position”) vary depends on the reference, mainly is described as one arm raised (elbow flexed 90° and shoulder abducted within 45-80°) and head rotated toward the raised arm; the other arm is positioned alongside the body with the palms facing inwards or upwards.

†For reverse Trendelenburg position the following degrees of inclination were reported: 10°, 25° to 30° and 30°.

‡Reported in only one study of patients with extracorporeal membrane oxygenation¹.

§Includes: half a crescent jelly, sponge donuts, C-letter-shaped pad, facial padding if the patient has a tracheostomy and bite block (for macroglossia).

||Including: Vollman Prone Positioner [Hill-Rom®], RotoProne bed® and the continuous lateral rotation therapy.

Table 6. Mitigation Strategies to Perform the Prone Positioning Maneuver

Strategies	Original studies n = 28, n (%)	Recommendations n = 13, n (%)	Overall n = 41, n (%)
Practical execution maneuver			
Manual prone positioning maneuver	12 (42.9)	2 (15.4)	14 (34.1)
Cornish Pasty technique (Envelope Maneuver)*	1 (3.6)	6 (46.2)	7 (17.1)
Tortoise Turning and Positioning System Prone†	1 (3.6)	0 (0.0)	1 (2.4)
Safety strategies			
One person at the head of patient‡	16 (57.1)	7 (53.8)	23 (56.1)
Pre-maneuver safety checklist	10 (35.7)	8 (61.5)	18 (43.9)
Vital sign monitoring	12 (42.9)	3 (23.1)	15 (36.6)
Rotation oppositely to the catheter side	8 (28.6)	2 (15.4)	10 (24.4)
Interruption of enteral nutrition	2 (7.1)	8 (61.5)	10 (24.4)
Discontinue non-essential infusions and monitoring	2 (7.1)	5 (38.5)	7 (17.1)
Rotation towards the ventilator side	1 (3.6)	5 (38.5)	6 (14.6)
Respiratory strategies			
Ensuring appropriate ventilator settings	9 (32.1)	3 (23.1)	12 (29.3)
Pre-oxygenation with 100% O ₂	4 (14.3)	6 (46.2)	10 (24.4)
Sedated but paralyzed when necessary	4 (14.3)	5 (38.5)	9 (22.0)
Sedated and paralyzed	2 (7.1)	1 (7.7)	3 (7.3)
Airway suction prior to procedure	3 (10.7)	5 (38.5)	8 (19.5)
Limbs positioning			
Arms along the body	2 (7.1)	4 (30.8)	6 (14.6)
Palms facing inwards or anteriorly	1 (3.6)	3 (23.1)	4 (9.8)
Palms under their buttocks	1 (3.6)	1 (7.7)	2 (4.9)
Avoid non-physiologic limbs movements	1 (3.6)	0 (0.0)	1 (2.4)
Participating health staff members			
Physician§	6 (21.4)	7 (53.8)	13 (31.7)
Nurse	4 (14.3)	7 (53.8)	11 (26.8)
Respiratory therapist	3 (10.7)	5 (38.5)	8 (19.5)
Physiotherapist	1 (3.6)	4 (30.8)	5 (12.2)

Anaesthetist	1 (3.6)	3 (23.1)	4 (9.8)
Occupational therapist	1 (3.6)	0 (0.0)	1 (2.4)
Medical student	1 (3.6)	0 (0.0)	1 (2.4)

*The Cornish Pasty technique (also called Envelope Maneuver) is described as a prone positioning maneuver that uses double sheets cocooning the patient inside (one below and one above).

†Tortoise Turning and Positioning System Prone (Mölnlycke Health Care, Gothenburg, Sweden) consist of two low-pressure air-filled pads and two fluidized positioners to support and offload the patient¹.

‡One person at the head of patient/bed dedicated to ensure the endotracheal tube, ventilator and nasogastric tube, directing, coordinating and supervising the procedure.

§Physician: including senior physicians and critical care specialists.