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# Considerations of invasive mechanical ventilation in prone position. A narrative review

## Consideraciones de la ventilación mecánica invasiva en posición prona. Revisión narrativa

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### Abstract

The evidence regarding logistic considerations and safety events associated with prone position ventilation (PPV) is summarized and a flow diagrama for safe provision of mechanical ventilation in the setting of the COVID-19 pandemic is proposed. A review of the literature was conducted in the Medline via Pubmed, Embase, and Lilacs databases, the Cochrane Database of Systematic Reviews, Cochrane Central Register of Randomized Controlled Trials, Cochrane Database of Abstracts of Reviews of Effects, ProQuest Nursing and Allied Health Database, and Google scholar. Overall, 31 articles were selected for the analysis. The incidence of PPV-related safety events varies between 1% and 11.9% and the most frequent complications are pressure ulcers and airway complications. Early initiation of enteral nutrition is recommended, and transfers are possible in patients on PPV. There is controversy regarding contraindications and recommendations for PPV. Recommendations for its safe provision are based on expert opinions and the establishment of protocols for healthcare staff training. Clinical studies are required to determine which are the recommendations that should be considered for safe and reproducible PPV use during this pandemic.

**Keywords:** Mechanical ventilation; Prone position; Prone positioning; COVID-19; Intensive care unit; Critical care; Anesthesiology.

### Resumen

Sintetizamos la evidencia con respecto a las consideraciones logísticas y los eventos de seguridad asociados a la ventilación mecánica en posición prona (VMPP) y proponemos un fluograma para realizarla de manera segura en el escenario de la pandemia por COVID-19. Para ello, realizamos una búsqueda de la literatura en las bases de datos Medline vía PubMed, Embase, Lilacs, Cochrane Database of Systematic Reviews, Cochrane Central Register of Randomized Controlled Trials, Cochrane Database of Abstracts of Reviews of Effects, ProQuest Nursing and Allied Health Database y Google académico. Se incluyeron 31 artículos para ser analizados. La incidencia de eventos de seguridad relacionados a la VMPP varía entre 1 % a 11.9 %, las complicaciones más frecuentes son las úlceras por presión y de la vía aérea. Se recomienda iniciar nutrición enteral temprana y es posible realizar traslado de pacientes con VMPP. Existe controversia acerca de las contraindicaciones y recomendaciones de la VMPP. Las recomendaciones para realizarla de forma segura se basan en opiniones de expertos y en la instauración de protocolos para el entrenamiento del personal de salud. Se requieren estudios clínicos para determinar cuáles recomendaciones son necesarias para que la VMPP se realice de forma segura y reproducible durante esta pandemia.

**Palabras clave:** Ventilación mecánica; Posición prona; Síndrome de dificultad respiratoria aguda; COVID-19; Unidad de cuidado intensivo; Cuidado crítico.

## INTRODUCTION

Betacoronavirus SARS-CoV-2 infection was first reported in December 2019 in Wuhan, China (1) and declared as a pandemic in March 2020 by the World Health Organization (2). Of all patients with COVID-19, 20% require treatment in the intensive care unit (ICU) and 3.2% require invasive mechanical ventilation (IMV); the most common severe complication of this disease is acute respiratory distress syndrome (ARDS) (3), and overall mortality rate is 3.4% (4).

Although only 16% of patients with severe ARDS received prone position ventilation (PPV) (5) before the pandemic, this strategy is one of the mainstays of treatment in COVID-19 patients (6). Technical considerations are the main challenges for this maneuver, together with strategies to reduce the risk of complications. Improving training and expertise of the team in order to avoid adverse events related to the change in position (7) is yet another challenge.

The main objective of this narrative review of the literature is to synthesize the information pertaining to logistics and safety events associated with PPV. Finally, this article proposes a flow diagram to achieve a safe intervention in the setting of the COVID-19 pandemic.

A literature search was conducted in the Medline via PubMed, Embase, and Lilacs databases, the Cochrane Database of Systematic Reviews, Cochrane Central Register of Randomized Controlled Trials, Cochrane Database of Abstracts of Reviews of Effects, ProQuest Nursing and Allied Health Database and Google Scholar. The free text and MeSH/Emtree search criteria were: "mechanical ventilation," "prone position," "prone positioning" and "critical care". A snowball search was also conducted based on the selected references.

Studies in adult populations (over 18 years of age) with a diagnosis of ARDS requiring prone position ventilation

that described clinical safety outcomes, prevention strategies and treatment of associated complications were included. The exclusion criteria were pediatric population and safety events associated with pronation in the surgical setting. After removing duplicates, references were screened by title and abstract by four reviewers working independently; disagreements were resolved by consensus. Full texts were reviewed, verifying inclusion and exclusion criteria before definitive selection.

### Included articles

The literature search in the databases mentioned above yielded 31 references that met the inclusion and exclusion criteria. The diagram shown in Figure 1 describes the selection process.

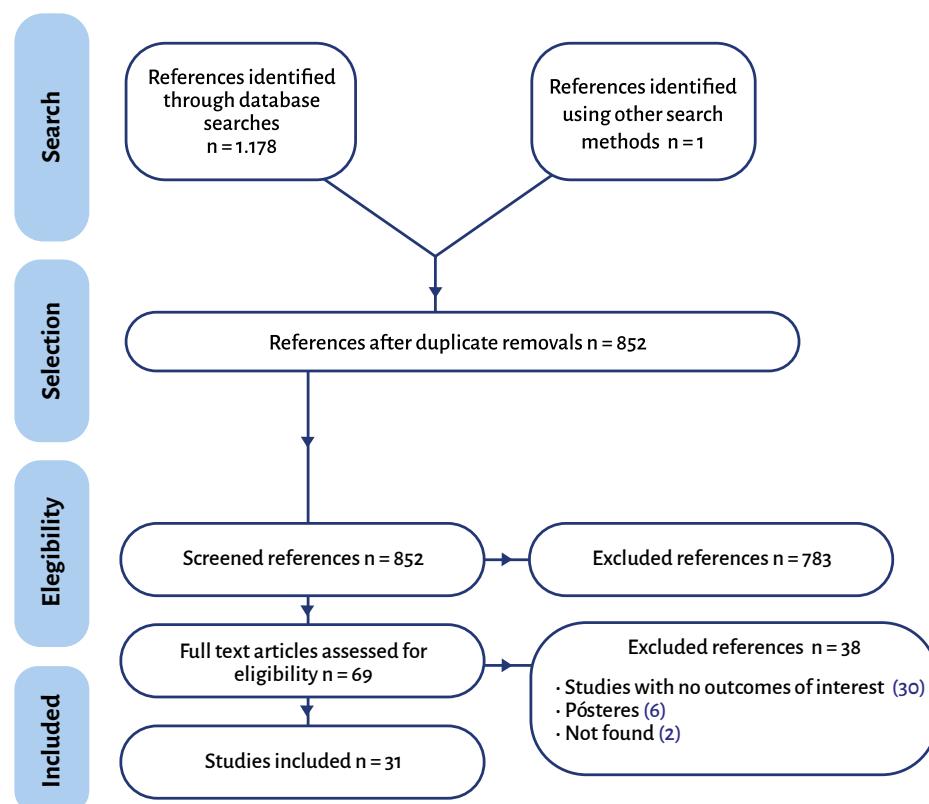
### Complications with the use of PPV

The incidence of VPP-related safety events described in the literature ranges between 1% and 11.9% (8,9). Table 1 summarizes the complications described in the literature as well as the associated risk factors.

The most frequent complications are associated with pressure ulcers in bone surface contact or sloping areas (OR 1.49; 95% CI [1.18-1.89];  $p = 0.001$ ;  $I^2 = 0.0\%$ ) (10). These frequently resolve without creating permanent harm for the patient.

Airway complications (OR 1.55; 95% CI [1.10-2.17];  $p = 0.012$ ;  $I^2 = 32.7\%$ ) are mainly secondary to an increased risk of endotracheal tube (ETT) obstruction (OR 2.16; 95% CI [1.53-3.05];  $p < 0.001$ ;  $I^2 = 0.0\%$ ) (10). The obstruction could result from increased secretions or mechanical ETT compression. No fatal consequences were reported in any of the included studies.

**FIGURE 1.** Assessment and selection of the articles found.



**SOURCE:** Authors.

**TABLE 1.** Complications related to mechanical ventilation in prone decubitus position.

Type of complication	Characteristics	Risk factors
Skin and soft tissues	Facial edema (11-14) Chest and limb edema (14) Facial (6-19) and thoracic pressure ulcers (16,20) Masseter myositis (12) Facial scar secondary to ETT fixation (21) Skin tears (15,19) Bilateral breast necrosis (22)	Hypoxemia (16,21) Microvascular lesion (20,23) Thrombosis (16) Continuous therapy > 8 h (12) Diabetes mellitus (21) Immobility (21) Edema (21) Age > 60 years (20) BMI > 28.4 (20) Vasopressor use (20)
Respiratory	Unforeseen extubation (6,9,14,15,17,19) ETT displacement (9,13-15,17,24) ETT obstruction (8,9,13-15,17,19,24) Aspiration (9) Barotrauma (25) Pneumothorax (23)	Inadequate preparation of the pronation maneuver (26) Failure to aspirate secretions (9) Gastric regurgitation (EN) (27)
Ophthalmological	Corneal lesion (8,11,12) Keratitis (12) Increase in intraocular pressure (28) Conjunctival edema (19) Conjunctival hemorrhage (14)	External ocular compression (12) Extreme neck flexion, extension or rotation (28)
Neurologic	Transient ICP increase (8) Injury to cranial nerves IX, X, XI, XII (29)	Cervical hyperextension (29)
Device-related	Catheter damage (9,11,14,23-25) Accidental disconnection (9,14)	Inadequate preparation of the maneuver (26) Device fixation (11)

BMI: body mass index; EN: enteral nutrition; ETT: endotracheal tube; ICP: intracranial pressure.

**SOURCE:** Authors.

## Transfer of patients on PPV

Information regarding transfer of patients inside and outside the hospital is limited to case reports and case series of air or land transportation of patients on prone position invasive mechanical ventilation. These experiences suggest the minimum requirements to ensure safe patient transfer without increasing the risk of complications. It is suggested that the team consist of at least 3 people, including one physician and one licensed practical nurse guided over the telephone by an emergency specialist or an anesthetist with transport training (30). All patients must be on continuous monitoring for

ventilation parameters, electrocardiogram, oxygen saturation, capnography and invasive and non-invasive arterial pressure measurement (30,31). An adequate level of sedoanalgesia and muscle relaxation must be ensured (31).

## Special considerations for enteral nutrition

Early initiation of enteral nutrition (EN) within the first 48 hours after admission to the ICU reduced hospital and ICU mortality, hospital length of stay and the risk of infection (32), with a grade B recommendation in patients with PPV (33).

The 2017 ESICEM guidelines recommend: 1) Prefer EN over early parenteral nutrition; 2) Start at low doses as soon as hemodynamic instability is under control; 3) Use in patients with stable hypoxemia, compensated or permissive hypercapnia and/or acidosis; 4) Use neuromuscular blocking agents; and 5) PPV should not delay EN initiation (34).

EN intolerance, defined as vomiting, gastroparesis and diarrhea (35) is a healthcare-related complication in critically ill patients and a higher incidence has been historically attributed to PPV (32). However, the evidence available to this date has not shown a significant difference in EN tolerance between supine and prone patients (32,35).

The implementation of therapeutic measures such as the use of prokinetic agents (IV erythromycin as first line), postpyloric feeding in case of aspiration risk or persistent EN intolerance (33), 30-degree elevation of the bedhead, and continuous instead of bolus administration is recommended in cases of EN intolerance. Additionally, frequent monitoring of residual gastric volume and enteral feeding rate adjustments are also recommended (32).

## Additional considerations

Regarding the association between ventilator-associated pneumonia (VAP) and prone positioning, the subanalysis of the PROSEVA study showed similar incidences between the groups in supine and in prone position: 1.18 (0.76-1.60) and 1.54 (1.15-2.02) for every 100 days of IMV ( $p = 0.10$ ), respectively. The 90-day cumulative probability of VAP was estimated at 46.5% for prone decubitus and at 33.5% for supine decubitus, with no statistically significant difference between the two ( $p = 0.11$ ) (27). Similar findings were described in the meta-analysis by Alexiou et al., with no statistically significant difference found in clinically diagnosed VAP between patients in prone and supine position (OR = 0.80; 95% CI [0.60-1.08]; 1,018 patients) (13).

To this date, there are no clinical studies assessing absolute contraindications for

PPV. Challenges associated with patient positioning suggest that PPV should be avoided in cases of severe burns, open wounds of the face or the ventral surface of the body, spinal instability, pelvic fractures, cardiac arrhythmias, hemodynamic instability and raised intracranial pressure (36,37). The relative contraindications described are limited to the presence of thoracic or abdominal drains, pregnancy, tracheostomy in the first 24 hours and intraocular hypertension (10,36).

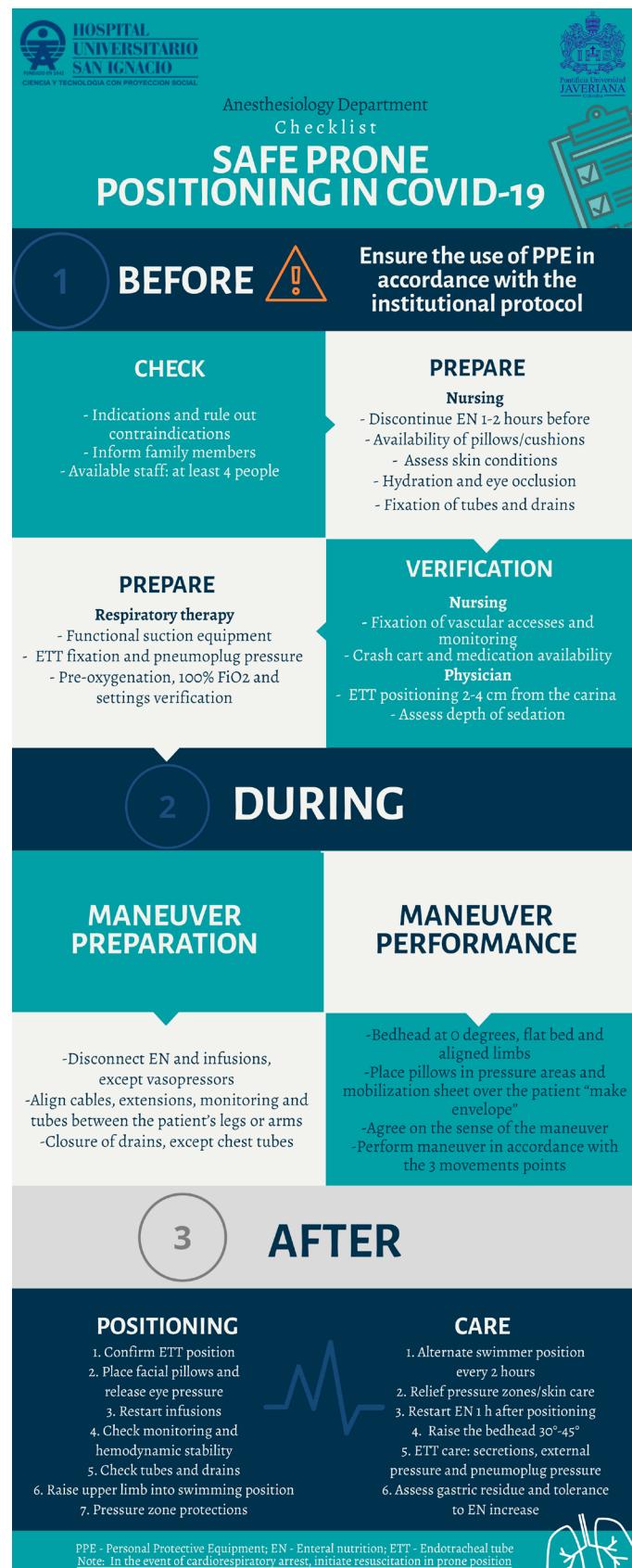
## DISCUSSION

This review led to the identification of the considerations for safe PPV in patients with severe ARDS. Based on the available evidence it is not possible to make definitive recommendations derived from clinical trials; most of the information comes from the experience of intensive care teams managing patients with severe ARDS needing PPV. Moreover, protocol implementations with limited results in times of pandemic lead to the emergence of other alternatives to management and the establishment of the recommended measures.

With the advent of the pandemic, the need for PPV has been more frequent as part of effective strategies in the management of patients with severe ARDS, given its impact on short and long-term mortality when implemented for  $\geq 16$  hours/day (7). Most of the studies described so far report the effectiveness and efficacy of this therapy from the respiratory point of view (24). Some authors describe potential adverse effects and/or complications associated with pronation cycles and recommend strategies that can be implemented as part of patient care in order to diminish their occurrence.

The described length of PPV varies: Guerin et al. (8) report 18 hours (16-23 hours); Mancebo et al. (14) establish an average of 10.5 días (0-54 days) with a time of 17 hours per day; and Taccone et al. (24),  $8.4 \pm 6.3$  pronation sessions lasting  $18 \pm 4$  hours per day in order to achieve 20 hours in all patients. Moreover, in patients with

**FIGURE 2.** Safe Prone Positioning in COVID-19 checklist.



**SOURCE:** Authors.

COVID-19 infection and ARDS, Douglas et al. found a statistically significant association between prolonged PPV (2.08-9.97 days) with the occurrence of ventral pressure ulcers (OR 1.34 for every additional day; 95% CI [1.13-1.68];  $p <0.001$ ) and concluded that the strategy is feasible and relatively safe (38).

The growing number of COVID-19 cases created a greater demand for the ICU, to the point that operating rooms were converted into intensive care units (39,40). For this reason, and given the lack of trained human resources, the information synthesized from the search conducted for this study can be of use for medical staff training and awareness.

Existing protocols for the care and prevention of complications in patients with PPV (41,42) must be adapted to the new conditions of the pandemic and case overloads. During the first wave of the pandemic, up to 11 surgical stations (6 in the operating theater and 5 in the catheterization lab) were needed as ICU beds at the San Ignacio University Hospital (Bogotá D.C., Colombia), not before having to provide training to the staff for their new roles.

Therefore, simulation strategies such as those used by Mouli et al. (43) for the training of anesthetists can be useful for enhancing familiarity with the recommended protocols. To ensure knowledge of this information by the staff in charge of these patients and in order to achieve standardization in their management, the authors of this paper propose an algorithm based on the review of the literature, focused on care before, during and after the implementation of prone positioning (Figure 2).

To conclude, severe ARDS requiring PPV has increased as a disease condition during the pandemic. There is controversy regarding the contraindications and recommendations for the care of patients undergoing prone positioning. The available information is based on expert opinions and/or case reports. This could be a source of future study aimed at answering the questions that have emerged.

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### Author's contributions

**LDB, JCSS:** Participated in study planning, data collection, analysis of the results and final drafting of the manuscript.

**NFCB, DSB:** Participated in the analysis of the results and initial drafting of the manuscript.

**MOE:** Participated in study planning and design, analysis of the results and initial drafting of the manuscript.

### Conflict of interest

None declared.

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### Submissions

None declared.

### Appreciation

None declared.

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