EDITORIAL

When Is a Patient Prone for Prone?

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Mechanical ventilation has been the main treatment of pulmonary insufficiency, especially acute respiratory failure and acute respiratory distress syndrome (ARDS), for the last 30 years. Because mechanical ventilation itself may cause or propagate lung injury, therapeutic strategies increasingly focus on the avoidance of these iatrogenic factors by including adjunct measures such as inhaled vasodilators, negative intravascular fluid balance, or prone positioning. It was almost 10 years after the clinical description of ARDS that Piehl and Brown (1) first described the benefit of positional changes to augment arterial oxygenation in five patients prone to develop respiratory failure. Their data were confirmed by a second, more extensive study by Douglas et al. (2), who also described a significant increase in Pa_{O_2} in most, but not all, patients studied. Possible mechanisms to explain the improvements of gas exchange were discussed and included the redistribution of blood flow and/or ventilation, an increase in functional residual capacity, and changes in the ventrodorsal transpulmonary pressure gradient. Both papers were based on the theoretical work of Bryan (3), who advocated the prone position in mechanically ventilated patients in order to improve regional inflation of the dorsal portions of the lung. Douglas et al. (2) Piehl and Brown (1) supported the use of positional changes to improve pulmonary gas exchange, to decrease possibly toxic inspiratory concentrations of oxygen, a potential iatrogenic factor in the promotion of the lung injury.

Despite the encouraging clinical results, prone position did not become an integral part of treatment of respiratory failure, possibly due to the technical problems and unpredictability of prone position. Clinical research focused instead on the development of new therapeutic strategies, e.g., ventilator modes and drugs to cope with acute respiratory failure and its high mortality. However, studies continued to investigate the interdependence of body position, gas exchange, regional ventilation, and blood flow.

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Ten years after the first clinical reports, prone position for the treatment of ARDS underwent a "renaissance" in Europe. This was stimulated by a study published by an Italian group in 1988, combining positional changes with computed tomography scan (4). Langer et al. (4) demonstrated that prone position resulted in the disappearance of densities in the dorsal regions of the lung visualized by computed tomography scan, accompanied by an increase in arterial oxygenation in some but not all patients. In their study, it was not possible to discriminate which of the mechanisms proposed by Douglas et al. (2) may be responsible for the improvement of gas exchange. In a study published in 1992, Pappert et al. (5) were able to differentiate the effects of prone position on ventilation/perfusion (V_A/Q) distribution using the multiple inert gas elimination technique in a series of 12 patients. The immediate reduction of pulmonary shunt blood flow in favor of an equal increase to regions with normal V_A/Q ratios without affecting low V_A/Q areas led to the assumption that the recruitment of atelectatic, but healthy lung regions may be the major mechanism responsible for the rapid improvement of gas exchange. This finding disagreed with the hypothesis that a gravitational redistribution of blood flow to ventilated areas in prone position was the basic mechanism for the observed increase in Pa_{O_2}. Gravitational forces have a major impact on blood flow distribution in healthy patients. However, in the diseased lung, blood is redistributed away from atelectatic (predominantly basal) lung regions due to hypoxic vasoconstriction. That this compensatory mechanism is not significantly hampered in the diseased lung has been demonstrated by an increase in shunt perfusion after the intravenous administration of vasodilators. The influence of posture on the spatial distribution of blood flow and ventilation has been addressed by several animal studies. Using radiolabeled microspheres in an animal model, Wiener et al. (6) demonstrated that blood flow is preferentially distributed to dorsal areas of the lung, independent of the animal's posture. This was confirmed by Beck et al. (7), who showed an increased homogeneity of blood flow and thereby of V_A/Q ratios in prone position

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compared with supine. More recently, a study by Lamm et al. (8) focusing on regional ventilation and perfusion in dogs with oleic acid–induced ARDS came to the conclusion that the increase in transpulmonary pressure in prone position is sufficient to exceed airway opening pressure and thus improves regional ventilation of dorsal lung regions without affecting ventilation to ventral portions of the lung. Atelectasis and V_A/Q heterogeneities are most severe in these areas during supine position and thus promote shunt, the major determinant for the development of hypoxemia in respiratory failure.

This is in accordance with the concept of the "baby lung" in ARDS, as proposed by Gattinoni et al. (9). They divided the regional appearance of a lung with ARDS into three zones: D (diseased), R (recruitable), and H (healthy). In combination with pressure-controlled ventilation, prone position offers the possibility to recruit alveolar space located in zone R without the risk of exposing these areas to overinflation due to high airway pressures. This would ideally follow Lachmann's recommendation for a ventilator strategy in ARDS—"open up the lung and keep it open"—without the need for further increases in the mean airway pressure (10). The decrease in the pleural pressure gradient results in more negative transpleural pressures sufficient to surmount airway opening pressures. Prone position thus prevents the repetitive alveolar reopening in the dorsal lung regions, a mechanism resulting in barotrauma due to increased stress forces (11).

The recruitment of alveolar spaces not only enhances the homogeneity of V_A/Q ratios but also increases the effects of inhaled vasodilators, e.g., nitric oxide. This has been shown in a study by Putensen et al. (11), who demonstrated an improved response to nitric oxide at higher positive end-expiratory pressure levels. Atelectatic areas are an ideal medium for the growth of bacteria and microorganisms, especially when reduced blood flow, altered airway mechanics, gravitational forces, and an inflammation-related reduction in ciliary activity promotes the stasis of bronchial secretion and enhances the risk for ventilator-acquired pneumonia. Prone position may result in improved clearance of airway secretions and thus decrease the risk of pulmonary infection.

Most of the clinical studies published focused on the short-term physiologic effects and the mechanisms of prone positioning. The importance of the article of Fridrich et al. (12) in this issue of *Anesthesia & Analgesia* is that they have been able to demonstrate a significant beneficial long-term effect on gas exchange in a group of patients with a defined etiology of ARDS. They proved that it is possible to perform periodical positioning over several days and up to 20 hours per day without major problems. In contrast to the studies published by Gattinoni et al. (9), Langer et al. (4), or Pappert et al. (5), this group chose patients with trauma-induced ARDS in whom they applied prone positioning as soon as the diagnosis of ARDS was established. The homogeneity of the patient group in terms of etiology, prestudy ventilator time, and early onset of positional therapy may be an important factor for the positive response in all patients.

Although kinetic therapy appears to be less invasive and easier to perform and requires less-skilled personnel, most groups who have experience with prone positioning believe this alternative to be inferior and less effective in terms of the improvement of gas exchange.

Prone position represents one option in a series of therapeutic measures that can be used in the treatment of respiratory failure. Although mechanical ventilation remains the mainstay in the therapy for ARDS, supportive therapies gain increasing interest in order to minimize the risk for an iatrogenic aggravation of lung injury induced by the therapy itself. The use of prone positioning pursues three therapeutic goals: 1) reduction of oxygen toxicity, 2) recruitment of alveolar space to reduce the risk of barotrauma during opening pressures, and 3) improvement of postural drainage of bronchial secretion.

Although not all patients will respond to prone position, its possible benefit and low costs may be worth a trial in many patients with ARDS.

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