Prone Positioning for Acute Respiratory Distress Syndrome

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KEYWORDS

• Prone position • Acute respiratory distress syndrome • Ventilator-induced lung injury • Hypoxemia

KEY POINTS

- Prone positioning can be applied safely to most patients with acute respiratory distress syndrome (ARDS).
- Prone positioning when applied early for an appropriate duration improves mortality in ARDS and should be used in most patients with moderate/severe ARDS.
- The mechanism by which prone ventilation reduces mortality in ARDS is likely a reduction in ventilator-induced lung injury.
- Prone positioning in patients with ARDS also improves oxygenation when compared with supine positioning.
- A protocolized approach to application of prone ventilation in ARDS reduces potential complications and maximizes benefit.

HISTORY

The benefits of prone positioning were first theorized in 1974 from studies on the effects of sedation and paralysis on the diaphragm.[1] However, the deleterious effects of supine ventilation were noted as early as the 1940s.[2,3] In 1976, Piehl and Brown[4] described marked improvement in oxygenation in 5 patients with hypoxemic respiratory failure, and a year later, Douglas and Finlayson,[5] reported similar findings in 6 individuals and also found that oxygenation worsened after turning patients back to the supine position in most instances. Despite these promising reports, no additional clinical or mechanistic studies on prone positioning were published for the next decade. In 1987, Albert and colleagues[6] used a model of acute lung injury (ALI), replicated the improvement in gas exchange that had been seen in humans, measured shunt using the multiple inert gas technique, and showed that it decreased from a mean of 23% supine to 8% prone and that the improvement occurred without changes in cardiac output, pulmonary vascular pressure, regional perfusion distribution, end-expiratory lung volume, or regional diaphragmatic movement (Fig. 1).

Since these initial clinical and physiologic findings, multiple animal and human studies have shown that prone positioning improves oxygenation and reduces ventilator-induced lung injury (VILI) in the setting of ALI or acute respiratory distress syndrome (ARDS). In this article, the physiologic changes explaining the improvement in oxygenation are reviewed, how prone positioning

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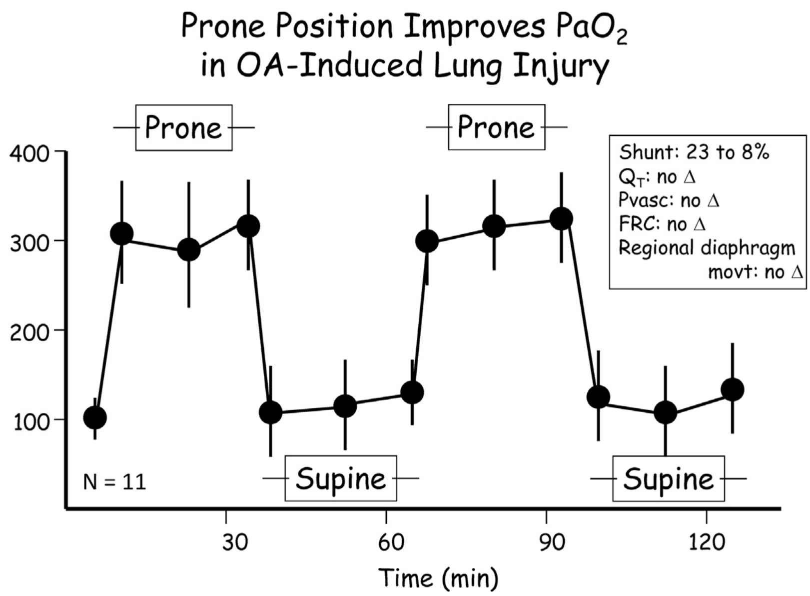

Fig. 1. Changes in oxygenation and pulmonary physiology between prone and supine positions in dogs with oleic acid induced lung injury. FRC, functional residual capacity; Movt, movement; Pvasc, pulmonary artery pressures; Qt, pulmonary blood flow. (*Data from* Albert RK, Leasa D, Sanderson M, et al. The prone position improves arterial oxygenation and reduces shunt in oleic-acid-induced acute lung injury. Am Rev Respir Dis 1987;135(3):628–33.)

reduces VILI is described, randomized controlled trials of prone ventilation in patients with ARDS are evaluated, the complications associated with prone ventilation are summarized, suggestions are made as to how these might be reduced or avoided, and when prone ventilation should start and stop and for what duration it should be used are discussed.

PHYSIOLOGIC RATIONALE

Multiple anatomic and physiologic changes take place when changing from supine to prone. These changes affect both normal and diseased lungs, but the consequences are more pronounced in the setting of atelectasis or conditions that predispose to atelectasis (eg, anesthesia, obesity, sedation, paralysis, abdominal distension).

Mechanism Behind Improvements in Oxygenation

Both observational studies and randomized trials have shown that oxygenation improves in 66% to 75% of patients with ARDS who are turned from supine to prone.[7]

Regional changes in perfusion

Computed tomography (CT) imaging and autopsy studies indicate that atelectasis preferentially develops and is more extensive in the dorsal caudal portions of the lung when normal individuals and patients with ALI/ARDS are supine. To the extent that these regions receive perfusion (Q) low ventilation-to-perfusion areas or shunt result. It was initially hypothesized that the mechanism of improved oxygenation on turning prone was the redistribution of Q to the better ventilated ventral lung in response to the change in the directional effect of gravity. However, Wiener and colleagues[8] reported that the increasing Q gradient from ventral to dorsal lungs changed little on turning from supine to prone (ie, dorsal lung regions continued to receive the greatest fraction of the perfusion, regardless of whether the animals were supine or prone). This finding has been confirmed by many others, resulting in revisions in the zonal perfusion distribution theory, which was previously used to explain regional Q variations.[9] In addition, Weiner and colleagues[8] also found that regional edema resulting from lung injury was uniformly distributed throughout the lung, regardless of position.

Regional changes in ventilation/recruitment

If shunt decreases but regional perfusion remains unchanged on turning from supine to prone, then, the regional distribution of ventilation must be changing. Measurements of regional pleural pressure (Ppl) in animals and estimates in normal individuals indicate that Ppl is more negative in nondependent regions and less negative (or even positive) in dependent regions, with a gravitational Ppl gradient in normal lungs of approximately