Received: 3 November 2022 | Revised: 23 December 2022 | Accepted: 13 January 2023

DOI: 10.1111/nicc.12889

RESEARCH ARTICLE

Nursing in Critical Care WILEY

Pressure ulcers after prone positioning in patients undergoing extracorporeal membrane oxygenation: A cross-sectional study

Filippo Binda CCRN, MSN[1,2] | Federica Marelli RN, MSN[1] | Alessandro Galazzi PhD[1] | Simone Gambazza PhD[1] | Elisa Vinci RN[2] | Paola Roselli RN[2] | Ileana Adamini RN, MSN[1,2] | Dario Laquintana RN, MSN[1]

[1]Department of Healthcare Professions, Fondazione IRCCS Ca' Granda Ospedale Maggiore Policlinico, Milan, Italy

[2]Department of Anesthesia, Intensive Care and Emergency, Fondazione IRCCS Ca' Granda Ospedale Maggiore Policlinico, Milan, Italy

Correspondence
Alessandro Galazzi, PhD, Department of Healthcare Professions, Fondazione IRCCS Ca' Granda Ospedale Maggiore Policlinico, Via Francesco Sforza 35, 20122 Milano, Italy.
Email: alessandro.galazzi@policlinico.mi.it

Abstract

Background: The combination of prone positioning and extracorporeal membrane oxygenation (ECMO) in patients with acute respiratory distress syndrome (ARDS) is recognized as safe but its use has been limited due to potential complications.

Aim: To report the prevalence of pressure ulcers and other complications due to prone positioning in adult patients receiving veno–venous ECMO.

Study Design: This cross-sectional study was conducted in a tertiary level intensive care unit (ICU) in Milan (Italy), between January 2015 and December 2019. The study population was critically ill adult patients undergoing veno–venous ECMO. Statistical association between pressure ulcers and the type of body positioning (prone *versus* supine) was explored fitting a logistic model.

Results: In the study period, 114 patients were treated with veno–venous ECMO and 62 (54.4%) patients were placed prone for a total of 130 prone position cycles. ECMO cannulation was performed via femoro–femoral configuration in the majority of patients (82.4%, 94/114). Pressure ulcers developed in 57.0% of patients (95%CI: 44.0%–72.6%), most often arising on the face and the chin (37.1%, 23/62), particularly in those placed prone. The main reason of prone positioning interruption was the decrease of ECMO blood flow (8.1%, 5/62). The fitted model showed no association between body position during ECMO and occurrence of pressure ulcers (OR 1.3, 95%CI: 0.5–3.6, $p = .532$).

Conclusions: Facial pressure ulcers were the most frequent complications of prone positioning. Nurses should plan and implement evidence-based care to prevent such pressure injuries in patients undergoing ECMO.

Relevance to Clinical Practice: The combination of prone positioning and ECMO shows few life-threating complications. This manoeuvre during ECMO is feasible and safe when performed by experienced ICU staff.

Filippo Binda and Federica Marelli equal contributors.

This is an open access article under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs License, which permits use and distribution in any medium, provided the original work is properly cited, the use is non-commercial and no modifications or adaptations are made.
© 2023 The Authors. *Nursing in Critical Care* published by John Wiley & Sons Ltd on behalf of British Association of Critical Care Nurses.

KEYWORDS
advanced life support, extracorporeal membrane oxygenation, intensive care units, pressure ulcers, respiratory distress syndrome

1 | INTRODUCTION

Prone positioning of patients with acute respiratory distress syndrome (ARDS) has several positive effects: it reduces lung strain and stress, minimizing the risk of ventilator-induced lung injury (VILI) and it increases ventilation via recruitment of the dorsal alveoli, thus improving oxygenation.[1,2] Early application of prone positioning in patients with moderate-to-severe ARDS is associated with a significant survival benefit.[3,4] Moreover, patients with refractory hypoxemia may need rescue therapy with veno–venous extracorporeal membrane oxygenation (ECMO) to ensure protective ventilation and reduce the risk of VILI.[5]

Similar physiologic benefits of prone positioning have been reported during veno–venous ECMO support for severe ARDS. Nevertheless, prone positioning remains underused mainly due to organizational issues and lack of experience.[6] The combination of prone positioning and ECMO is recognized as safe[7] but its use has been limited due to potential complications such as partial or complete cannula dislodgment, reduction of circuit blood flow or catastrophic bleeding.[8] Another potential complication of prone positioning during ECMO is pressure ulcers,[9,10] which are localized damage to the skin and underlying soft tissue usually over a bony prominence or related to medical or other devices.[11] The hemodynamic instability with related poor tissues perfusion and the risk of accidental decannulation of the ECMO are possible reasons for not repositioning the patient, which increases the risk of pressure ulcers.[10]

Data on specific complications associated with prone positioning during ECMO are scarce yet[12–14] and understanding factors associated with the risk of pressure ulcers remains important for nursing clinical practice. To fill this gap, the present study investigated the prevalence of pressure ulcers and other complications due to prone positioning in adult patients receiving ECMO.

What is known about the topic

- Early application of prone positioning in patients with moderate and severe acute respiratory distress syndrome (ARDS) is associated with a significant survival benefit.
- Pressure ulcers are the most frequent complication related to prone positioning.
- Prone position during ECMO is a difficult manoeuvre that may be associated with additional complications when performed in ECMO centers lacking specific expertise.

What this paper adds

- Face is a high-risk site for pressure ulcers development in patients placed prone during ECMO.
- Despite the high number of prone positioning cycles, no major complications during the ECMO circuit management (such as cannulas dislodgement) were recorded in this study.
- The etiopathogenesis of pressure ulcers is multifactorial: future research is needed to further understand the role of patient-related or medical-related factors associated with pressure ulcer development in patients placed prone.

2 | METHODS

2.1 | Study design

This cross-sectional study was conducted at the Fondazione IRCCS Ca' Granda Ospedale Maggiore Policlinico, an academic tertiary-level hospital in Milan (Italy), between January 2015 and December 2019. The study population was adult patients admitted to our intensive care unit (ICU) and treated with veno–venous ECMO. Patients submitted to other systems of carbon dioxide removal or with veno-arterial ECMO were excluded.

The study was approved by the local Ethics Committee (approval number 765_2022). Written informed consent was waived because of the retrospective nature of the study. We estimated a prevalence of pressure ulcers of 28.9% in ICU patients based on the largest international observational study published to date.[15] Given the higher risk of pressure ulcers associated with ECMO and prone positioning, we expect a twofold higher prevalence in ICU patients receiving ECMO. Accordingly, 112 patients were deemed necessary to estimate a prevalence of 58% with a 95% confidence interval width of 18%.

2.2 | ECMO procedure

Our hospital is an ECMO referral center with 12 medical ICU beds. Veno–venous ECMO is implemented for patients with severe ARDS unresponsive to maximal medical therapy, as recommended by Extracorporeal Life Support Organization (ELSO) guidelines.[16] Two experienced intensivists, a perfusionist and a critical care nurse usually perform percutaneous cannulation using Seldinger's technique. The ECMO system is composed of a centrifugal pump, a heat exchanger, and an oxygenator[17]: the devices for cardiopulmonary support are the Cardiohelp system and the HU 35 heater unit (Maquet Cardiopulmonary GmbH, Rastatt, Germany). Two single cannulas are inserted for

ECMO cannulation (HLS cannulae, Maquet Cardiopulmonary GmbH, Rastatt, Germany or Bio-Medicus™, Medtronic, Milano, Italy) in femoro–femoral configuration. Alternative circuit configurations are with two cannulas (femoro-jugular with the one cannula for blood drainage from the superior vena cava to the ECMO circuit, the other returns the oxygenated blood to the right atrium or the left internal jugular vein) or with a double-lumen cannula (Avalon Elite Catheter, Getinge, Göteborg, Sweden).[17] Intravenous unfractionated heparin is the anticoagulant of first choice to manage risk of thrombosis during ECMO.[18]

2.3 | Prone positioning management

Patients with ARDS are placed prone according to the available literature.[19] Considering the presence of the ECMO, four nurses, one experienced intensivist and one perfusionist are necessary to perform a safety procedure. Patients are rolled into the prone position and the upper limbs are carefully placed in the swimmer position, as recommended by United Kingdom Intensive Care Society guidelines.[20] This position offers the advantages that it affords easy access to intravenous lines and to clearly inspect the ECMO jugular cannula. As per clinical practice, patients are layed on an air loss pressure mattress (TheraKair Visio™ Mattress, ArjoHuntleigh AB, Malmö, Sweden) to minimize the risk of pressure ulcers.[21] A hydrocolloid dressing (DuoDerm Extra Thin, ConvaTec Inc, Greensboro, USA) is usually applied to protect the anatomical sites most at risk for pressure ulcers (i.e., forehead, cheekbones) or to prevent direct contact between the skin and the ECMO cannula; a self-adhesive bandage is also applied to anchor the femoral cannula at the medial side of the leg or the jugular cannula at the forehead. Skin status is assessed before and after pronation to check for early-stage oedema or pressure ulcer according to National Pressure Ulcer Advisory Panel (NPUAP) criteria.[11]

2.4 | Data collection

For this retrospective analysis, the data were retrieved from medical records. Demographic (sex and age) and clinical data including Body Mass Index (BMI), cause of ICU admission, score of severity disease (Sequential Organ Failure Assessment Score and Simplified Acute Physiology Score), risk assessment score of pressure ulcers development (Braden scale), days of invasive mechanical ventilation (IMV), presence of a tracheostomy, ICU length of stay (LOS), and outcomes at ICU discharge. Particularly, Braden scale was used to assess the risk of pressure ulcers, taking into account sensory perception, skin moisture, activity, mobility, nutrition, friction and shear.[22] Each category is rated on a scale of 1 to 4, excluding the friction and shear category which is rated on a 1–3 scale. This combines for a possible total of 23 points, which means no risk for developing a pressure ulcer whereas a score equal or less than 9 points represents a very high risk.[23] The scale was administered by nurses at ICU admission and the assessment was repeated daily. Number of days of ECMO support, circuit cannula configuration, and number and length of each prone positioning cycle were also recorded. Complications (facial oedema, vascular catheters dislodgement, intolerance to enteral nutrition administration, pressure ulcers) were reported as collected in the nursing charts.

2.5 | Statistical analysis

Metrics are reported as counts and percentage (%), mean and standard deviation (SD) or median and interquartile range (IQR). Patient characteristics are presented in descriptive tables, stratified by type of body positioning during ECMO treatment. Wilcoxon signed-rank, Chi-Square or Fisher's exact tests were applied to explore differences between groups (patients placed prone or not). Spearman's correlation (ρ) was calculated to determine the degree of correlation between number of pressure ulcers and hours spent in prone position, exposure to vasoactive drugs and to ECMO, accounting for multiplicity using Benjamini–Hochberg procedure. Statistical association between pressure ulcers (presence *versus* absence) and the type of body positioning was explored by fitting a logistic model that accounted for variables selected according to the literature: age at ICU admission, BMI, SOFA score, days spent on ECMO, days of IMV, and ICU LOS. Continuous variables were entered in the final model as linear based on the lowest Akaike information criteria. A likelihood ratio test guided the selection of the best-fitting model, which did not include the type of ECMO cannulation. Results are commented as odds ratio (OR) and 95% confidence intervals (CI, lower-upper bound). Statistical analysis was performed using R Core Team (version 4.1.2).[24]

TABLE 1 General characteristics of the patients.

General characteristics	$N = 114$
Age (years)	48.5 (14.6)
Sex (females)	45 (39.5%)
Body Mass Index (kg/m^2)	26.4 (6.9)
Cause of ICU admission	
Pneumonia	67 (58.8%)
Primary Graft Disfunction	14 (12.3%)
End-stage respiratory failure	10 (8.8%)
Other	23 (20.2%)
SAPS II score	44.1 (16.7)
SOFA score	10.0 (4.5)
Patients referred from other centers	67 (58.8%)
Prone positioning manoeuvre	
Patients treated with prone positioning	62 (54.4%)
Total hours of prone positioning	35.5 (23.5)
Number of prone positioning cycles	2.0 (1.0, 3.0)

Note: Data are expressed as mean (SD), median (IQR) or absolute frequency (% of the study group).
Abbreviations: ARDS, acute respiratory distress syndrome; ICU, intensive care unit; SAPS, simplified acute physiology score; SOFA score, sequential organ failure assessment score.

TABLE 2 Characteristics of study population stratified by treatment.

Clinical characteristics	Supine ($n = 52$)	Prone ($n = 62$)	p value
Length of mechanical ventilation (days)	10.4 (10.9)	29.0 (20.1)	<.001
Vasoactive drugs (days)	3.8 (3.5)	11.7 (13.2)	<.001
Enteral nutrition (days)	10.1 (10.8)	29.8 (20.4)	<.001
Renal replacement therapy (days)	12.5 (12.9)	25.5 (22.4)	.060
Patients with tracheostomy	9 (17.3%)	32 (51.6%)	<.001
ICU length of stay (days)	13.5 (10.4)	32.1 (21.0)	<.001
Patients discharged alive from ICU	40 (76.9%)	44 (71.0%)	.613
ECMO support			
Duration of ECMO support (days)	6.3 (6.1)	17.3 (13.3)	<.001
Femoro–femoral cannulation	41 (78.8%)	53 (85.5%)	.514
Femoro-jugular cannulation	4 (7.7%)	2 (3.2%)	
Jugular double-lumen cannula	7 (13.5%)	7 (11.3%)	

Note: Data are expressed as mean (SD) or absolute frequency (% of the study group).
Abbreviations: ECMO, extracorporeal membrane oxygenation; ICU, intensive care unit.

A p-value <.05 was considered statistically significant.

3 | RESULTS

In all, 114 patients underwent veno–venous ECMO during the study period. Table 1 presents the demographic and clinical characteristics of the study population.

Prone position was used as rescue therapy in 40.3% (27/67) patients transferred from other hospitals before ECMO cannulation. A total of 130 prone positioning cycles was recorded; the mean duration of each cycle was 15.7 (4.3) hours.

Clinical characteristics stratified by treatment are presented in Table 2.

Overall, worse clinical characteristics were noted for the patients treated with ECMO and placed prone than those who did not require the manoeuvre (Table 2). On average, the LOS on ECMO was 10.9 (95%CI: 7.2–14.7) days longer and on IMV 18.7 (95%CI: 12.8–24.6) days longer for patients placed prone. ECMO cannulation was performed via femoro–femoral configuration in most patients (82.4%, 94/114). The Braden score was 1.4 (95%CI: 0.5–2.2) points lower in the patients placed prone on assessment at ICU admission than in those never placed prone ($p < .001$): the Braden score was ≤9 points in 90.3% (56/62) and in 67.3% (35/52) of patients ($p = .004$), respectively. Patients transferred from other hospitals with at least one pressure ulcer were 22.4% (15/67); overall, pressure ulcers developed in 57.0% (65/114) of patients, most often on the face. The distribution of pressure ulcers by anatomical district is shown in Figure 1.

Complications due to prone positioning are reported in Table 3.

At least one complication (pressure ulcers due to prone positioning included) was recorded during pronation cycles in 38.7% (24/62) of patients and 6.9% (9/130) cycles were interrupted requiring the staff urgently rolled back the patient to the supine position. One of the reasons for prone position interruption was a decrease of ECMO blood flow in 8.1% (5/62) of patients; bleeding occurred in one patient. No ECMO cannula dislodgment events were recorded nor unplanned extubation or accidental removal of the chest drainage tube.

Statistical analysis showed a moderate correlation between length of ECMO support and days of vasoactive drugs administration ($\rho = 0.58$, $p < .001$), whereas the number of pressure ulcers was fairly correlated with the number of days on ECMO ($\rho = 0.45$, $p < .001$) and weakly correlated with hours spent in prone position ($\rho = 0.27$, $p = .003$). The fitted logistic model showed no association between prone position and the presence of pressure ulcers (OR 1.3, 95%CI: 0.5–3.6, $p = .532$). There was no association between outcome and other variables like age (OR 0.8, 95%CI: 0.4–1.5, $p = .517$), BMI (OR 1.3, 95%CI: 0.8–2.0, $p = .346$), SOFA score (OR 1.6, 95%CI: 0.7–3.3, $p = .249$), days on ECMO (OR 1.4, 95%CI: 0.8–2.7, $p = .258$), days of IMV (OR 1.6, 95%CI: 0.3–8.1, $p = .585$) and days of vasoactive drugs administration (OR 1.4, 95%CI: 0.8–2.4, $p = .222$), despite the uncertainty of estimates. While the model is not meant for prediction, its discriminative ability was 0.70 (adjusted C-index), where 0.50 means that it is not better than assigning observations randomly.

4 | DISCUSSION

This study reports the prevalence of pressure ulcers and complications due to prone positioning in adult patients undergoing ECMO in ICU. The main findings show that the presence of pressure ulcers is not associated with the body position (prone or supine) during ECMO. There was a weak correlation between number of pressure ulcers and the duration of prone positioning. No major complications of management of the ECMO circuit (such as cannulas dislodgement) occurred during the manoeuvre.

The most frequent complication in patients placed prone is pressure ulcers.[25] Despite the use of air loss pressure mattress to distribute body weight evenly, the overall prevalence of pressure ulcers was 57.0%. Prevalence varies considerably in relation to the difference in

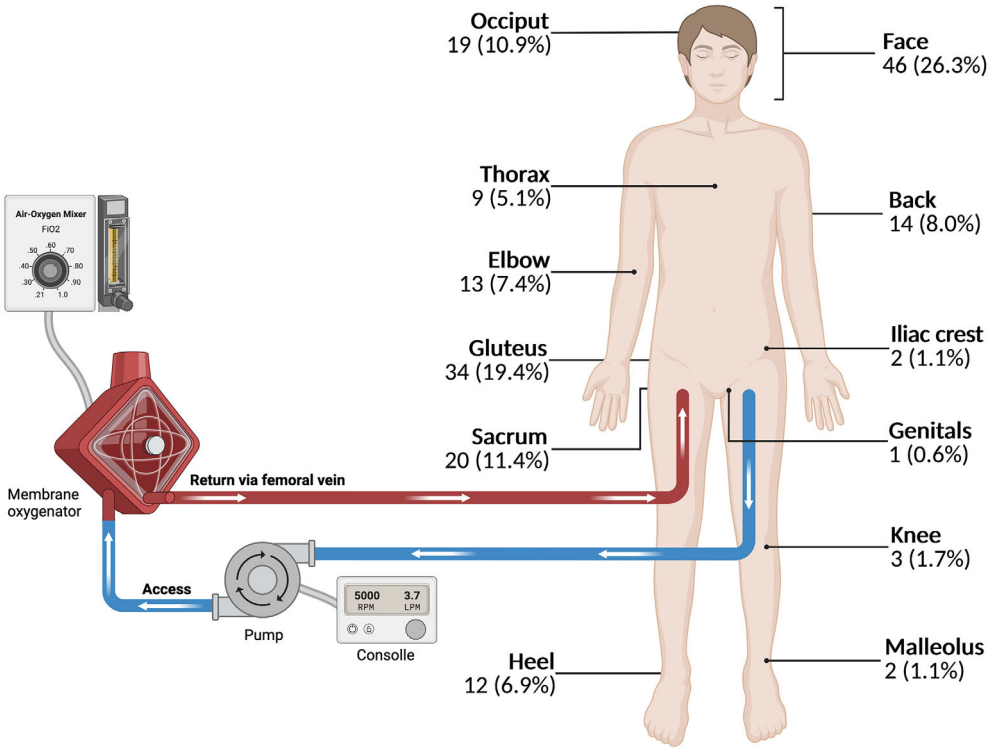


FIGURE 1 Topographic distribution of pressure ulcers in adult patient undergoing ECMO in our study. A total of 175 pressure ulcers were recorded: 37.2% (65/175) were on the head, 8.5% (15/175) were on the frontal surface of the body, 30.9% (54/175) were on sacrum and gluteus, and 23.4% (41/175) were in other sites. The most frequent NPUAP stage was stage II (68.6%, 120/175), followed by stage I (16.0%, 28/175). The stage III was recorded only on gluteus (1.7%, 3/175) while the other pressure ulcers (13.7%, 24/175) were unstageable. No association between the stage of pressure ulcers and body position was found ($p = .729$). The figure was created with permission of BioRender.com

TABLE 3 Complications of prone positioning.

Reasons of prone positioning interruption	$N = 62$
Drop in ECMO blood flow	5 (8.1%)
Prolonged oxygen desaturation	3 (4.8%)
Bleeding of upper airways	1 (1.6%)
Pressure ulcers site	
Face	
Chin	14 (22.6%)
Cheekbone	11 (17.7%)
Nasal fold	10 (16.1%)
Forehead	5 (8.1%)
Ear	4 (6.5%)
Lips	2 (3.2%)
Body	
Thorax	9 (14.5%)
Knee	3 (4.8%)
Iliac crest	2 (3.2%)
Genitals	1 (1.6%)

Note: Data are expressed as absolute frequency (% of the study group).
Abbreviation: ECMO, extracorporeal membrane oxygenation.

study population and observation period (i.e., during the COVID-19 pandemic).[15,26,27] Complications of prone positioning specific to veno–venous ECMO include bleeding at the cannulas insertion sites, facial region injuries, and higher incidence of pressure ulcers.[28] The face is particularly at risk because it has too little muscle mass to provide sufficient blood supply to the skin and the subcutaneous facial tissue deformed by the weight of the head. Also, the configuration of the ECMO cannula (i.e., jugular cannula) does not allow for periodic alternating head rotation (as recommended in the swimmer position), which increases the risk of pressure ulcer development because pressure on the cheek, chin, and forehead cannot be redistributed. However, other anatomical districts are also at risk of developing pressure ulcers, considering the presence of several medical devices such as femoro–femoral cannulas or just the prolonged contact of body prominence (i.e., knee) on the bed surface.

Despite its poor predictive value to assess the risk of pressure ulcer development in ICU patients,[29] the Braden scale showed evidence of a difference between patients who were placed prone or not as additional therapy during ECMO. The Braden scale remains useful as a risk assessment tool to evaluate patients on admission to the ICU.

Complications usually arise when turning the patient into the prone position: accidental removal or dislodgement of the central venous catheter, the tracheal tube, the chest drainage tube or the ECMO cannula.[30] Our study did not record any ECMO cannula-related complications or loss of vascular catheters (central venous lines or arterial lines): these observations are also shared by previous safety reports involving paediatric and adult patients on ECMO.[7,31–35] The expertise of nursing staff is fundamental in the prevention of complications due to prone positioning during ECMO. We may speculate that no cannula-related complications were recorded because the manoeuvre is safely performed at our hub center by an experienced team (one intensivist, four ICU nurses, one perfusionist). The literature more often reports the occurrence of medical device dislodgment

during prone positioning in multicenter trials, which may include ICUs with less trained and experienced staff than centers specialized in the treatment of ARDS.[7] The healthcare personnel skills and the protocol in place at our center for prone positioning[36] might also explain why we found no association between the presence of pressure ulcers and body position, as reported in a large multicenter trial.[37] The experience of nurses and physicians seems to be the key factor in safe prone positioning manoeuvre and minimizing the risk of complications.[3]

ECMO duration and ICU LOS are significantly longer in patients placed prone compared with those never placed prone.[32,38] Such patients are likely to be in more critical condition, which would explain the need for prone position and the longer duration of ECMO, as reported in our study. Duration of ECMO is often linked to hemodynamic instability, for which vasoactive drugs are administered.[39] These potent vasoconstrictor agents counteract the effects of inadequate tissue perfusion by increasing arterial pressure. Also, these drugs may play a role in altering tissue perfusion over bony prominences, leading to pressure ulcer development.[40] Although recognized as a risk factor for pressure ulcer development, the etiopathogenesis is multifactorial and may depend on patient and clinical characteristics (i.e., BMI, sex, ICU LOS, disease severity). While holding these variables constant, however, we found no association between exposure to vasoactive drugs and pressure ulcers.

Despite body position during ECMO was not associated with the presence of pressure ulcers in our study, considering also that hours spent prone were poorly correlated with the number of pressure ulcers, as found in our study, it is important to stress that high number of hours spent in prone position can increase the risk of pressure ulcers development. This poses a challenge for nursing staff to prevent or anticipate the occurrence of potential complications.

4.1 | Strength and limitations

To the best of our knowledge, this is the second largest study involving adult patients placed prone during ECMO. Owing to its retrospective design, we were unable to control for minor events perhaps missing from the medical records, which could have led to an underestimation of the occurrence of complications. Furthermore, this single-center study was conducted in an ICU with specialized staff and equipment, which may preclude generalization of our findings to other clinical settings. Finally, because we did not collect data on the type and dosage of vasoactive drugs, we cannot determine what role certain drugs might play in the develop of pressure ulcers.

4.2 | Implications and recommendations for practice

Presence of highly skilled ICU nursing staff, the use of air loss pressure mattress and protective coverings might not be enough to minimize the risk of facial pressure ulcers development in critical ill patients with most severe conditions. Therefore, nurses working in ICU should implement timely assessment of the skin when patients are in prone position, due to the constrain of the head when jugular cannulation is the chosen ECMO support.

5 | CONCLUSION

In our hub center specialized in the treatment of patients with ARDS, the presence of pressure ulcers was not statistically associated with prone positioning during ECMO. Facial pressure ulcers are the most frequent complication in our cohort of critical ill patients with most severe conditions; therefore, nurses should plan and implement evidence-based strategies to prevent or minimize facial skin breakdown during ECMO.

AUTHOR CONTRIBUTIONS

Filippo Binda and Federica Marelli contributed equally (co-first author). Filippo Binda, Federica Marelli and Alessandro Galazzi designed the study, coordinated data collection, data curation and writing the original draft. Simone Gambazza performed formal analysis of data and reviewed the manuscript. Federica Marelli, Elisa Vinci and Paola Roselli made the data collection. Ileana Adamini and Dario Laquintana gave expert content and reviewed the manuscript. Dario Laquintana also contributed to study supervision. All authors read and approved the final version of the manuscript.

ACKNOWLEDGMENT

Open access funding provided by BIBLIOSAN.

FUNDING INFORMATION

This study was partially funded by Italian Ministry of Health - Current Research IRCCS.

CONFLICT OF INTEREST

The authors certify that they have no affiliations with or involvement in any organization or entity with any financial or non-financial interest in the subject matter discussed in this manuscript.

DATA AVAILABILITY STATEMENT

The data presented in this study are available on request from the corresponding author.

ETHICS STATEMENT

The study was approved by the local Ethics Committee of Fondazione IRCCS Ca' Granda Ospedale Maggiore Policlinico – Milan, Italy (approval number 765_2022). All methods were performed in accordance with the relevant guidelines and regulations. Written informed consent was waived because of the retrospective nature of the study.

ORCID

Filippo Binda https://orcid.org/0000-0002-2937-2698
Federica Marelli https://orcid.org/0000-0002-4511-7996

Alessandro Galazzi https://orcid.org/0000-0003-0085-7015
Simone Gambazza https://orcid.org/0000-0002-6225-2989
Elisa Vinci https://orcid.org/0000-0002-2412-9410
Paola Roselli https://orcid.org/0000-0002-7604-9551
Ileana Adamini https://orcid.org/0000-0001-9720-471X
Dario Laquintana https://orcid.org/0000-0001-8552-2630

REFERENCES

1. Guérin C, Baboi L, Richard JC. Mechanisms of the effects of prone positioning in acute respiratory distress syndrome. *Intensive Care Med*. 2014;40(11):1634-1642.
2. Henderson WR, Griesdale DEG, Dominelli P, Ronco JJ. Does prone positioning improve oxygenation and reduce mortality in patients with acute respiratory distress syndrome? *Can Respir J*. 2014;21(4):213-215.
3. Guérin C, Reignier J, Richard J-C, et al. Prone positioning in severe acute respiratory distress syndrome. *N Engl J Med*. 2013;368(23): 2159-2168.
4. Taccone P, Pesenti A, Latini R, et al. Prone positioning in patients with moderate and severe acute respiratory distress syndrome: a randomized controlled trial. *JAMA*. 2009;302(18):1977-1984.
5. Cherian SV, Kumar A, Akasapu K, Ashton RW, Aparnath M, Malhotra A. Salvage therapies for refractory hypoxemia in ARDS. *Respir Med*. 2018;141:150-158.
6. Papazian L, Schmidt M, Hajage D, et al. Effect of prone positioning on survival in adult patients receiving venovenous extracorporeal membrane oxygenation for acute respiratory distress syndrome: a systematic review and meta-analysis. *Intensive Care Med*. 2022;48(3):270-280.
7. Kipping V, Weber-Carstens S, Lojewski C, et al. Prone position during ECMO is safe and improves oxygenation. *Int J Artif Organs*. 2013; 36(11):821-832.
8. Culbreth RE, Goodfellow LT. Complications of Prone positioning during extracorporeal membrane oxygenation for respiratory failure: a systematic review. *Respir Care*. 2016;61(2):249-254.
9. McEvoy NL, Friel O, Clarke J, et al. Pressure ulcers in patients with COVID-19 acute respiratory distress syndrome undergoing prone positioning in the intensive care unit: a pre-and post-intervention study. *Nurs Crit Care*. 2022. doi:10.1111/nicc.12842. Online ahead of print.
10. Clements L, Moore M, Tribble T, Blake J. Reducing skin breakdown in patients receiving extracorporeal membranous oxygenation. *Nurs Clin North Am*. 2014;49(1):61-68.
11. European Pressure Ulcer Advisory Panel, National Pressure Injury Advisory Panel, Pan Pacific Pressure Injury Alliance. Prevention and Treatment of Pressure Ulcers/Injuries: Clinical Practice Guideline. The International Guideline. EPUAP/NPIAP/PPPIA; 2019.
12. Chaplin H, McGuinness S, Parke R. A single-Centre study of safety and efficacy of prone positioning for critically ill patients on veno-venous extracorporeal membrane oxygenation. *Aust Crit Care*. 2021; 34(5):446-451.
13. Petit M, Fetita C, Gaudemer A, et al. Prone-positioning for severe acute respiratory distress syndrome requiring extracorporeal membrane oxygenation. *Crit Care Med*. 2022;50(2):264-274.
14. Guervilly C, Prud'homme E, Pauly V, et al. Prone positioning and extracorporeal membrane oxygenation for severe acute respiratory distress syndrome: time for a randomized trial? *Intensive Care Med*. 2019;45(7):1040-1042.
15. Labeau SO, Afonso E, Benbenishty J, et al. Prevalence, associated factors and outcomes of pressure injuries in adult intensive care unit patients: the DecubICUs study. *Intensive Care Med*. 2021;47(2):160-169.
16. Tonna JE, Abrams D, Brodie D, et al. Management of Adult Patients Supported with Venovenous extracorporeal membrane oxygenation (VV ECMO): guideline from the extracorporeal life support organization (ELSO). *ASAIO J*. 2021;67(6):601-610.
17. Pavlushkov E, Berman M, Valchanov K. Cannulation techniques for extracorporeal life support. *Ann Transl Med*. 2017;5(4):70.
18. Kato C, Oakes M, Kim M, et al. Anticoagulation strategies in extracorporeal circulatory devices in adult populations. *Eur J Haematol*. 2021; 106(1):19-31.
19. Guérin C, Albert RK, Beitler J, et al. Prone position in ARDS patients: why, when, how and for whom. *Intensive Care Med*. 2020;46(12): 2385-2396.
20. Bamford P, Denmade C, Newmarch C, et al. Guidance for: prone positioning in adult critical care. *Intensive Care Soc*. 2019;1-39. https://www.wyccn.org/clinical-guidelines.html
21. Tayyib N, Coyer F. Effectiveness of pressure ulcer prevention strategies for adult patients in intensive care units: a systematic review. *Worldviews Evid Based Nurs*. 2016;13(6):432-444.
22. Bergstrom N, Braden BJ, Laguzza A, Holman V. The Braden scale for predicting pressure sore risk. *Nurs Res*. 1987;36(4):205-210.
23. Jiricka M, Ryan P, Carvalho M, Bukvich J. Pressure ulcer risk factors in an ICU population. *Am J Crit Care*. 1995;4(5):361-367.
24. R Core Team. *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria. 2022. https://www.R-project.org/
25. Poon WH, Ramanathan K, Ling RR, et al. Prone positioning during venovenous extracorporeal membrane oxygenation for acute respiratory distress syndrome: a systematic review and meta-analysis. *Crit Care*. 2021;25(1):1-9.
26. Binda F, Galazzi A, Marelli F, et al. Complications of prone positioning in patients with COVID-19: a cross-sectional study. *Intensive Crit Care Nurs*. 2021;67:103088.
27. Rodríguez-Huerta MD, Díez-Fernández A, Rodríguez-Alonso MJ, Robles-González M, Martín-Rodríguez M, González-García A. Nursing care and prevalence of adverse events in prone position: characteristics of mechanically ventilated patients with severe SARS-CoV-2 pulmonary infection. *Nurs Crit Care*. 2022;27(4):493-500.
28. Liu C, Chen Y, Chen Y, Chen B, Xie G, Chen Y. Effects of prone positioning during extracorporeal membrane oxygenation for refractory respiratory failure: a systematic review. *SN Compr Clin Med*. 2021; 3(10):2109-2115.
29. Deschepper M, Labeau SO, Waegeman W, Blot SI. DecubICUs study team, European Society of Intensive Care Medicine (ESICM) trials Group collaborators. Pressure injury prediction models for critically-ill patients should consider both the case-mix and local factors. *Intensive Crit Care Nurs*. 2021;65:103033.
30. Galazzi A, Adamini I, Consonni D, et al. Accidental removal of devices in intensive care unit: an eight-year observational study. *Intensive Crit Care Nurs*. 2019;54:34-38.
31. Chen Z, Li M, Gu S, et al. Effect of prone position in patients with acute respiratory distress syndrome supported by venovenous extracorporeal membrane oxygenation: a retrospective cohort study. *BMC Pulm Med*. 2022;22(1):1-9.
32. Giani M, Martucci G, Madotto F, et al. Prone positioning during Veno-venous extracorporeal membrane oxygenation in acute respiratory distress syndrome a multicenter cohort Study and propensity-matched analysis. *Ann Am Thorac Soc*. 2021;18(3):495-501.
33. Haefner SM, Bratton SL, Annich GM, Bartlett RH, Custer JR. Complications of intermittent Prone positioning in pediatric patients receiving extracorporeal membrane oxygenation for respiratory failure. *Chest*. 2003;123(5):1589-1594.
34. Guervilly C, Hraiech S, Gariboldi V, et al. Prone positioning during veno-venous extracorporeal membrane oxygenation for severe acute respiratory distress syndrome in adults. *Minerva Anestesiol*. 2014; 80(3):307-313.
35. Kredel M, Bischof L, Wurmb TE, Roewer N, Muellenbach RM. Combination of positioning therapy and venovenous extracorporeal membrane oxygenation in ARDS patients. *Perfusion*. 2014;29(2):171-177.

36. Binda F, Marelli F, Galazzi A, Pascuzzo R, Adamini I, Laquintana D. Nursing Management of Prone Positioning in patients with COVID-19. *Crit Care Nurse*. 2021;41(2):27-35.
37. Girard R, Baboi L, Ayzac L, Richard J-C, Guérin C. The impact of patient positioning on pressure ulcers in patients with severe ARDS: results from a multicentre randomised controlled trial on prone positioning. *Intensive Care Med*. 2014;40(3):397-403.
38. Rilinger J, Zotzmann V, Bemtgen X, et al. Prone positioning in severe ARDS requiring extracorporeal membrane oxygenation. *Crit Care*. 2020;24(1):397.
39. Gutsche JT, Mikkelsen ME, McCarthy FH, et al. Veno-venous extracorporeal life support in hemodynamically unstable patients with ARDS. *Anesth Analg*. 2017;124(3):846-848.
40. Cox J. Pressure ulcer development and vasopressor agents in adult critical care patients: a literature review. *Ostomy Wound Manage*. 2013;59(4):50-54. 56–60.

How to cite this article: Binda F, Marelli F, Galazzi A, et al. Pressure ulcers after prone positioning in patients undergoing extracorporeal membrane oxygenation: A cross-sectional study. *Nurs Crit Care*. 2024;29(1):65-72. doi:10.1111/nicc.12889