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## Review

## Is the prone position indicated in critically ill patients with SARS-CoV-2 during the peri-operative period?



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## ABSTRACT

Coronaviruses including SARS-CoV-2 are a large family of viruses that cause illnesses ranging from the common cold to more severe diseases. A SARS-CoV-2 is a new strain that has not been previously identified in humans. The majority of critically ill patients admitted to intensive care units with confirmed severe infection with SARS-CoV-2 developed an acute respiratory distress like syndrome. The main objective of this opinion paper is to raise the discussion about the possible benefit of keeping the patient with COVID-19 disease and acute hypoxemic respiratory failure (AHRF) in the prone position during the perioperative period, especially where this position is not a required factor for the surgical or invasive procedure. We believe that the prone position, due to its favorable pulmonary physiology, can improve the V/Q ratio in the perioperative period.

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## 1. Introduction

On January 30, 2020, the WHO Director-General declared the novel coronavirus outbreak a public health emergency of international concern [1]. Approximately 80% of critically ill patients admitted in intensive care units with confirmed infection of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) developed

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acute hypoxemic respiratory failure (AHRF) [2–4]. For patients with AHRF, the specific characteristics of the syndrome, such as respiratory mechanics, remain unknown. In a recent study, Pelosi et al. tries to associate the response to mechanical ventilation with distinct phenotypes that require distinct respiratory management strategies in severe COVID-19. They identified that chest computed tomography (CT) patterns in COVID-19 may be divided into three main phenotypes: 1) multiple, focal, possibly over-perfused ground-glass opacities; 2) inhomogeneously distributed atelectasis; and 3) a patchy, ARDS-like pattern. Each phenotype can benefit from different treatments and ventilator settings [5].

The clinical manifestations of the patients with SARS-CoV-2 pneumonia, which is also referred to as novel coronavirus pneumonia or Wuhan pneumonia, have been summarized [6]. An important clinical question for personalizing the management of these patients is whether the lungs are recruitable with high positive end-expiratory pressure (PEEP) for each individual patient. Investigators from China and Canada retrospectively reported on 12 SARS-CoV-2 cases and documented the effect of body positioning in mitigating AHRF [6]. Prone positioning ventilation is most used today in intensive care units (ICU) for patients with acute respiratory distress syndrome (ARDS) [7] and for prevention of ventilator-induced lung injury [8,9]. Patients with COVID-19-related AHRF benefit from an alternating body position, in particular, having them spend periods in prone position to improve lung recruitment capacity [10]. In patients with AHRF who require urgent/emergency surgery in which specific positioning is not necessary, can the patient be placed in the prone position during the perioperative period?

### 1.1. Perioperative context of COVID-19 pandemic

In a recent study, Nepogodiev et al., identified that postoperative pulmonary complications occur in half of patients with perioperative SARS-CoV-2 infection and are associated with high mortality [11]. This has direct implications for clinical practice around the world. The increased risks associated with SARS-CoV-2 infection should be balanced against the risks of delaying surgery in individual patients, mainly in procedures that cannot be postponed. This study identified men, people aged 70 years or older, those with comorbidities (ASA grades 3–5), those having cancer surgery, and those needing emergency or major surgery as being most vulnerable to adverse outcomes. Men aged 70 years and over who have had emergency or major elective surgery are at particularly high risk of mortality, although minor elective surgery is also associated with higher-than-usual mortality. Postoperative outcomes in SARS-CoV-2-infected patients are substantially worse than pre-pandemic baseline rates of pulmonary complications and mortality. Dmitri Nepogodiev, commented: “Worldwide an estimated 28.4 million elective operations were cancelled due to disruption caused by COVID-19. Our data suggests that it was the right decision to postpone operations at a time when patients were at risk of being infected with SARS-CoV-2 in hospital. There’s now an urgent need for investment by governments and health providers in to measures to ensure that as surgery restarts patient safety is prioritised. This includes provision of adequate personal protective equipment (PPE), establishment of pathways for rapid preoperative SARS-CoV-2 testing, and consideration of the role of dedicated ‘cold’ surgical centres.” [11].

### 1.2. Physiological effects of the prone position

The most significant physiological effect of the prone position is improved oxygenation, which is seen in approximately 80% of ARDS patients placed in this position. This improvement in oxygenation

can be attributed to several mechanisms that may occur in isolation or in combination. Among these are the reduced number of factors that contribute to alveolar collapse and to ventilation and perfusion mismatch. In the supine position, the motion of the human diaphragm is uniform, whereas, in the prone position, there is greater movement in the dorsal region [12]. This probably occurs due to decreased compression of the diaphragm by the abdominal organs. In the supine position, sedation and paralysis of patients on mechanical ventilation depress the diaphragmatic muscular tonus, causing the abdominal content to induce a cephalic deviation of the most posterior regions of the diaphragm, contributing to the collapse of these regions [12]. In the prone position, the weight of the abdominal content rests on the surface of the bed, diminishing the deviation of the diaphragm. In the supine position, there is less pulmonary expansion in the dependent portions due to the weight of the lung, the weight of the cardiac mass, diaphragmatic motion and the shape of the chest cavity. The effects of these factors are minimized in the prone position, which propitiates better aeration of these regions.

Among obese patients (BMI>30) prone position also increases lung volumes, lung capacity and oxygenation [13]. There is little evidence of prone positioning in pregnant women, who might benefit from being placed in the lateral decubitus position.

### 1.3. Perfusion redistribution

In physiologic conditions, perfusion increases progressively from the non-dependent to the dependent regions (ventral to dorsal in the supine position), according to the effects of gravity. Although other factors such as hypoxic vasoconstriction, vascular obliteration and extrinsic venous compression, may interfere with the perfusion distribution in individuals with acute lung injury and ARDS, perfusion keeps following the gravitational gradient into the lungs.

Regarding the V/Q ratio, it presents a more homogenous pattern, improving oxygenation, both in healthy anesthetized volunteers and in patients submitted to surgeries [14]. Prone positioning, during general anesthesia, minimally affects respiratory mechanics while improving functional residual capacity and increasing oxygen tension.

In summary, reducing the size of the areas of lung atelectasis propitiates better distribution of ventilation, which, along with better distribution of perfusion, leads to a more homogeneous ventilation/perfusion ratio, thereby explaining the fact that the prone position successfully improves oxygenation.

## 2. Discussion

Prone position offers several physiological beneficial effects that may improve clinical conditions of SARS-CoV-2 patients submitted to surgeries. It increases functional residual capacity and oxygenation, without changing airway resistance.

There is a robust amount of evidence in the literature supporting the benefits of prone position on ventilatory physiology and its value on the treatment of SARS patients. Pelosi et al. demonstrated that prone position does not alter respiratory mechanics and improves lung volume and oxygenation [15]. Bryan AC. also suggested that prone positioning might lead to improved oxygenation [16]. His prediction was fully confirmed in most of the subsequently published studies, which undoubtedly showed that in approximately 70% of patients with acute respiratory distress syndrome, prone position, always applied in association with some degree of PEEP, improves oxygenation [17].

Prone positioning is a supplementary strategy available for management of patients with ARDS and it proves to be in alignment

with two major ARDS pathophysiological lung models. It improves gas exchange, respiratory mechanics, lung protection and hemodynamics as it redistributes transpulmonary pressure, stress and strain across the lung, and unloads the right ventricle [18]. Application of prone ventilation is strongly recommended for adult patients and may be considered for paediatric patients with severe ARDS but requires sufficient human resources and expertise to be performed safely [18]. In adult patients with severe ARDS, prone ventilation for 12–16 h per day is recommended.

COVID-19 can rapidly progress to AHRF, an inflammatory process in the lungs that induces non-hydrostatic protein-rich pulmonary oedema. The consequences AHRF associated with COVID-19 infection are profound hypoxemia, and increased intrapulmonary shunt and dead space. The biological aspects include severe inflammatory injury to the alveolar-capillary barrier with 10–20 times interleukin 6 levels, surfactant depletion, and loss of aerated lung tissue [19].

By extrapolating the results from articles such as cardiopulmonary resuscitation in the prone position [20–24] and respiratory physiology in the prone position, one can infer that this position improves the ventilation/perfusion ratio (V/Q ratio or V/Q ratio) in patients with COVID-19. In fact it is not surprising that lung-protective ventilatory strategies that are based on underlying physiological principles have been shown to be effective in improving outcomes of SARS-CoV-2 patients [19].

These patients should be placed on low tidal volumes and low FiO<sub>2</sub> to maintain acceptable oxygenation. Ventilation should be on volume-controlled mode with tidal volume at 6 ml/kg of predicted body weight, since some studies have demonstrated that both female and obese patients are more likely to be placed on high tidal volume ventilation [25]. Such pattern is often reported in other studies and likely reflects the calculation of tidal volume based on actual body weight. PEEP should be individualized at the bedside, guided by recruitment (degree of pulmonary collapse), used decrementally and recalculated whenever body position is changed, especially in obese patients.

Yang et al. [3], first described lung behaviour in patients with severe COVID-19 requiring mechanical ventilation and receiving positive pressure. They concluded that among patients who did not respond to high positive pressure, prone positioning in bed was helpful. The findings of the Yang et al. may not be generalizable to all cases of COVID-19 associated AHRF, both due to the sample size and the fact that the study was not randomized. While they called their findings surprising; they wrote that any relation to body position and increased lung recruitability should be further explored.

In anesthesia practice prone position was initially introduced in paralyzed subjects for surgical specific reasons. Later, it was used during acute respiratory failure to improve gas exchange. Since the interest on prone position during COVID-19 pandemic progressively increased, we further enquire whether the vast experience from intensive care of respiratory distress syndrome using decubitus change, with its strong evidence in the literature may also be extrapolated to anesthesia for COVID-19 patients submitted to surgeries [15].

### 2.1. Surgical procedure and timing

Emergency/urgent surgical procedures are by definition characterized by an elevated number of unpredictable factors that might precipitate patient's conditions. Therefore, modifiable risk factors should be identified and managed appropriately, including timing and choice of interventions [26].

There is low evidence regarding the best ventilator settings in patients with or at risk of AHRF in the specific setting of emergency/urgent surgery. However, optimization of mechanical ventilation

with the use of protective ventilation is important and improve outcome in patients with AHRF [27] and those at risk of AHRF undergoing surgical procedures [28,29].

Therefore, we should take into consideration that in a patient with critical lungs due to SARS-CoV-2, who needs to undergo surgery or an invasive procedure, prone position during or immediately after the intraoperative period can improve lung oxygenation and should be considered. It is important to highlight that some SARS-CoV-2 patients clinically present with relatively high lung compliance, yielding only modest benefits from prone position, and at the expense for high demand of the already overwhelmed human resources. Thus, the benefits of adopting this strategy should be weighed against the human resources available and the surgical suitability to the position.

It is also important to remind that there is no cross effect of PEEP and prone position, and thus, adoption of prone position does not affect the PEEP strategy, as they both act synergistically to improve PaO<sub>2</sub>/FiO<sub>2</sub>. From the Petersson et al. study findings in anesthetized human volunteers on the effects of prone positioning and PEEP on V/Q [29], we suggest that the best indication for the adoption of prone position is when the ventilation settings are: FiO<sub>2</sub>: 0.6, PEEP: ~10 cmH<sub>2</sub>O, VT: 6 ml/kg and PaO<sub>2</sub>/FiO<sub>2</sub> remains <150 [30].

We should remember that some surgeries cannot be postponed, due to its emergency character, such as subdural hematoma [31], open fractures [32], bronchoscopy, pleural and pulmonary biopsy, and pleural drainage among others. We should also consider that there has been a steep slope rise on morbidity and mortality in both elective and urgent surgeries since the beginning of the pandemic, with unplanned ICU admissions as high as 3% direct from operating theatre and 4.6% from the ward, with a 7-day mortality of 6.2% and a 30-day mortality of 25.6% when considering all emergency surgeries [11].

### 2.2. Contraindications and complications of prone position

There are contraindications to prone positioning, such as spinal instability and unmonitored increased intracranial pressure. For other relative contraindications (e.g., open abdominal wounds, multiple trauma with unstabilized fractures, pregnancy, severe hemodynamic instability, and high dependency on airway and vascular access), the risks related to the procedure should be balanced against the possibility of foregoing the application of a potentially life-saving treatment. Some complications, fully described in the major trials, such as transient desaturation, transient hypotension, accidental extubation, and catheter displacement, relate to the mechanics of the proning maneuver itself. Another series of complications, such as pressure ulcers, vomiting, and need for increased sedation, are associated with the duration of staying prone. Particularly harmful is the compression of nerves and perioperative vision loss (POVL). The incidence of these problems decreases with experience routinely using this intervention or with the use of special devices and beds that facilitate the mechanics of safe proning [33].

## 3. Author conflict of interest checklist

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unavoidable. Only in exceptional cases does the Journal consider author conflict-of-interest in the peer review process. Please see the Instructions for Authors for additional instructions.

#### 4. Conclusions

We believe that the physiology of the prone position provides an improvement in the V/Q ratio in a critical patient with acute hypoxemic respiratory failure due to SARS-CoV-2 pneumonia, who do not respond to the usual lung protective strategies and supportive care. Critical care physicians and anesthesiologists should consider maintaining patients in the prone position as an extreme alternative during invasive procedures in the intensive care unit or even for surgeries in the operating room when it is feasible. It is important to remember that there is no cross effect of PEEP and prone position, and thus, adoption of the prone position does not affect the PEEP strategy as they both improve PaO<sub>2</sub>/FiO<sub>2</sub> in a patient with acute hypoxemic respiratory failure due to SARS-CoV-2 pneumonia.

#### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.tacc.2020.06.006>.

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