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LASTING LEGACY IN INTENSIVE CARE MEDICINE

Prone position in mechanically ventilated patients

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Rationale for using prone position

The use of prone position (PP) during invasive mechanical ventilation was first reported more than 45 years ago as a mean to improve oxygenation in patients with acute hypoxemic respiratory failure [1]. Improved oxygenation in the prone position has subsequently been confirmed in many studies [2, 3]. The mechanisms by which PP improves oxygenation include better aeration and ventilation in the most vertebral parts of the lung, which continue to receive most of the pulmonary blood flow (reducing the intra-pulmonary shunt in the vertebral parts of the lung). The aeration and the ventilation-to-perfusion ratios distribution are more homogeneously distributed throughout the lung in during PP [4]. Due to its combined effects of recruiting the vertebral parts of the lung, making the distribution of ventilation more homogeneous, and reducing the intra-cycle recruitment/derecruitment, PP dampens lung stress and strain stemming from mechanical ventilation (improved lung compliance, reduction in trans-pulmonary driving pressure). Combined with a moderate level of positive end-expiratory pressure (PEEP), PP may limit mechanical power [5]. Facilitating respiratory secretions drainage and maintaining or even improving hemodynamics are other important additional beneficial effects of PP in patients with acute respiratory distress syndrome (ARDS). Since the recent pandemic, PP is now used in awake not intubated patients (out the scope of the present article). Failure to awake proning does not contra-indicate the use of PP after intubation.

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Use of prone positioning in the clinical setting and effects on outcome

Early studies of prone positioning evaluated its application across all severities of ARDS [6]. Over time, it was noted that the subgroup of more severely hypoxemic patients derived the greatest benefit. These findings were the ground work for the PROSEVA trial [3]. This trial was unique compared to prior studies given its focus on (1) persistent moderate-severe ARDS ($PaO_2/FiO_2 < 150$ mmHg) after a 12–24 h period of optimization, (2) greater time spent sustained in the prone position, and (3) lower thresholds for terminating daily prone sessions. Across the 466 patients enrolled in the trial, 28-day mortality was significantly lower in the patients mechanically ventilated in the PP (16% vs. 33% for those remaining in the supine position; $p < 0.001$). A meta-analysis of 8 randomised controlled trials (RCTs) (2129 patients) demonstrated a mortality benefit of PP across studies restricted to moderate-to-severe ARDS [6] and subsequently PP has been recommended by societies and guidelines committees in the management of moderate-to-severe ARDS [7]. A recent meta-analysis also suggested an improvement in survival when PP is used in ARDS patients receiving extracorporeal membrane oxygenation (ECMO) [8].

Soon after the publication of the PROSEVA trial, an international epidemiologic study was conducted across 29,144 patients evaluating the management of patients with ARDS [9]. PP was used in only 16.3% of patients with severe ARDS. Reports, however, during the coronavirus disease 2019 (COVID-19) pandemic, have shown greater adoption of PP in recent years. In one study evaluating management COVID-19 patients, 79% of those presenting with severe COVID-19 ARDS were managed with PP [10].

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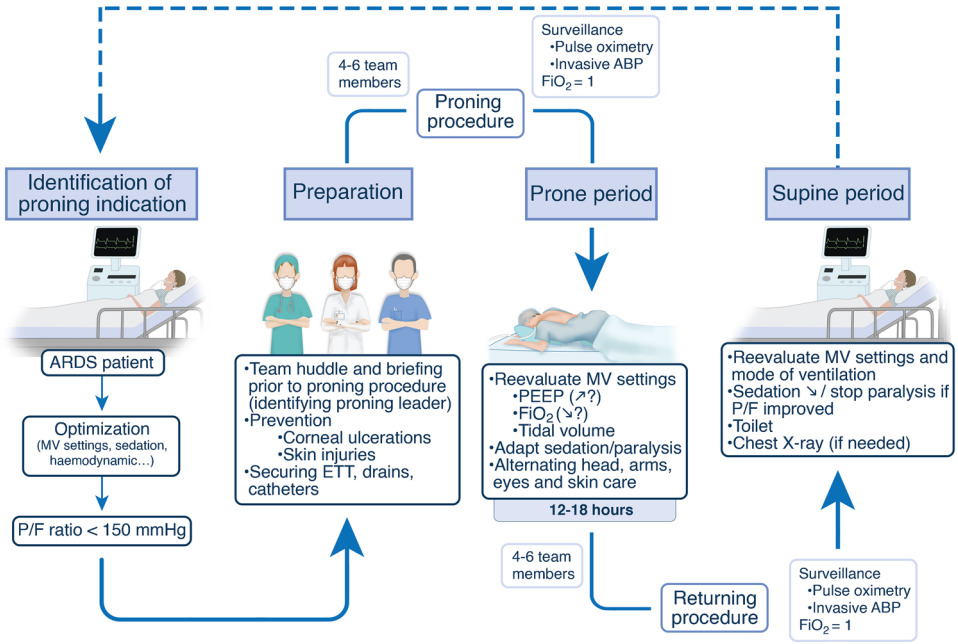

Fig. 1 Patients' selection and prone positioning procedure. *MV* mechanical ventilation, *P/F* PaO_2/FiO_2 ratio, *ETT* endotracheal tube, *ABP* arterial blood pressure

How to implement prone position at the bedside

PP should be done early in the course of moderate-to-severe ARDS in the presence of persisting hypoxemia ($PaO_2/FIO_2 \leq 150$ mm Hg) after adjusting mechanical ventilation settings and particularly PEEP level (avoiding right ventricular dysfunction) (Fig. 1). In the presence of extensive fibrosis (late ARDS), the improvement in oxygenation during PP is very limited. Absolute or relative contraindications to PP during mechanical ventilation include severe haemodynamic instability; life-threatening arrhythmia; evidence of elevated intracranial, intraocular or intra-abdominal pressures; seizure; multiple trauma; facial, chest, spine or pelvic fractures; tracheotomy less than 24 h old; recent cardiothoracic surgery and open abdominal wound [2, 11]. Data surrounding the feasibility, effectiveness and outcomes of PP in late second and third trimester pregnancy patients is lacking but it was employed during the COVID-19 pandemic and warrants evaluation.

Beds

Many times, standard beds in intensive care unit (ICU) are used as in the PROSEVA study [3]. Low-airloss bed system is also employed in some ICUs [11]. In contrast, automated pronating beds are not necessary and may be cumbersome and time consuming to set up.

PP maneuver

There are many ways to place a patient in the PP. Lack of experience and education on prone therapy for staff may increase complications. Although eye occlusion is recommended to prevent conjunctivitis and corneal ulcerations, application of thin hydrocolloid dressing for pressure ulcer prevention is controversial. Meticulous securing of endotracheal tube, catheters, chest tubes, drains and ECMO cannulas is mandatory. Positioning of transverse rolls placed under the pelvis and the chest has not been proven to improve oxygenation [12]. For patients with tracheostomy, specially designed disposable PP head cushion with a mirror improves the access to the tracheostomy tube and facilitates suctioning using a closed system [13]. The standard monitoring during the entire procedure should involve pulse oximetry and invasive arterial blood pressure. Pronation of patients requires a complex and coordinated effort, involving physicians and nurses (video [3]) particularly when performed in obese patients. When PP is performed in ECMO patients [14], at least six staff are implicated (video [13]). Pulse oximetry allows a continuous surveillance. However, arterial blood gas analyses performed just before proning, after 1 h of PP, at the end of the proning session and 1–2 h after returning supine permit to evaluate the response (absence, early, late, both, persistent) and to adapt

mechanical ventilation settings. However, simplest surveillance is accurate when the patient is stabilized.

Concomitant therapeutics

Regarding mechanical ventilation settings, PP may have additive effects with PEEP. While in the supine position, increasing PEEP can induce end-tidal regional hyperinflation in less injured and less dependent lung areas, PP reduces the regional heterogeneity and decreases chest wall compliance, which in turn facilitates increases in PEEP and improved lung recruitment. Mechanical ventilation settings should be re-evaluated in the PP and after returning the patient supine.

Sedation is often employed to avoid dysynchrony between the patient and the ventilator across moderate to severe ARDS. However, in most instances when PP is being considered, neuromuscular blockers are added. In the PROSEVA study [3], the concomitant use of paralyzing agents was required. However, their systematic use needs to be evaluated. Inhaled nitric oxide administration is feasible during PP and may have additive effects when combined with PP.

Duration of PP

The PROSEVA study for discontinuing PP required a $PaO_2/FIO_2 > 150$ mm Hg on a $FIO_2 \leq 0.6$ and PEEP ≤ 10 cm H_2O in the supine position [3]. Sometimes, less strict criteria can be used to mitigate the risk of prolonged duration of mechanical ventilation due to sedatives. A PaO_2/FIO_2 ratio deterioration > 20% relative to supine or the occurrence of a life-threatening complication during PP suggest not repeating PP [3].

It has been shown that duration of PP ≥ 12 h is associated with better outcomes [6]. A major point is that in the PROSEVA study [3], the PP was done every day even if there was no improvement in oxygenation during the previous session. Indeed, the mechanisms explaining the outcome improvement are complex and not limited to the improvement in gas exchange. The localization of lung infiltrates (chest X-ray, echo, computed tomography scan) does not predict the improvement in oxygenation [15].

Adverse events

Various complications can occur during PP such as device displacement, vomiting, loss of venous access, accidental extubation, endotracheal tube displacement and obstruction, haemodynamic instability, brachial plexus injury and pressure sores [6, 16]. Pressure ulcers are mainly observed on face and anterior part of the thorax (role of pillows) [17]. It is likely that all complications may be avoided with staff training and collaboration. Only minor complications have been reported when proning ECMO patients by experienced and trained teams [14].

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